2012 **NSUARB-E-ENSC-R-12/M04819**

NOVA SCOTIA UTILITY AND REVIEW BOARD

IN THE MATTER OF: The ***Public Utilities Act***, R.S.N.S. 1989, c.380 as amended

IN THE MATTER OF: An Application by Efficiency Nova Scotia Corporation ("ENSC"). for Approval of its Electricity Demand Side Management Plan for 2013

Evidence of

Canadian Oil Heat Association – Nova Scotia (COHA-NS)

May 22, 2012

Q. On whose behalf is this evidence filed?

A. This evidence is filed on behalf of the Canadian Oil Heat Association – Nova Scotia (COHA-NS).

Q. What is COHA-NS?

A. The Canadian Oil Heat Association was established in 1983 by a group of fuel oil dealers to work collectively on matters that affect the oilheat industry. Since then, COHA has grown into a national body with a membership of over 400 oilheat professionals, including fuel oil dealers, major oil companies, manufacturers, wholesalers, contractors, trainers, and other professionals.

COHA serves as the industry's voice to provincial and federal regulators and government decision makers on matters of policy, safety, and certification. It works with government and other stakeholders to foster a sustainable business environment for its members.

In addition to the national body, COHA is comprised of provincial Chapters in Ontario, Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland & Labrador focusing on provincial regulatory, training, and promotion activities.

There is a demand for home heating oil in all communities across Nova Scotia, from the remote rural communities to the core urban areas. To serve this market, there are currently more than 85 home heating oil retailers with approximately 150 locations in Nova Scotia. Small independent companies comprise the majority of these locations.

The home heating oil retail sector provides local employment, contributes to provincial GDP both directly and indirectly and, because many retailers are locally owned, the economic benefits remain in the communities where they live, work and play. These firms also contribute to many local charities and community activities.

Q. What is the position of COHA-NS in this proceeding?

A. The oilheat industry has been denied participation in the Efficiency Nova Scotia Corp (ENSC) fuel substitution/fuel switching programs apparently based on initial screening carried out by Dunsky Energy Consultant in its *Fuel Choice/Switching Policy and Planning Guidance – Final Report to acting DSM administrator NSPI, February 25th, 2010.* In his initial assessment of fuels, Dunsky screened out oil apparently on the basis of risk related to price volatility and policy issues related to air quality and a perceived risk of fuel spills from tank corrosion. COHA states that Dunsky's assumptions are incorrect and that oilheat is a valid option to advance the objectives of the *Efficiency Nova Scotia Corporation Act*, S.N.S. 2009 c. 3.

The oil heat industry currently serves approximately 55% of the home heating market in Nova Scotia yet is the only source of energy, either fossil fuel or renewable that has been denied participation in the programs offered by ENSC, violating the intended position of fuel neutrality. This position of fuel neutrality, was explicitly stated by Conserve Nova Scotia but apparently not followed by ENSC.

Q. What are the purposes of the *ENSC Act*?

A. The purposes of the *Act* are stated to be establishing an administrator to manage DSM, establishing a fund to defray the costs, providing for regulatory oversight of the administrator, the fund and programs and providing the administrator with the authority to engage in energy efficiency *and* conservation programs other than electricity DSM programs.

Q. How is ENSC authorized to meet the purposes of the *ENSC Act*?

A. Section 8 of the *ENSC Act* states that the objects of ENSC as the independent DSM Administrator are to (a) design and administer DSM electricity programs with a view to restraining future electricity demands in the Province and (b) engage in energy efficiency and conservation programs other than electricity DSM programs.

ENSC acknowledged "There is no stipulation within the *ENSC Act*, or any other legislation or regulation, as to any specific type of measure or program that must be included within the electricity DSM (or other energy efficiency) programs to be developed and implemented by ENSC."[1]

The content and eligibility of DSM programs are subject to the oversight by the Board and its approval. ENSC further acknowledged in response to ENSC (COHA) IR-2, "The *ENSC Act* itself does not prescribe, or prohibit, either a Fuel Substitution Program as a particular DSM program, or the particular fuels or appliances that may apply for inclusion in that (or any other) DSM program."

[1] ENSC (COHA) IR-2

Q. What do you recommend?

A. We recommend that the Board direct ENSC to adjust its DSM Plan to include incentives to fuel switch to Energy Star (84%-97%) oilheat equipment technologies in both existing houses and new construction, consistent with the list of alternative fuels now included.

From a policy perspective, COHA-NS would like to be recognized as a stakeholder in future proposed DSM programs and have further oilheat options be considered for inclusion when considering energy efficiency and conservation programs.

Q. Please discuss the background that led to the fuel switching incentives.

A. **2009 – 2010**

In the application for 2010 DSM programs (2009 NSUARB 116), the Board's consultant, Dr. David Nichols recommended that an independent study be undertaken to determine whether the DSM program could incorporate fuel choice measures. He noted "Alternatives to electric heat may include oil heat, gas or propane, or the use of indigenous resources, such as wood pellets."

The Board ordered NSPI (the DSM administrator at the time) to undertake a study to consider the use of fuel choice so that its results could be considered in the 2011 DSM plan.

Following the Board's decision, in September, 2009, NSPI engaged Navigant to conduct an analysis of the potential for fuel substitution in the Residential new construction and existing buildings markets. Navigant prepared a February 24, 2010, report, "2010-2019 Fuel Substitution Potential Analysis".[2] The purpose of the study was to analyze the potential of fuel substitution from electric-fuelled equipment to non-electric-fuel (natural gas, oil, propane, cord wood, wood pellets or solar energy) over the ten year period. Navigant discussed technical, economical, achievable and program potential. Based on market research data, Navigant estimated that fuel substitution could reduce electric demand and energy by approximately 5 MW and 8 GWh in the first year increasing to 127 MW and 218 GWh after 10 years.

---

[2] Exhibit N-2, Appendix B, NSPI-P-884(3).

To explore "policy issues" NSPI engaged Dunsky Energy Consulting to prepare a Policy White Paper and Planning Guidance Report for NSPI.[3].

Dunsky submitted a framework for screening fuel switching opportunities that included an initial, high-level assessment of five fuels: natural gas, oil, propane, cord wood and wood pellets. Dunsky observed that screening of fuel switching opportunities should use the Total Resource Cost (TRC) test *consistent with other DSM* but, he added, some components of a "complete" TRC test are not currently addressed in NSPI's and the UARB's version of the TRC. He recommended that the benefits of avoided fuel supply as well as the costs of increased alternative fuel supply costs, connections and emissions from the new fuel be accounted for and in his screening, purported to fill in the blanks.[4]

Dunsky observed that "*while not the focus of this mandate*", he conducted a "*simplified, preliminary assessment*" of opportunities for fuel switching. He concluded that the best potential was switching to gas in the retrofit residential market and to wood pellets in the commercial markets.[5]

Dunsky recommended that in parallel with pilot projects, a framework to assess fuel switching opportunities be developed and refined and that stakeholders be engaged. These stakeholders were identified to include government and, among others, COHA-NS.[6]

2010 – 2011

These two reports from Navigant and Dunsky were submitted as part of NSPI's filing in 2010 for the 2011 DSM Program Plan.

Dunsky recommended one or more pilot projects be designed in 2010 and implemented in 2011. NSPI had not included these pilot projects specifically in its proposed DSM Plan for 2011 but was agreeable to doing so.

In the Board's September 2010 decision (2010 NSUARB 155) it found that a fuel substitution pilot project should be developed with a "focus on electricity reduction".

[3] Exhibit N-2, Appendix C, NSPI-P-884(3), Dunsky Energy Consulting, Fuel Choice/Switching as an Electric Demand Side Management Strategy, Policy White Paper and Planning Guidance, Feb. 25, 2010 ("Dunsky White Paper")

[4] Dunsky White Paper, at p.8

[5] Dunsky White Paper, at p.13

[6] Dunsky White Paper, at p.69 and 71.

2011 – 2012

Thereafter, responsibility for DSM transitioned from NSPI to ENSC. Dunsky continued to be involved as consultant and prepared a fuel substitution pilot project for residential customers.

In its filing for the 2012 DSM program, ENSC submitted Dunsky's 2011 Residential Fuel Substitution Pilot which encouraged existing residential homes to use gas, cord wood, wood pellets or propane for space heating and domestic hot water.[7] Dunsky stated that heating oil was excluded as a measure, primarily because of its significant negative environmental and economic impacts for Nova Scotia relative to other fuel substitution options, as well as concerns around price volatility. Heating oil is also problematic for residential heating because of increasing issues with home insurance policies due to potential soil contamination from fuel leaks.[8] It stated that lessons learned from the pilot would be used to define fuel substitution measures in the existing houses program proposed for 2012.

In its findings, the Board stated that it had considered the Pilot Projects considered by ENSC, including the Residential Fuel Substitution Project and noted there appeared to be general support for this pilot project, with which the Board agreed. <u>COHA-NS was not an intervenor in the 2012 DSM hearing.</u> The Board stated that it expected ENSC to implement the fuel switching pilot project in 2011 and to provide updates in its future filings to the Board (2011 NSUARB 99).

2013 – 2015

In its current filing, ENSC included a November 3, 2011, analysis of the Fuel Switching/Substitution Pilot Program (Appendix G) launched in April 2011. There have been 350 pre-approved applications of which 25% have been completed. 93% added a wood or pellet stove and 4% switched from electricity to either wood or pellet boilers; only 3% converted to natural gas.

The 2013-2015 Plan also includes the promotion of "Green Heating Systems" targeting the residential sector; it will incent space and water heating systems that provide all or substantially all of their heat from renewable energy sources including sun (solar thermal), heat in the air (air-

---

[7] ENSC Evidence, Appendix D, Final Report – Residential Fuel Substitution Pilot Program, E-ENSC-R-10, December 16, 2010 ("Pilot Program").

[8] Pilot Program, p.5.

source heat pumps), ground or groundwater (ground source heat pumps), or biomass (wood or pellet stoves, furnaces and boilers). (Appendix E).

Q. Has the DSM Administrator ever included incentives relating to oil heating?

A. It is not really clear to COHA-NS. We have reviewed the DSM Technical Tables filed in response to IRs. In 2012, one of the residential measures was for an energy star oil furnace (AFUE=85%); it showed a positive TRC of 4.1 (pdf p. 8/32). Despite the positive TRC, that measure appears to have disappeared from the 2013-2015 plan without explanation. Oil heat is also not listed in the fuel substitution program on the ENSC website. ENSC has never given any indication to COHA that it would or has incented conversion from electric to oil heat.

Q. Why do you believe oil heat should be included in the fuel switching opportunities?

A. It appears that the oilheat industry has been denied participation in the ENSC fuel substitution/fuel switching programs based on a preliminary screening done by Dunsky which was outside the mandate of the RFP, not fully informed and did not follow the current TRC test. The primary focus of DSM is generation avoidance i.e. electricity reduction. COHA states that as a fuel provider servicing every part of Nova Scotia, it is in a far better position than some of the alternatives to assist ENSC to achieve its electricity reduction targets.

Q. Please elaborate on why you believe that Programs based on the preliminary screening by Dunsky are incorrect.

A. Dunsky concluded that higher emissions of $C0_2$ and other pollutants made it unlikely to receive government support - therefore, heating oil was an unlikely candidate for fuel switching. Under risks, he raised the spectre of oil spills and price volatility.

- **<u>AIR QUALITY</u>**

Q. What does COHA say about emissions?

Dunsky has selectively focused on $C0_2$ emissions, omitting other major GHG contributors such as methane (CH_4) and nitrous oxide (NO_2) and he also ignores “other air pollutants” even though his analysis identifies air quality issues as a concern in relation to the province’s policy issues. ENSC has included wood and wood pellet appliances within its fuel substitution programs even though Dunsky’s White Paper raises serious concerns with regard to particulate emissions from the burning of both fuel sources.[9] Within the promotion to have Nova Scotians incorporate wood/wood pellet appliances in their homes, ENSC fails to mention any concerns with regard to human health issues that result from these pollutants. Greenhouse Gasses (GHGs) do not directly cause human health issues.

Transforming the marketplace with incentives to move toward wood and pellet (biomass) heating systems, while reducing GHG's, simply replaces and exceeds GHG's from oil with "other air pollutants". COHA acknowledges that reducing GHGs is a chief priority for dealing with climate change, however *other air pollutants* also contribute to climate change and poor air quality. Under the current fuel substitution options, ENSC is suggesting that we increase energy efficiency and lower greenhouse gas emissions, but increase the release of other air pollutants that are a result of burning wood and pellets.

Health Canada has well documented information on the main pollutants in wood smoke that pose health concerns.[10] While these options are renewable, they are not air quality neutral and the public should not be lead to believe that by switching to biomass they do not carry an environmental impact.

Q. What about GHG and the Nova Scotia Climate Change Action Plan?

A. *Nova Scotia Climate Change Plan* ***Reducing Greenhouse Gas Emissions*** has as its Target: 5 megatonnes annually by 2020. The two most cost-effective means of reducing emissions from power generation in Nova Scotia are identified, neither of which are to eliminate home heating oil as a residential home heating option.

"Nova Scotia aims to reduce GHG emissions by at least 10 per cent from 1990 levels by 2020".

Electricity generation

The greatest single reduction will be achieved by imposing caps on emissions from Nova Scotia Power Incorporated (NSPI), which produces 46 per cent of the province's GHG emissions. The caps will take effect in 2010, 2015, and 2020.

