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**Benefits and Advantages of Marketing Low Sulfur Heating Oil Including**  
**Results from a New York State Low Sulfur Market Demonstration**

**Roger J. McDonald**  
**Brookhaven National Laboratory**  
**Building 526**  
**12 North Six Street**  
**Upton, NY 11973**  
**Phone: 631-344-4197**  
**Fax: 631-344-2359**  
**E-mail: [mcdonald@bnl.gov](mailto:mcdonald@bnl.gov)**  
**Internet: [www.bnl.gov](http://www.bnl.gov)**

**and**

**John Batey, PE**  
**Energy Research Center, Inc.**  
**35 Fawn Rd.**  
**Easton, CT 06612**  
**(203) 459-0353**  
**E-mail: [erc@optonline.net](mailto:erc@optonline.net)**

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# **Benefits and Advantages of Marketing Low Sulfur Heating Oil Including Results from a New York State Low Sulfur Market Demonstration**

Roger J. McDonald, Brookhaven National Laboratory and  
John E. Batey, Energy Research Center Inc.

## **1.0 Introduction**

This paper combines a discussion of the benefits and advantages of marketing low sulfur (0.05% by weight) heating oil with recent results obtained in New York State, where this fuel has been marketed to over 1000 customers for the last three years. It contains a summary of findings discussed in an interim report for an ongoing project sponsored by the United States Department of Energy (DOE) and the National Oilheat Research Alliance (NORA). The results discussed in the interim DOE/NORA report document the advantages of marketing low sulfur heating oil. The report summarizes over ten years of research into the subject including work conducted at Brookhaven National Laboratory (BNL), CANMET Energy Technology Centre in Canada, the United States Environmental Protection Agency (EPA), the National Association of Oil Heat Service Managers (NAOHSM) and the New York State Energy Research and Development Authority (NYSERDA). It clearly lays out the case for the many advantages associated with the marketing of low sulfur content fuel including, environmental benefits, maintenance reduction advantages and business advantages. Results from the field study are included as experience has been gained by several companies including a New York State marketer who has been delivering this fuel to over a 1000 customers for the last three years. The field evaluation project is a joint effort conducted by Energy Research Center Inc. (ERC) and BNL and is sponsored by NYSERDA.

## **2.0 Background**

In the years leading up to 1991 when the heating oil industry first started to have the opportunity to seek out low sulfur fuel for their customers for the very first time, researchers at BNL had already been working for several years on the question of sulfur content and its impact on heating equipment and efficiency. The presence of sulfur in the fuel contributes to the corrosive nature of the products of combustion which is a major contributor to the fouling of heat exchangers in boilers and furnaces. The build up of fouling deposits contribute to a slow degrading of system efficiency over time and is costly in terms of the time and effort of the service technician's effort to remove them.

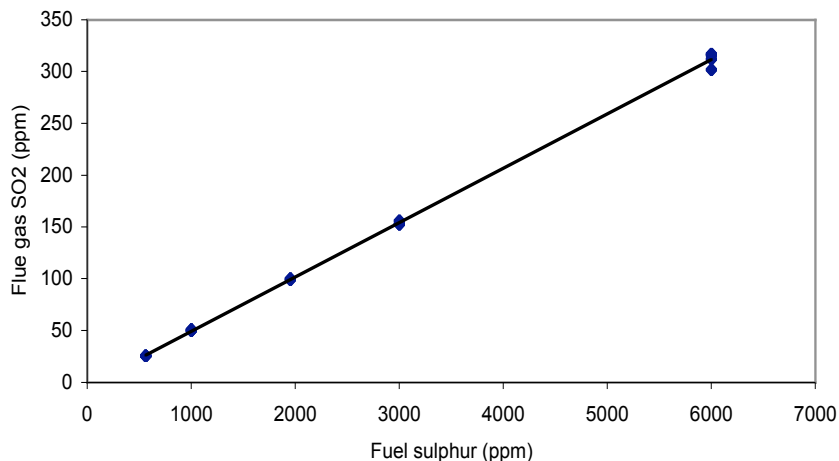
The EPA in 1991 mandated that on highway diesel fuel be limited to 0.05 percent sulfur by weight to reduce tailpipe emissions. Prior to this time, light distillate used for heating oil and diesel engines had very similar physical and chemical properties and were at times co-mingled in the same bulk storage tank. The new low sulfur highway diesel provided both a reason to study the potential benefits (or detriments) of using this low sulfur content fuel as a substitute for higher sulfur content heating fuel in residential oilheat systems. This led to a series of experiments that resulted in a great deal of knowledge on the subject. BNL ran experiments to determine the nature of the fouling process, the role sulfur plays, and the benefits of reducing sulfur content of ASTM No.2 heating oil. BNL also analyzed the environmental benefits of

