

The Oilheat Combustion R&D Program – Stakeholders, Accomplishments, and Future Potential

The U.S. Department of Energy and Brookhaven National Laboratory (BNL) conduct an on-going program of R&D related to the efficient use of distillate oil in boilers, furnaces, direct-fired chillers, and integrated power generation equipment. This work provides for this diffuse industry a critical core resource for the generation of new technology, resolution of technical issues, and impartial evaluation of new concepts. This capability is a necessary tool to achieve improved efficiency, reduced air pollutant emissions, and increased reliability.

“The research at Brookhaven National Laboratory has been central to the advancement of clean and efficient oilheat.” “The work done at BNL on deposition rates with low sulfur fuels was indispensable to the development and acceptance by ASTM of a recent proposal to offer a cleaner-burning alternative to existing fuels.”

- Victor J. Turk, P.E., Director of Engineering, R.W. Beckett Corporation



Who Benefits?

Distillate fuels include No. 2 fuel oil, kerosene, and various forms of jet fuel. These middle distillate fuels hold an important place in the U.S. energy supply mix because they are available, economical, safe, and easily transportable. Currently the U.S. consumes 450 million barrels of distillate

fuel for non-transportation use annually. Of this 37.5 % is used in the residential sector, 17.8 % is used in the commercial sector, 44.7 % is used in industry. Roughly 9 million U.S. homes use No. 2 fuel oil and many of these are in the Northeast and Mid Atlantic regions. Beyond home heating, distillate oil is used widely in schools, offices, apartment buildings, and many other applications. In some parts of the country it is the only fuel available. In others it is used as a critical backup fuel. In New York, for example, many large buildings have dual fuel boilers, which fire gas when the temperature is high and switch to oil when the temperature falls below a set level. This capability provides an economic and practical balance. At present, concerns about

adequate gas supply heighten the importance of oil as a part of the supply mix. With increasing need for reliable supply of electricity and the benefits of distributed generation well established, high performance, oil-fired DG technologies are growing in importance for this program.



own.” “Overall NYS has benefited from many National research programs over the years, but in my opinion, none has provided as much direct value as BNL’s oil heat work.”

- Gunnar Walmet, Program Director,

Industry and Buildings Research and Development Program, New York State Energy Research and Development Authority

The distribution and marketing of oil and manufacturing of related equipment are significant U.S. industries, although the companies involved are typically small businesses. There are currently estimated to be 3200 heating oil marketers located in 30 states. The size of the oil equipment manufacturing market has been estimated to be well over \$600 million/year. The retail value of just the residential oil market is \$10 billion/year.

American manufacturers are under pressure from European companies where there has been a much greater level of investment in R&D for advanced technology.

Market History

Oil surfaced as a primary heating fuel in the 1940's and the 1950's, replacing coal furnaces, which required daily attention and maintenance. At the time, oil was seen as a modern, clean alternative to coal, which was much more difficult to store, often generated noxious fumes and resulted in ashes and cinder which the homeowners had to dispose of manually. The combination of the Gulf oil crisis of the 1970's, aggressive marketing by the natural gas industry, and the public's misconception of oil as old-fashioned and environmentally harmful, has led to a gradual decline in the percentage of U.S. households and commercial buildings using oil. Oil offers the consumer a product that compares very favorably with other energy sources. Modern oil combustion systems produce very low levels of environmental emissions. Oil combustion appliances typically offer 85% efficiency or higher. Due to its very high energy density, oil offers the option of storing up to a full year of energy on site, providing energy security. Oil is a commodity and has experienced temporary price spikes over the years, but oil has also been the lowest average priced energy option in the Northeast and Mid-Atlantic regions where oil use is most heavily concentrated. Building owners receive the best value when they choose oil as fuel source. The current and forecasted rising prices of natural gas coupled with its already high price and the traditionally higher prices associated with electric power all point to the viability of oil as an economical energy choice for many years into the future. It is also a very mobile source of energy, easy to transport and store unlike electric power which must be used as it is generated or natural gas which requires an infrastructure that can't respond to market forces in a timely manner and can take five to ten years as currently predicted in response to the shortage which continues to drive prices ever higher.

Industry Impact

The research at Brookhaven continues to be a proven and critical resource for the oil combustion industry and its market sector, illuminating the technology and issues that drive consumer decisions when it comes to energy choices for thermal comfort, water heating, and new choices for cooling technologies and distributed power generation. The advantages of employing efficient oil combustion technologies resulting from the program activities at BNL has already resulted in more than \$12 billion in accumulated consumer energy savings. Even the terminology used to describe how a system responds to dynamic load changes; "cyclic efficiency" and "seasonal efficiency" were coined at BNL. The flame retention head oil burner capable of saving 15% or more on annual fuel bills became the standard of the industry for residential heating applications as a result of BNL and its extensive evaluation, testing and technology demonstration efforts. The emissions associated with small oil combustion systems have also dropped significantly causing the US Environmental Protection Agency to re-evaluate published emission factors for this sector, dropping them to between one sixth and one seventh of the prior published level. EPA's reduction of the emission factors was in direct response to documented research conducted by BNL. Research in fuel technology has documented the advantages of new low sulfur content fuels which are now beginning to impact the fuel oil market and will be offered to consumers as a fuel that is much more friendly to the environment making further dramatic reductions possible.

