BNL- 52529
FORMAL REPORT

BNL/DOE/NORA

OILHEAT RESEARCH AGENDA

A Ten Year Blueprint for Residential Oilheat Research and Development in the Twenty-First Century

Roger J. McDonald, and John E. Batey

May 1996

Prepared for:
Office of Building Equipment
Office of Building Technology, State and Community Programs
United States Department of Energy
Washington, DC 20585

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Conservation Division

DEPARTMENT OF APPLIED SCIENCE

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Department of Applied Science
Brookhaven National Laboratory
Associated Universities, Inc.

Under Contract No. DE-AC02-76CH00016 with the
United States Department of Energy

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Executive Summary

This report summarizes a joint research agenda planned for the United States Department of Energy and the National Oilheat Research Alliance (NORA) under a cooperative effort between the Federal government and the private sector industries involved in oilheat marketing.

The objective of the oilheat research program is to develop the technical basis for improved equipment designs and operating strategies based on an enhanced understanding of oil-burning fundamentals, heat transfer, and associated environmental factors. The program will continue to provide the oil-fueled heating equipment industry with the basis for developing a new, modern generation of equipment and provide the oil marketers, equipment installers, and consumers with improved knowledge of how best to install, maintain, and operate such equipment for maximum performance and minimum fuel use and environmental impact.

Oilheat is the energy choice for millions of Americans. There are 10.8 million U.S. households that use fuel oil (ASTM No. 2 Heating Fuel) for space and/or water heating. In addition there are 3.6 million U.S. homes that use kerosene (ASTM No. 1 Heating Fuel). Together they represent 14.4 million homes or 15% of the 96.6 million households in the United States. In 1993 these households consumed a total of 7.38 billion gallons of heating fuel (No. 2) and 340 million gallons of kerosene (No.1). The total market expenditure in 1993 dollars was $6.64 billion for fuel oil and $0.370 billion for kerosene for a $7 billion total in residential fuel costs.

The oilheat industry is represented by over 7,000 mostly small family businesses which together employ almost 250,000 skilled workers in the field. It is a highly competitive industry and the consumers generally benefit by having many companies to choose from in their location, allowing for comparison shopping for price and service. Full service oilheat providers offer many advantages like twenty-four hour service, charge accounts, budget payment plans, and service contracts.

Improved oilheat technology will result in numerous and very important tangible benefits for both the homeowner and the oil marketer alike. These included improved fuel utilization efficiency, enhanced environmental responsibility, maintenance of a diversity of usable energy resources, reinforced safety, improved resistance to foreign competition and technology. These benefits will also provide economic support to millions of American households by reducing fuel bills and thousands of small family businesses in the United States who will gain from having satisfied consumers and reduced operating costs.

The goal of the oil heat research and development program is to accomplish the research objectives that were prioritized in this report by working on a comprehensive range of research areas and projects. The list that follows outlines specific research areas and projects that are needed to achieve the objectives which are based on past and on-going research at BNL.

The research areas are separated into 10 functional groups that range from fuel properties and fuel quality to advanced diagnostic tools and system engineering and integration. The ten research elements areas are:

- Fuels and Fuel Quality
- Control Advances
- Equipment Diagnostic Tools
- Venting Systems
- Oil Combustion and Burners
- Heat Transfer Advances
- New Applications for Oil - Residential/Commercial
- Heat Distribution Systems
- System Engineering and Integration
- Information Transfer and Education

The responses to the industry survey conducted by BNL have clearly indicated a high level of concern with issues that relate to reliability, maintenance, and clean operation of the existing technology and equipment. There are many areas of research that will help address these concerns. These include fuel quality research, control advances, equipment diagnostics-service tools, and venting research. The second level in prioritization of the work is associated with better understanding the basic concepts and principles that govern system operation and performance. These include oil combustion, burner design, and heat transfer leading to new oilheat applications and uses. The third level is understanding the way oilheat equipment works with the house and the environment as a system. The work in heat distribution and systems integration will result in realizing the full potential of new oilheat technologies as they are developed. All during the program there will be an important need for communication between the researchers, oil marketers, and equipment manufacturers to keep the research on track. This is the critical role of information and technology transfer. This effort will also be coupled with the other main NORA functions associated with industry training and consumer education.

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

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

This NORA/DOE/BNL Program will develop a large number of improvements to current capabilities in oil-fired equipment and its use. Some of the planned improvements should be completed within two years; others will take longer. The primary goal of the program, one or more complete new equipment concepts, should take 5 to 8 years. All work is expected to take place within a total DOE and NORA funding scenario of approximately $2.5 million per year. Funding on specific research elements is expected to shift somewhat as different stages of the various elements progress and trade off against one another.

This report has outlined the nature of the research elements required to advance oilheat technology into the Twenty-First Century. The challenge is to establish a balanced program of research and development. A balance between developing new technologies for the future that will highlight and feature the full range of advantages associated with oilheat while at the same time resolving the issues and concerns associated with today's existing technology and industry infrastructure.

1.0 Introduction

This multi-year plan for oilheat research was developed by Brookhaven National Laboratory (BNL) with assistance from Energy Research Center Inc. and with the cooperation of a myriad of oilheat industry representatives and equipment manufacturers across the country. The effort was directed by the Office of Equipment and Appliances Program within the U.S. Department of Energy (DOE), Office of Building Technology, State, and Community Programs.

The National Oilheat Research Alliance (NORA) has recently been formed and is currently working to establish a Congressionally approved oilheat check-off program to provide the resources for long term funding support for oilheat research, educational programs, and industry training to benefit oilheat consumers, the general population, and U.S. oilheat industry. It is envisioned that the NORA research component will provide significant potential for industry cooperation, cost sharing , enhancement, and expansion of the very successful DOE oil heat research and development program at BNL. This report details the plan for future oilheat research based on the assumption that the NORA check-off program will be approved by Congress and that DOE will continue to support oilheat research at a level which would allow BNL to work with NORA now and in the future.

1.1 Program Objective and Scope

The objective of the oilheat research program is to develop the technical basis for improved equipment designs and operating strategies based on an enhanced understanding of oil-burning fundamentals, heat transfer, and associated environmental factors. The program will continue to provide the oil-fueled heating equipment industry with the basis for developing a new, modern generation of equipment and provide the oil marketers, equipment installers, and consumers with improved knowledge of how best to install, maintain, and operate such equipment for maximum performance and minimum fuel use and environmental impact.

1.2 Document Organization

This document introduces an agenda for a proposed joint cooperative DOE/BNL/NORA government-industry sponsored oilheat technology research program. Section 2 contains the important characteristics that define oilheat. These include detailed census demographics, industry data, and a basic discussion of how oil from the ground becomes heating comfort in the home. It also includes the approach taken to develop this research agenda and the management and program resources which will be required to carry out the work. Section 3 provides background on past research efforts sponsored separately by industry (1960-70's) and government (1980-90's) and past conferences which focused on oilheat research needs including the 1996 BNL Oilheat Technology Conference which in part, specifically dealt with developing the research agenda contained in this report. This section also includes a technical background and description of specific problem areas and the effort in gaining industry's prioritization of research objectives. Section 4 presents the contents of the research agenda, the ten specific program elements that resulted from the scoping, ranking and planning activities conducted by

BNL and ERC during 1996. These ten functional elements include brief descriptions of individual project activities which will be described in much greater detail during the development of individual statements of work for each project once the general program has been agreed to and initiated. Section 5 provides an initial working strategy for the research effort by establishing the Ten-Year Oilheat Research Agenda. It provides for a balanced approach between short term needs to make today's technology even better than it is while taking a long term approach to developing new oilheat technology options for the Twenty-First Century.

2.0 Background / Approach

This chapter presents the consequential characteristics of the U.S. oilheat market sector. It reviews recent household energy consumption statistics and associated expenditures. It discusses the nature of the oilheat industry and its infrastructure. It briefly reviews the basic technology of oil heating equipment operation and its design. It points out important technological, environmental, economic, and energy conservation issues associated with the oilheat industry as it exists today and how research can help the industry make major strides towards the future.

2.1 U.S. Oilheat Household Energy Consumption and Expenditures

Oilheat is the energy choice for millions of Americans. There are 10.8 million U.S. households that use fuel oil (ASTM No. 2 Heating Fuel) for space and/or water heating. In addition there are 3.6 million U.S. homes that use kerosene (ASTM No. 1 Heating Fuel). Together they represent 14.4 million homes or 15% of the 96.6 million households in the United States. In 1993 these households consumed a total of 7.38 billion gallons of heating fuel (No. 2) and 340 million gallons of kerosene (No.1). The total market expenditure in 1993 dollars was $6.64 billion for fuel oil and $0.370 billion for kerosene for a $7 billion total in residential fuel costs.

The average household using fuel oil (No. 2) used 684 gallons for space heating. The average additional usage for those who also choose to use fuel oil for water heating, 4.6 million households, was 189 gallons. The average cost for space heating alone at $0.90 per gallon (1993 national average) was $612 with an additional $158 for domestic water heating for those that use it ($780 combined cost). The average household had a floor space of 2,262 square feet and was typically a single family home (8.0 million homes). The typical house was located in the Northeast (7.4 million homes are located in New England & Mid-Atlantic states) and experienced over 4,000 heating degree days (10.2 million homes). More than half of all oil heated homes (5.8 million) experience more than 5,500 heating degree days. The typical home was built before 1950 (7.4 million), is owned by the householder (7.7 million), and is occupied by 2 or 3 people, 2.65 is the numerical average. In total, 28.6 million Americans live in oil heated homes. The age of householders using oil heat is above average. Out of the 10.8 million householders 34% are 60 years old or older and another 25% are between the ages of 45 and 59.

Reference: Household Energy Consumption and Expenditures 1993
Report # DOE/EIA-0321(93), October 1995, Energy Information Administration, Office of Energy Markets and End Use, U.S. Department of Energy

2.2 Oilheat Industry Characteristics

The oilheat industry is represented by over 7,000 mostly small family businesses which together employ almost 250,000 skilled workers in the field. It is a highly competitive industry and the consumers generally benefit by having many companies to choose from in their location, allowing for comparison shopping for price and service. Full service oilheat providers offer

Figure 2.1 Oilheat: Building Data

EIA Household Energy Consumption and Expenditures 1993 Report

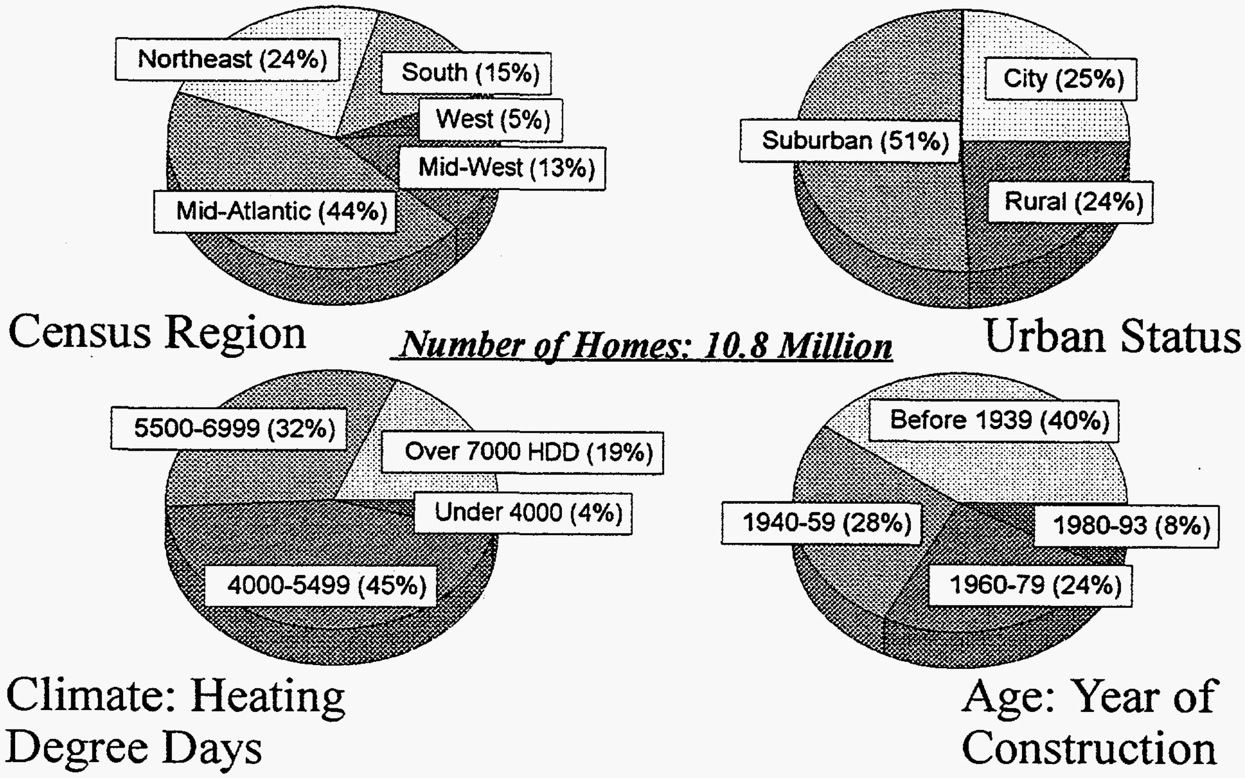
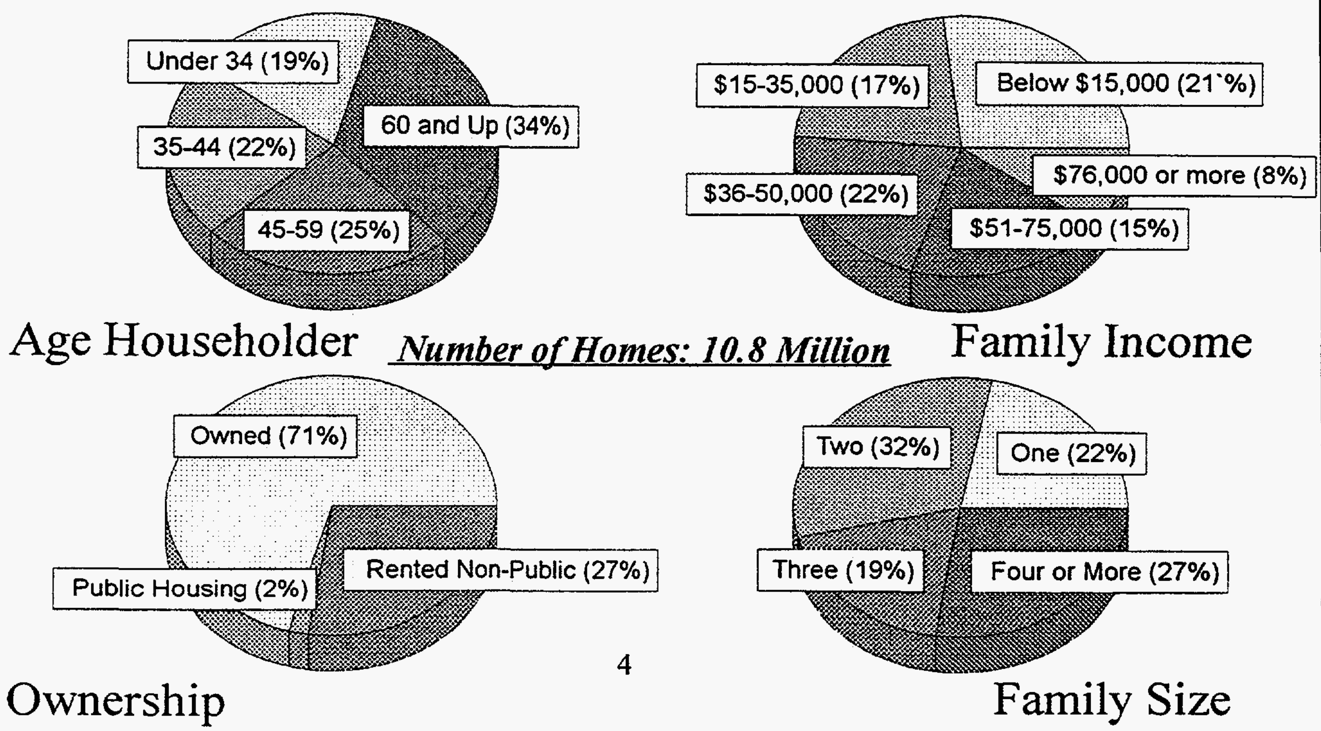