reducing sulfur and the associated reduction of emissions of sulfur dioxide into the environment. BNL conducted initial studies in employee homes on Long Island, NY to fully understand the role of sulfur on the fouling process over an entire heating season under real operating conditions. Inquires were sent to the manufacturers of oil pumps to answer the important issue of pump wear and lubricity. There were no reported concerns with the use of low sulfur oil at the 0.05% (500 ppm) sulfur level. Laboratory studies at BNL were supplemented by additional studies at the CANMET Energy Technology Centre in Canada sponsored by the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) which had excellent correlation to the results obtained at BNL. There were many benefits to be realized and no down side to burning low sulfur (0.05% by weight) fuel. One marketer, E.T. Lawson in Hampton, Virginia felt so strongly that marketing low sulfur fuel had merit that they began marketing it as a premium heating fuel starting in 1993 and has been supplying it ever since. E.T. Lawson sells under the product label “Ultra.” The Ultra product has been a success for nearly ten years and this marketer who now only sells his customers this premium fuel. This paper will present the case for this superior fuel for the oilheat marketplace.

### 3.0 Air Emissions Reduction

#### 3.1 Sulfur Oxide Emissions

The sulfur in any fuel results in sulfur dioxide being released into the atmosphere when it is burned. During combustion in residential heating systems, roughly 99% of the sulfur in the fuel is oxidized to form sulfur dioxide (SO<sub>2</sub>) and emitted from the stack. The remaining 1 percent of the fuel sulfur is converted to sulfur trioxide (SO<sub>3</sub>) in the flame. Changing to low sulfur content fuel (0.05%) could eliminate roughly 75 to 80 percent of the sulfur dioxide generated by residential oil heating systems. In volunteering to market a lower sulfur fuel, heating oil dealers can make a substantial contribution to helping preserve the clean air that we all breathe. Although this result requires knowledge of combustion science, there are numerous studies that can also be cited to provide evidence. This was reinforced most recently in a recent paper (Ref 1) reported by S. Win Lee, Ph.D., of the CANMET Energy Technology Center-Ottawa, Natural Resources Canada as reported at the 2002 NORA Technology Symposium. Figure 1 is a plot of SO<sub>2</sub> emission rates for fuel oils of various sulfur contents from 0.05 percent (500 ppm) up to 0.6 percent (6000 ppm). This illustrates the linear relationship between sulfur content in the fuel and



**Figure 1 Effect of fuel sulfur on flue gas SO<sub>2</sub> emissions**

SO<sub>2</sub> emission rate resulting from combustion of the fuel. This confirms the analytical results obtained by BNL based on calculations related to the fuel composition and knowledge of combustion science.

Currently in the U.S., heating oil for residential use has an average sulfur content of about 0.20-0.25 percent (%). The ASTM limit for No. 2 heating oil is 0.5 % sulfur by weight. Considerably higher levels have been allowed, however, and regulations vary by state and area. Low sulfur fuel, 0.05 % by weight, is now mandated for use in highway diesel engines as an emissions control measure. Recently ASTM approved an additional Low Sulfur No.2 Heating Oil specification. The Oilheat Manufacturers Association in November 2001 recommended its use as a fuel of choice when possible to improve air quality and reduce equipment maintenance requirements.

More recently, on April 30, 2003 the NORA Board of Directors passed a resolution (during the report on the National Oilheat Research Institute) that stated; ***“Resolved: That the National Oilheat Research Alliance endorses the use of low sulfur Oilheat in residential and commercial combustion. That NORA publicize the advantages of this fuel to the industry participants, and prepare communications tools and information that will be valuable to customers in their decision making. That the goal of the National Oilheat Research Alliance shall be that 80 percent of the fuel consumed as heating oil shall contain not more than 500 ppm sulfur by 2007.”*** This is a major commitment on the part of the oilheat marketers of the United States that will benefit not only oilheat consumers but all Americans with regard to the environment as documented in this paper.