Accomplishments

This on-going program has been involved in all aspects of this industry including applied combustion research; advanced application testing and development; outreach through conferences, publications, and training materials; cooperative projects with specific manufacturers; and participation in a wide range of industry organizations. Some specific advances, which have resulted in large part, from this program include:

- Real, measurable reductions in oil use per square foot – R&D conducted by BNL early-on in this program quantified and explained the efficiency benefits of key technical advances such as retention head burners, increased heat exchanger area, and low mass purging boilers. Some of these advances now totally dominate the market and a trend in reduced oil use per square foot of home living space has been well documented. This valuable technology evaluation role that BNL plays in providing independent third party engineering evaluations of emerging technologies is critical to all parties in terms of which technologies have true promise, which don't work and where manufacturers, marketers and consumers should invest limited resources to maximize efficiency and environmental benefits.

**Annual Fuel Consumption Trend
In Oilheat Consumer Households**



“The Energy Kinetics System 2000 product line is an example of the resulting successful commercialization efforts based on concepts documented by BNL. We look forward to the realization of further sustainable technological advances and their transfer to the broad residential, commercial and military sectors to support a cleaner environment, optimal fuel efficiency and economy of operation resulting from future BNL research in the science of oil combustion systems.”

- John Marran, President Energy Kinetics Inc.

- In the 1970s, concern with oil supply and price volatility increased interests in improving the efficiency of fuel oil use. DOE sponsored work by Brookhaven National Laboratory on the Oil Combustion Research and Development program, which established the energy conservation, benefits of several efficient technology advancements for oil burners, boilers and furnaces. Consumer savings were documented in a 1996 US GAO audit of several DOE success stories, which verified that more than \$5 billion in accumulated energy costs had already been saved as a result of the Oil Combustion R&D program. Today the accumulated savings exceeds \$12 billion.
- BNL conducted R&D on the impacts of fuel sulfur content on boiler and furnace heat exchanger fouling and efficiency degradation. This work was extended and confirmed by others cooperatively with this program. The result was a high quality argument for the benefits of reduced sulfur. As a result a new low sulfur ASTM heating oil standard has been established. Industry organizations are very enthusiastically promoting widespread use of low sulfur oil. Benefits of this include increased efficiency of conventional equipment, introduction of very high efficiency, condensing appliances; dramatic reductions in fine particulate emissions (PM 2.5 or “soot”); and, of course, reduced SO₂ emissions.

“Brookhaven National Laboratory's testing of effects of low sulfur oil (500 ppm) and its effects on heat transfer and clean burn technology is the most significant demonstration of the benefits and necessity of introducing this new product into the marketplace.”

- Peter J. Carini, Champion Energy Corporation

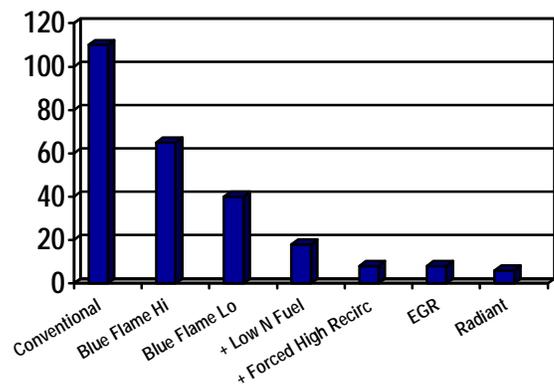
- Invention of a novel, optical concept for remote monitoring of flame quality. This concept received the R&D 100 Award, Popular Science Best of What’s New Award and the DOE Energy 100 Award. It has been licensed by DOE to Insight Technologies Inc. and the technology is now produced commercially by Honeywell, Inc.

“The ongoing Oil Combustion R&D program at Brookhaven National Laboratory has been the single most important venue for our company to bring leading edge relevant technologies to the market place.”
- Doug Davis, President, Insight Technologies, Inc.

- The US military forces also benefit from oil combustion research. The military is dedicated to the use of diesel fuel as the sole source of energy in all of its tactical ground applications. This simplifies the logistics of supplying fuel on a worldwide basis. Diesel fuel is the fuel of choice based on its global availability and its inherent safety when compared to mobile fuel choices. Diesel, obviously used in military vehicles, is also the fuel of choice for cooking, mobile facility heating, cooling technology and even lightweight single troop-portable power generation systems. An example of this is a tray ration heater produced for the US Marines, which is designed based on an oil combustion system originally developed for the BNL research program.

- One important aspect of the current work is reduced emissions of NO_x – a pollutant that contributes to ozone problems in the atmosphere. This program has completed important reviews on NO_x formation and relevant NO_x reduction methods. In very recent work technical steps required to achieve dramatic reductions in NO_x have been developed and levels under 10 ppm (a 90% reduction from current practice) have been measured. U.S. burner manufacturers are responding and expectations are that low NO_x options will start to be commercially available even on the residential scale in 2004.