Figure 2.2 Oilheat: Householder Characteristics

EIA Household Energy Consumption and Expenditures 1993 Report



many advantages like twenty-four hour service, charge accounts, budget payment plans, service contracts, etc. The sales of light distillate fuel oils used in the residential (~$7 billion) and commercial (~ $3 billion) building sectors for space and water heating represents about $10 billion annually (1993 EIA Data) in total. "Oilheat is Made in America!" Ninety-seven percent of the finished petroleum products sold in the USA are refined in the USA. Workers in the USA provide the added value to the product in 157 refineries. The U.S. is a net exporter of distillate fuel oil. In 1993 the American Petroleum Institute reported exports of 101,178,290 barrels of distillate fuel oil and imports of 67,203,000 barrels. This represents a net export of 34 million barrels, 3% of the total U.S. diesel fuel and heating oil production. [OILHEAT ADVANTAGES PROJECT Engineering Analysis and Documentation, J.E. Batey & R.G. Hedden, 1995]

2.3 Oilheat Basics

The process of how oil from the ground becomes clean, economical, efficient oilheat comfort in the home.

Liquid fuels including heating oil are refined from crude oil at an oil refinery. The finished product, the fuel, is transported by pipe-lines, barges, railroads, and highway tanker trucks to local bulk storage facilities (terminal facilities). These fuel terminals provide a means for loading smaller fuel delivery tank trucks owned by the various different oilheat providers in a given geographic region. In some parts of the country larger oil marketeers sometimes own their own private fuel storage terminals. The smaller tank trucks are used to deliver the fuel to the consumers tank, which is typically located in the basement, garage, or utility room. The fuel deliveryman uses the trucks on board fuel pump, metering equipment, and fuel hose to fill the householder's fuel tank. Residential tanks typically store 275 to 500 gallons of fuel and require several fuel deliveries each year. Even in the coldest regions the smaller tank will provide adequate storage capacity to supply heat for a typical house for a full month.

The fuel is burned in a furnace or boiler (heat exchanger) to heat air, water, or to make steam which carries the heat absorbed from the combustion process to the rooms in the house. This is accomplished by circulating the warm air, hot water, or steam through ducts or pipes to registers/vents, baseboard hot water convector units, or radiators. In recent years, radiant floor heating systems which also rely on hot water circulation have come back into popular use.

Oil-fired heating systems consists of several sub-systems. The oil burner pump draws fuel from the tank, the fuel is atomized, it is mixed with just the right amount of air for clean combustion, a spark provides the ignition of the fuel/air mixture, and the flame produces the heat released to the heat exchanger to heat in turn the air, water, or make steam. A series of controls or an integrated control package provides for temperature regulation, starting and stopping the burner, flame sensing (safety), furnace or boiler over heating, and room temperature control via the thermostat. The flue pipe connects the unit to a chimney or an alternative means of safely exhausting the products of combustion from the system into the outside ambient environment. Maintenance of the oil-fired heating system is most often provided on an annual basis by a trained service technician who works in the service department of the full service fuel marketer.

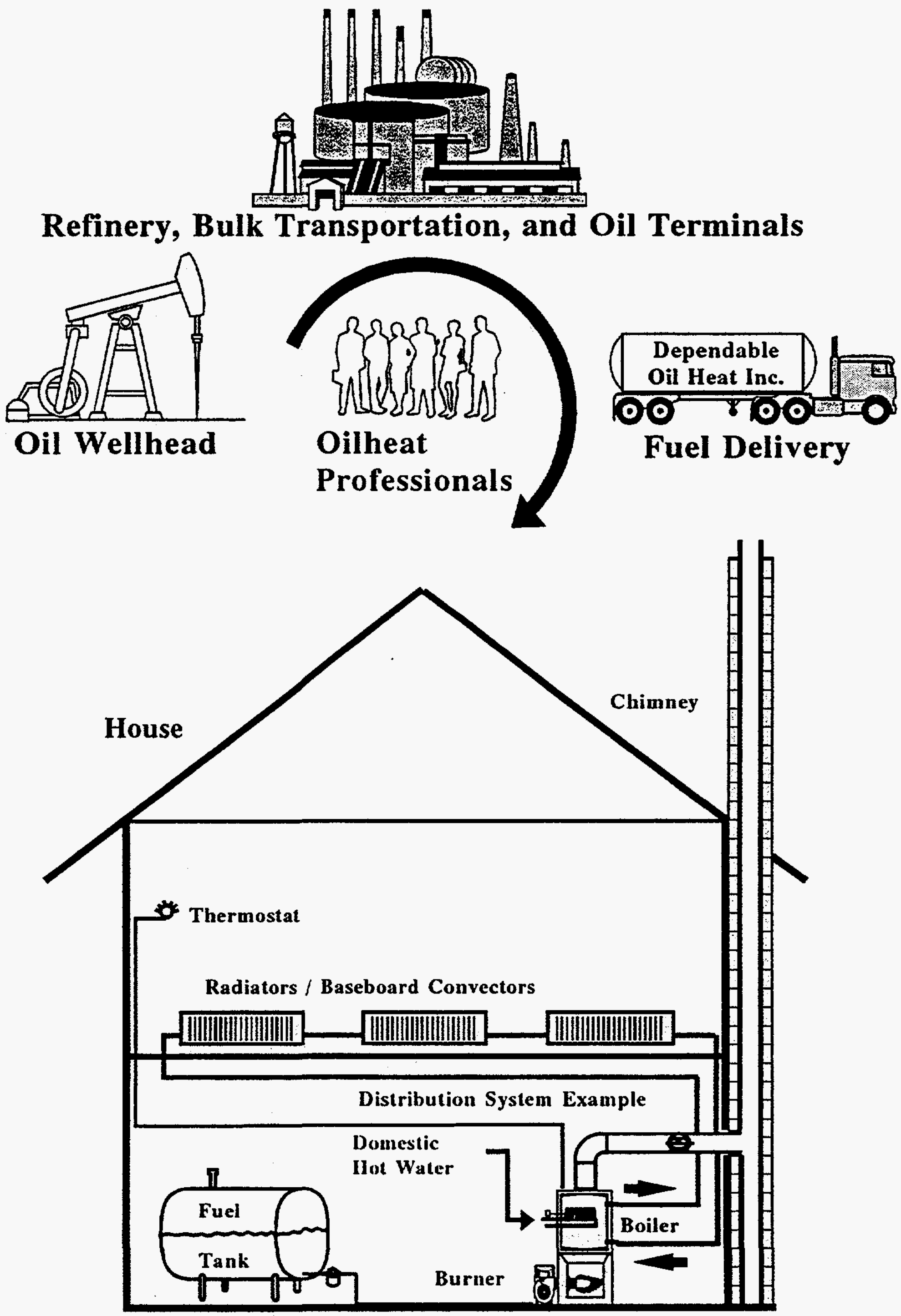


Figure 2.3 **Oilheat Basics**

2.4 Benefits From Oilheat Research

Improved oilheat technology will result in numerous and very important tangible benefits for both the homeowner and the oil marketer alike. These included improved fuel utilization efficiency, enhanced environmental responsibility, maintenance of a diversity of usable energy resources, reinforced safety, improved resistance to foreign competition and technology. These benefits will also provide economic support to millions of American households by reducing fuel bills and thousands of small family businesses in the United States who will gain from having satisfied consumers and reduced operating costs.

Efficiency

The most important benefit associated with improved technology will be gains in equipment efficiency. These increases in efficiency result in lower fuel consumption and lower fuel bills.

New oil heating equipment currently available in the marketplace have seasonal efficiency levels of 80-85% (AFUE) but the average efficiency in the field is much lower (70-75%). New oil heat technology developments are targeted to attain efficiencies of 90-95% and even higher with diesel engine driven heat pump technology, effectively breaking the 100% efficiency barrier by utilizing the low grade heat available in the ambient air or by using ground source designs.

The improvement in efficiency will also translate to improved comfort levels by reducing pressures to zone off parts of the home and augment oil heating with secondary fuels such as wood, coal, and kerosene used as a space heating source. These supplemental heating systems often contribute disproportionate amounts of air pollutants into the ambient air (wood and coal) and increase safety concerns regarding house fires and indoor air quality (wood, coal, and kerosene). Electric space heaters are also a safety concern with regard to house fires when improperly used, as is so many times the case.

Environment

The combustion of fuel oils (No. 1 & No. 2), which are primarily hydrocarbon molecules, results primarily in the formation of water vapor and carbon dioxide. The process also results in much smaller amounts of sulfur dioxide (which is proportionate to the sulfur content of the fuel), and trace amounts of other sulfur oxides, nitrogen oxides, and particulate matter (unburned hydrocarbon based materials) in the range of parts per million to parts per billion or less.

The research proposed in this document will contribute to the current success in dramatically reducing the amount of environmental emissions resulting from small oil burners which has been realized to date by previous efforts. Every increase in energy efficiency translates to a direct reduction in emissions because less fuel is consumed to produce the same useful output of heat energy. Already oil heat research has accomplished a cumulate reduction of carbon dioxide emissions of 87.4 million tons over baseline levels. When low sulfur(0.05%) fuel oil is burned it results in an 80% reduction in sulfur dioxide emissions. In addition specific new burner design advances will contribute to better controlled combustion processes which can be engineered to limit oxides of nitrogen, particulate matter, and other sulfur oxides which relate to heat exchanger corrosion and fouling.

Diversity of Energy Options

One of the free market advantages in the United States is the ability to seek out and utilize the most economical fuel at any given point in time. It is important to maintain or improve the ability to use a variety of fuels in order to preserve this option. The consequences of a one fuel economy could be disastrous. There has been a focus, for some time now, on reducing oil use because it as a fuel has achieved an important strategic value in the context of national energy policy. In the area of residential and commercial heating it is the ability to efficiently use oil that still requires some level of improvement. Lagging oil-burning technology will be even more important in the future as current trends lowering heating oil quality continue and better technology becomes necessary in order to effectively use the fuel. Ability to optimally utilize this type of fuel is also important from a national security viewpoint, for defense as well as long term energy reasons. In addition, the petroleum refining and distribution system is currently well optimized. Any significant changes in the patterns of fuel use will cause increased costs from re-optimization.

Safety

Oil heat is already one of the safest forms of home heating. Fuel oil is unique in being portable, storable, safe to handle, as well as having high energy content and being relatively clean to burn. Fuel oil is a liquid which is nonexplosive. Oil in the liquid state does not easily combine with air to support combustion. The fuel must first be atomized and vaporized, as in the controlled environment of a furnace or boiler using an oil burner. Carbon monoxide emissions from fuel oil combustion are generally lower than for other fossil fuels. Future oil heat research will be directed at new technology developments that will at a minimum maintain the high level of safety associated with modern oil heating systems and at best make large strides to enhance the safety of oil heat in residential and commercial applications.