---

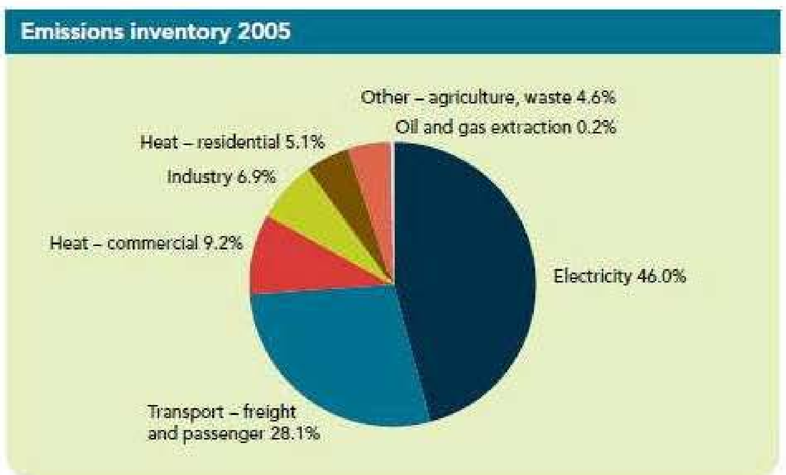
[9] Dunsky White Paper, p. 56, "The DSM Administrator should, however, discuss particulate matter issues with provincial and municipal governments before embarking on electric-to-cordwood FS programs"

[10] Wood Smoke – It's Your Health, http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/wood-bois-eng.php
The Canadian Lung Association, Heating with Wood – What You Need to Know http://www.lung.ca/protect-protegez/pollution-pollution/outdoor-exterior/heating-chauffage_e.php#wood

The two most cost-effective means of reducing emissions from power generation in Nova Scotia are straightforward: generating less electricity and generating it from clean, renewable sources.

We will also reduce our dependence on fossil fuels, which are expected to rise in cost over the long term.[11]

NSPI emissions account for close to half (46%) of GHG production in Nova Scotia. It is interesting to note that residential home heating accounts for only 5.1% of GHG production in this province. Transportation GHG production is the second largest GHG contributor.



Source: Environment Canada, revised May 2008

Q. To what extent does Dunsky consider life cycle emissions?

A. He does not. He observes that the province's emissions targets for NSPI do not currently consider life cycle emissions from the extraction, refinement and transportation of the fuel used to produce electricity but only the emissions generated from production. Accordingly, he concludes that a consistent treatment for electricity to other fuel switching program would consider only energy supplier emissions.[12]

Q. What is the significance of this?

A. Dunsky's recommendation to not incorporate full fuel life-cycle emissions contradicts federal NRCAN assessment protocols for evaluating various energy sources. NRCAN utilizes GHGenius, a modelling software that calculates full life-cycle emissions, as does the USA

[11] ***Nova Scotia Climate Change Action Plan***
[12] Dunsky White Paper, p.38.

modelling software GREET. By not including emissions from the extraction, transportation and storage of other fossil fuels and their relative GHG emissions specific to these areas, oil is once again misrepresented.

Q. Please explain the significance of using life cycle emissions comparing natural gas and oil.

A. Since methane is a product of combustion for both natural gas and fuel oil, the important differentiation between the fuels is leakage during the supply and disposition of natural gas, which, being primarily composed of methane, is a greenhouse gas even before combustion. Clearly, due to the GHG potency of methane any leakage of raw natural gas can have a significant impact on the formation of GHG. Indeed, the high GHG forming issues found with natural gas in the United States by the various studies are related to leakage in the distribution stream. Ironically, the GHGenius analysis for Canada did not find these issues and upon enquiry to NRCAN, the consultant was told that these rates were provided by the natural gas industry in Canada. Inexplicably, Canada's leakage rates are reported as less than half of the newest natural gas infrastructures in the world and more than five times better than the average of the world producers (after excluding Asian exporters whose leakage rates are notoriously high). NRCAN has asked COHA to submit these findings for their review.

The leakage data used by GHGenius are shown in Table 2.

DATA ON GAS PRODUCERS

	gas lost, % of stage output			Total
Natural gas produced in:	Recovery	Processing	T&S*	
U. S.	0.46%	0.21%	0.65%	1.33%
Canada	0.13%	0.09%	0.05%	0.28%
Mexico	0.60%	0.20%	1.00%	1.80%
India	0.35%	0.20%	0.11%	0.66%
N. Europe	0.60%	0.20%	1.00%	1.80%
S. Europe	0.60%	0.20%	1.00%	1.80%
North Africa (Algeria, Libya)	0.60%	0.20%	1.00%	1.80%
Indonesia	0.60%	0.20%	1.00%	1.80%
Persian Gulf	0.60%	0.20%	1.00%	1.80%
Target developed (domestic)*	0.60%	0.20%	1.00%	1.80%
Target LDC (domestic)*	0.60%	0.20%	1.00%	1.80%
Asian Exporters	1.00%	0.50%	2.00%	3.50%

Note: *Transmission and Storage. (% of total to distribution systems). Recovery is % of dry gas production; processing is % of dry residue gas from NGL plants. (Source: Greenhouse Gas Impact of Natural Gas versus Fuel Oil. Devonport Engineering. August 2011)

Full fuel cycle analysis has been recognized as the best technique to evaluate the greenhouse impact of specific fuels. The transportation industry was the first to recognize that there were more contributors to GHG than what directly exits the automobile tailpipe. This philosophy was termed “wells to wheels”. The Argonne National Laboratory developed a full fuel cycle, mathematical model using Microsoft Excel called GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation). It allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis. This model was used for the full fuel study Final Report, Resource Analysis of Energy Use and Greenhouse Gas Emissions from Residential Boilers for Space Heating and Hot Water, Reference 1[13].

Robert Howarth of Cornell University has written several papers stating that methane is a far more potent greenhouse gas than previously thought and that other forms of fuel, including coal, look good when compared to the actual greenhouse gas production of natural gas and especially shale gas[14].

Q. How has the oil heat industry responded to the Action Plan?

A. Firstly, the oil heat industry has never been contacted by ENSC to discuss ways to implement reductions for our industry. COHA was contracted by its predecessor, Conserve Nova Scotia/Dept. of Energy to administer two oil heat appliance rebate programs; “Retire Your Furnace” and “Energy Efficiency Furnace Initiative” (“EEFI”). In fact, in 2006, Conserve NS launched with the announcement of the oil heat appliance rebate. GHG emissions reductions resulting from these programs are shown below. Oilheat retailers and installers upgraded close to 7,000 oil appliances to assist the province in achieving its GHG reduction goals as well as reducing the quantity of imported oil. Conserve Nova Scotia marketed these programs on its website and the cost of these programs was paid for by COHA members. The oil heat industry

[13] Greenhouse Gas Impact of Natural Gas versus Fuel Oil. Devonport Engineering. August 2011

[14] Preliminary Assessment of the Greenhouse Gas Emissions from Natural Gas obtained by Hydraulic Fracturing. Robert W. Howarth. Cornell University. April 2010, “A complete consideration of all emissions from using natural gas seems likely to make natural gas far less attractive than oil and not significantly better than coal in terms of the consequences for global warming… The leakage of methane gas .. 72 times more powerful than is $C0_2$ per molecule in the atmosphere.”

has demonstrated within these programs that it can deliver on GHG reduction and energy efficiency initiatives.

INDUSTRY/GOVERNMENT PARTNERSHIPS AT WORK IN NOVA SCOTIA

Achieving Provincial Greenhouse Gas Reduction Emissions Targets TOGETHER

RETIRE YOUR FURNACE (October 12, 2005—March 31, 2007)
Total Boiler/Furnace/Indirect applications received under program..................4,030

ENERGY EFFICIENCY FURNACE INITIATIVE (September 11, 2008—September 10, 2009)
Total Boiler/Furnace/Indirect applications received under program...................3,159

Total Applications..7,189
Total 'Qualified' units replaced under programs...6,912

EMISSIONS REDUCTIONS ACHIEVED WITH REBATE PROGRAMS:

(CO2 Equivalents)

(A) 6,707* units x 3000 litres = 20,121,000 litres x 25% = 5,030,250 litres saved**
(B) 5,030,250 x 2.912 = 14,648,088 Kgs of CO2
OR 14,648 tonnes

DID YOU KNOW?
14,648 tonnes CO2 saved is the equivalent of removing 4,902* vehicles from our highways.**

* Representative of Furnaces and Boilers only; does not include indirect water heaters
** Sustainable Liquid Fuels Research. 2008. National Oilheat Research Alliance & Brookhaven Laboratory Inc.
*** Stats Canada: Average car releases .116 kgs CO2/km. Average motorist drives 18,000 km/yr.
Therefore 18,000 x .116 = 2,988 kilograms CO2/yr per vehicle.

Q. Please compare the results of the COHA/Conserve emissions reductions programs compared to the ENSC pilot program.

A. According to the ENSC evidence, despite significant expenditures, it has managed to entice a total of only 296 homeowners to switch from electric heat, 93% of whom have installed a wood/pellet stove "supplement"[15]. Only 3% have converted to natural gas. COHA states that the above results show what types of efficiency measures and programs have real impacts on GHG reductions.

ENSC seems to have clouded the primary focus of electricity reduction with other peripherals such as GHG emission reductions. However, COHA states that if this truly is a factor then the

[15] ENSC Evidence, p. 11, line 21 and Appendix G, p.7

previous results from the COHA-NS/Conserve Nova Scotia joint efforts to incent switching to more energy efficient appliances have shown far greater benefits than achieved in ENSC's fuel switching program. In fact, most experts agree the biggest impact to GHG emission reduction is to conserve, not convert.

- **OIL TANK CORROSION**

Q. ENSC and Dunsky seem to have given some weight to risks associated with oil tank leakage issues. What does COHA say in response?

A. First, this seems somewhat arbitrary as no other fuel is evaluated for "possible mishaps". The worst-case scenario for heating oil is a leak; the worst-case scenarios for natural gas and propane are explosions. The worst-case scenario for wood/wood pellets is a house-fire.

Q. But isn't there a risk of oil leaks from old corroded tanks?

A. It is true that single-wall metallic storage tanks are prone to corrosion over time. However, today's modern storage systems are made from non-corrosive materials such as fibreglass and resin. When considering a conversion, it is more than likely that any conversion would be to a modern non-corrosive oil containment system.

There is also a double-bottom steel tank on the market, so while it may corrode as would all steel tanks over time, the secondary containment bottom will catch the leaked oil should the primary containment bottom be compromised. This would avoid a release. The interstitial monitoring system advises the homeowner the primary containment has been compromised and he or she replaces the tank without incident. In addition, a number of oilheat retailers in the province have implemented a "non-corrosive only" tank policy when it comes to installations on a go-forward basis[16].

As discussed above, COHA developed a national risk management and spill prevention initiative entitled "Retire Your Tank". Homeowners were encouraged to upgrade from their single-wall steel tanks to fibreglass, resin or double-bottom steel tank. Given the choice, ninety percent (90%) of all single-bottom steel tanks replaced under the program were replaced with non-corrosive storage. COHA- PEI Chapter results echoed those of COHA-Nova Scotia and

---

[16] E.g. Parkland/Bluewave has a policy to install non-corrosive only. Irving and Wilsons Home Heating install steel as a last resort. Approximately 85-90% of Wilsons tank installations are non-corrosive.

New Brunswick saw 83% of upgrades move to non-corrosive storage options. The trend in the marketplace is clearly toward non-corrosive storage, eliminating the risk of a catastrophic oil release as a result of corrosion.

In addition, CSA-B139.09, the Code for the installation and maintenance of oil heating systems no longer allows for the installation of single-wall steel tanks in an outside installation in the province of Nova Scotia. The NS Department of Labour & Advanced Education has adopted this latest version of B139.

Based on COHA's risk management program results, one would expect a homeowner incented to fuel switch would choose to install a non-corrosive tank. Accordingly, any perceived risk by Dunsky relating to fuel oil spills would appear overstated and unsupported by the evidence regarding installation and replacement of domestic fuel oil tanks.

Q. Did Dunsky consider high efficiency condensing oil heating furnaces in his preliminary screening?

A. No; it appears that he did not because of concerns regarding the availability of ultra low sulphur fuel for these furnaces and corrosion concerns. This resulted in Dunsky's economic analysis comparing an 85% efficient oil furnace to a 94% efficient gas furnace for residential space heating, clearly not an apples to apples comparison.

Q. Is this appropriate?

A. No; it is based on outdated information. Oil heat manufacturers have made great strides in the area of efficiencies for their heating appliances. Condensing oil warm air furnaces have now been available on the market for a number of years, achieving efficiency ratings of 95% AFUE. The "Kerr Paradigm" model, for example, is made in Nova Scotia and is designed and rated to withstand the adverse affects of sulphur content in Nova Scotia heating oil.

Granby Industries is also about to launch its condensing furnace this fall, the "Conforto". Production is expected to begin in June 2012. The Conforto's Annual Fuel Utilization Efficiency (AFUE) rating is 95.7% and it has undergone the standard lifetime testing process at a sulphur content of 1500 ppm (parts per million). The majority of our heating fuel in this province is rated between 500 and 1000ppm.[17]

- **SUPPLY AND PRICE VOLATILITY**

Q. What is the issue with price volatility?

A. Dunsky stated that oil supplies are likely to remain stable in the mid-to-long term, but oil prices will be subject to strong volatility.[18]

Q. What does COHA say about volatility?

A. No one can predict with certainty, where energy prices will go; all energy commodities are exposed to supply and demand pressures that drive prices up and down. Consumers should never be led to believe they will save money by switching fuels. Investing in a new heating system is a long-term investment; the energy landscape changes daily. The only true way to save on energy is to use less of it.