### **3.2 Particulate Emissions**

Particulates in the ambient air are an important pollutant concern. These tiny particles can cause lung disease, cancer, and premature death. Sources of fine particulates in the atmosphere include power plants, vehicles, road dust, and industrial processes. Particulates from oil-fired heating systems can be considered as two major parts, solid particulates and condensable particulates. The solid particulates include soot emitted directly from the boiler and this is composed of unburned carbon particles and any ash residue in the fuel. The condensable particulates are not actually particles when the combustion products leave the boiler or furnace but vapors which condense into particulates when the exhaust gas cools after leaving the vent and mixing with cool ambient air. These condensable particulates include some hydrocarbons but the major part is sulfates formed from a tiny fraction of the sulfur in the fuel.

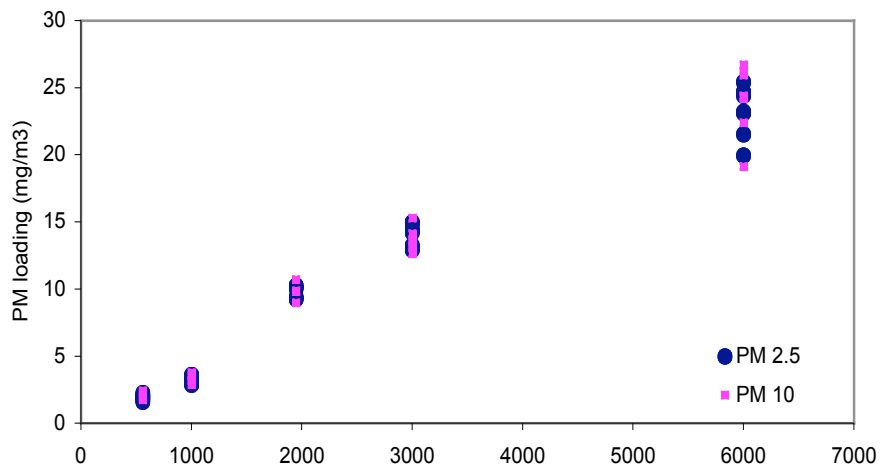
For large stationary pollutant sources, such as power plants, the traditional method of measuring particulate emissions involves drawing an undiluted sample of the flue gas through a hot filter. This basically measures the solid particulates but not the condensable particulates. EPA Method 5 defines this in detail and this is the basis for particulate emission regulation. It is also the basis for particulate emission factors assigned to stationary sources in AP 42 – a compilation of standard emission factors. There is growing recognition, however, that the condensable particulates are very important for health and there is now great interest in measuring these using sampling systems which simulate what happens after the exhaust leaves the vent. These sampling systems have a controlled cooling / dilution section prior to sampling on a cooler filter. For engine applications dilution sampling has long been used as the measurement standard.

Combustion sources emit particulates with a range of sizes. Health effects are most strongly associated with the smallest particles – those under 2.5 microns (2.5 millionths of a meter), roughly 1/30<sup>th</sup> the diameter of a human hair. For many power plants some fraction of the total particulates are in this “fine particulates” category. Condensable particulates are all fine particulates. For oil-fired residential boilers and furnaces all particulate, both solid and condensable, are under 2.5 microns.

For diesel engines, a large fraction of the particulate emissions (solid + condensable) are sulfates, derived from the sulfur in the fuel. This situation has been a key driver in the recent reductions in allowable diesel fuel sulfur content. The situation is similar in oil-fired heating appliances where, for a typical fuel sulfur content, the composition of emitted particulate matter is roughly: 23 % filterable and 77 % condensable (Ref 2). The condensable particulate matter is largely sulfates. Based on this it would be expected that the particulate emissions from oil burners are a strong function of the fuel sulfur content.

### 3.2.1 CANMET Particulate Measurements

Figure 2 shows the results of recent measurements made at the CANMET Energy Technology Center with fuels with a range of sulfur content. This clearly shows the impact which fuel sulfur has on total particulates (Ref 1). A shift from ASTM No.2 fuel with 0.2% sulfur to a fuel with 0.05 percent sulfur translates to a reduction of about 80 percent in particulate matter.