When fuel oil prices have in the past been high, many homeowners reverted to supplemental electric or kerosene space heaters or used wood or coal burning stoves or fireplace inserts. These devices were and are still associated with higher risks of house fire and indoor air quality problems affecting health. The ability of utilizing oil at higher efficiency with lower costs reduces the incentive to use supplemental heating options thus improving residential safety in yet another way.

Economics

The oil heat industry is comprised of many small business (over 7,000) that together represent a very large sector of commerce in the United States. It directly employees approximately 250,000 skilled workers. It markets $10 billion in fuel each year. It depends upon 100's of support businesses including component and equipment manufacturers, major fuel suppliers, truck manufactures, tank builders, computer support companies, advertizing companies, banks, insurance companies, etc.

Oil heat is also an important industry in Europe as well as in Korea and Japan. These countries are supporting advanced research in oil heat technology. In Japan kerosene is a primary and traditional heating fuel. European manufacturers have continued to develop improved oil heat technologies while the U.S. industry has been relatively static. Imports of European heating equipment into the U.S. have been slowly increasing over the last ten years but there is still a good deal of resistance to European designs based on current price differentials. The size of the U.S. oil heat market continues to present a significant attraction to European manufacturers. Unchecked by improvements in U.S. oil heat technology the trend towards importing European equipment will likely continue to grow as they gain more footholds in the U.S. The development of improved U.S. oil heat technology will prevent this growth and could reverse it by providing advanced equipment concepts that will present an attractive export opportunity.

2.5 Oilheat Research Agenda Development Approach

An effort to define the basis of a joint U.S. Department of Energy (DOE) and Oilheat industry (marketers) program for future oilheat equipment research and development has been conducted. At the request of NORA steering committee representatives, BNL with DOE concurrence, coordinated the development of a research agenda. This also serves to update a prior oil-fueled research plan developed for DOE ten years ago which has been the road map for DOE's very successful Oil Heat R&D program at BNL.

The objective of the oil heat equipment research program is to develop the technical basis for new equipment and operating strategies based on improved understanding of oil-burning fundamentals. The program will continue to provide the oil-fueled heating equipment industry with the basis for developing a new, modern generation of equipment and provide the oil marketers, equipment installers, and consumers with improved knowledge of how best to install, maintain, and operate such equipment for maximum performance and minimum fuel use as well as minimal environmental impact.

Every effort was placed on seeking the broadest national representation of the oilheat industry in the development of the research agenda. BNL worked to obtain extensive input from the private sector through a series of workshops and formal and informal surveys. Workshops were coordinated to take advantage of those major industry associations sponsoring trade shows and conferences during 1996. These include the 1996 BNL Oil Heat Technology Conference in March, the 1996 Atlantic Regional Energy Exposition in April, and the 1996 NAOHSM Trade Show in June. All sectors of the industry were included representing manufacturers, marketers, and service technicians. The effort involved liaison with all key industry associations including PMAA, NEFI, NAOHSM, OMA, and of course the NORA steering committee. BNL involved the members of the existing BNL Oil Heat R&D Technical Advisory Group in seeking additional input in the process.

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

Specific work sub-tasks for developing this multi-year research agenda included the following:

Task 1. Needs Assessment

BNL reviewed the current state of technology and obtained recommendations from oil heat equipment manufacturers and fuel marketers about priorities for oil heat research and new equipment. This activity included:

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

Task 2. Develop Preliminary R&D Objectives

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

Task 3. Oilheat Industry Review and Prioritization of Preliminary Research Objectives

The preliminary research objectives were distributed in the form of a survey which was widely distributed including publication in one of the major monthly industry trade journals. It was reviewed by a wide range of oil heat companies and associations that included all major equipment manufacturers, fuel oil marketers, service associations, and regional, state, and national associations. The prioritized survey responses and letters were sent back for BNL and ERC to review. The surveys and comments included some additions (or suggested changes) as well prioritization which was used as the basis for developing a final research agenda listing elements and specific project areas.

Task 4. Produce Final Report

This final report summarizes the multi-year research agenda, activities to be completed with U.S. DOE assistance, research to be completed with industry funding, joint projects and a plan for completing the work and coordinating efforts with NORA. These efforts include demonstration projects that can accelerate the market acceptance of new oil heat technologies. This research agenda will require periodic efforts to update and refine the contents as more industry representatives learn about the activity and take an active interest in the process.

When the program is initiated the first step in each specific project area will be to develop a detailed and specific research and development work plan earmarking the human resources required, the statement of work (specific tasks), the schedule, and the budget requirements. Inclusive in the individual project plans will be a project schedule, milestone requirements, progress reports, budget reporting, and periodic reviews with industry participation leading to major decision points by the management team.

2.6 Program Resources and Management

Management Structure

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

Brookhaven National Laboratory (BNL) has program management responsibilities for the oilheat equipment research. BNL can and has issued Requests for Proposals, evaluated proposals, executed contracts and monitored contractor performance, and otherwise performed the bulk of the interaction with other research institutes, universities, and manufacturers. It has also performed a variety of in-house research that it is best suited to do, and coordinated technology transfer on work done in-house and by others. Finally, Brookhaven continually interacts with DOE/HQ, serving as the primary information channel for program control as well. This activity is typical for OBT and other DOE research programs.

DOE/BNL Management Approach

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

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

Resources

This NORA/DOE/BNL Program will develop a large number of improvements to current capabilities in oil-fired equipment and its use. Some of the planned improvements should be completed within two years; others will take longer. The primary goal of the program, one or more complete new equipment concepts, should take 5 to 8 years. All work is expected to take place within a total DOE and NORA funding scenario of approximately $2.5 million per year. Funding on specific research elements is expected to shift somewhat as different stages of the various elements progress and trade off against one another.

3.0 Technical Background and Research Objectives

3.1 Past Research Efforts

Past research activities related to oil heating equipment have centered on two major programs. The first was the industry-wide oil burner research program funded by the major oil companies through the American Petroleum Institute (API) from 1960 through 1967 and continued through 1974 by the National Oil Fuel Institute (NOFI). The second group of major research activities is still supported by the DOE through programs at Brookhaven National Laboratory which can be split into two distinct phases. The first phase was an intensive effort to identify the seasonal efficiency characteristics of oil heating equipment and to evaluate the options available for upgrading the efficiency of equipment in-use in homes all across the United States. The second phase is one of basic development for the improvement of the technology associated with residential heating oil combustion equipment generating equipment with higher efficiencies and cleaner emissions. Technology transfer to the industry is an important element. BNL has planned and conducted ten oil heat technology conferences since 1984 to present the status of oil heating technology and to identify future research and development needs. These efforts are discussed in more detail in the following sections.

3.1.1 Industry Sponsored Research Programs for Advanced Oil Heating Equipment

From 1960 through 1967, the major oil companies funded a significant research program to advance oil heat equipment technology. Individual oil companies supported this program by contributions to the API, and by R&D efforts conducted within research departments operated by the oil companies. The overall goal of this program was to develop efficient, low-cost equipment with improved reliability to compete with natural gas-powered heating systems.

- The API research program began with a needs survey (Locklin 1960) which was the basis for recommending research activities in several categories:
- combustion fundamentals and burner concepts, including atomization, vaporization, ignition, fuel/air mixing, combustion process and smoke formation, surface combustion, and experimental techniques
- equipment development, including burners, heat exchangers, and water heaters
- residential equipment applications, including fuel storage and exhaust gas venting
- industry codes and standards
- new applications for fuel oil.

The API research program did not implement all of these recommendations; rather it focused on equipment development and made advances in the burner area of the program. It ended in 1966 when responsibility for oil heat research was transferred to NOFI, representing marketers and heating equipment manufacturers. Major oil companies continued to support oil heating equipment research and development through the commercialization of advanced equipment concepts.

Some important technical advances were produced by the API and NOFI research programs, notably the flame retention burner concept. Later work at Brookhaven demonstrated the improved efficiency of flame retention burners, which helped to eliminate barriers and accelerate market acceptance of this efficient design.

The R&D projects ended in 1974, when major oil company support was withdrawn, and NOFI merged with the National Oil Jobbers Council (NOJC). Now called the Petroleum Marketers Association of America (PMAA), this organization does not have the funding support required for an R&D program to develop improved oil heat equipment. The major oil companies have not sponsored research to develop advanced oil heating equipment since the API and NOFI programs ended. It is important to realize that what are left of the major oil companies have almost totally with drawn from the oilheat industry. The oilheat industry today, is comprised of the 7,000 or so mostly small family run local oilheat dealers and less than 100 oilheat equipment manufacturers, most of whom are also small family run businesses.

3.1.2 Government-Sponsored Research Programs for Advanced Oil Heating Equipment

The DOE has funded research activities to study oil heating systems and to develop advanced oil-burning equipment designs. Initially the DOE programs focused primarily on efficiency-improving technological advances.

From 1976, Brookhaven National Laboratory has taken the leading role in the DOE's residential oil heat conservation program. The Brookhaven activities included development of an efficiency test laboratory for oil-fired systems to identify energy-saving equipment designs and to evaluate the technical merit of production and prototype heating equipment. The Brookhaven work expanded to include subcontracted efforts by private organizations (Thermacore 1982; Mariano 1982), universities (Schladitz 1982), and individuals to develop advanced heating equipment and diagnostic methods for improving oil heat technology. The laboratory tests were used to characterize the performance of existing and new heating systems at full- and part-load so that the annual fuel use could be determined. Many retrofit options such as vent dampers, flue heat reclaimers, boiler water temperature controls, and new burner designs featuring reduced or variable firing rates were tested and analyzed (Woodworth and Dennehy 1981).

One Canadian government agency, the Combustion and Carbonization Research Laboratory (CCRL), operated by the Canadian Department of Energy, Mines and Resources, has been particularly active, conducting research programs for oil heating systems for the past 24 years. This work has emphasized practical research projects designed to supply consumers and service technicians with useful guidelines for improving the efficiency of oil heating equipment, and has included evaluation of burner furnaces, new heating systems, smoke production levels, pollutant emissions, fuel properties, alternative fuels, and heating equipment modifications. Recent studies have focused on venting system improvements.

Important advances also are being made by governmental and private efforts in several European countries, including France, Sweden, and Germany. However, the results of such work are not, at present, readily accessible to the research effort in this country.

3.1.3 **Past Conferences to Identify Oil Heat Research Needs**

Many conferences and meetings have been conducted over the years to determine the state of oil heat technology, and to identify existing research and development needs for improved equipment efficiency. These meetings included a Reston, Virginia, workshop on research needs for space conditioning (Andrews 1982), the Airlie House Building Energy Equipment Workshop held in December 1983, and ten Oil Heat Technology Conference and Workshop meetings held during the period September 1985 through March 1996 at Brookhaven National Laboratory. These conferences were organized by DOE, PMAA, American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), NAHB, American Institute of Architecture (AIA), and other concerned organizations, and attended primarily by those in the oil-fuel industry and related fields. They were oriented both toward discussion of immediate, practical problems and broad, sweeping, long-term technological issues. Several key areas received emphasis in most or all of these conferences, an indication that these areas are of chief concern to those in oil heat research and industry:

- fuel quality degradation
- low-firing-rate and modulating oil burners
- venting system improvements, such as direct venting, chimney lining, and vent system modeling for updating Codes and Standards
- building/heating system interaction and controls
- education and technology transfer to ensure optimal selection, use, and maintenance of oil heating equipment.

While the list of items above seems to include problems widely varied in scope, a coherent plan combining fundamental and applied research on all combustion equipment technology can bring about marked improvement in most of the areas. The information in Section 3.2 will, by way of introduction discuss the technical problems encumbering oil-fueled equipment research and how the current BNL program has been addressing those associated with efficiency improvements. However, first, in Section 3.1.4 the most recent BNL Oilheat Technology Conference Workshop to deal with research needs will be reviewed in detail.

3.1.4 Oilheat Research Agenda Forum Workshop (1996)

At the March 28-29,1996 BNL/DOE/PMAA Oilheat Technology Conference and Workshop the Oilheat Research Agenda Forum was attended by industry representatives including marketers, equipment manufacturers, and researchers. Part of the time was spent discussing general research objectives and their relative priority ranking based on the opinions of those present following an exchange of ideas and viewpoints. The chairman also entertained thoughts and suggestions for discussions on specific research topics recommended by the participants at the workshop.

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

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

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

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

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

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

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

In looking at prioritization of the various research areas reviewed by the group the categories fell into traditional lines. The group tended to give the highest priority to items that appear to have the potential for the most immediate benefit for the industry. These included fuel related research to resolve issues associated with sludge, better diagnostic tools, information related projects, and systems integration of available technologies. The non-traditional areas with longer range opportunities like oil-fired cooling technology and co-generation fell into lower priority classifications.

3.2 Technical Background

This chapter describes, from a long-term perspective, the technical problems that formed the basis for BNL's program in oil-fueled equipment. It serves as a technical introduction to the ongoing BNL program which is focused on the goal of efficiency improvement.