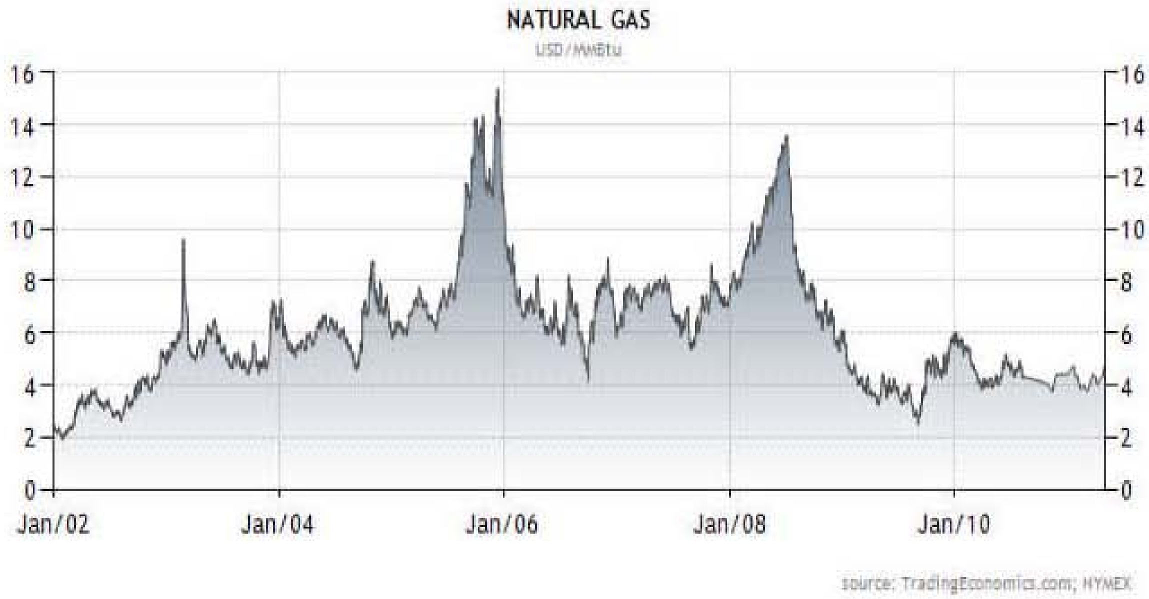
COHA observes that other fuels such as natural gas, propane and wood pellets have been included in the fuel substitution pilot program and ENSC's current fuel switching measures even though Dunsky's analysis has attributed risk in the area of price volatility[19]. In fact, a review of the past 10 years of natural gas pricing confirms such volatility.

---

[17] See also Attached, Brookhaven National Laboratory Project Report prepared for the U.S. Department of Energy, Technical Foundation for Oil-Fired Condensing Appliances, p.18 discussion re durability.

[18] Dunsky White Paper, p.57

[19] Dunsky White Paper, p. 55, "gas markets have seen substantial price volatility… the long term costs of these resources are still an issue of debate. p. 57, "propane supplies are likely to remain stable… but with the same volatile pricing faced by other fossil fuels." P. 57, "Despite this past stability, pellet producers indicate that they are facing increased pressure from biomass prices, and have further concerns regarding mid and long-term supplies because of new biomass power generation plans in the region… periodic short-term pellet shortages.."



Q. What does COHA say about supply?

A. The installation of a heating system is a capital expense which should have a useful life of 20-25 years, therefore the availability of supply needs to be weighted heavily in such a decision. Again, Dunsky stated that oil supplies are likely to remain stable in the mid to long term but does not analyze the supply of natural gas in Nova Scotia. Had he done so, he would have had to conclude that the “local” resource has a finite lifespan of roughly 10 years. Mention is made in North American supply, however no attempt is made to “cost” such supply landed in Nova Scotia, despite price being significant enough to exclude heating oil as an energy option. With such small natural gas consumption in Nova Scotia, the transmission cost in a reversed pipeline or to land LNG/CNG would be very expensive.

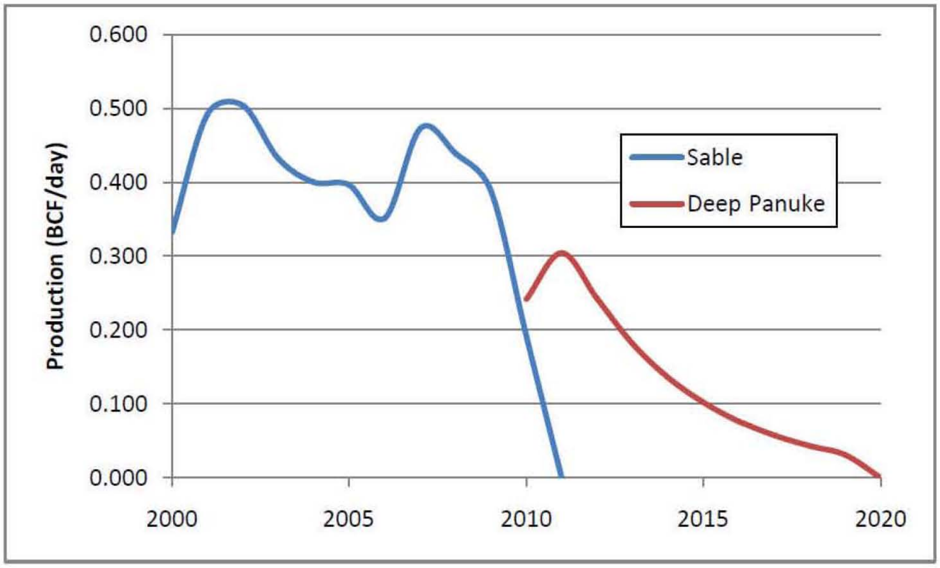


Figure 2: Nova Scotia's offshore (actual 2000-06 and projected 2007-2020) (NEB, 2007)

Q. Does this conclude your evidence?

A. Yes, it does.

Technical Foundation for Oil-Fired Condensing Appliances

Project Report

Thomas A. Butcher and Roger J. McDonald

Prepared for the
Building Technologies Program
Office of Energy Efficiency and Renewable Energy
United States Department of Energy

Energy Resources Division
Department of Energy Sciences and Technology

Brookhaven National Laboratory
Brookhaven Science Associates
Upton, NY 11973-5000

Under Contract No. DE-ACO2-98CH10886 with the
United States Department of Energy

Abstract

The introduction of oil-fired condensing boilers and furnaces to the U.S. market offers the potential for a significant step increase in efficiency. With oil, the energy loss in a conventional, non-condensing appliance associated with latent heat of uncondensed water vapor is 6.5%. The actual combustion efficiency improvement of an oil condensing appliance relative to a non-condensing appliance is a combination of both sensible and latent heat recovery. In the case of a warm air furnace, combustion efficiencies as high as 98% have been measured. The amount of condensation that can occur is constrained by the heat exchanger surface temperatures. This is particularly important in the case of boilers where return water temperature is strongly dependent upon the distribution system and the control strategy.

In this project, detailed lab studies were done to map the performance of a condensing boiler / indirect hot water tank integrated system over the entire load range. A direct energy input/output method was used. Field studies were also done with both furnaces and boilers to evaluate corrosion and performance. In the case of furnaces, energy savings associated with the replacement of old non-condensing units with condensing units was found to be a remarkable 25-45%. This is based on an analysis of weather-corrected fuel consumption for a small population set (4 units). In the case of boilers the annual energy savings were not evaluated in the field. For some of the sites examined the return water temperatures were too high to yield condensing operation and the boilers were found to be operating as high efficiency, non-condensing units. For both furnaces and boilers, the corrosion-related fouling was found to be acceptable, based on visual observation.

Table of Contents

List of Figures

List of Tables

Introduction

Condensing boilers and furnaces achieve very high efficiency by recovering both sensible heat from flue gas dry components (N_2, CO_2, O_2) and both sensible and latent heat from flue gas water vapor. Generally the transition from conventional non-condensing appliances can raise efficiency from the upper 80% range to the 93-98% range.

Fuel properties strongly influence the amount of water vapor in flue gas, the amount of latent heat that can be recovered, and the flue gas temperature (and efficiency level) at which condensation starts to occur. The higher the hydrogen to carbon ratio in a fuel the more water vapor there will be in the flue gas. Table 1 shows the amount of latent heat that can be recovered for natural gas, propane, and oil.

Table 1. Latent Heat Loss for Natural Gas, Propane, and Oil in a Non-Condensing Boiler or Furnace (ASHRAE 1993)

Fuel	Latent Heat Loss (% of Input Based on Higher Heating Value)
Natural Gas	9.55
Propane	7.99
Heating Oil	6.50

Gas-fired condensing boilers currently have a substantial market in Europe and the U.S. Oil-fired condensing boilers are starting to capture market share in Europe and have very recently been introduced into the U.S. market. In the U.K., all new boilers after 2007 are required to be condensing.

Condensation only starts to occur when the boiler return water temperature is below the saturation temperature of the water vapor, which is affected by the fuel, excess air level, and, to a lesser degree, the ambient air humidity. Figure 1 shows saturation temperature versus excess air for gas, propane, and oil at an ambient humidity ratio of 4 g/kg (.004 lb/lb) considered typical of winter conditions.

In condensing appliances, condensation occurs on the surface and not in the bulk gas flow. In other words, boiler and furnace surfaces "sweat" much like cold water pipes commonly sweat in a humid summer basement. For condensation to start to occur, the surfaces must be below the saturation temperature. In the case of a furnace, where return air is on the order of 70 F, it is relatively easy to achieve condensing conditions. In a boiler, the amount of condensation that can occur is very much dependent upon the return water temperature which can vary considerably. With radiant floor heating systems, return water temperatures well below 100 F are common and so this is a perfect match for condensing boilers. With traditional baseboard heating systems, return water temperature is often in the 140 F range, too high to achieve condensing with any fuel. As part of this project an earlier study was completed of the potential for condensation with an oil boiler and baseboard radiator distribution system where an outdoor reset control is used (Butcher, 2006). It was shown that, depending upon baseboard oversize factor, a very significant amount of condensation can occur for a large part of the heating season.

The market growth in condensing systems for gas has been much stronger because of the higher flue gas water vapor content, and the higher saturation temperature (ease of achieving condensation). Also, another important factor is the difference in the sulfur content. Heating oil typically contains on the order of 1800 ppm sulfur which leads to higher sulfuric acid content in the flue gas condensate and higher corrosion rates (Locklin and Hazard, 1980).

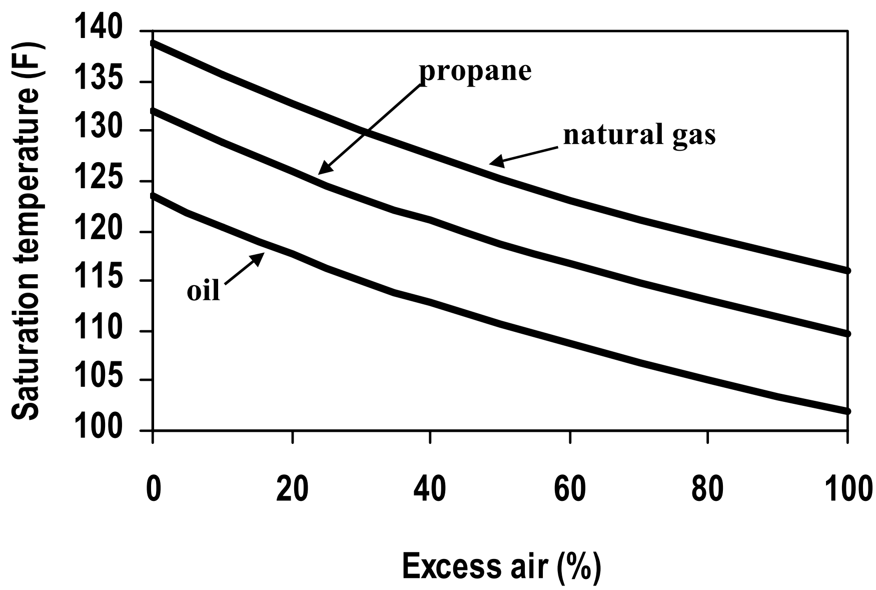


Figure 1 Impact of excess air and fuel type on flue gas water vapor saturation temperature

In addition to corrosion and materials cost concerns, other factors that affect the market growth of oil condensing systems include condensate disposal and "pluming". The later refers to the visible appearance of the white exhaust from a condensing appliance under some weather conditions, although these concerns apply to gas as well as oil (Weber et. al., 2002).

In the 1980 – 2004 time frame oil-fired condensing appliances were completely absent from the U.S. market with the exception of one warm air furnace, which realized only a tiny market penetration. During roughly the 1998 – 2006 time frame there was a very strong growth of interest in oil-fired condensing boilers in Europe. Currently there are 30 European manufacturers offering oil-fired condensing appliances. Furnaces are totally absent from the European market. A range of products are on the market including wall-hung boilers with very compact heat exchangers that can only operate on low sulfur oil, conventional boilers to which corrosion resistant secondary heat exchangers have been added, and floor-standing larger condensing boilers which have "wide open" heat exchanger designs and can operate on fuels with normal sulfur levels (to about 2500 ppm). The development efforts in Europe have led to new materials choices including stainless steel and aluminum alloys.

The recent advances that have been made in this area present an opportunity for the U.S. to achieve higher levels of energy efficiency through the use of condensing boilers. In addition, in the U.S. market has a large market share is furnaces which can benefit much more than boilers from condensing technology due to the low return temperature. In the U.S. market, however, prior experience with condensing oil has left strong concerns over heat exchanger fouling, blockages, and maintenance costs. There is also uncertainly over how much energy savings can actually be realized with condensing.

In the past three years, two boiler manufacturers have started introducing oil-fired condensing residential boilers on the U.S. market. One furnace manufacturer has developed and introduced a redesigned oil-fired condensing furnace which offers the potential for reduced corrosion, fouling and maintenance. Two of these initiatives have been made with support from an industry organization, the National Oilheat Research Alliance (NORA).

The objectives of this project were to examine the efficiency gain achievable with condensing boilers under representative conditions and to study the field operation of condensing furnaces and boilers. In the field specific questions included heat exchanger corrosion and fouling as well as, in the case of boilers, the way these boilers are being installed, specifically: are they condensing? This work has been undertaken to technically support and promote the use of this energy efficient technology.

Work under this project has included laboratory studies of the performance of oil-fired condensing boilers, field evaluation of the performance of oil-fired condensing boilers, and cleaning / inspection of oil-fired condensing boilers and furnaces in the field after typically one year of service.

Laboratory Studies

Experimental

The purpose of the laboratory studies was to develop a performance map for the condensing boiler over the range from idle to full load. This performance map would then be used in a simple bin analysis to estimate the annual oil consumption for an assumed load profile. BNL is currently engaged in a study in which this approach is being used with a variety of integrated hydronic systems to enable comparison of annual performance and identify methods of reducing annual oil consumption. More details of this related effort can be found in a recent BNL paper (Butcher, 2006).