**Figure 2 Effect of fuel sulfur on PM<sub>2.5</sub> and PM<sub>10</sub> emissions**

### 3.3.2 EPA Standards

Dr. S. Win Lee (Ref 1) reported that “The U.S. Environmental Protection Agency (USEPA) promulgated revised National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter in 1997 to address ambient concentrations of very fine PM. The particles with an aerodynamic diameter less than 2.5  $\mu\text{m}$ , commonly known as PM<sub>2.5</sub>, are introduced to the standards based on the reported concerns over human health effects associated with these respirable substances. Several studies have shown associations between fine PM concentrations and adverse health effects including increased mortality and cardiopulmonary and cardiovascular illnesses in most susceptible people although only a few key reports are referenced here. The

effect of ambient fine PM on the visibility degradation has also been widely reported in industrialized countries. Similar regulatory considerations are given in Europe with the World Health Organization’s acknowledgment of the evidence of associations between PM concentrations and adverse effects on human health at low levels of exposure commonly encountered in developed countries. The Office of Air and Radiation of the EPA reported the U.S. implementation timeline for PM standards in 2000, as shown in Table 1.”

**Table 1. The US implementation timeline for PM standards**

1997	EPA issues Final PM <sub>2.5</sub> NAAQS
1998-2000	Ambient PM monitors put in place nationwide
1999-2003	Collect monitoring data
2002	EPA completes 5-year scientific review of standards
2003-2005	EPA designates non-attainment areas
2005-2008	States submit implementation plans for meeting the standard
2012-2017	States have up to 10 years to meet the standards plus one year extensions

Even though the EPA has not finished its studies, it is very likely if not guaranteed that New England and East Coast States, which is the heart of oilheat marketplace, will be designated as non-attainment areas. This has been the case in most prior EPA designations of this nature. The oilheat community can get ahead of the curve by voluntarily shifting to low sulfur fuel and dramatically reducing the potential for negative publicity in this area. In fact, the oilheat industry has a unique opportunity to become a leader in this environmental area.

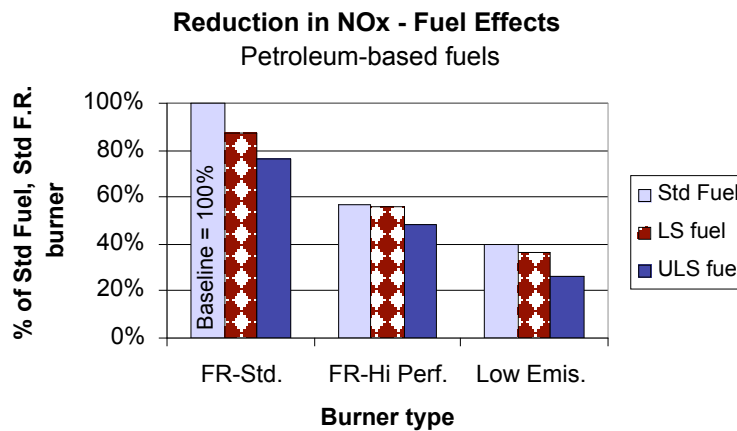
### 3.3 Nitrogen Oxides

All petroleum crude stocks contain varying small amounts of non-hydrocarbon materials or impurities, and the more important of these (at least from the emissions standpoint) are nitrogen- and sulfur-bearing compounds. The hydro-treating processes that are used to reduce sulfur during refining also reduce nitrogen by a similar mechanism. Although the two reactions have different rates and the effects are independent because nitrogen and sulfur are present independent of each other in different refinery stocks, the general rule is that by reducing sulfur content the nitrogen content of the fuel is reduced as well. Typical sulfur and nitrogen contents in common petroleum-based fuels are shown in Table 2.

**Table 2 Typical Sulfur and Nitrogen contents in Petroleum Fuels**

(all values, ppm)	<u>S-Nom</u>	<u>N-Nom</u>	<u>S-Range</u>	<u>N-Range</u>
Hi-Way Diesel (Gr. 2-D low sulfur)	360	150	< 500	100-200
Off Road Diesel (Gr. 2-D diesel)	3260	350	2000-5000	200-500
Heating Oil (Gr. 2 fuel oil)	1700	650	1000-3000	< 900

Work reported by Victor Turk, Director of Engineering of the R.W. Beckett Corporation (Ref 3) evaluated the effect of reduced sulfur / nitrogen fuels in three burner designs, and showed important reductions in NO<sub>x</sub> formation. The reductions shown in Figure 3 show the cumulative effects of both fuel and burner effects. These fuel-related reductions were similar from burner to burner, with the low sulfur fuel reducing NO<sub>x</sub> 5-10% compared to the standard fuel, and the ultra low sulfur fuel reducing NO<sub>x</sub> by 20-30% compared to the standard fuel.