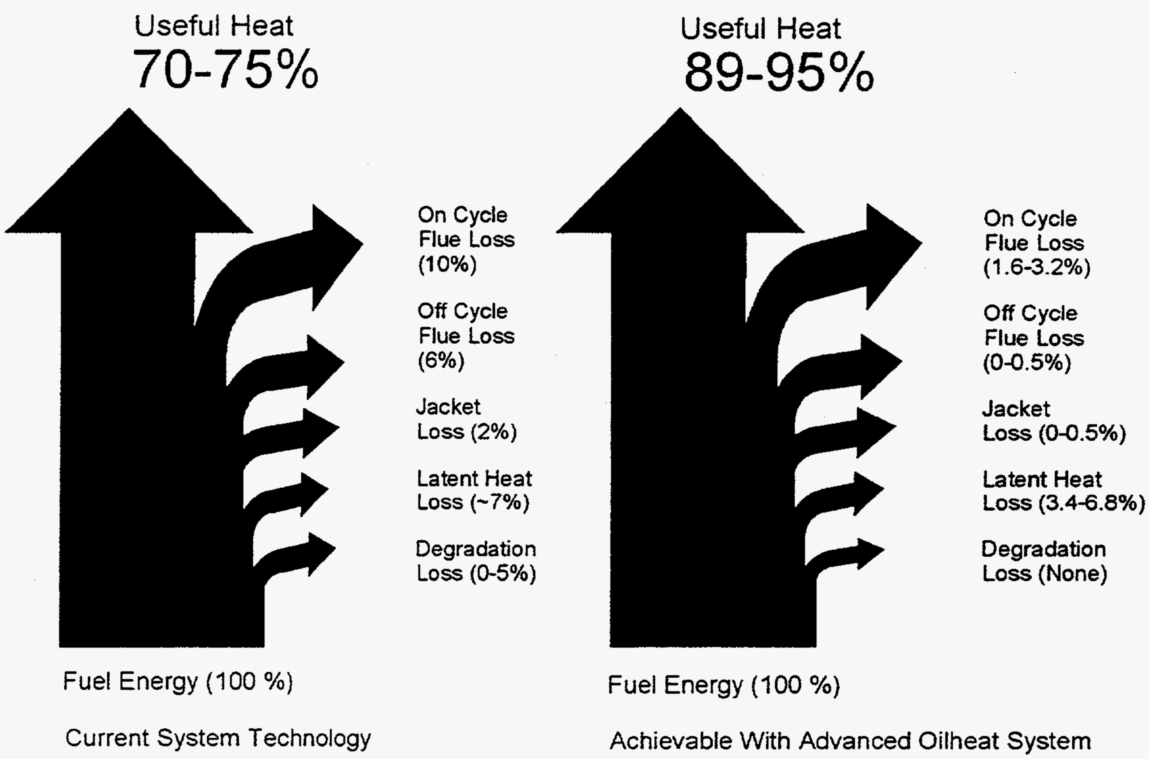
3.2 Current Status and Program Thrust

The *Sankey* diagrams in Figure 3.1 illustrate the relative capabilities of current and future oil-fueled equipment in steady-state operation, in actual use, and with degradation over a period of continued use. Because of their relatively slow turnover, currently operating oil-fired boilers and furnaces average about 75% efficient in steady state, while new equipment operate between 80% and 85% efficiency (the major portion close to 85%), and the very best new equipment may reach 87-88% efficiency. The potential efficiency in operation, however, could be as high as 95%. Furthermore, as Figure 3.1 shows, none of the existing equipment provides anywhere near these efficiencies in actual operation, because of losses from on-off cycling and from degradation in performance over time. The fundamental long-term need is for higher net (operational) efficiency. Research must therefore explicitly address ways to decrease these operating efficiency losses, as well as improve the base, steady-state conversion efficiency. The 100% thermodynamic barrier can also be effectively breeched by using engine driven oilheat heat-pump technology. The total delivered energy in this case comes from both the fuel-oil along with the energy gained from the low temperature heat pump source, either ground water or the ambient air which is pumped into the house through the heat-pump cycle.

The goal of the program was to address key technical barriers to improved efficiency in three major equipment types. First, there are a number of loss reduction possibilities in fixed-firing-rate (conventional) equipment. Second, there are important problems with low fixed-firing-rate equipment. Finally, there are a wide range of research problems for variable-output equipment, including the problem of what type of variable-output equipment would be most effective.

The remainder of this chapter will outline the technical barriers to developing and using advanced, high-efficiency equipment, and note the possible improvements that can be made in more conventional equipment by a particular technical advance. The barriers will be treated in an order roughly paralleling the type of research required--from the most fundamental to the most applied. Thus, fuel oil combustion and combustion diagnostics come first, followed by heat exchangers, controls, venting strategies, fuel quality, and equipment maintenance and installation.

Figure 3.1 **Typical Heat Losses for Oil-Fired Heating System Current Technology Versus Advanced Oilheat System**



3.2.2 Technical Problem Areas

Fuel Oil Combustion

Understanding the process of oil combustion is essential to all advanced research in this field. A key element in the combustion process that influences overall performance is vaporization of the liquid fuel oil before fuel/air mixing and ignition. Conventional oil burners typically rely on high-pressure atomizing nozzles that produce a spray of small fuel droplets. These droplets begin to evaporate, forming the fuel vapors necessary for rapid dissociation of the hydrocarbons and chemical reaction with the oxygen contained in combustion air.

One problem with pressure atomizing nozzles is that a range of droplet sizes is produced. Small fuel droplets completely vaporize before entering the combustion zone, but the larger droplets do not. These larger fuel droplets contribute to incomplete combustion and smoke formation by oil flames, particularly in older furnaces. This can cause soot deposits on heat transfer surfaces of the boiler or furnace, which reduce the overall efficiency of the heating plant. Excess combustion air is then required to reduce smoke formation, and this also can lower efficiency. The severity of the problem varies according to burner design; some examples are burners with vigorous air swirl that creates internal recirculation patterns (i.e., flame retention burners) and burners with exhaust gas recirculation that can operate with lower smoke levels than other burner types.

Other operating limitations also are imposed by pressure-atomizing nozzles. The lowest practical fuel firing rate is limited to about 0.5 gallons per hour because the nozzle orifice becomes extremely small below this flow rate and can easily become plugged. This firing rate is too high for many applications, and can degrade the efficiency of the heating system. In addition, low firing rates reduce heat exchanger size and cost and permit development of more efficient systems. A further limitation of pressure-atomizing nozzles is that the fuel flow rate cannot be easily varied, while variable-firing-rate burners would improve efficiency by reducing off-cycle heat loss and by permitting variable heat outputs for zoned heating applications.

Fuel/air mixing is another important requirement for fuel oil combustion that can impact overall efficiency. Combustion air swirl, recirculation, and other basic physical occurrences within oil flames can have an important effect on smoke formation and on the amount of combustion air that is required. Changes in combustion air supply caused by seasonal variations in chimney draft and changes in air density can impact smoke production and equipment efficiency. In addition, strong fuel/air mixing forces, accompanied by large pressure drops across the burner head, tend to reduce burner off-cycle heat losses.

Transient effects that occur during burner startup and shutdown can cause smoke formation and efficiency degradation by soot accumulation. The details of this smoke formation mechanism are unknown. The severity of this problem depends on physical interactions during flame ignition, including the rapid volumetric expansion of combustion air following ignition.

Diagnostics

Improved diagnostics and monitoring methods are critical to the successful development and sustained use of advanced equipment. The major problem in this area is smoke. Excessive smoke causes soot deposits on internal heat transfer surfaces. This reduces heat transfer efficiency and produces elevated exhaust gas temperature, increasing fuel consumption. Studies have shown increased fuel consumption rates of 5% to 10% for moderate smoke levels. Smoke production in oil flames is usually controlled by increasing the combustion air supply. However, excess combustion air also reduces efficiency. Optimal burner adjustment, a delicate balance between smoke formation and excess air, varies with burner design and is determined in the field during oil burner installation and periodic servicing.

Existing smoke measurement and burner adjustment methods could be improved significantly by advanced measurement techniques. The smoke measurement procedure that is currently used was developed several decades ago and it is time consuming, which discourages its widespread use. The procedure uses a hand-operated pump that draws a sample of flue gas through a piece of filter paper to determine smoke density. This measurement is performed only by service technicians during burner servicing, and changes in the fuel/air ratio that can occur between service calls will go undetected by the homeowner for an extended time period. This represents a preventable source of inefficient fuel use.

Heat Exchangers

The development of an improved heat exchange component will be a central factor in the design of improved oil heating equipment. Conventional heat exchangers in boilers and furnaces result in significant heat loss during both steady-state and transient operation. Boilers and furnaces transport energy from the hot flame gases to the water, steam, or air that is used for space heating. Generally, the overall heat transfer resistance is dominated by the hot gas film coefficient and the warm air or hot water film coefficient. These coefficients directly limit the overall heat transfer rate for the boiler or furnace. Typical heat transfer coefficients are quite low (in the range of 2 $Btu/h/ft^2 * {}^\circ F$), meaning that the equipment must be quite large to produce the desired heat output.

Some heating systems with improved design features have begun to appear on the market, but many of these units continue to use conventional construction and venting technologies. Research is needed to examine innovative heat exchange processes and devices that may be applied to improve the overall efficiency of oil-fired space heating equipment. A key technical limitation for oil systems, however, is smoke formation that can restrict the applicability of equipment advances such as those already developed for gas equipment. Many design alternatives have been suggested, but nearly all of them have fundamental problems including high pressure drops, flow stability, corrosion, materials required for construction, complexity of construction methods, noise levels, overly small dimensions of flow passages, and soot deposition.

Controls

The development of viable control strategies for regulation of oil-fueled equipment, a difficult problem currently treated only very crudely, has two aspects: the thermal dynamics of the building in which the equipment is installed, and the thermal behavior of the equipment itself. Each of these aspects involves difficult problems about which little is known; in addition, there are problems associated with the interaction of the two.

The control system of an oil-fueled equipment system responds to the equipment's operating environment. That environment consists of the air around the equipment jacket, the equipment's flame medium, the air or water side that is being heated, and the exhaust system. All of these have varying temperatures and flow and heat transfer rates (Berlad 1980). The control system balances these processes and the combustion/burner operation to maintain safety and desired outlet air or water conditions, and at the same time to maximize overall efficiency. The control system must therefore link the performance of all the equipment components, including proposed advanced elements.

Venting Systems

Conventional oil-fired heating system designs use a chimney for venting combustion product gases to atmosphere outside of the building. Heated exhaust gases enter the base of the chimney and rise, creating a negative pressure (i.e., draft) at the chimney inlet. From the standpoint of energy, however, current chimney design suffers from several important disadvantages.

When the burner starts, the chimney is cool and produces less draft; this affects the burner fuel/air ratio, contributing to smoke production and efficiency loss. Chimneys, typically of large thermal mass, remain hot after the burner goes off. Off-cycle draft then continues to pull cool air through the heating unit, removing some of its stored heat. Studies at Brookhaven (Batey et al. 1979) and other research agencies have found that off-cycle heat loss can increase annual fuel use by 15% in some systems.

A second important source of chimney-related heat loss is the dilution air required for draft control. Typically, a barometric damper is installed that automatically admits cool room air into the exhaust flue to maintain a constant chimney draft. This air (and the combustion air) is often taken from heated building space and replaced by infiltration of cold outdoor air. In the majority of in-place systems, a minimum temperature of about 300 to 350 °F is required to produce adequate chimney draft for proper venting, and also to prevent corrosion damage from flue gas condensation. Use of chimneys is therefore a strict limitation on possible equipment improvements such as condensing or pulse combustion operation. Furthermore, in addition to the technical problems involved in developing alternative venting systems, there are strict safety codes and other institutional barriers that will have to be overcome or taken into account. The extent of these barriers is not fully specified at present, although a brief review has been undertaken at Brookhaven.

Fuel Quality

Fuel oil properties and their degradation during storage can have an important impact on fuel atomization, vaporization, and combustion, in turn directly affecting thermal efficiency and pollutant emissions. The current standard for fuel oil properties is the ASTM D-396 specification for fuel oils. This standard sets acceptable limits for many key performance and physical properties of fuel oil produced by oil refiners for use in residential and commercial heating equipment. Variations from these standards can cause burner performance problems. Fuel quality degradation during storage in residential and commercial fuel tanks can also produce problems that include losses in heating system efficiency because of contamination by water or biological agents or because of sludge formation. These effects can range from efficiency degradation to equipment malfunction and breakdown. Industry concerns regarding fuel quality have indicated a negative trend in some key fuel oil properties including stability. This is becoming a major issue to the industry because of the potential for sludge formation and resulting problem in fuel burning efficiency and cleanliness.

Some key fuel properties that affect efficiency are listed below.

- Viscosity indicates resistance to flow. Increased viscosity can cause the production of larger droplets by pressure atomizing fuel nozzles, which in turn contributes to smoke formation and lower efficiency.

- Distillation temperatures affect the temperatures at which the fuel oil components vaporize. Higher distillation temperatures can contribute to incomplete combustion and smoke formation. Fuel volatility can also affect efficiency, because generally, higher volatility fuels have lower density thus lower volumetric energy density. Fuel volatility is best measured by distillation.

- Pour point is a measure of the temperature at which the fuel stops flowing. High pour points can cause serious problems for above-ground fuel tanks that are subjected to low outdoor temperatures. Cold oil contributes to atomization problems and smoke production.

Equipment Installation and Maintenance

Oil-fueled equipment installation and maintenance are typically performed by heating oil distributors. As they are small, independently owned businesses, the typical level of technical sophistication is very low. Technical training programs within industry have focused on safe and reliable operation of the equipment. One case of carbon monoxide poisoning from poorly installed or adjusted equipment can ruin an oil distributorship. Because of this, energy efficiency and the role of installation and maintenance in achieving it are often poorly understood. This problem will be compounded by the more sophisticated and possibly more exacting equipment needed to achieve significant performance improvements.

3.3 Oil Heat Research Objectives

The research objectives included in this section cover a wide range of opportunities to advance oil heating technology through research and development programs. These objectives are typically general in nature, such as *improved reliability* of oil heating equipment, but also include specific equipment advances such as *self-adjusting oil burners*. A brief description of each follows:

Improved Reliability: This can include advances in fuel quality, fuel filtering, burner design, heating equipment design, and in-home equipment monitoring that reduce the frequency of equipment breakdowns and permit longer time intervals between service calls. This is important so that oil equipment can compare favorably with other home energy sources in the future and provide homeowners with long term high-efficiency performance with lower maintenance requirements.