The basic test arrangement is shown in Figure 2. The "system" in this figure may include a boiler and water storage tank, a boiler with an internal coil for hot water production, a tank type water heater used also for domestic hot water, or any other integrated system. Fuel input is measured using a coriolis flow meter calibrated against a precision balance. The fuel heating value and density are measured using ASTM standard procedures.

For the heating load, boiler water is circulated through a plate heat exchanger. The mass flow rate of cooling water through the heat exchanger is directly measured with a platform weigh scale which communicates with the lab computer. Average flow rate during a heat load period is determined using a linear regression of the scale readings. The mass flow rate is combined with inlet and outlet temperature readings on the cooling water to determine heating energy output.

For the domestic hot water load the approach is similar. Mass flow of hot water is measured with a platform weigh scale in the same way and temperature rise of the water, integrated over a draw period, is used to determine domestic hot water output.

Steady state efficiency is determined for hydronic heating only and the effect of supply water temperature on efficiency is determined by adjusting the cooling water flow rate. The boiler supply / return differential temperature is essentially set by the internal flow rate. Each steady state test is about two hours in duration.

In the idle state the average fuel consumption required to maintain the system under a no-load condition is measured. This can vary widely among systems and is very dependent upon control decisions such as cold-start or maintain temperature and the degree of system insulation. These tests normally take several days. Where systems have indirect storage tanks the temperature profile in the tanks is measured and a correction is made for differences in the amount of stored energy between the start and end of a test.

For part load tests periodic loads are imposed on the system and these may include heating only, domestic hot water only, or a load pattern that combines both load types. Test periods typically last from 12 to 72 hours. The load patterns can be very complex if desired.

All load patterns are defined in an input file to the computer which controls the flow on/off valves, controls the weigh tank fill and draining, adjusts the modulating flow control valves, and records system temperatures and water flows.

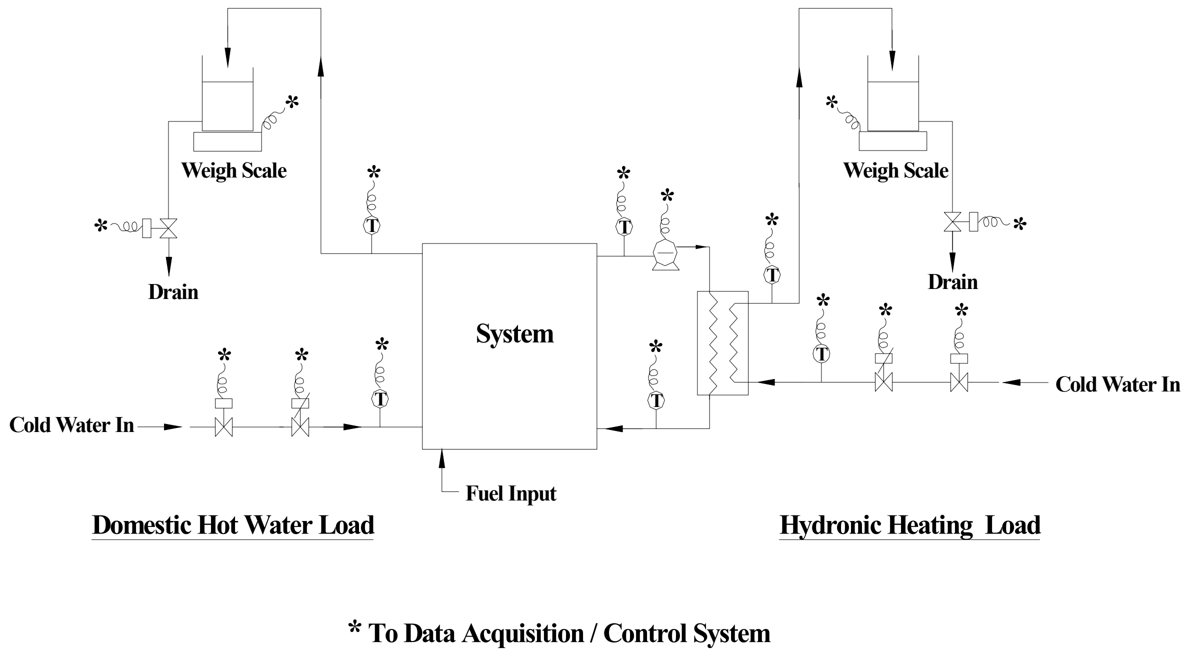


Figure 2 Illustration of the experimental setup

Results

A basic description of the unit as tested is as follows:

Unit Description:	condensing, steel, rated as a water heater to UL 732
Fuel:	No. 2 fuel oil
Nominal heat output	76109 Btu/hr
Aquastat:	custom control - packaged by manufacturer.
Domestic Hot Water:	40 gallon indirect
Burner type:	conventional, yellow flame, retention head
Features:	adjustable supply temperature with mixing valve
Nominal AFUE:	not rated

Table 2, below, provides a summary of all test results.

This boiler is configured with a primary (non-condensing) and secondary (condensing) heat exchanger configuration. It has two hot water "supply" connections. One is hot water directly from the primary heat exchanger and this is directed to the domestic hot water tank to provide rapid recovery. The second supply connection is a mix of water from the primary part of the heat exchanger and the return flow from the heat distribution system (e.g. baseboard convectors). A circulation pump and thermal mixing valve are integrated within the boiler jacket. The thermal mixing valve can be either fixed, manually adjusted or an automatic mixing valve with an outdoor temperature sensor can be used to implement an outdoor reset function. With the manual valve, the temperature of the supply water to the heating system would be adjusted based on the type of distribution system – a radiant floor heating system, for example, would have a lower mix supply temperature.

Table 2. Summary of Tests Done with Condensing Boiler and Results:

Parameter:	Test ID	Condition Code	Date Ended	Total Duration	Draw Pattern	Average Input	Average Output	Thermal Efficiency	Maximum Boiler Temp
Units:	-	-	-	hrs	on/off	Btu/hr	Btu/hr	(%)	F
	1	SS	5/5/2006	2	Steady On	77657.51	70745.98	91.10	120
	2	SS	5/5/2006	2	Steady On	77657.51	68726.89	88.50	164
	3	SS	5/5/2006	2	Steady On	77657.51	68338.6	88.00	177
	4	SS	5/5/2006	2	Steady On	77657.51	71444.9	92.00	136
	5	SS	5/5/2006	2	Steady On	77657.51	72454.45	93.30	131
	6	BI	5/10/2006	24	Idle	868	0	0.00	157
	7	SI	5/15/2006	24	Idle	1168.1	0	0.00	140
	8	HO	5/17/2006	12	5/55	7489	4600	61.42	157
	9	HO	5/19/2006	14	10/50	12619	10498	83.19	168
	10	DO	5/24/2006	12	5/55	7255	6208	85.57	183
	11	DO	5/25/2006	24	DHW	2833	1555	54.89	180
	12	HO	6/2/2006	5	15/15	36899	31955	86.60	180
	13	DO	6/6/2006	14	2.5/57.5	3641	2285	62.76	180

Notes relevant to the Results Summary Table Above:

Condition Codes:
BI = idle test, boiler only
SI = idle test, system (DHW indirect tank included)
HO = heating load only, part load test
DO = domestic hot water load only, part load test
HD = combined heating and hot water, part load test
SS = steady state test, heating only

1.refers to on/off pattern of the draw, not the burner operation. The burner operated under control of the aquastat as normal.

The boiler also has two return connections. One is at the end of the secondary heat exchanger such that this return water flows through the entire condensing heat exchanger. The second is also into the secondary heat exchanger but close to the transition between the primary and secondary heat exchangers so that this return flow would pass through only part of the secondary heat exchanger. For these tests both returns were connected to the first return port and so the flow was through the entire secondary exchanger at all times.

Figure 3 provides a simple illustration of how this boiler was setup for these tests.

In the test arrangement during steady state, heating mode tests, the temperature of the supply and return, can be varied in two ways: 1) With a fixed setting of the mixing valve the flow rate of cooling water to the heat exchanger can be varied and 2) With essentially constant boiler temperature, the setting of the mixing valve can be changed. For the tests presented in Table 2, the first approach was used with the mixing valve adjusted to a high setting. Following completion of all tests covered in Table 2 a separate study was done of the impact of each of these two methods and results are presented later in this section.

Two idle tests are included in Table 2, one with the boiler only and one with the boiler and domestic hot water tank. Clearly the idle losses with the boiler only are lower. This particular boiler is not intended for operation in a cold start mode, so that the burner will operate to keep the boiler at its setpoint temperature even when there is no heating or domestic hot water load.

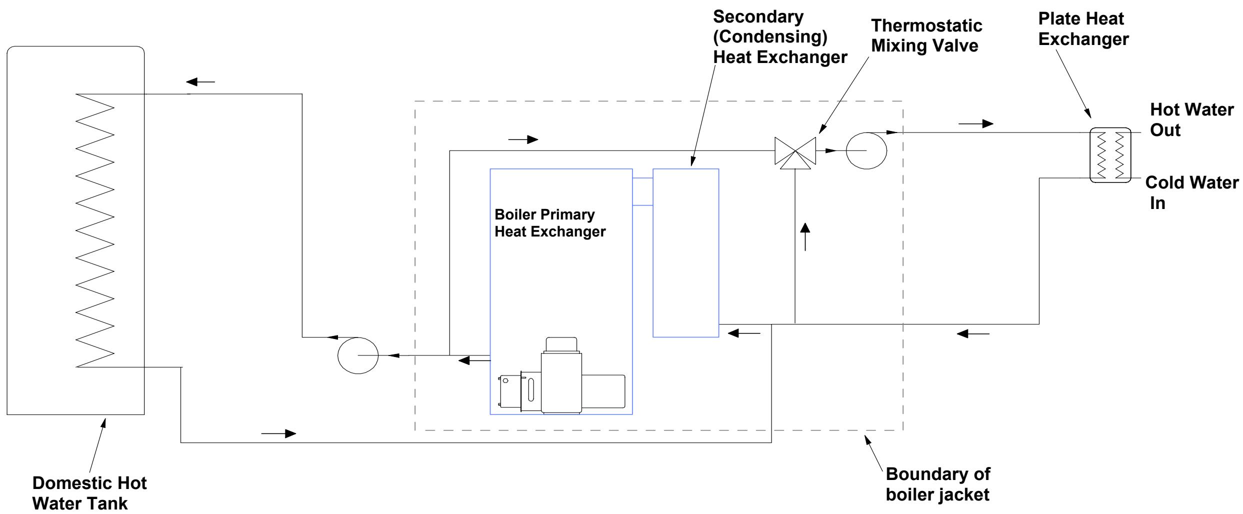


Figure 3 Basic test arrangement for oil-fired condensing boiler

<u>Analysis of Input / Output Relationship</u>

Figure 4 shows all input output points with the exception of the boiler-only idle point. At the highest load point there are a cluster of data points because these steady state tests were run at different water temperature conditions as shown in Table 2. This plot is repeated in Figure 5 with only one steady state data point shown, Test 2, during which the boiler average temperature was similar to that used during the part load tests. A comparison of Figures 4 and 5 shows that this step does not significantly affect the regression which is subsequently used to develop the efficiency / load curve. Figure 6 is the same data with only points with output under 20,000 Btu/hr shown.

From this curve, and the unit data, the steady state thermal efficiency of this unit is 88.5% and the idle loss is 1.53%. The efficiency of this system for an average domestic hot water only load of 1720 Btu/hr would be 55.4%.

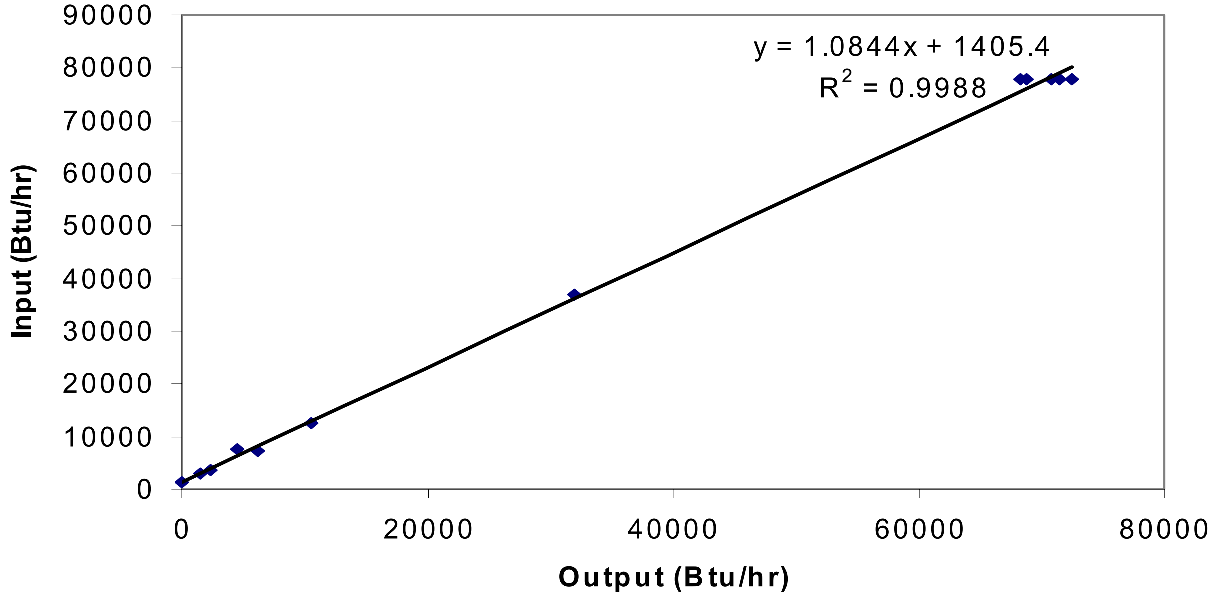


Figure 4 All measured condensing boiler input/output points with exception of boiler idle (only system idle shown)