**Figure 3 Fuel sulfur effects on NO<sub>x</sub> formation**

#### 4.0 Fuel Stability and Sulfur in Distillate Fuels

In the ongoing NORA/BNL research project related to maximizing fuel quality and performance (Ref 4), BNL is investigating the nature of fuel quality issues and will provide the oilheat industry with guidelines to begin to resolve these concerns. These issues are related to fuel instability, sludge formation, filter and nozzle fouling. Together they represent the largest number of unscheduled service calls in the oilheat industry. These problems are the result of numerous contributing factors, many of which are beyond the scope of this report. The instability of fuel oil and sludge formation are related issues that can not be separated. Contamination due to exposure to air, dust, humidity and other environmental factors combine with the chemical nature (and inherent instability) of the fuel as it was refined. Stability always degrades with time. It is a related to the inherent instability of the product, how fast it is transported, the storage time and the use or nonuse of fuel stabilizers. Product roll-over and mixing with older product is also a factor. However, part of the problem is related to variations in the fuel chemistry including the feed stocks at the refinery (the source and type of crude). The type of the refinery processing to which the fuel is exposed is yet another factor as is the use of cracked stocks in blending the heating fuel product. The production of other products, refined for other markets such as gasoline, how the barrel of crude is cut up, is another factor, which can vary seasonally. These factors all can have an affect on the chemical stability of the heating fuel. One of the ways chemical degradation can occur is related to the reactive compounds based on sulfur and nitrogen found in the fuel. Although the exact mechanisms are still not known, reactive hydrocarbons, sulfur and nitrogen compounds contribute to fuel instability. Hydrotreating is currently the most

viable refining process for removing sulfur in diesel; nitrogen containing compounds are also removed by this process. Known or anticipated effects of hydrotreating on fuel properties include improvement in fuel storage.

In the NORA/BNL fuel performance research project, initial test results reported to date indicate that **low sulfur** (less than 0.05% sulfur by weight) fuels are **more stable** and generate less particulate matter than normal sulfur content fuels. The sulfur content of the fuel appears to be an indicator of the chemical stability of the fuel. In addition, the fuels treated with after-market stabilizing additives of the same sulfur classification were more stable and generated less particulate matter than untreated fuels of the same sulfur classification. In all cases reported, stability numbers for the low sulfur content fuel samples fell within the higher (more stable) end of the range.

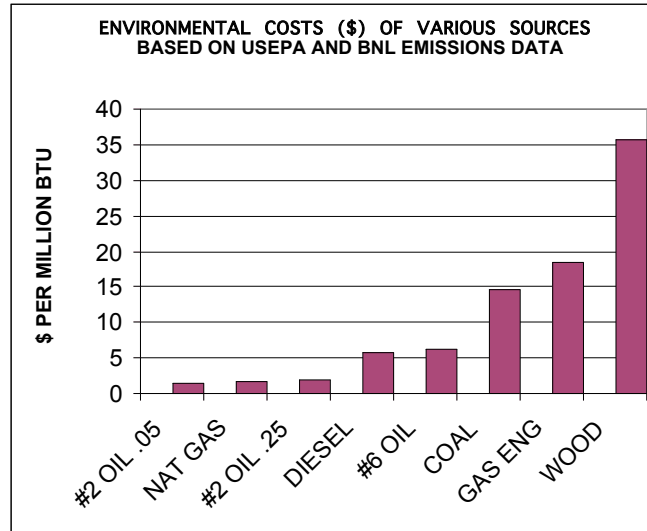
The study is not yet complete and only a few marketers in the nation currently market low sulfur heating fuel. However, all evidence collected to date does support the conclusion. The use of low sulfur fuels will not eliminate all fuel stability problems and will not resolve many fuel related service calls. As stated earlier, many factors other than fuel chemistry contribute to fuel stability problems. The stability tests that exist are more comparative than predictive. The basic conclusion that lower sulfur levels do correlate to better fuel stability has been reported in other end use sectors as well as reported in several references. At this time all available data indicate that the use of low sulfur fuels will help improve the fuel quality.