Reduced Equipment Service Costs: Equipment service costs can be reduced by using advanced service tools and service methods and by developing new burners, and heating equipment that are easier to service. Lower service costs can help improve customer satisfaction.

Advanced Diagnostics and Service Tools: These advances can include: field devices to diagnose problems and guide service technicians such as: *electronic smoke meters*; advanced *combustion test instruments* (such as a flame quality indicator); *hand-held computers* to assist burner servicing in the field; and *telecommunication links* that connect home equipment to oil service companies. These new tools can advance oil heat service into the 21st century.

Self Adjusting Oil Burners: Recent advances in burner design and flame sensing form the basis for oil burners that can perform some degree of self-adjustment in the field to permit continued safe, clean, and efficient operation before the in-home service can be supplied. This could revolutionize oil burner service methods.

Reduced Equipment Size and Cost: Advanced oil burners that are now under development can open the door for a new generation of reduced size and lower cost heating units that could include local space heaters, small side-wall vented appliances for heating, cooling, water heating, refrigeration, cooking and many other non-tradition thermal applications for fuel oil in homes. Reduced size and cost are two important features of these future oil appliances.

Higher Equipment Efficiency: Improved efficiency for oil equipment which can exceed existing and future gas and electric appliances is possible by developing and applying new oil heating technologies. This can lower operating costs for the consumer while enhancing the level of comfort provided by oilheat and reducing the environmental impacts associated with combustion emissions.

Improved Safety: Heating oil has always been one of the safest home energy sources, but advances to further improve safety may include, for example, guidelines for minimizing the risk of carbon monoxide exposure. Development of warning devices and equipment lock-outs can be an important part of oil heat R&D. New monitoring techniques (the flame quality indicator, for example) may offer the technical basis for improved safety with fuel oil.

Cleaner Burning Equipment: Over the past 3 decades smoke and soot emissions from properly adjusted oil burners has decreased by approximately 95%. Equipment advances to further reduce smoke during start-up and shutdown, and during off-design operation can improve the cleanliness of all oil systems. This is important to promote oil heat's image as a modern and premium home energy source.

Lower Air Pollutant Emissions: Modern oil burners produce very low air emissions when compared to most other home energy sources, but improvements are possible in lowering sulfur oxides and nitrogen oxides, for example, that may become important goals in the future for all energy sources. While oil equipment today compares favorably to natural gas, propane, and electric powered equipment, continued research is needed to develop new burner advances to reduce nitrogen oxides and other air pollutants. Federal and state air pollution regulations are moving toward lower emission requirements in the future.

Reduced Fuel Oil Odors: Lowering or eliminating fuel and combustion odors is an important goal for expanded oil use in the future especially in air tight energy-efficient homes where odors can linger. This can be especially important for expanded use of oil in air conditioning, refrigeration, cooking, and other household applications.

Venting: Advances in oil heating equipment venting and guidelines to assist equipment manufacturers and service technicians is an important goal of future oil heat research. It impacts efficiency, safety, and equipment cost especially for electric heated homes being converted to oil. Low cost venting systems are an important element for increased conversions to oil heat from electric heat and heat pumps, and for expanded use of current and future high efficiency oil boilers, furnaces, and water heaters that operate with extremely low exhaust temperature.

Increased Conversions To Oilheat: Oilheat is now one of the most efficient, economical, cleanest, and safest home heating sources, and new equipment advances can improve each of these areas in the future. One important objective of oil heat R&D is to convert homes from other energy sources such as electric heat, air-to-air heat pumps, and outdated gas heaters over to home heating oil. This will reduce annual energy costs, fuel use, and air pollutant emissions.

New Residential and Commercial Oil Applications: Innovative oil burner designs have demonstrated that fuel oil can be used for many applications in homes that include space heating, efficient water heating, cooling, refrigeration, cooking, and electricity generation. Some of these applications are now being developed and have been successfully demonstrated. Expanded uses for fuel oil for non-space-heating purposes can enhance oil heat businesses and help stabilize industry employment levels year round which now fluctuate seasonally.

Keeping Track of Electric and Gas Advances: Fuel oil competes against natural gas, propane, electricity and other energy sources for residential customers. It is important to monitor recent equipment advances by competing energy sources such as the geothermal electric heat pump and gas-fired heat pumps in terms of their strengths and weaknesses. Some of these advance may be applied directly or in modified form to oil fired equipment.

Equipment Adjustment - Guidelines and Training: One objective of an oil R&D program is to develop guidelines to assist with optimum servicing of existing and new oil heat equipment. These guidelines may include: distribution system design, venting system upgrades, water heating equipment selection, optimizing heating equipment/house interactions, and using new diagnostic procedures to improve system performance. Training programs can be established to educate service technicians.

Testing and Recommendation of Oil Heat Equipment Upgrades: An important service that Brookhaven National Laboratory has historically supplied is impartial "third party" testing of new equipment and evaluation of performance advances. This has included measuring efficiency improvements, calculating costs savings, and evaluating typical payback periods for new equipment. This remains an important function for future oil R&D programs.

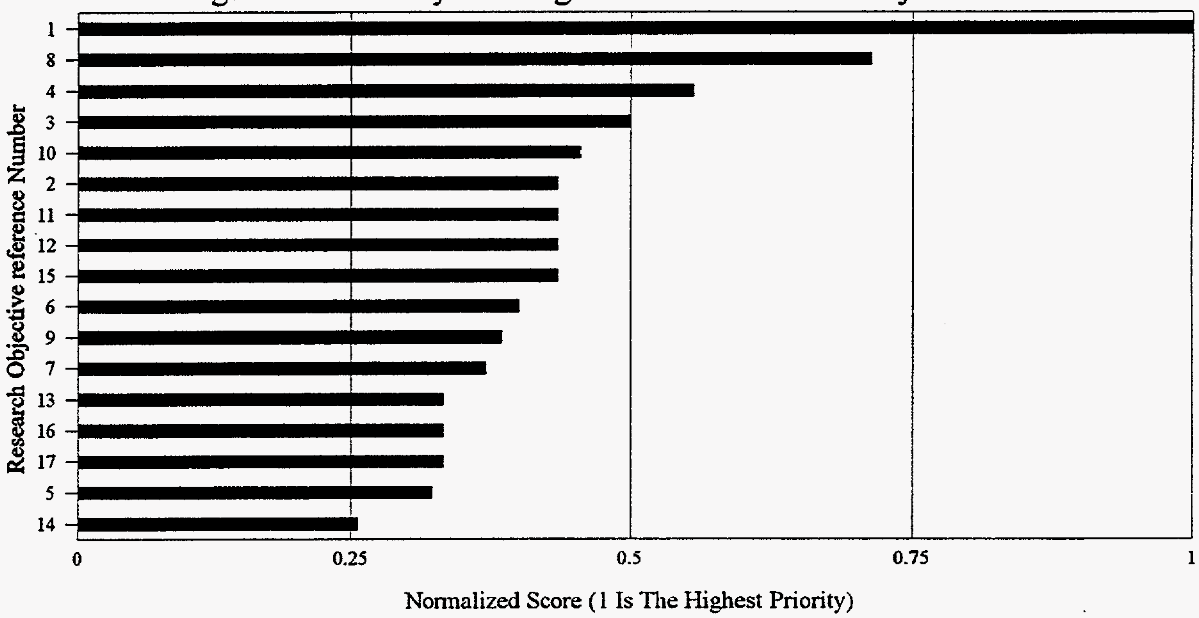
Technology Transfer/Oil Heat Information Center: One objective of oil R&D programs is to establish an organized way to distribute information on recent equipment advances, installation guidelines, and other technical information to all interested parties. This may include an "oil heat information center" which can serve as an oil heat information clearinghouse. This is a continuing need that increases as new oil heat technologies and guidelines for using existing equipment are developed.

3.4 Prioritization of Research Objectives

The preliminary list of oil heat research objectives was reviewed, modified, and prioritized by a series of workshops held with industry representatives at various conferences and trade shows during 1996. As part of those discussion, a survey asking individuals to prioritize the research objectives was disseminated. The survey was widely distributed to oil heat marketers, equipment manufacturers, and other interested parties. The survey was also published in a major oilheat industry trade journal, ***Fuel-Oil and Oil Heat*** Magazine. The survey results were returned to BNL and ERC for analysis with regard to prioritization of the research objectives.

Figure 3.2 is a bar chart of the normalized scores from the survey. The highest rated objective is #1 - **Improved Reliability** with a normalized score of "1". This is, in the opinion of the people who responded, the most important objective for future oil heat research to address. The second highest priority is research objective #8 - **Cleaner Burning Equipment** with a score of "0.714". Although particulate emissions have decreased by a factor of 20 over the past 20 years, cleaner burning equipment continues to be a high priority for the oil industry. The third highest rating was #4 - **Self-adjusting Oil Burners** and it had a normalized score of "0.556". The fourth

Figure 3.2 Industry Ranking of Oilheat Research Objectives



Research Objective Reference Number

1- Improved Reliability
2- Reduced Equipment Cost
3- Advanced Diagnostic Tools
4- Self-Adjusting Oil Burners
5- Reduced Size equipment
6- Higher Efficiency Equipment
7- Improved Safety
8- Cleaner Burning Equipment
9- Lower Air Pollution
10- Reduced Oil and Combustion Odors
11- Venting Improvements
12- Increased Conversions to Oil Heat
13- New Oilheat Applications: AC/Refrigeration/Cooking
14- Tracking Electric and Gas Equipment Advances
15- Equipment Adjustment Guidelines
16- Testing and Certification of Oil Equipment Upgrades
17- Technology and Oilheat Information Transfer

highest priority is #3 - **Advanced Diagnostic Tools** had a rating of "0.5". It is interesting that all four of the top rated research objectives are related to, or contribute to, improved equipment reliability. Cleaner burning equipment requires less frequent servicing; self-adjusting burners can extend the time between service calls and reduce and help improve burner reliability; and advanced diagnostic tools can improve service techniques and produce more reliable burner and heating system adjustment which contributes to improved reliability and reduces service requirements.

The fifth highest priority is objective #10 - **Reduced Oil and Combustion Odors**. This was an area that was added to the preliminary list after the first prioritization meeting held at the Oil Heat Conference at Brookhaven National Laboratory on March 29, 1996.

Four research objectives had the same normalized ranking score and share the sixth spot with regard to prioritization :

- # 2 - **Reduced Equipment Service Costs**
- #11 - **Venting Improvements and Guidelines**
- #12 - **Increased Conversions to Oil Heat**
- #15 - **Equipment Adjustment Guidelines**

These four objectives are related to the application of existing and new technologies to increase oil markets, and improving the performance of existing technologies. These include venting systems upgrades, equipment adjustment guidelines, and reduced equipment service costs. In contrast, the first four priorities primarily refer to new equipment that is more reliable, cleaner burning, and self-adjusting and to new advanced diagnostic instruments. This demonstrates that improving the performance of existing oil heating equipment is a high priority.

The next highest rated research objectives are seventh - **Higher Efficiency Equipment**, eighth - **Lower Air Pollution**, and ninth - **Improved Safety**. These are lower in priority because substantial progress has been made in all three of these areas in the past 10 to 20 years. The efficiency of oil boilers and furnaces has steadily increased so that Annual Fuel Utilization Efficiency ratings are now typically in the low to above mid-80% range. Dramatic revisions in equipment design such as oil-fired heat pump systems (which extract heat from the outdoor air or ground sources) and other non-conventional approaches are needed to break through to substantially higher space heating efficiencies. The environmental emissions are relatively low, with particulate emissions from properly adjusted modern oil burners in the range of 0.003 pounds per million BTU which is comparable to gas heating equipment. Oil equipment has typically performed safely with low risk of fire, explosion, and carbon monoxide exposure. Furthermore, new flame monitoring advances such as the Flame Quality Indicator developed by the DOE/BNL Oil Heat R&D Program can further improve safety.

The next three research objectives evaluated by the survey respondents received equal normalized scores (again) and share the tenth priority in the ranking list:

- #13 - **New Oil Heat Applications**
- #16 - **Testing and Certification of Oil Equipment Upgrades**
- #17 - **Technology Transfer and Oil Heat Information Programs**

While **Increased Conversions to Oil Heat** shared, along with three other research objectives, the sixth level in the ranking, **New Oil Heat Applications** which includes equipment innovations to produce air conditioning, cooking, electricity generation, and other residential and commercial energy uses shared in the tenth place of the ranking with two others. Therefore, improving and expanding the use of existing oil heat technologies appears to be more important to respondents. Perhaps new applications are viewed as a longer-term priority while expanding oil markets using existing technology is viewed as a near-term objective. The research objectives **Testing and Certification of Oil Equipment Upgrades** and **Technology Transfer and Oil Heat Information Programs** which also shared the tenth place in the ranking have both been part of the important services supplied by the U.S. Department of Energy through BNL over the past two decades. These are on-going activities that do not represent new technology developments, but help demonstrate the advantages of oil equipment innovations and begins to transfer this information to the fuel marketers and the public.

The research objective ranked in the eleventh level was **Reduced Size Equipment**. This is not perceived as a particularly important objective by the industry representatives that responded.

The twelfth and lowest rated objective was **Tracking Electric and Gas Equipment Advances**. While this may not be highly rated on it own, it may ultimately be an important task in achieving the other objectives by permitting oil equipment manufacturers to borrow innovations that have been developed for other home energy sources. For example, gas-fired heat pumps are under development that can substantially increase overall efficiency, and it is possible that oil powered heat pumps using similar technologies can be advanced. Advances in gas boiler and furnace design may be adaptable to oil firing when new low firing rate oil burners are available.