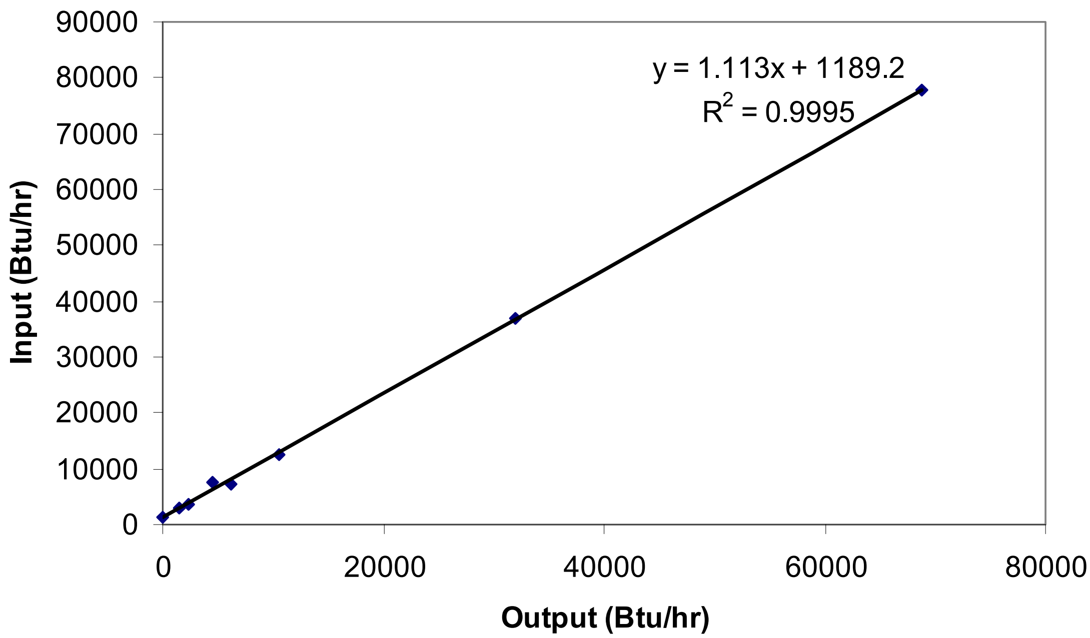


Figure 5 Input / output points with only 164 F supply steady state point included

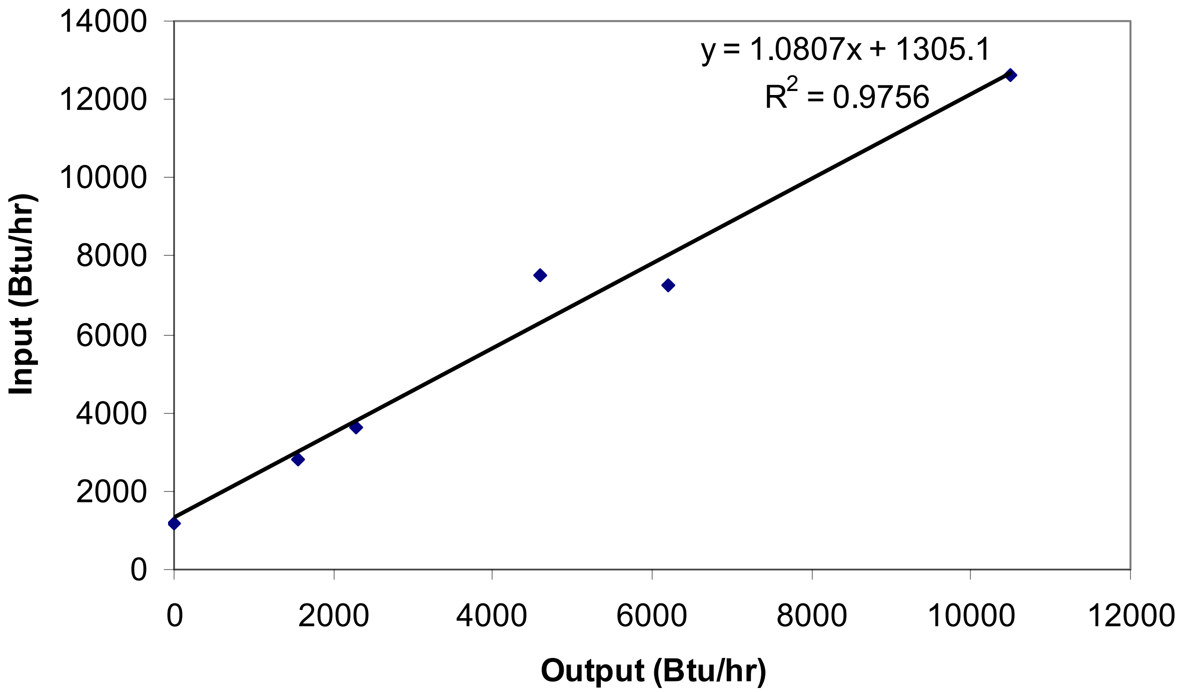


Figure 6 All data with input under 20,000 Btu/hr

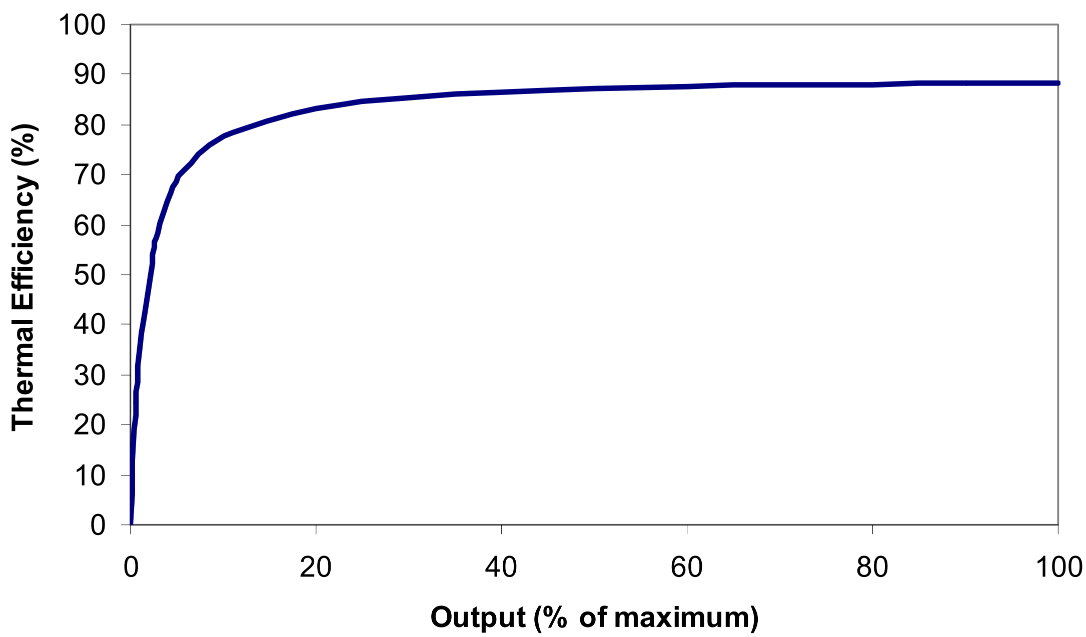


Figure 7 Thermal efficiency vs output expressed as a percentage of maximum output. Using regression from Figure 5

Example Temperature Profiles

Figure 8 shows a typical profile for the supply and return water from the domestic hot water tank during a system idle test. During this test the burner fired to maintain just the boiler temperature at a time interval of 3 hours. The burner typically fired for about 1 ½ minutes. Every 12 hours the domestic hot water tank called for heat under this no-load test. The return water temperature as shown is much too high for condensing to occur during this type of load.

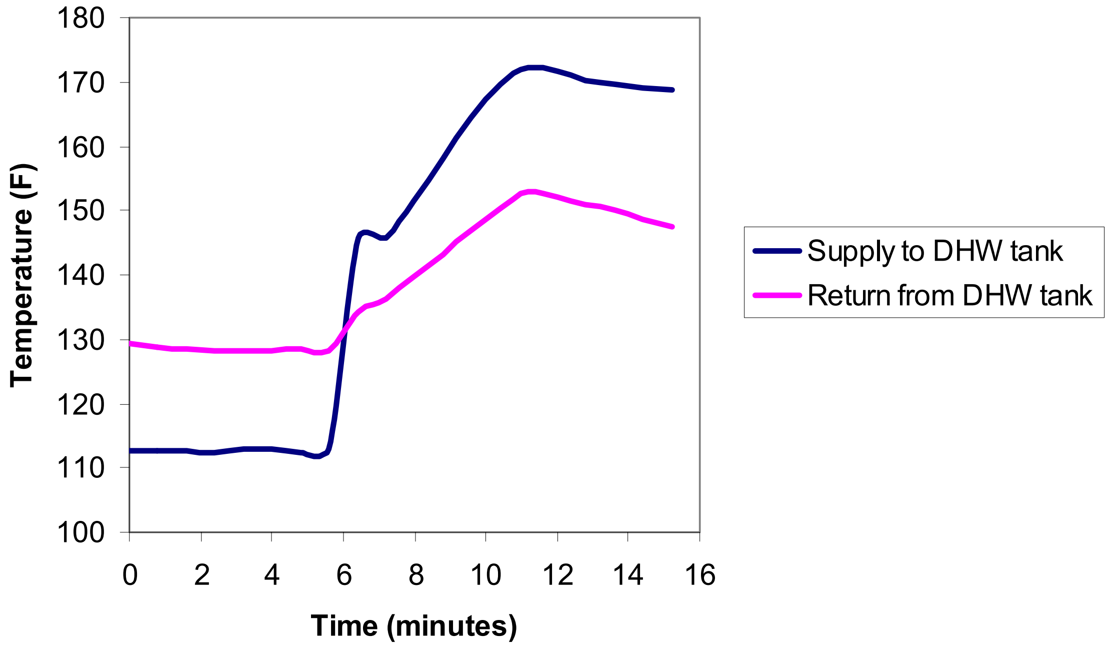


Figure 8 Example boiler supply and return water temperatures during a tank heat call in a system idle test. The tank aquastat "called" at about the 5.5 minute point.

Figure 9 shows how the tank average temperature varies during a DHW draw test. This specific data set was taken during Test 10. The time interval between "points" shown in this figure is 3 seconds. Figure 10 shows how the tank internal temperature varied during a DHW draw test.

Figure 11 provides example data during a typical heat call in a heat only test. In this figure boiler temperature is the temperature of the boiler water entering the mixing valve. Supply is the mix temperature. Gas temperature is measured between the primary and secondary heat exchangers. This measure is a useful indicator of burner operation. Heat call started at the 1 minute point and ended at the 6 minute point. The cooling water out temperature is the temperature of the cooling water leaving the heat exchanger.

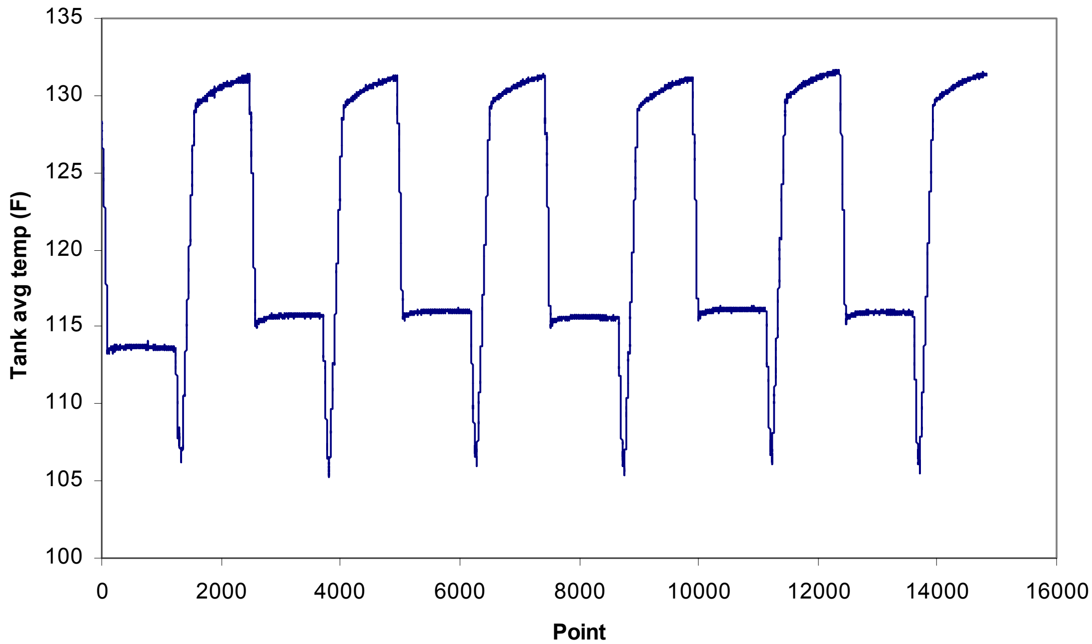


Figure 9 Example average DHW tank temperatures during DHW draw test, Test 10.