## **5.0 Environmental Costs and Externalities for Low Sulfur Fuel Oil and Other Sources**

Environmental costs, sometimes called externalities, were developed in order to evaluate the impact of electric power generation on the environment. Environmental cost factors have been historically estimated by evaluating the impact of various air pollutants on the environment by assigning a cost value (in dollars per pound) for each air pollutant that is emitted. These cost factors sometimes reflect measured values such as crop damage and other times are based on other values such as a cost of control equipment to reduce air pollutant omissions. These “environmental costs factors” are then added together and compared to evaluate the overall impact of all air emissions from different combustion sources. This is a complex subject matter has been evaluated for many years by groups including the Pace University Center for Environmental Legal Studies, the New York State Energy Office and the Massachusetts Department of Public Utilities.

A spreadsheet table in the NORA/DOE interim report compares the Environmental Costs of various fuels in \$ per Million BTU of fuel consumed. The spread sheet table (Ref 6) shows environmental costs for various combustion sources based on the above environmental cost factors, in dollars per pound, and actual emissions rates of all air pollutants by each fuel. The actual emission rates are based on publications by the U.S. EPA and test conducted by BNL. The lowest values are: Low sulfur No. 2 oil at \$1.36, natural gas at \$1.65, and No. 2 fuel oil (0.25% sulfur) at \$1.80 per Million BTU of fuel consumed. These are all much lower than most other combustion sources, and, therefore, produce the least environmental damage. Diesel engines and #6 fuel oil are higher in the range of \$5 to \$6 per Million BTU. Coal and gasoline powered engines are much higher at \$14.64 and \$18.45 per million BTU. The highest environmental cost

is for wood stoves at \$35.69 per million BTU, which is 20 to 25 times higher than oil or natural gas equipment. Clearly ASTM No. 2 oil and natural gas equipment produce comparable and very low environmental impact, and are much cleaner than all other combustion source that were evaluated. In fact, when the methane leakage from gas pipelines is included, low sulfur No. 2 oil has an environmental cost that is slightly lower than natural gas. These environmental costs for low sulfur fuel oil and other fuels are compared in the Figure 4.



**Figure 4**

## **6.0 Field Tests by the New York State Energy Research & Development Authority**

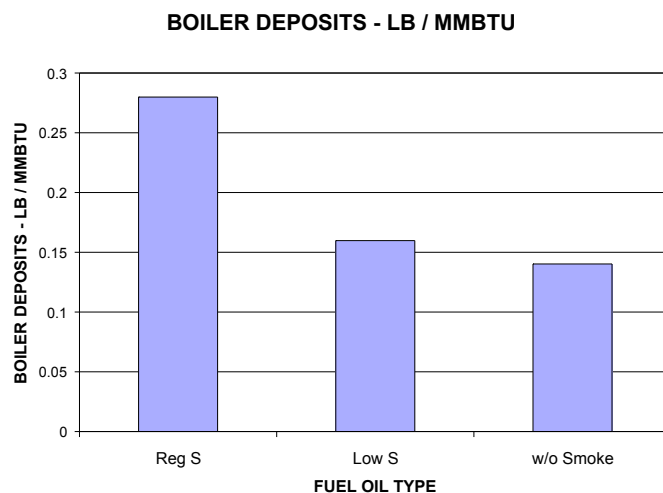
NYSERDA has been conducting a multi-year evaluation of the benefits of low sulfur heating oil in homes over the past two heating seasons with the assistance of the Energy Research Center, Inc and BNL, the Empire State Petroleum Association, and Buhrmaster Energy Group in Scotia, New York. NORA is co-funding Phase II of this work which is ongoing at this time. The objective of this project is to demonstrate the advantages of low sulfur fuel oil in actual homes, measure the performance improvement, evaluate potential reductions in cleaning costs, and identify problems with its widespread use. Initial estimates indicate potential reductions in service (vacuum cleaning) costs as high as \$56 million a year in New York State.

This study involves one entire division of the customer base, approximately 1,000 homes which receive low sulfur (0.05%) heating oil in comparison to the other delivery divisions of the Buhrmaster Energy Group that receive normal heating oil. The baseline or normal fuel has typically been 0.15 to 0.20 % by weight in sulfur content. Work included tracking fuel use statistics and service requirements for the different groups, regular and low sulfur content fuel use. It is worth mentioning that the Buhrmaster Energy Group has experienced no negative issues related to delivering the low sulfur fuel, no unusual non-scheduled service issues and no consumer complaints over the entire three year study. The one comment by members of the

service department is that the technicians prefer assignments working with the equipment that have received the low sulfur product because it has a much more pleasant odor, more neutral in odor, in comparison to the homes using regular fuel.