Summary of Industry Survey

A final summary of the ranking of the research objectives as determined by analysis of all the individuals responding completely to the industry survey is presented in Table 3.1 on the next page.

Summary Table 3.1

Industry Survey -- Ranking of Research Objectives

Rank	Objective #	Research Objective
1	#1	Improved Reliability
2	#8	Cleaner Burning Equipment
3	#4	Self-Adjusting Oil Burners
4	#3	Advanced Diagnostic Tools
5	#10	Reduced Oil and Combustion Odors
6	#2	Reduced Equipment Service Costs
6	#11	Venting Improvements and Guidelines
6	#12	Increased Conversions to Oil Heat
6	#15	Equipment Adjustment Guidelines
7	#6	Higher Efficiency Equipment
8	#9	Lower Air Pollution
9	#7	Improved Safety
10	#13	New Oil Heat Applications
10	#16	Testing and Certification of Oil Equipment Upgrades
10	#17	Technology Transfer and Oil Heat Information Programs
11	#5	Reduced Equipment Size
12	#14	Tracking Electric and Gas Equipment Upgrades

4.0 Program Elements and Research Areas

The goal of the oil heat research and development program is to accomplish the research objectives that were prioritized in the previous section by working on a comprehensive range of research areas and projects. The discussions that follow outline specific research areas and projects that are needed to achieve the objectives which are based on past and on-going research at BNL.

The research areas are separated into 10 functional groups that range from fuel properties and fuel quality to advanced diagnostic tools and system engineering and integration. The ten research elements areas are:

- Fuels and Fuel Quality
- Control Advances
- Equipment Diagnostic Tools
- Venting Systems
- Oil Combustion and Burners
- Heat Transfer Advances
- New Applications for Oil - Residential/Commercial
- Heat Distribution Systems
- System Engineering and Integration
- Information Transfer and Education

A brief description of specific projects envisioned for each of these general areas is included in this section of the plan. While many of these areas are inter-related, each will be described individually.

4.1 Fuels and Fuel Quality

This research area includes specific near-term projects to investigate the impact of varying fuel properties and fuel quality degradation during transportation and storage on the combustion process and burner/heating system performance. Recent discussions with residential fuel oil marketers and equipment service groups have indicated that fuel properties and fuel quality problems may account for up to one-half of all service calls in homes. Fuel properties that may impact burner performance include: sulfur content, fuel additives, dyes, cold flow characteristics, viscosity, fuel aromatic content, fuel component distillation ranges, and microbial growth and sludge formation in fuel tanks. Existing fuel specifications may not be able to adequately track and restrict fuel changes that can effect performance.

The **objectives** of research and development activities in this area primarily focus on improving the performance of existing oil heating equipment and include:

- Quantify the effects of various fuel properties and changes in fuel quality on the performance and reliability of oil burners including older models, conventional flame retention burners, and new alternative oil burners that may include innovative design features for a wide range of field conditions

- Identify solutions to fuel quality problems related to revised fuel specifications, fuel additives, fuel storage methods, fuel processing, and fuel handling techniques

- Fully test solutions and combinations of solutions to fuel quality problems in the laboratory and the field, and establish technical guidelines.

Specific work activities include the following project areas:

- BNL will actively participate in the ASTM Subcommittee responsible for the specifications applied to fuel oils, D-396.

- Laboratory and field testing of the effect of various fuel properties including aromatic content, viscosity, distillation range, sulfur content, dye content, and cloud point on burner performance including nozzle and filter fouling and smoke, soot, and coke formation rates during start-up, shut-down, and steady operation.

- Study the effects of field conditions on fuel quality. Perform a large scale survey of the extent of tank sludge problems in the field in a coordinated effort with oil marketers and service technicians correlating with service call frequency and cost to the industry. Include issues associated with severe winter conditions on cold flow and wax formation properties. Revise current bench top methods and/or establish new methods for determining cold fuel properties appropriate for on site field evaluation and selecting corrective actions. Investigate and report on current field experience and practice concerning fuel additive use and/or misuse.

- Perform fundamental study of the causes of sludge formation to compliment the study of field effects on sludge formation.

- Effects of fuel handling and fuel storage methods on fuel quality including fuel stability, cold flow characteristics, combustion performance, tank sludge formation, microbial and water contamination, identify and fully evaluate alternate fuel storage methods. Develop on-site field test method for simple quantitative evaluation of microbial spoilage of fuels including guidelines for sampling, testing, and interpretation of results. Develop a code of practice for dealing with microbial contamination and potential remedies and handling of tank sludge.

- Study the effects of fuel additives on sludge formation, fuel stability, cleanliness, fuel filter fouling, combustion characteristics, and corrosiveness of flue gases. Develop laboratory methods and criteria for testing additive effectiveness and coordinate large scale, long term testing of products under actual field conditions with the essential participation and monitoring support of the oilheat industry. Establish an industry database and guidelines based on both laboratory testing and statistical field test application information of various market products.

- Monitor, and investigate when appropriate, trends in Europe regarding alternative diesel fuels. Evaluate the long term effects on storage and combustion performance of alternative fuels and conventional- /alternative fuel blends including ultra-low (0.01%) sulfur products and bio-diesels fuels produced from non-petroleum sources (example: soy bean oil). Issues to investigate include heating content variations, lubricity, fuel stability, and additive effects.

- Investigate options for fuel odor neutralization mechanisms.

- Participation and support of cooperative work with other research and standards organizations regarding fuel quality issues including the US ARMY Fort Belvoir Fuels and Lubricants Research Facility, the International Association for Stability and Handling of Liquid Fuels, and ASTM (D-396) to develop and use revised fuel specifications for improved burner performance and reliability.

4.2 Control System Advances

The development of new oil burners and heating equipment offers the opportunity for innovative control components and systems that fully utilize the advanced performance features of the new equipment. Burner and equipment advances combined with the availability of low cost electronic sensors and components provides the basis for important control system advances.

The **objectives** of this research area includes:

- Develop new control concepts, components and system advances that improve the safety, reliability, efficiency, and image of existing oil heating equipment and developing technologies, and test these advances in laboratory and field environments.

- Work with manufacturers to develop, commercialize, and distribute control system advances for both existing and new oil burning equipment.

Specific work activities include the following project areas for both existing and new oil burning equipment:

- Incorporation of the flame quality indicator into conventional oil burner controls and expansion of field diagnostic functions as an original equipment component and as an upgrade to existing burners.

- Automatic adjustment of burner fuel-to-air ratio to extend service intervals and to correct for changes in ambient conditions that impact the combustion process thereby reducing smoke and soot production by the burner.

- Automatic burner shut-down by elevated smoke, carbon monoxide levels, or other undesired exhaust gas to improve burner safety and reduce service costs.

- Burner safety sensors and controls to prevent operation during unsafe conditions such as house depressurization or vent system back drafting.

- Ventilation air controls for central heating equipment or zoned heaters using ambient carbon dioxide monitors or other air quality sensors to regulate fresh air supply to house through the warm air furnace or an outdoor air ventilation system.

- Furnace air modulation controls to vary the furnace air flow rate for zoned heating systems for maximum efficiency and comfort.

- Computer-based heating ***system*** controls that optimizes operation based on the thermal dynamics of all heating system components including the house, boiler/furnace, distribution system, outdoor air temperature, and other key variables.

4.3 Equipment Diagnostics and Service Tools

The reliability, efficiency, and cleanliness of conventional and future oil heating equipment could be improved and the service costs could be reduced by developing new diagnostic and service tools that can assist oilheat service technicians. These advanced tools may include: ***flame quality indicators*** to electronically monitor combustion conditions including smoke levels; ***electronic smoke meters*** for service technicians to replace the outdated filter paper method developed more than 40 years ago; and ***hand-held notebook computers*** to assist service technicians to quickly and accurately diagnose and correct equipment problems similar to the way technicians now service automobiles.

The **objectives** of research and development activities in the area of diagnostic and service tools include:

- Develop and test advanced diagnostic methods and tools that can be used by oilheat service technicians to: reduce service time and costs; improve equipment adjustment procedures for better reliability and increased service intervals; produce in-field guidance for technicians using hand-held computers and other diagnostic and service aids.

- Work with equipment manufacturers to produce advanced diagnostic tools and test equipment for oilheat technicians to assist with equipment servicing and increased sales of advanced oil heating equipment.

- Develop sensors (e.g. the flame quality indicator) and other advanced diagnostic instruments that are capable of electronic telecommunication with oilheat service companies to enable continuous monitoring of oil heating systems.

Specific work activities include the following project areas:

- Electronic smoke meters that quickly and accurately measure smoke levels to allow rapid and precise oil burner adjustment in the field.

- Develop a reliable, rugged, and easy to use oxygen measurement device for stack gas efficiency analysis.

- Hand-held notebook computers that are programmed with service procedures and diagnostic methods to help service technicians to identify and correct burner and system related equipment problems quickly and accurately using data entry in the field.

- Advanced oil burner tune-up instruments (e.g. modified flame quality indicators) for accurate burner servicing and for supplying input to hand-held computers for heating system diagnostics.

- New concepts for electronic monitors or out-of-adjustment indicators for oil burners.

- **Low cost** flame quality indicators to improve burner service methods and to permit continuous monitoring of the burner.

- Electronic fault sensors that are built into the heating equipment or are part of the ***diagnostic package*** used by service technicians that may include: flame performance, flue gas temperature, smoke and soot emissions, elevated carbon monoxide levels, oil filter pressure drop, heating equipment pressure drop, house depressurization, fuel flow rate changes, and other important operating variables.

- Telecommunication links between the equipment in homes and commercial buildings and the oil service company so that service can be supplied as needed.

- Fuel quality sensors that indicate the onset of fuel-related problems before equipment performance degrades.

- ***Heating system*** test procedures (within the hand-held computer) that evaluate the entire system from fuel storage to venting components and recommends upgrades that may range from installing a new oil burner to venting system improvements.

- Diagnostic tools for field use that measure and evaluate chimney performance and recommends upgrades.

- Standardized heating equipment efficiency tests and computations that predict fuel savings, cost savings, and payback periods for a range of equipment upgrades to promote sales of new oil heating equipment.

4.4 Venting Systems

Venting systems remove the products of combustion from houses and buildings and have a direct impact on *safety*, *reliability*, *efficiency*, and *cost* of residential heating systems. Chimneys continue to be the most common method for venting oil heating equipment, but they produce several important disadvantages. These include: safety concerns for deteriorated chimneys, performance variation as outdoor air temperature changes; incompatibility with high efficiency heating equipment with low flue gas temperature; increased off-cycle heat losses and lower efficiency; and high installation costs which can limit conversions to oilheat. Alternatives to chimney venting that include power sidewall exhaust and other options are required to meet the needs of both existing and new oil heating equipment.

The **objectives** of oil equipment venting research and development activities include the following:

- Identify a range of ***venting options*** for existing and future oil heating equipment and expand computer-based venting system models to evaluate their performance.

- Conduct comprehensive ***field studies*** to: identify and measure the extent of chimney problems; test venting models that were developed for oil heating equipment; evaluate guidelines for improving chimney performance; and test alternative venting systems.

- Conduct ***laboratory testing*** to validate the computer models and measure the effect of key variables including materials and design on chimney and alternative venting system performance and lifetime.

- Develop new ***diagnostic tools and methods*** for evaluating venting system performance and recommend guidelines for their use by service technicians.

Specific work activities include the following project areas:

- Identify a range of alternatives to conventional chimney venting including: sealed combustion, power sidewall venting (forced draft and induced draft), chimney liner inserts, relined chimneys with induced draft or forced draft fans, and other options.

- Continue to develop computer-based venting models that accurately evaluate the dynamic performance of conventional chimneys, chimney liners, induced and force draft vents, and the full range of venting options

- Use venting model to develop expanded tables for service technicians that include recommendations for masonry chimneys, chimney lining systems, power sidewall venting, power chimney venting, and other options as a function of height, flue connector length, number of elbows, and other key variables

- Field studies to: establish a database on the condition and performance of lined and unlined chimneys; to identify problems with deterioration with age and operating conditions such as low flue gas temperature; and to validate and/or revise computer venting models

- Field studies to establish chimney inspection checklists and remediation actions to improve the performance and lifetime of chimneys and alternative venting systems

- Develop diagnostic tools to evaluate the performance of chimneys as part of annual service that may include: manometers to measure draft and house depressurization, temperature measurements of the heating equipment and chimney, calculators to compare actual and theoretical draft, testing protocol for identifying chimney problems, and guidelines for recommended actions to improve the venting system

- Laboratory studies to test chimney designs for a range of key variables, identify venting problems, study problems observed in the field in more detail, and assist with validating the computer venting model and recommended guidelines

- Laboratory and field studies of materials for chimneys and venting system for improved performance and lifetimes including corrosion-resistance and non-metallic materials

- Supply technical support to the National Fire Protection Association, American National Standards Institute, and other groups that produce installation standards for oil heating equipment

- Develop improvements and guidelines for sidewall venting systems to reduce problems

- Develop low-cost chimneys, prefabricated chimneys, liners, and venting systems for oil heating equipment

- Formulate venting recommendations and guidelines for converting electrically heated homes to oilheat including adaptation of new oilheat venting methods

4.5 Fuel Oil Combustion and Burners

Research on fuel oil combustion and burners can be separated into two parts: 1) Improvements to conventional oil burning equipment, and 2) Development of advanced oil burners that can improve efficiency, cleanliness, safety, and lower air pollutant emissions, and open the door to a new generation of oil heating equipment and new residential applications for fuel oil. These are applied combustion projects that focus on equipment development and advancement as a goal instead of more detailed understanding of fundamental combustion processes. However, some of the physical and chemical process such as fuel atomization, fuel air mixing, droplet vaporization, and chemical processes (including formation of air pollutants) may be included in this research.