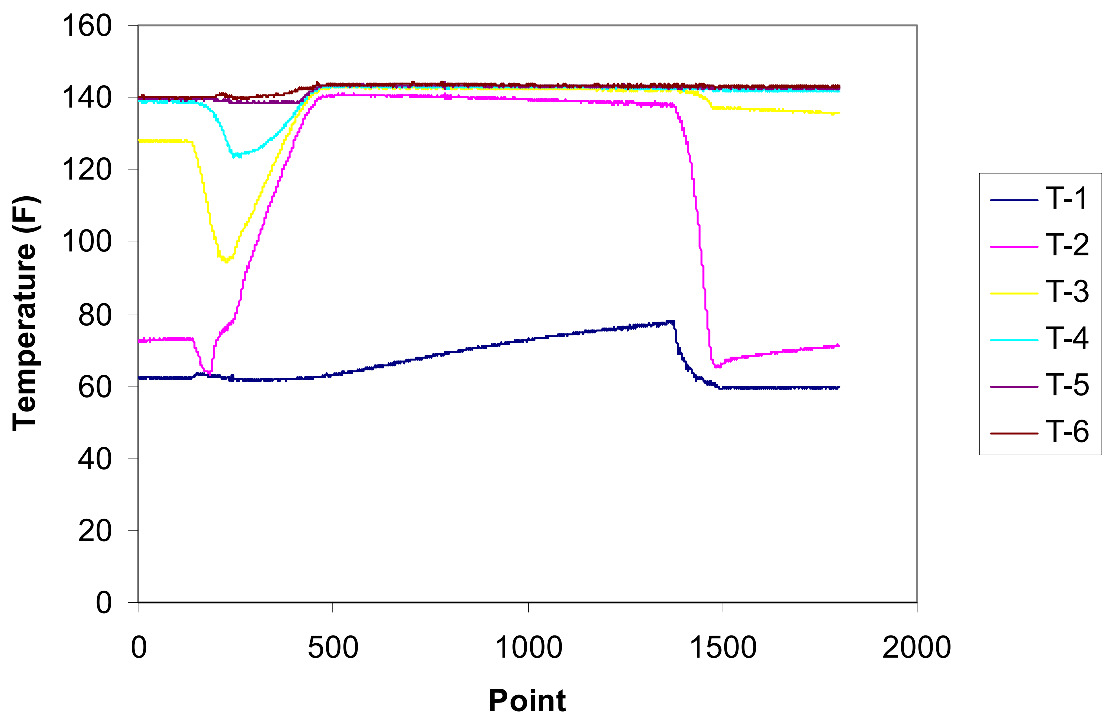


Figure 10 Typical internal water tank temperatures during a DHW draw test. Temperatures are measured from the bottom (T1) to the top (T2)

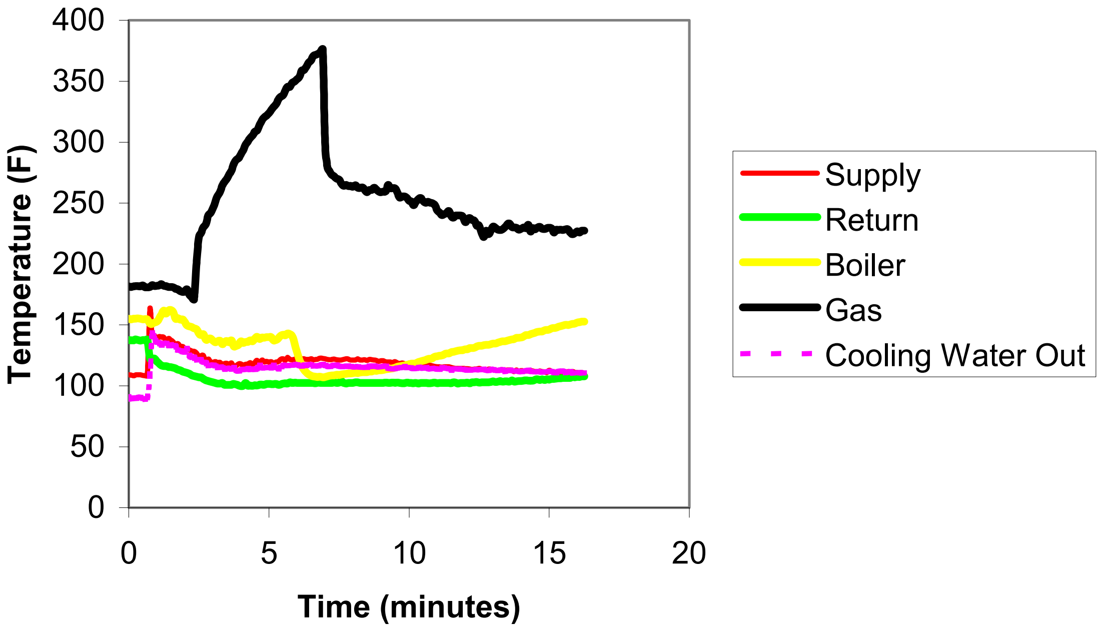


Figure 11 Example temperature data during a heating only call (Test 8)

Supplemental Tests on the Impact of Water Temperature

As discussed above, the temperature of the boiler water can be controlled in two ways: 1) With a fixed setting of the mixing valve the flow rate of cooling water to the heat exchanger can be varied and 2) With essentially constant boiler temperature, the setting of the mixing valve can be changed. The actual temperatures in the field will depend very much upon the control settings, which in turn are based on the type of distribution system. Baseboard radiators will require higher temperature water than radiant floor heating. With an outdoor reset or other type of control the temperature of the supply water can vary considerably during the heating season. To evaluate the impact of water temperature on efficiency a series of steady state tests were done using both of the two above approaches. Figure 12 shows the measured steady state thermal efficiency and indicates that somewhat higher efficiency can be reached, particularly at lower return water temperatures if the entire boiler temperature is modulated. While this specific boiler is not designed for operation in this mode as it would lead to condensation and, likely, high corrosion rates in the primary heat exchanger, some other condensing boilers are designed in this way. It is not an unexpected result – if the boiler can condense anywhere it will achieve higher efficiency than if it condenses only in the secondary heat exchanger. All of these steady state tests were conducted with a relatively low excess air setting: flue gas O_2 was 2.7% and the corresponding CO_2 is 13.7% and excess air is 14.3%.

For this same set of tests Figure 13 shows the rate of condensate collection from the boiler as a function of return water temperature and Figure 14 shows this in the form of latent heat recovery. This latent heat recovery is expressed as a percentage of the fuel energy input. In other terms, it is the improvement in the boilers thermal efficiency due only to the latent heat recovered by condensation.

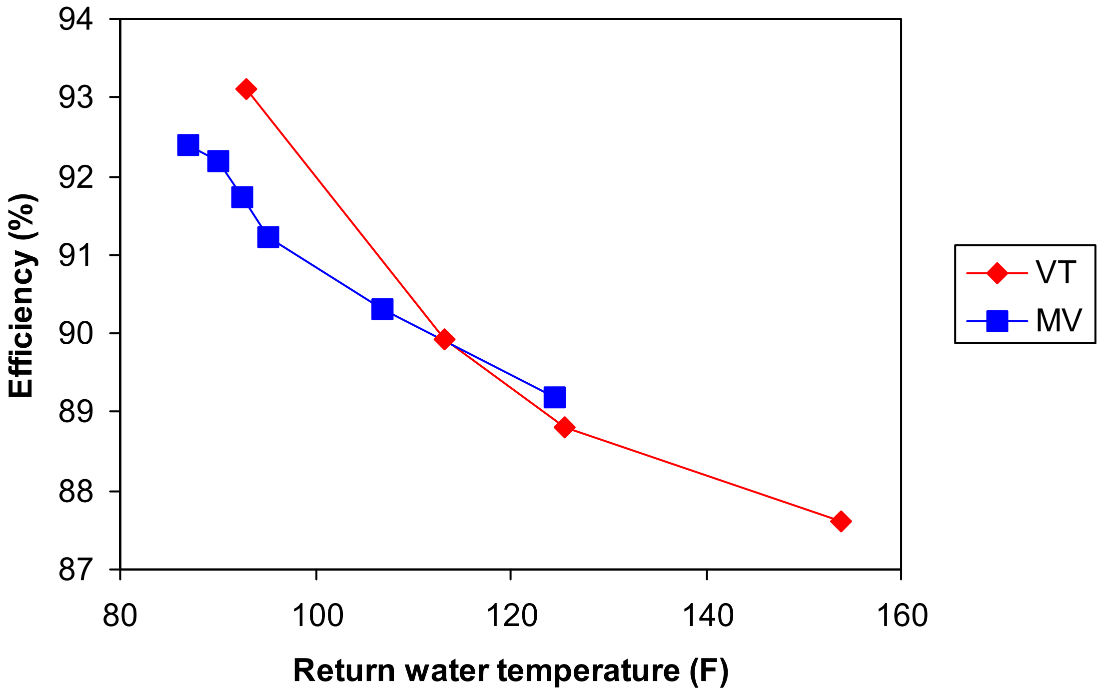


Figure 12 Steady state thermal efficiency as a function of water temperature (return water temperature selected as independent variable. MV – refers to case with constant boiler water temperature and supply/return temperature changed by changing the mixing valve setting. VT- refers to case where temperature of entire boiler is modulated. In this case the mixing valve is set to provide boiler water directly (unmixed) to the heating load.

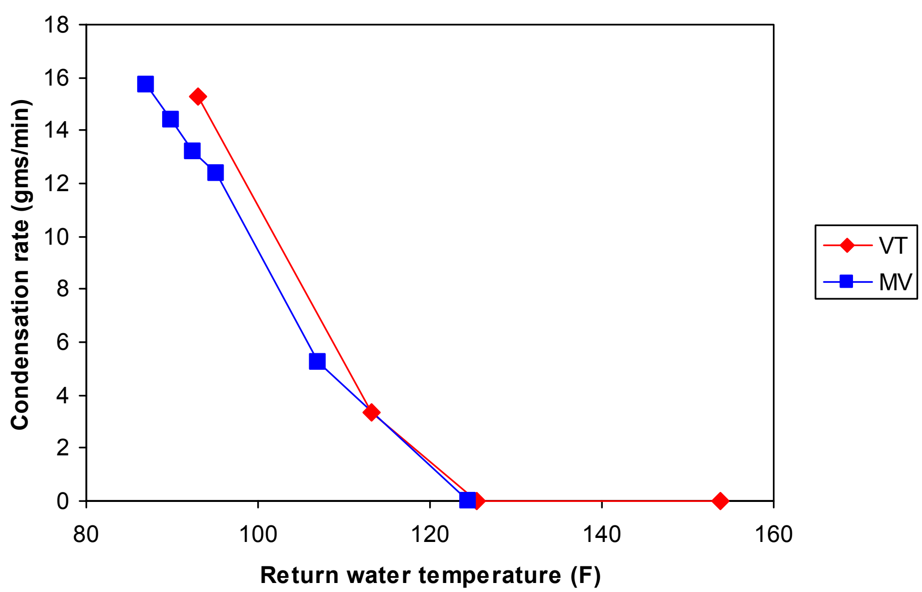


Figure 13 Steady state tests with variable water temperature. Condensation rate vs. return

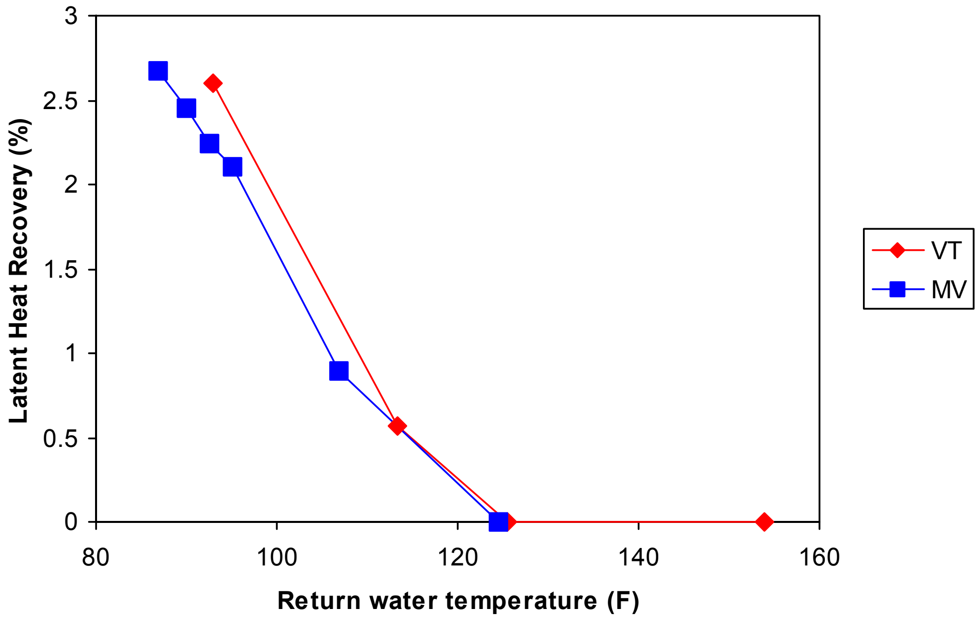


Figure 14 Steady state tests with variable water temperature. Latent heat recovery vs. return

Electric Power Consumption

Measurements of individual burner components were made as follows:
Boiler control system alone: 40 watts
Circulator: 84 watts
Burner with igniter on – 203 watts
Burner with igniter off – 273 watts.

The burner primary control has interrupted ignition feature so that, on startup the igniter is on but after ignition has been proven the igniter power is off. Total running power for the burner, circulator, and controls then is 327 watts.

Field Studies

Warm Air Furnaces

Background Related to the Development of Oil-fired Condensing Furnace Designs: The benefits associated with condensing oil-fired warm air furnace systems are smaller then for gas-fired units due to the nature of the fuel as discussed earlier. Heating oil has a lower hydrogen content level that of utility gas. The amount of energy loss due to water vapor (steam) formed during oil combustion is approximately 6.5% compared to 8.8% for gas-fired systems. Regardless of fuel type, the design of a condensing warm air furnace is much easier to accomplish in comparison to a hydronic boiler. The thermal distribution system with air as the working fluid provides a much lower return temperature that can be used effectively in the design to allow for condensation to occur in the heat exchanger. This is accomplished by increasing the heat exchanger surface area to allow for the return air to flow over the extended surface areas or more typically the use of a secondary heat exchanger in series with the primary heat exchanger. The cooling the combustion gases to a level sufficient to accomplish condensation of the water vapor formed during combustion. This allows for the recovery of the latent heat of vaporization of the steam formed during the combustion process. As discussed earlier this is much more challenging when considering hydronic heating systems that have traditionally been designed with much higher water temperatures in the thermal distribution portion of the heating system.

There is however a common issue related to materials and the higher potential for corrosion of those materials. This is more of a concern with oil in comparison to utility gas due to a higher sulfur content of the fuel. Traditional heating oil has a sulfur content of approximately 0.18% by weight although in some regions a low sulfur content heating oil of less then 0.05% sulfur has been marketed as a premium fuel option. A small but significant amount of the sulfur forms sulfuric acid that as it condenses, attacks the common steel used to construct non-condensing furnaces. In addition other lesser amounts of nitric acid and chlorides (related to the combustion air) cause additional corrosion concerns with both gas and oil-fired condensing systems. Chlorides are of particular concern when stainless steels are used as they contribute to stress corrosion pitting and cracking. This mixture of acidic components required a great deal of material research during the late 1970s and early 1980s to determine which materials should be selected to provide a good product that could withstand the corrosive environment that a condensing heat exchanger needed to survive. Several materials were deemed suitable and manufacturers designed both gas and oil heating products.