## 6.1 Deposition Data and Analysis

A sub-set of twenty homes out of the 1,000 homes included in the broader study was selected for a more detailed investigation into the issues associated with fouling deposits. This also included a similar sub-set of the homes receiving regular sulfur content fuel as a control group. These boilers in the test program were cleaned by specially trained oilheat service technicians using a method developed at BNL for collecting all the boiler deposits and placing them in a sample bottle for analysis. Figure 5 summarizes the data analyzed to date.

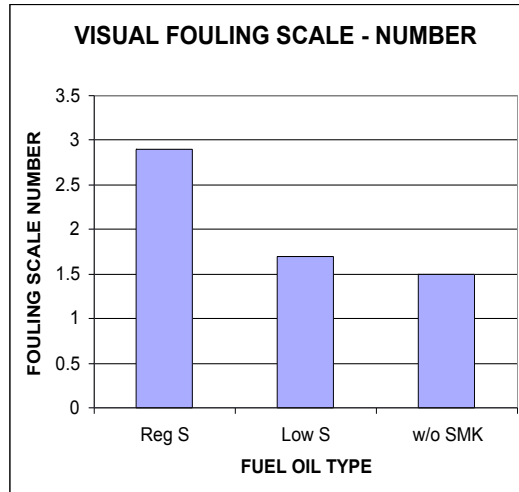


**Figure 5**

The normal sulfur fuel oil produced **0.28 pounds of deposits** per million BTU of fuel consumed. This is significantly higher than the deposits from the low Sulfur boilers. When the “heating only boilers” and with “high smoke number boilers” are removed, the average deposits in the low sulfur group equals **0.14 pounds** per million BTU of fuel. This is a two to one (**2:1**) reduction in deposits for the low sulfur oil. This is consistent with the laboratory results obtained from detailed studies at both BNL and the CANMET Energy Technology Centre in Canada.

## 6.2 Visual Inspection Data and Analysis

As part of the evaluation program for the NYSERDA field study, BNL engineers developed a **Visual Fouling Scale** that was used by service technicians to evaluate the level of deposition on the heat exchangers prior to cleaning. This fouling scale was applied to the detailed study homes, and also in about 100 other homes to see how the visually observed scaling compares for the normal sulfur and low sulfur homes. Excellent correlation was observed between this fouling scale and the mass of deposits collected for the normal and low sulfur homes. Figure 6 shows that the Visual Fouling Scale averages for normal and low sulfur homes. It is very similar to the measured differences in deposition mass shown in Figure 5, with about a two to one (2:1) difference.



**Figure 6**

A similar difference in fouling factors was obtained for approximately 100 normal and low sulfur homes that did not have their deposition rates measured (Figure 6). The average Visual Fouling Scales for the Normal sulfur homes in this group was 2.6, and for the low sulfur homes was 1.7. The visual fouling scale appears to accurately predict the measured deposition rates, and gives similar difference when comparing the normal and low sulfur fuels.