Methods of achieving ultralow NO_x



- A wide range of technical contributions in other areas includes exploration of advanced modulation concepts, evaluation of the potential widespread use of domestic biofuels, and novel oil-combustor concepts for portable power generators for military and domestic use.

“The Oil Combustion Research Program at Brookhaven National Laboratory continues to supply critically important technology and research support to equipment manufacturers, consumers, and fuel marketers. It is one of the most impactful and successful programs ever undertaken by the US Department of Energy, an example of government/industry collaboration at its best.”
- John E. Batey, Technical Director, Oilheat Manufacturers Association

Technology Transfer, Reports, and Conferences for Industry

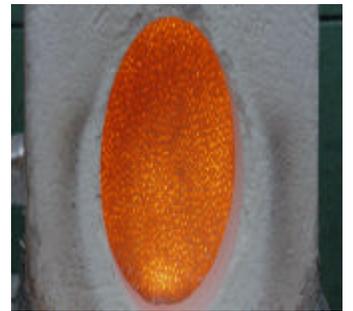
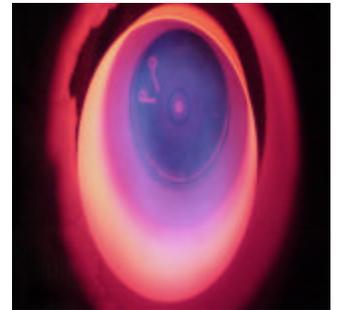
BNL has hosted fifteen major technical conferences to provide a platform for the exchange of information and perspectives among US, Canadian and international researchers, engineers, manufacturers, service technicians, and marketers of oil-fired equipment. These conferences provide a conduit by which information and ideas can be exchanged to examine present technologies, as well as helping to develop the future course for oil heating advancement. The objectives of these conferences are to identify and evaluate the current state-of-the-art and recommend new initiatives for higher efficiency, a cleaner environment, and to satisfy consumer needs cost-

effectively, reliably, and safely and secondly to foster cooperative interactions among federal and industrial representatives for the common goal of sustained economic growth and energy security via energy conservation. BNL takes this opportunity to report to industry the most recent BNL research and to invite other research institutions and members from the private sector to report on significant technology trends and developments. BNL has also produced over 110 technical reports and professional journal papers on subjects related to oil combustion technology in an ongoing effort to transfer the results of our research to the oil combustion industry where this research is put to use in new products, systems and industry practices to enhance efficiency and improve the environment.

Future Potential

Recently, a wide range of industry stakeholders worked with DOE and BNL to develop a detailed Roadmap for the future and research plan. Completion of this ambitious plan will ensure that we have oil as an available part of our supply mix, which meets higher expectations for efficiency and environmental performance, reliability, flexibility in supply and end use, and customer service. The goals will be achieved through industry cost-shared development projects with a core of technical support from BNL. Key aspects of this future include:

- Achieving the potential for ultrahigh efficiency heating equipment, direct-fired cooling equipment, and distributed power generation equipment through combustion R&D to develop economical concepts, which can operate under flexible conditions. This work involves basic concepts for modulation, advanced atomization development, burner aerodynamics R&D, and long term testing of condensing heat exchangers with low sulfur oil.
- Integrated system development – many of the technical advances, which have already been identified, can only reach commercial realization when packaged together. Industry teams will tackle this challenge and key aspects include low NO_x, modulation, actual efficiency performance in the field, load matching controls, and off-cycle energy management strategies.
- Advanced R&D on ultralow NO_x – prior work has shown how sub-10 ppm NO_x levels might be achieved. In this continuing R&D, by BNL with industry coordination, advanced methods such as fuel vaporization and porous media combustion will be developed to provide truly advanced future options.
- Development of sensor and control options to provide greater reliability and ensure that equipment operating in the field maintains high performance levels with great reliability.
- Improved fuels for end use applications. The formation of deposits in unstable fuels is a major concern for the industry at present. R&D will be conducted cooperatively with industry to reduce this problem and also to provide more fuel source options. Biofuels, for example, which are made from domestic vegetable oils, offer the potential for a partial replacement of imports by a sulfur-free, renewable source.
- Development of safe effective venting options which can enable a new generation of higher efficiency systems to be marketed to a broad base of consumers where the current use of high cost electric based heating systems fail to meet consumer expectations of affordable comfort while at the same time increasing demands on a national power grid that is marginal in its ability to satisfy load and distribute power to consumers. New venting technology options will also increase the number of top end high



efficiency system installations where current venting systems limit choices based on potential for condensation of combustion products and possible damage to the vent system integrity and safety.

Partners in a Cost Shared Program

The work defined in the Roadmap and is underway with sponsorship by DOE and other organizations including the New York State Energy Research and Development Authority; the National Oilheat Research Alliance; industry directly; and internal BNL funds (LDRD). The program works very closely with these organizations and industry on many different levels demonstrating a high degree of relevance. In FY 2003 direct DOE funding was 41% of the total oil combustion funding at BNL. The non-DOE sponsored projects exist because of the direct DOE funding and the maintenance of these capabilities at BNL.