The additional cost of using these materials to construct condensing furnaces was significant. The benefits associated with gas-fired systems were also quite significant. A typical replacement condensing gas-fired furnace with an efficiency of 95% would replace a low efficiency atmospheric gas furnace with an efficiency of about 60%. The best non-condensing gas fired furnace having an upper limit of about 80%. If a gas fired furnace is designed so that its efficiency is between 80 and 90% it creates yet another problem related to corrosion in the venting system of the furnace. Its temperature is still too high to allow it to be vented with plastic materials (used with fully condensing systems) yet its too low for commonly used gas-venting systems. The typical B-vent (gas fuel) is not designed for the potential of corrosive environment and with the high hydrogen content of the fuel there exists a significant potential for excessive condensation to occur in the vent. To design robust vent systems would have driven the total cost well over what was viable given the economics. High efficiency oil-fired systems on the other hand could and were designed with efficiencies as high as 88% without condensation and the typical chimneys being of masonry construction did not generally exhibit issues due to corrosion. In those cases where the potential did exit the chimneys could easily be relined using a corrosive resistant liner material. As a result of the characteristics of the fuel, oil-fired systems had a much smaller potential for efficiency gain of about 7% and the incremental costs were quite high to design fully condensing oil fired furnace. In the early 1980s two companies choose to offer products of this type for use with heating oil. One company suffered problems with inadequate vent design and vent sizing issues. This company subsequently went out of business. The other small furnace manufacturer had a very efficient design that did not have issues related to venting the furnace but its design lacked adequate access for periodic cleaning of the internal surfaces of the heat exchange. The models built from 1986 to 1994 did not have a rear cleanout or access for proper service. Without being able to clean the condensing coil from the rear, the coil would plug up causing high temperature and the unit would fail on auxiliary limit. A plugged coil would also cause build-up of soot at the rear of the heat exchanger and due to materials (cold rolled steel). Soot combined with condensate would destroy the rear of the heat exchanger. In general many of units were removed when service related issues caused consumer dissatisfaction. Some units have remained in use for a period of up to twenty years. Those units that remained in the field did provide evidence of the durability of the material selected for fabrication of the condensing heat exchanger, a highly corrosion resistant alloy called AL 29-4C, could hold up to the corrosive environment of oil-fired applications. AL 29-4C alloy is a superferritic stainless steel designed by Allegheny Ludlum for extreme resistance to chloride ion pitting, corrosion and stress corrosion cracking as well as general corrosion in oxidizing and moderately reducing environments.

More recently the first examples of a newly redesigned oil-fired condensing furnace design developed by a small furnace manufacturer under a National Oilheat Research Alliance (NORA) development grant have begun to be introduced on the market. This design incorporates changes that now allow for proper access, disassembly and cleaning of the condensing secondary heat exchamger fabricated of AL 29-4C. These furnaces utilized materials and design recommendations supported by prior research findings published by Brookhaven National Laboratory based on work contracted by Battelle under DOE-EERE funding.

In the current design the complete primary heat exchanger section is made of a 409 stainless steel instead of cold rolled steel. The secondary heat exchanger is the condensing section and is made of AL 29-4C stainless steel with 60 turbulators (baffles). The materials used were based on those recommended in prior BNL reports. After an intense study on the effects of sulfur and other chemicals on metals used as heat exchangers in heating equipment. The heat exchanger is shown in Figure 15.

The primary heat exchanger is where the oil burner is mounted (409 stainless steel) and the secondary or condensing heat exchanger is formed of smaller diameter AL 29-4C with fins on the outside and baffles on the interior or flue gas hot side.

The secondary heat exchanger works like a self-cleaning process as the condensate (mildly acidic water) passes thru the heat exchanger it washes the soot away. The secondary heat exchanger is tilted six degrees to allow for drainage. The furnace must be level at installation to ensure that the drainage works properly. For every gallon of oil combusted there is approximately ¾ of a gallon of condensate that dilutes help wash the internal passages. The stainless steel used and the continuous drainage of the fluid help eliminate areas where acids might otherwise build up and cause an increased potential for corrosion of the metal.

Figure 15. Condensing furnace heat exchangers, front and rear view

Energy Savings with Oil-fired Condensing Warm Air Furnaces
In the United States oil-fired warm air furnaces are used in approximately five million homes to supply comfort control during the heating season. To date only a handful are designed to operate in the condensing mode as represented by this new product line.

BNL has analyzed fuel delivery records obtained from a major fuel oil marketer located in Hampton, Virginia for both condensing and non-condensing furnace replacements.

In all, there were nineteen condensing oil-fired furnaces installed within the customer base. Each customer's fuel delivery file and service record were analyzed with regard to actual energy saved as a result of the installation. Of the nineteen homes most had only recently had the furnace replaced with the condensing high efficiency furnace with an AFUE rating of 95%. Any that had less then the minimum one-year of prior history in the customer base and additionally at least one year's experience with the condensing furnace were eliminated from the analysis. Most were exempted because the number of fuel deliveries either before or after installation was too few to allow for a proper assessment of fuel usage versus accumulated degree-days. Experience with this type of comparison to evaluate energy savings has proven to be not reliable without sufficient data. Issues of short fills of the tank, record-keeping errors, etc. are generally the cause of poor conclusions. Of the nineteen homes with a condensing furnace, only four homes satisfied the requirements. These resulted in an average energy savings of 25-45% as compared to the prior period of use. The average savings was 35% in annual fuel use for the condensing furnace. The savings calculated was based on normalization of degree-data and by correcting usage by using a long term K-factor (degree-days per gallon of fuel) for the entire period before or after and using the average number of degree-days for the years before and after installation and fuel delivery dates and quantities.

This was compared to homes where the furnace was replaced during the same time period with a non-condensing but high efficiency replacement furnace. Out of a group of forty homes where the furnace had been replaced with a new but non-condensing furnace twenty were found to be acceptable for full analysis based on the same selection criteria used for qualifying the condensing furnaces. The savings ranged from 2 to 32% with an average fuel use reduction of 19.3%. Four cases, which were ignored, actually had an increase in fuel usage after the furnace was replaced. This might have been due to other changes that occurred that were not documented in the service records that were obtained. A modification to the structure increasing its size could explain this or a change in operating habits resulting from occupancy changes.

These results are in fairly good agreement with the expected savings based on an AFUE rating of typical modern non-condensing oil-fired furnaces have an AFUE rating of 80 - 82 % and the condensing units have an AFUE rating close to 95% The AFUE values for a older furnace typical of one needing replacement would have an average AFUE value of about 65% and when replaced with a conventional furnace would be expected to result in a fuel use reduction of 19-20%. The same unit replace with a condensing furnace with an AFUE of 95% would be expected to result in a savings of 32%. The results from the field study are in fairly good agreement with the expected results based on AFUE ratings of warm air furnace replacements.

Durability of Oil-fired Condensing Warm Air Furnaces

BNL secured the cooperation of a major fuel oil marketer in Hampton, Virginia allowing a staff member to visit the company for the purpose of inspecting several condensing warm air furnaces that had been in service for one or two heating seasons. A staff member accompanied a representative of the fuel oil marketer to the home of three customers. The purpose of the inspections was to access the durability of the condensing heat exchangers and associated materials. These were some of the same furnaces reported earlier where pre- and post-installation fuel use records were used to evaluate the energy savings with this newly emerging product line. These are the first examples of a redesigned oil-fired condensing furnaces design developed under a NORA development grant. These furnaces utilized materials and design recommendations supported by prior research findings published by Brookhaven National Laboratory based on work contracted by Battelle under DOE funding.

The condition of all three units was found to be excellent. Absolutely no indication of corrosion was detected in any of the heat exchangers. The unit installed in the first house, “Unit A,” had been in use for almost two years (20 months) and there is no indication of corrosion. There was evidence that a gasket was not sealed well and condensate had dripped out from around the condensate collection / exhaust cover. The representative of the fuel oil marketer rectified this condition at the time of the site inspection. Pictures of the unit and the condensing heat exchanger are shown in Figure 16.

The unit installed in the second house “Unit B” had been in service for 14 months and was also found in excellent condition with regard to the condition of the heat exchanger. The unit was located in a crawl space under the home. No evidence of corrosion was present. This unit had recently been cleaned as part of the annual service provided by the fuel oil dealer. According to the service representative from the company, it is typical of the condition that the heat exchangers after cleaning. There is generally some evidence of a very thin coating of black soot that is easily removed and the units are brought back to like new condition without much cleaning effort. The shiny condition of the heat exchanger material, alloy 29-4C, is the end result. The furnace and the condition of the heat exchanger are shown in Figure 17.

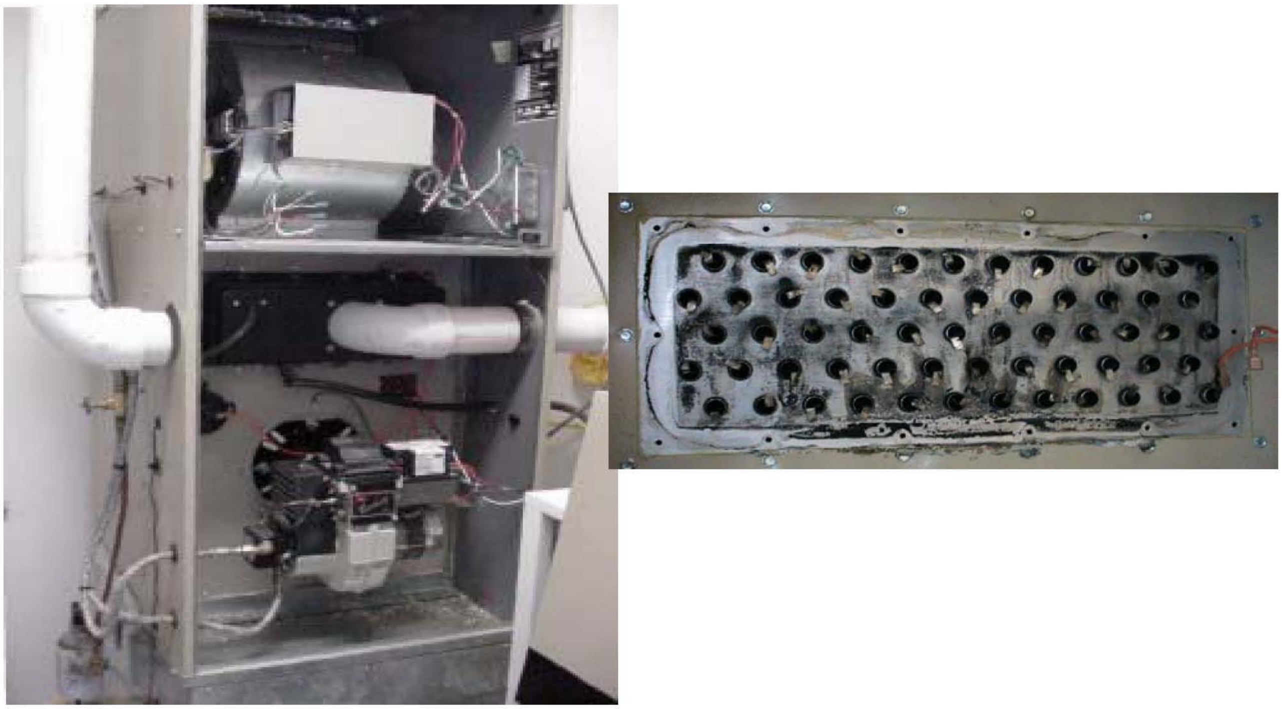


Figure 16 Condensing furnace, Unit A, during inspection after ~2 years field operation.

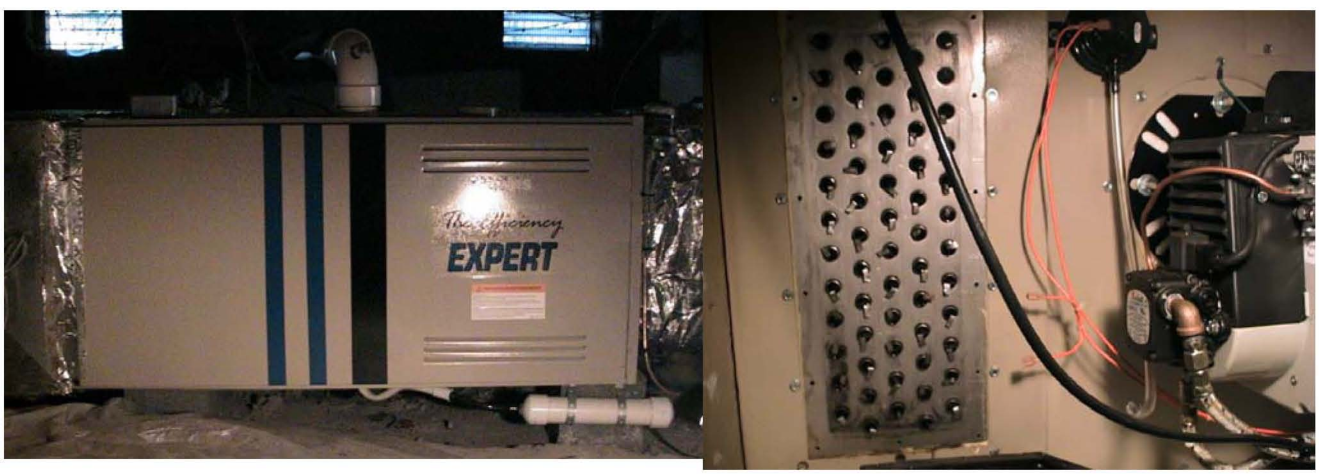


Figure 17 Condensing furnace and heat exchanger from house "B"

The unit installed in the third home, house "C" had been in service for 24 months (2 years) and also does not exhibit any signs of corrosion in the condensing heat exchanger. This unit had a similar gasket leak as in the first location, house "A" but in this case the gasket appeared to be leaking at the top of the condensate / exhaust cover as indicated by two small soot spots. There was no evidence of a condensate leak. Again, the service technician rectified this after the inspection. Although the heat exchanger had a light coating of soot, no evidence of corrosion was evident. The furnace and the condition of the heat exchanger before cleaning are shown in Figures 18. The heat exchanger after cleaning is shown in Figure 19.