The **objectives** of the fuel oil combustion and burner research program include:

- Advancing the technology of conventional oil burners to improve reliability, improve cleanliness, minimize combustion process related air emissions and expand the application of oil burners to existing new boiler, furnace, and water heater designs.

- Strengthen the ability to effectively, cleanly, and reliably burn fuel oil with a wide range physical and chemical properties, including fuel that has been degraded during storage.

- Developing new oil burner designs that can improve the performance of existing oil boilers and furnaces and also provide the technical basis for a range of new applications for fuel oil that may include: reduced size space heaters, cooling, refrigeration, cooking, electricity generation, and other energy-related functions.

Specific work activities include the following project areas:

Combustion research on conventional and new oil burner designs that will develop a better understanding of key oil burner processes including:

- Fuel atomization techniques; including pressure, air, ultrasonic, sonic, pre-vaporization, jet impaction, pre-filming, and pre-foaming approaches that may produce improved burner performance.

- Size and velocity profile flow mapping of oil droplets and burner air flows to evaluate new atomizing methods and study off-design operation including partially plugged fuel nozzles.

- Mixing of combustion air with fuel droplets/vapor including the impact of recirculation patterns within the flame and other key fuel-air mixing processes.

- Studies to characterize fuel-air mixing rates, combustion intensity, excess air, radiative heat transfer, combustion gas recirculation, and other controlling variables on nitrogen oxide formation rates to help modify both conventional and new oil burner designs for low NOx emissions.

- Computational fluid dynamic studies of cold and hot flow for better burner design and reduction of nitrogen oxides and other air pollutants generated by the flame.

- Effect of fuel properties, chemical composition, and burner design features on particulate, smoke, soot and coke formation for a range of atomizer and burner designs.

- Effect of refractory materials in the combustion zone on burner performance including the formation of carbon, carbon monoxide, incomplete combustion products, nitrogen oxides, and efficiency (excess air requirements); and evaluate tradeoffs in performance.

- Low firing rate oil burners including such features as: low excess air, variable firing rate capability, high efficiency, low smoke and soot, and low air emissions; and compatibility with new applications for fuel oil.

- Investigate the potential for radical departures from conventional oil burner design approaches specifically including pulsed and catalytic burners.

- Host a continuing series of oil combustion technology research seminars for equipment design engineers and other researchers to provide a forum to discuss and exchange new information and research techniques being used in ongoing oilheat research and development efforts throughout the industry.

4.6 Heat Transfer Advances

Oil boiler and furnace design advances have occurred over the past 10 to 15 years that include low mass boilers, furnaces and boilers with extended heat transfer areas for improved efficiency, and higher pressure drop heat exchangers with improved heat transfer rates. At the same time, gas-fired equipment has been developed which includes many innovative concepts such as pulsed combustion boilers and furnaces, heat pipe furnaces, and variable firing rate heaters. The availability of advanced oil burners which feature load matching lower firing rates and soot-free operation should allow some of the promising heat exchanger advances that were developed for gas appliances to be used for oil equipment also. This can open the door for a wide range of new and retrofit applications for oilheat based on new burner and heat exchanger designs. Some of the key features of new heat exchangers for oil heating equipment may include the following: reduced size, chimney-less venting, improved heat transfer rates and high efficiency, lower heat output rates, improved reliability, lower maintenance requirements, and lower equipment and installation costs.

The **objectives** of the heat transfer research and development activities may include:

- Identify, develop, test, and evaluate advanced heat transfer methods for oil heating equipment that achieve the goals of reduced size, direct venting, enhanced heat transfer rates, low cost, and other key criteria that will be established at the start of the research program.

- Materials research for reduced heat exchanger soot and scale fouling, and development of high efficiency **condensing** heat exchangers with extended lifetimes.

- Work with equipment manufacturers to develop and produce prototypes and demonstration models of advanced heat exchanger for laboratory and field testing that are technically and economically viable for residential applications.

This research to develop advanced heat exchangers will be coordinated with the work on oil burner advances.

Specific work activities include the following project areas for both conventional and advanced oil burners:

- Corrosion and fouling resistant heat exchanger designs and materials.

- Research on oil burner-heat exchanger compatibility including the effect of radiative heat transfer rates and combustion performance.

- Compact heat exchangers for boilers and furnaces that operate with higher heat transfer rates and efficiency coupled with reduced size and mass as compared to conventional boilers and furnaces.

- Optimally designed heat exchangers for use in equipment packages for conversion of homes heated by electric heat pumps

- Optimally designed heat exchangers for use in equipment packages for conversion of homes heated by electric furnaces or electric baseboard

- Compact oil fueled space heaters for homes, apartments, and other applications.

- High efficiency hot water heaters that are stand-alone or integrated into the space heating equipment system.

- Heat exchangers and heat recovery units for engine-powered equipment that may include heat pump operation, electric power generation, space heating, and water heating.

- Condensing heat exchanger design and materials research.

- Heat pipe exchangers that can enhance heat transfer rates and reduce equipment size by applying technology developed for the space program and modified for use by the gas industry for space heating.

- Direct contact exchangers that allow combustion gases to flow directly through the transfer media (air or water) for enhanced heat transfer rates and higher efficiency.

- Pulsed combustion oil boilers and furnaces that operate with enhanced heat transfer rates and lower nitrogen oxide emissions using advanced clean burning oil burners for reliable and low maintenance operation.

- Pulsed flow heat exchangers that apply the heat transfer enhancement of turbulent pulsed flow using steady (non-pulsed) oil combustion.

- Investigate acoustically enhanced heat exchangers.

4.7 New Applications for Fuel Oil - Residential and Commercial

Fuel oil use in residential and small commercial applications in the past has been limited by the size of the flame produce by conventional pressure atomizing nozzles which typically cannot reliable operate below one-half gallon per hour (approximately 70,000 BTU per hour input). Recent developments in fuel oil atomization which include air-atomizing nozzles now permit fuel oil to burn efficiency and cleanly at firing rates as low as 500 BTU per hour. In fact, the US government is now developing many new applications for distillate fuel oil in military applications that include tent heaters, refrigerators, cooking appliances, lighting, electric power generation, and other non-conventional uses for distillate fuel oil. These are based on innovative oil burners. Many of these new uses for fuel oil may also be applied to residential and commercial applications. These oil burning advances can open the door for a new generation of reduced size oil heating equipment and many other uses for oilheat in the future.

The **objectives** of this research program include:

- Near-term development of oil heating equipment and equipment packages to replace electric heat, electric heat pumps, outdated gas heaters, and electric water heaters.
- Longer-term development of other fuel oil uses in residential and commercial applications that include: reduced size space heaters, space cooling, refrigeration, electric power generation, oil powered heat pumps, cooking, and other applications.

Specific work activities include the following project areas:

Near-term projects:

- Oil heating equipment to assist or replace electric heat pumps in homes including a reduced-size and low cost ***booster boiler*** that can be sidewall vented with a heating coil that is installed in the existing heat pump duct-work.
- New low-cost oil boilers and furnaces that are designed for converting homes heated by electric baseboard or electric furnaces, including low-cost easy to install heat distribution components.
- Oil heating equipment ***package*** that is specifically designed for replacing outdated gas boilers and furnaces and include low cost: oil heater, venting modifications, and innovative fuel storage approaches.
- New low cost oil powered water heaters using advanced oil burners that are efficient and are specifically designed for replacing electric water heaters.

Longer-term projects:

- Oil powered cogeneration that produces electric power, space, and water heating with an engine-driven system applying research findings for gas-fired equipment.

- Heat pumps that are driven by oil fueled engines and supply heating and cooling at efficiencies higher than conventional space heating equipment, and that apply technologies that were developed for natural gas fired heat pumps.

- Oil powered air conditioning systems that use absorption refrigeration cycles that are optimally powered by new low firing rate oil burners.

- Oil powered refrigerators using an absorption cycle coupled with a very low firing rate oil burner which is sidewall vented.

- Oil fired cooking appliances including ovens and stoves that are powered by new low and variable firing rate oil burners that are clean burning.

4.8 Heat Distribution Systems

Past research has suggested that heat losses from the distribution ducts or pipes that transport warm air or hot water to the house can account for a substantial part of annual fuel use. Upgrades to distribution systems can be applied to both **existing** oil heating systems and to **new** houses during construction. Furthermore, these upgrades can be combined with other energy improvements (e.g. replacing electric heat pumps with an oil boiler) to produce better pay backs and returns on investment to homeowners.

The **objectives** of research in the area of distribution systems include the following:

- Develop standard procedures to evaluate "distribution system efficiency" for a full range of home heating fuels and system types; and evaluate and compare distribution systems.

- Identify and evaluate a range of upgrades for improving distribution system effectiveness including fuel conversions

- Develop guidelines for existing houses and new construction

Specific work activities should include the following project areas:

For upgrading **existing** heating systems:

- Test and validate proposed ASHRAE rating methods for oilheat distribution systems.

- Develop computer models of the dynamic performance of oilheat distribution systems.

- Develop, test, and validate test procedures for calculating "seasonal efficiencies" for pipe and duct systems that are appropriate for oil heating equipment.

- Investigate and evaluate the advantages of local space heaters.

- Study the distribution system for domestic hot water and recommend improvements.

- Formulate guidelines for improving distribution system design for existing and new installations.

- Establish guidelines for effective low-cost heat distribution methods for conversion of electric heated homes to oil heat.

For **new** oilheat equipment and heating systems:

- Identify and evaluate new concepts for residential heat distribution including, for example, fan-coil units for hydronic heating and cooling with lower boiler water temperature, and ducts located within the heated space.

- Evaluate benefits associated with and optimization of radiant heating concepts including radiant warm-air panels.

- Study options for ventilation air supply with zoned heat distribution to maintain a high level of acceptable indoor air quality.

- Identify optimum heat and domestic hot water distribution systems including options for new houses and commercial buildings and establish guidelines for their use.

- Develop, test, and validate rating methods for comparing heat distribution systems for new buildings.

4.9 Systems Engineering and Integration

While research projects often focus on individual system components such as burners, or venting equipment, this research area addresses the interactions of all the parts that comprise the heating system. This is an important because it looks at <u>system</u> problems such as burner/combustion chamber compatibility problems and other complicated system issues.

The **objectives** of research projects in the area of systems engineering and integration include the following:

- Develop an understanding of the interaction of all system parts that interact to improve overall system performance including reliability, low smoke production, minimum energy loss, maximum efficiency, and fuel use.

- Formulate design tools, rating methods, and guidelines for designing and installing heating equipment and heating systems with optimum performance and minimum costs.

Specific work activities include the following project areas:

- Studies to investigate noise mitigation and reduction options related to the oil burner, fans, pumps, system vibrations, system resonance, and distribution system dynamics.

- Studies of the interaction of combustion and heat transfer components from the start of the design process and development of design tools to avoid problems of burner/furnace mismatch which has been a problem in the past.

- Studies to investigate adapting heating appliances designed for gas burners to operate with conventional and advanced oil burners.

- Reliability improvement studies to identify key problems (e.g. fuel quality, venting, fuel nozzles) and recommend programs to improve component and system reliability.

- System dynamics studies that include formulation of computer models of burner/ heat transfer/venting/heat distribution/building structure interactions that can be used by equipment manufacturers; improve control strategies and devices; and produce revised equipment efficiency ratings for components and systems.

- Formulate guidelines for new construction and retrofit of oil heating equipment with optimum reliability, smoke levels, heat loss, and efficiency.

- Investigate potential and formulate design options for an in-home oil distribution system that would serve multiple oil-burning appliances through out the house (or commercial building) supplying oil from a single tank. Plan for early code committee involvement.

- Investigate integrated ***HVAC systems*** that incorporate heating, cooling, water heating, ventilation, air filtration, air humidification, air cleaning, energy storage, and other related functions into a single engineered and optimized appliance.

- Evaluate thermal storage media and applications for heating and cooling.

- Formulate optimum retrofit packages for existing oil systems and conversions to oil based on system dynamics computer models.

- Revised efficiency rating and labeling programs for each system component and the complete HVAC system.

- Laboratory and field studies to validate computer models and to identify modifications that are needed.

4.10 Information Transfer, Technical Training, and Education

A critical step in the application of new oilheat technologies is the transfer of technical and non-technical information about these advances to a wide range of groups including: oilheat equipment manufacturers, oilheat service technicians, oilheat companies, engineers and architects, home builders and contractors, real estate companies, and homeowners. This information transfer process is essential for general acceptance and use of advanced oilheat technologies by homeowners and it is needed for each of these research projects and research areas included in this plan. The basic approach of this activity is to provide general non-technical information to the public; technical information, diagnostic tools, and guidelines to service technicians; and engineering guidance for equipment manufacturers through a variety of media, training programs, demonstration projects, workshops, and other educational activities which include initiating a central clearing house for technical oilheat information. This task must be closely coordinated with NORA's plans for consumer education and industry training programs. The function of technology transfer within the research plan is to provide the technical basis for consumer information and industry training materials as required but certainly not supplant these efforts which are to stand on their own.

Specific work activities include the following projects in the information transfer, technical training, and education areas:

Primary Oilheat Research Technology Transfer Projects (BNL Lead Role):

- Design and initiate the ***OILHEAT HOUSE OF THE FUTURE*** demonstration project(s) that will showcase a range of new oilheat technology advances from new burners to integrated HVAC ***systems*** along with innovative heat distribution methods.