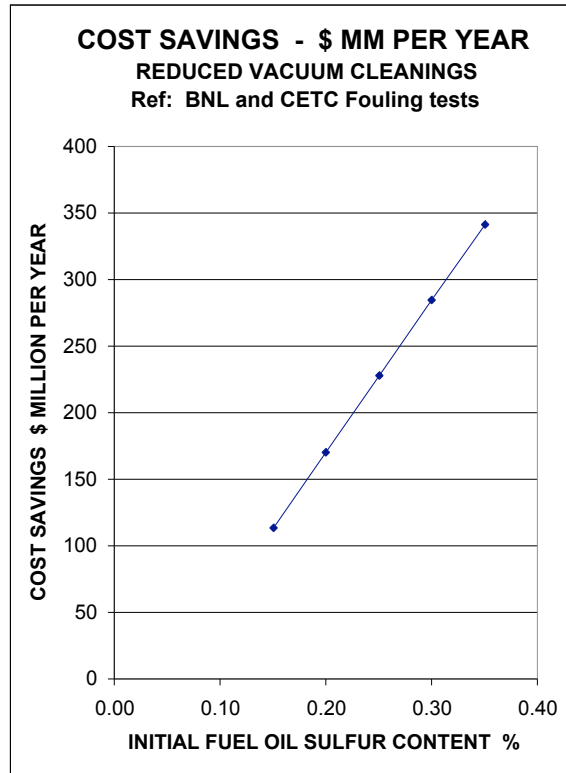
In terms of the effect that the use of low sulfur had on the service requirements for the division receiving low sulfur fuel, BNL and ERC sought input from the Buhrmaster Energy Group. The selected division required three full time service technicians prior to the beginning of the low sulfur marketing study. After two years of experience with delivering the low sulfur content product the service requirements have decreased to the point where this division is serviced by the equivalent of one and a half technicians per year. This is a fifty percent reduction in terms of the costs to satisfy the service required by this division. In addition this division now contains almost two hundred additional homes as compared to the beginning of the study due to additions brought on by an acquisition of another fuel delivery company by the Buhrmaster Energy Group during the three year period.

This field study is important because it is the first documented long-term evaluation of the performance of low sulfur fuels in actual homes. It validates many years of laboratory testing and demonstrates the important advantages of low sulfur fuel oil in homes served by oil marketers.

## **7.0 Preliminary Cost Saving Potential**

In the DOE/NORA report a preliminary evaluation of service cost savings was completed using the BNL/CETC data on reduced boiler deposition rates. This was combined with information from a survey conducted by the National Association of Oilheat Service Managers (NAOSHM) and RW Beckett Corporation two years ago (Ref 7), which shows average values for: existing service intervals, labor costs for service, and the time required for vacuum cleanings. This evaluation is summarized in Figure 7 which shows potential costs savings nationwide. More details on these preliminary cost saving estimates are included in the interim report. The data is

preliminary for now as a more detailed investigation into the range of factors involved and the source data for service rates and job time factors is required to finalize the calculations.



**Figure 7**

## 8.0 References

**Ref 1.** Proceedings of the 2002 National Oilheat Research Alliance technology Symposium, BNL report 52670, August 2002, Paper No. 02-13, Assessing PM<sub>2.5</sub> Emissions from Distillate Fuel Oil Heating, S. Win Lee, I He, T. Herage, E. Kelly and B. Young, CANMET Energy Technology Center-Ottawa, Natural resources Canada

**Ref 2.** United States Environmental Agency, AP-42, Fifth Edition, Volume 1, Chapter 1: External Combustion Sources, Table 1.3-1 Criteria Pollutant Emission Factors for Fuel-oil Combustion, Table 1.3-2 Condensable Particulate Matter Emission Factors for Fuel-Oil Combustion

**Ref 3.** Proceedings of the 2002 National Oilheat Research Alliance (NORA) Technical Symposium, BNL Report 52670, August 2002, Paper No. 02-10, Factors Affecting Oil Burner NOx Emissions, Victor Turk, R.W. Beckett Corporation, August 19-20, 2002.

**Ref 4.** Proceedings of the 2002 National Oilheat Research Alliance (NORA) Technology Symposium, BNL report 52670, August 2002, Paper No. 02-03, Maximizing Fuel Oil Quality and Heating System Performance, Wai Lin Litzke, Brookhaven National Laboratory and

associated presentation viewgraphs provided at the NORA Technology Symposium at the Oilheat Visions Conference, August 19-20, 2002

**Ref 5.** Oilheat Advantages Project – Engineering Analysis and Documentation Report by J.E. Batey and R. Hedden, Copyright 1995 by the Oilheat Manufacturers Association

**Ref 6.** Advantages of Low Sulfur Home Heating Oil, Interim Report of Compiled Research, Studies and Data Resources, National Oilheat Research Alliance and the United States Department of Energy, Prepared by: John E. Batey, Energy Research Center Inc. and Roger McDonald, Brookhaven National Laboratory, December 2002 (Available from the National Oilheat Research Alliance.)

**Ref 7.** Letter to ASTM Subcommittee EW Chairman, from Victor Turk of the RW Beckett Corporation, dated December 2, 1999, regarding proposed revisions to fuel oil specifications, and supporting engineering analyses of the impact on heating equipment cleaning intervals of lower sulfur oil.

## **9.0 Acknowledgements**

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