- As part of the *OILHEAT HOUSE OF THE FUTURE* a **Concept Heating System** would be designed and demonstrated. This would be a working model of all the best technologies conceivable. The purpose of the idea would be to provide a focal point for the public relations and facilitate technology transfer to the manufacturing sector. This could include such features as variable flow nozzle to optimize the duty cycle, side wall venting, reduced heat exchanger clearances for maximum heat transfer, variable over fire air, a self cleaning heat exchanger, and a complete computer monitoring system for oxygen and flue gas temperature measurement, indicating efficiency, flame monitoring, and feed-back controls for zoned temperature response, fuel flow, over fire, and self cleaning control.

- Continue the annual series of **BNL Oilheat Technology Conferences** designed for industry audiences ranging from non-technical groups (government agencies, code groups, building inspectors) to service technicians, service managers, and equipment manufacturer representatives.

- Provide documented research quality case studies of new oilheat technologies.

- Develop new construction guidelines for using oilheat *systems* for the building industry.

- Publish technical notes and technical bulletins for technicians and engineers regarding recent advances in oilheat technology.

- Produce burner and heat exchanger design handbooks for equipment manufacturers that summarize key results from the research program.

- Provide technical presentation at engineering association meetings regarding new oil heating technologies and equipment.

Secondary Oilheat Research Technology Transfer Projects (BNL Support to NORA):

- Provide technical information and support for consumer education programs that inform homeowners about the advances in oil heat technology and the benefits that are produced by installing new equipment.

- Provide technical support to oilheat outreach programs run by national, state and regional oilheat associations to architects and engineers, real estate companies, builders, building contractors, heating contractors, consumer groups and others indicating the benefits of advance oilheat equipment.

- Assist in developing oilheat technician training programs that include: technical manuals, training seminars, videotape programs, computer CD-based educational materials that include recent equipment advance, recommended installation service procedures, instructions on using new diagnostic and service tools, and how to explain these technology advances to homeowners and sell new equipment.

- Provide technical support advanced training programs for oilheat educators and service managers who can then educate service technicians.

- Cooperate in the development of prototype pilot workshops for service technicians on how to use new oil equipment, service tools, and service procedures.

- Start-up and operation of a central library and clearing house for technical and non-technical information on existing and new oil heating technologies in cooperation with other elements of NORA.

5.0 Initial Working Strategy for Establishing a Ten-Year Oilheat Research Effort

This report has outlined the nature of the research elements required to advance oilheat technology into the Twenty-First Century. The challenge is to establish a balanced program of research and development. A balance between developing new technologies for the future that will highlight and feature the full range of advantages associated with oilheat while at the same time resolving the issues and concerns associated with today's existing technology and industry infrastructure.

5.1 Starting Point for Ten-Year Schedule

The responses to the industry survey conducted by BNL have clearly indicated a high level of concern with issues that relate to reliability, maintenance, and clean operation of the existing technology and equipment. There are many areas of research that will help address these concerns. These include fuel quality research, control advances, equipment diagnostics-service tools, and venting research. The second level in prioritization of the work is associated with better understanding the basic concepts and principles that govern system operation and performance. These include oil combustion, burner design, and heat transfer leading to new oilheat applications and uses. The third level is understanding the way oilheat equipment works with the house and the environment as a system. The work in heat distribution and systems integration will result in realizing the full potential of new oilheat technologies as they are developed. All during the program there will be an important need for communication between the researchers, oil marketers, and equipment manufacturers to keep the research on track. This is the critical role of information and technology transfer. This effort will also be coupled with the other main NORA functions associated with industry training and consumer education.

The opinions and prioritization reflected in the industry survey (see Section 3.3) coupled with a strong need to evolve a balanced approach to oilheat research is reflected in the initial ten-year schedule as proposed in Figure 5.1 by BNL. This is an initial starting point for further discussion and as with any plan is subject to change and revision. The first working plan and schedule will of course reflect the more immediate goals, policies, and directions of NORA and DOE upon initiation of what is intended to be a jointly co-sponsored government/industry research program and subject to periodic revisions as the work progresses. Upon initialization of the program the first activity in each of the research areas will be a scoping effort to develop and write specific and detailed statements of work including; project goal, objectives, task/sub-task descriptions, human resource requirements, discussion of sub-contracting efforts when and where, appropriate, schedule, milestones, decision points, and budget requirements. This level of effort is beyond the reach of the current report and premature at this point in time. It is however an important step in the planning process which also will include dovetailing these individual projects into a cohesive long term program plan.

Returning to the initial ten-year schedule proposed on in Figure 5.1, a strong initial emphasis is planned to help improve current oilheat technology and practice in the field. There will be a major reinvestment in research related to fuel quality, field diagnostics, maintenance, venting,

Figure 5.1 Initial Ten-Year Plan for Oilheat Technology Development

Research Element	Program Year 1	2	3	4	5	6	7	8	9	10
1. Fuels & Fuel Quality										
- Fuel Properties Investigation	Intense	Intense	Medium	Medium	Medium	Little	Little	Little	Little	Little
- Field Experience Survey	Intense	Intense	Intense	Intense	Medium	Medium	Little	Little	Little	Little
- Develop Evaluation Techniques	Intense	Intense	Intense	Intense	Medium	Medium	Medium	Little	Little	Little
- Fuel Additive Research	Medium	Intense	Intense	Intense	Intense	Intense	Medium	Medium	Medium	Little
- Alternative Fuel Composition	Little	Little	Little	Little	Little	Medium	Medium	Medium	Intense	Intense
- Odor Neutralization	Little	Little	Little	Little	Medium	Medium	Medium	Intense	Intense	Intense
2. Controls										
- Develop Self-Tune Burner	Medium	Intense	Intense	Intense	Intense	Medium	Medium	Medium	Little	Little
- Incorporate FQI with Primary	Intense	Intense	Medium	Medium	Little	Little	Little	Little	Little	Little
- Enhanced Controls for Safety	Little	Little	Medium	Medium	Medium	Intense	Intense	Medium	Medium	Little
- Distribution System Controls	Intense	Intense	Medium	Medium	Little	Little	Little	Little	Little	Little
- Whole House *System* Control	Little	Little	Medium	Medium	Medium	Medium	Intense	Intense	Intense	Intense
3. Diagnostics and Service Tools										
- Electronic Smoke Meter	Intense	Intense	Intense	Intense	Medium	Medium	Medium	Little	Little	Little
- Electronic Diagnostic Notebook	Little	Medium	Medium	Intense	Intense	Intense	Intense	Medium	Medium	Medium
- Color Flame Adjustment Analyzer	Medium	Medium	Medium	Intense	Intense	Intense	Intense	Intense	Medium	Medium
- Chimney Inspection Devices	Intense	Intense	Intense	Medium	Medium	Medium	Little	Little	Little	Little
- Efficiency Improver Calculator	Medium	Medium	Intense	Intense	Intense	Medium	Medium	Little	Little	Little
4. Venting										
- Field Study on Venting Experience	Intense	Intense	Medium	Medium	Little	Little	Little	Little	Medium	Medium
- Laboratory Chimney Simulator	Medium	Intense	Intense	Medium	Medium	Medium	Little	Little	Little	Little
- OHVAP Applications Expansion	Intense	Intense	Intense	Medium	Medium	Medium	Little	Little	Little	Little
- Dev. Alternative Venting Options	Little	Little	Medium	Intense	Intense	Intense	Medium	Medium	Little	Little
- Vent Materials Assessment	Medium	Medium	Medium	Intense	Intense	Intense	Intense	Medium	Little	Little
5. Combustion & Burner Design										
- Technology Assessment	Intense	Intense	Medium	Little	Little	Little	Little	Little	Little	Little
- Atomization Research	Intense	Intense	Medium	Medium	Medium	Medium	Little	Little	Little	Little
- Air/Fuel Mixing Investigations	Medium	Medium	Intense	Intense	Intense	Medium	Medium	Little	Little	Little
- Burner Fluid Dynamic Modeling	Medium	Medium	Medium	Medium	Medium	Intense	Intense	Intense	Intense	Intense
- Burner Design & Trial Testing	Intense	Intense	Intense	Intense	Intense	Intense	Medium	Medium	Medium	Medium
- Burner Product Development	Little	Little	Medium	Medium	Medium	Medium	Intense	Intense	Intense	Intense

Intense Effort **Medium Effort** **Little Effort**

Figure 5.1 (continued) Initial Ten-Year Plan for Oilheat Technology Development

Research Element	1	2	3	4	5	6	7	8	9	10
6. Heat Transfer										
- Heat Transfer Design Assessment	Little	Little	Medium	Intense	Intense	Medium	Medium	Little	Little	Little
- Compact Heat Exchanger Design	Little	Little	Little	Medium	Intense	Intense	Intense	Medium	Medium	Medium
- Exchanger Process Enhancement	Little	Little	Little	Medium	Medium	Intense	Intense	Medium	Medium	Medium
- Materials Research	Little	Little	Medium	Medium	Intense	Intense	Intense	Intense	Intense	Medium
- Alternative Heat Exchangers	Little	Little	Little	Little	Little	Medium	Intense	Intense	Intense	Intense
- Corrosion Resistance	Medium	Medium	Medium	Intense	Intense	Medium	Medium	Medium	Little	Little
7. New Oil Applications										
- Elec. Heat Pump Oil-Pac	Medium	Intense	Intense	Intense	Medium	Medium	Little	Little	Little	Little
- Dev. Fuel Oil Heat Pump	Little	Little	Little	Little	Medium	Medium	Intense	Intense	Intense	Intense
- Oilheat Cogeneration	Little	Little	Little	Little	Medium	Medium	Intense	Intense	Intense	Intense
- Oil-Fired Cooking Range	Little	Little	Little	Little	Little	Medium	Medium	Intense	Intense	Intense
- Oil-Powered Refrigerator	Little	Little	Little	Little	Little	Little	Medium	Medium	Intense	Intense
8. Heat Distribution										
- Study House *System* Dynamics	Medium	Intense	Intense	Medium	Little	Little	Little	Little	Little	Little
- Dist. For Electric-Oil Conversion	Intense	Intense	Medium	Medium	Little	Little	Little	Little	Little	Little
- Evaluate ASHRAE Dist.. Labeling	Medium	Intense	Intense	Medium	Little	Little	Little	Little	Little	Little
- Distribution System Repair Guide	Little	Medium	Intense	Intense	Intense	Medium	Medium	Little	Little	Little
- Guidelines for Dist.. Sys. Design	Little	Little	Little	Little	Medium	Intense	Intense	Intense	Medium	Medium
9. Systems Engineering										
- Sys. Noise Mitigation/Reduction	Intense	Intense	Intense	Medium	Medium	Medium	Little	Little	Little	Little
- Construct. Design/Layout Tools	Little	Little	Medium	Intense	Intense	Intense	Medium	Medium	Little	Little
- *System* Design Approach	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
- Thermal Storage & Controls	Little	Little	Little	Little	Little	Little	Medium	Intense	Intense	Intense
- In-Home Oil-Distribution Sys.	Little	Little	Little	Little	Little	Little	Little	Medium	Intense	Intense
10. Technology Transfer										
- Oil-Heat Home of the Future	Intense	Intense	Intense	Medium	Medium	Medium	Medium	Medium	Medium	Medium
- Oilheat Conferences	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
- Oilheat Industry Out-Reach	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
- Technology Development Notes	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
- Documentation Oilheat Story	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
- Dev. Technical Training Materials	Medium	Medium	Medium	Intense	Intense	Medium	Medium	Medium	Intense	Intense

Program Year

Intense Effort **Medium Effort** **Little Effort**

and controls. Many of these areas cross over the boundary between developing more efficient technology concepts and getting the older ones to work better in the first place. Poor fuel quality by itself does not translate directly to poor efficiency performance, however, poor fuel quality can result in problems that when not detected or corrected results in poor efficiency, higher emissions, and more costly maintenance down the road. Solution paths include; improve and maintain fuel quality, prevent fuel quality degradation, detect and correct problems sooner, and design systems that are more tolerant to poor fuel quality. The answer is not a simple one and it requires research.

Prior to any major new ventures in developing still more advanced approaches to oilheat systems assessments will be conducted to determine where the technology of fuel burning needs to be directed in the future. The status of prior DOE funded programs will be documented and analyzed regarding current status in the marketplace, future viability, and need for additional research and support. When appropriate field demonstrations will be conducted to support concept introduction. New avenues for advanced concepts leading to product development will be investigated, paths not chosen in the past will be re-investigated. Developing entirely new approaches will take time. The initial effort must be planned carefully from the beginning. These areas will begin immediately but not at a intense level of effort, other areas with higher immediate priorities will be pushed forward first.

5.2 Technical Oversight

This report primarily addresses the technical agenda for future oilheat research. The details of actual program structure, budget, schedules, and formal management of the effort will be subject to NORA and DOE requirements assuming a jointly funded program evolves. However, there is one aspect of future program management that should be included from the very beginning, **technical oversight**. The current BNL program as funded by the U.S. DOE has employed a useful mechanism for keeping the work on track, by meeting on a regular basis with a technical advisory group comprised of voluntary and interested industry representatives. These include representatives from oil equipment manufacturers, service organizations, oil marketers, and other industry organizations. This group meets periodically to review the oilheat R&D program at BNL, discuss progress and issues, and provide their professional opinions regarding prioritization of follow-on efforts planned for the next year. BNL will certainly encourage the continuation of this mechanism under a joint future program co-sponsored by DOE and NORA. In the future the **Technical Advisory Committee** could be modified to more formally organize its structure and operation, and/or sub-divided into more clearly focussed sub-committees designed for each individual research area. The size and level of effort of the DOE current program does not warrant this degree of detail. The most important element is that a wide range of industry representatives address research results, plans, issues, and concerns early-on so that the research when completed is both beneficial and useful in the field.

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