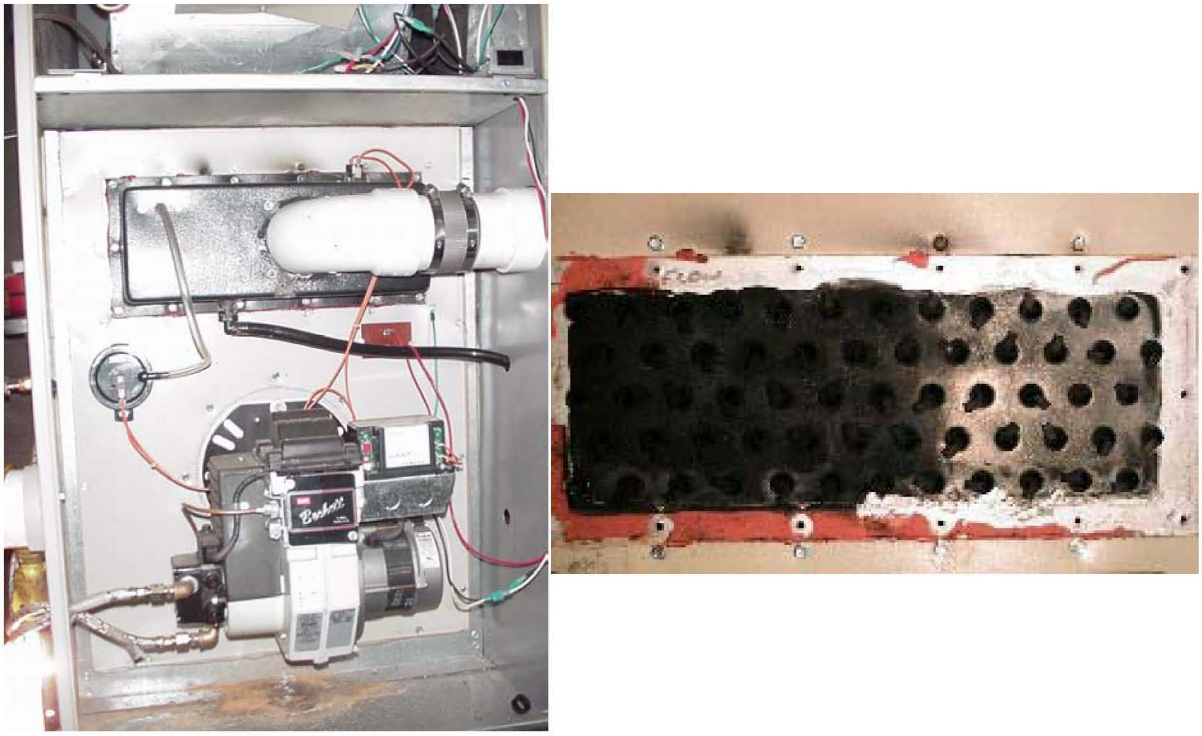


Figure 18 Furnace and heat exchanger, Unit C, prior to cleaning

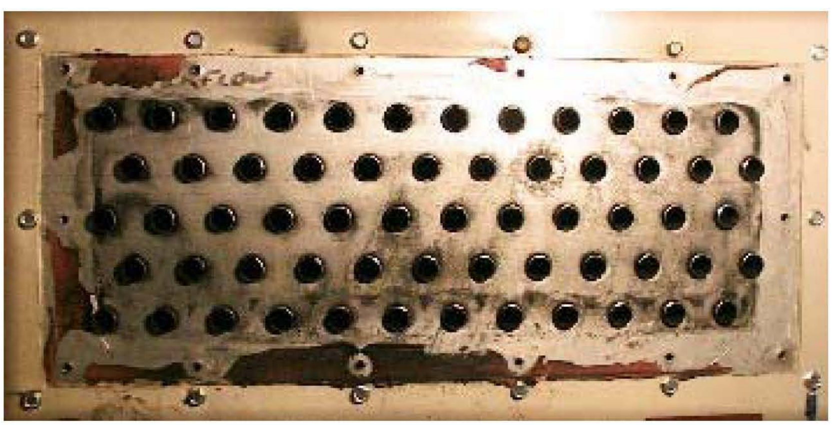


Figure 19 Unit C, condition of the heat exchanger after cleaning

An earlier test site of a condensing warm air furnace (see Figure 20) had been surveyed after its installation on Long Island but due to a change in ownership and issues related to an early production unit's mechanical failure the furnace was removed before this study was concluded. The unit's efficiency, stack gas determination, was 93% with an exit temperature of 120 F. Figures are included to illustrate air intake and vent configuration.

Figure 20. Installed unit and vent arrangement. Site visited early in project. Unit was removed before study was concluded

Condensing Hydronic Boiler Field Experience

Earlier in this project several site visits were made in an attempt to find a location to monitor the performance of a condensing oil-fired boiler. Of these one has been discussed in great detail in a recently published report (Butcher, 2004). This test site has been extensively instrumented and the report describes the experience with one condensing boiler over the course of a heating season. It discusses the use of condensing boilers in residential heating systems and the potential for significant improvements in efficiency. For condensing boilers to operate in a condensing mode the return water temperature needs to be about 10 degrees below the saturation temperature for the flue gas water vapor. This saturation temperature depends on fuel type and excess air and ranges from about 110 F to 135 F. Conventional baseboard hydronic distribution systems are most common and these are designed for water temperatures in the 180 F range, well above the saturation temperature. Operating strategies, which may allow these, systems to operate in a condensing mode have been considered in the past. In this study an approach to achieving this for a significant part of the heating season has been tested in an instrumented home. The approach involves use of an outdoor reset control, which reduces the temperature of the water circulating in the hydronic loop when the outdoor temperature is higher than the design point for the region. Results showed that this strategy allows the boiler to operate in the condensing region for 80% of the winter heating season with oil, 90% with propane, and 95% with gas, based on cumulative degree-days. The heating system as tested combined a space heating and domestic hot water function using an indirect, 40-gallon tank with an internal heat exchanger. Tests conducted during the summer months showed that the return water temperature from the domestic hot water tank heat exchanger is always below the temperature, which will provide condensing operation of the boiler. In the field tests both the condensing boiler and the conventional, non-condensing boiler were in the test home and each was operated periodically to provide a direct performance comparison." The result was a level of understanding of the challenges associated with installation using condensing boilers in the field with existing hydronic thermal distribution.

The research staff visited several other sites with somewhat different results regarding the degree to which the condensing boilers actually condensed. One located in Standfordville New York is shown in Figure 21. Temperature data loggers were installed and the site was monitored over a two-week period. This condensing boiler at this site was not installed properly with regard to condensing operation. Future modifications were planned and underway that might result in condensing operation but at the time of inspection the condensate drain line wasn't even connected as no condensate was possible with baseboard return temperatures were above 140 F on a consistent basis during the two weeks of recorded temperature data. The unit was found to operate with a high efficiency but not at the level where condensing mode operation would be expected.

Stack efficiency measurements were made during the site visit the results were an efficiency of 91.7%, with a stack temperature of 149 F at the flue outlet, oxygen level of 3.7%, the CO level was 2 ppm, NOx emissions were 109 ppm and the SO2 level was 62 ppm.

Figure 21 Condensing boiler at Standfordville, NY site

Another located in Walden, New York is shown in figure 22. Temperature data loggers were again installed and the site was monitored over a two-week period. This condensing boiler at this site was not installed properly with regard to condensing operation either. Stack efficiency measurements were made during the site visit the results were an efficiency of 90.8%, with a stack temperature of 173 F at the flue outlet, oxygen level of 5.3%, the CO level was 3 ppm, NOx emissions were 177 ppm and the SO2 level was 50 ppm. The site did have a complex thermal distribution system shown in Figure 22 but it was not optimized for condensing operation of the boiler. The home was an older structure where the first floor had been retrofitted with radiant floor heating but yet retained its baseboard convectors on both the first and second floors as well.

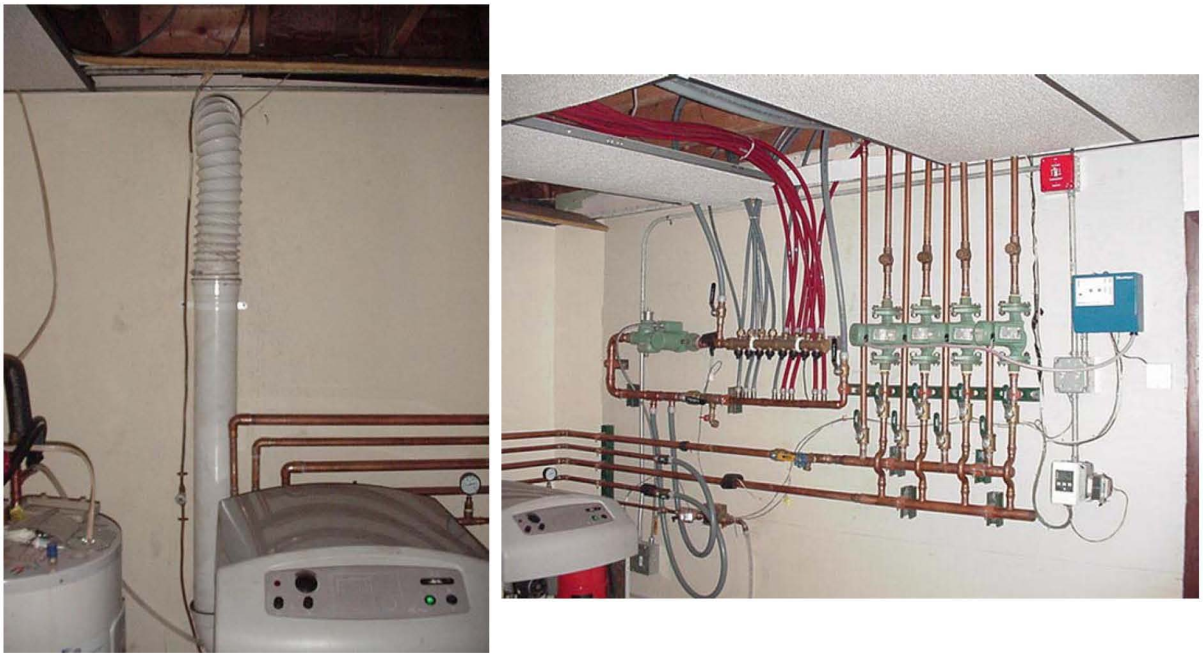


Figure 22 Condensing boiler and complex distribution system, Walden, N.Y.

BNL Participation In Field Trials of a New Condensing Boiler Design

In its efforts to support the development of new high efficiency options for the oil heat marketplace NORA once again has supported a private sector company with a research and development grant to commercialize a condensing boiler. In this instance the company working with NORA asked BNL for its input on several European condensing boiler technology options and selected one company to work with. By using the European heat exchanger along with a proven US oil burner option and with US controls a product was rapidly developed for evaluation in field trials. BNL was asked to participate in the field evaluations and a suitable test site was selected, the same one that had been used in the work described in BNL--73314-2004-IR (Butcher, 2004).

During the 2005/2006 heating season BNL conducted a field study of a prototype oil fired condensing boiler. This unit, recently introduced to the market, is a residential oil-fired condensing appliance that achieves efficiency of 93% AFUE. The heating surface is a simple cylinder that is easy to clean and is made of 904L stainless steel. This boiler is available with an input of 70,000 Btu/Hr (0.5 GPH) or 84,000 Btu/Hr (0.6 GPH) and uses a conventional flame retention head oil burner.

Traditional boilers will condense if the return water temperature and firing rates are low enough. However, if a traditional boiler condenses in the heat exchanger, the materials are not designed to resist chemical attack by acidic condensate. These materials will degrade and fail under condensing conditions. Therefore, manufacturers of traditional boilers warn against designing systems with very low return water temperatures or very low firing rates. Many hydronic heating systems utilize low-temperature water for heating. Radiant floor heating systems may only require 100ºF boiler water, while snow melt systems can use even lower temperatures.

BNL recently (2004) completed a study that indicates a condensing boiler can run in the condensing mode for 60 to 80 percent of the heating season if an outdoor reset control is used. These controls allow the appliance to operate at their highest temperatures only when the heating load is the greatest (during the coldest weather). When the outdoor temperature increases, the boiler water temperature decreases. This allows a condensing boiler to operate in its optimum mode for most of the heating season. The boiler tested comes equipped with an outdoor reset-capable control.

For combustion products to condense, they must contact a surface that is below the dew point of the gases. For oil combustion, about 6.5 percent of its energy is in latent heat. The theoretical maximum condensation that can occur is about 1.3 pounds of condensate per pound of fuel oil. A radiant floor heating system should be able to achieve 30 percent to 50 percent of that.

Boiler Design
The geometry of the boiler is a simple vertical cylinder (904L stainless steel) with an inner diameter of about 12 inches by 40 inches in height and is designed so that the oil burner fires down the centerline. Within the diameter of the cylinder are a series of seven baffles (also stainless) assembled into what the manufacturer refers to as an "upper jet," with three baffles and "lower jet" with four baffles. The baffles are formed as shallow (about 3 inches) pans with solid bottoms and walls perforated with holes (ranging from about ½ to1/4 inch diameter depending on if in the upper or lower jet assembly). The holes that form the perforations channel (or "jet") the hot combustion gases sideways before they travel down to the next pan shaped baffle. In this way the gases are forced to flow past the walls of the cylindrical heat exchanger providing excellent heat transfer. The temperature drops as the gases travel lower and lower. Eventually condensation starts to occur and the condensate runs down the walls of the heat exchanger and is collected at the bottom of the unit.

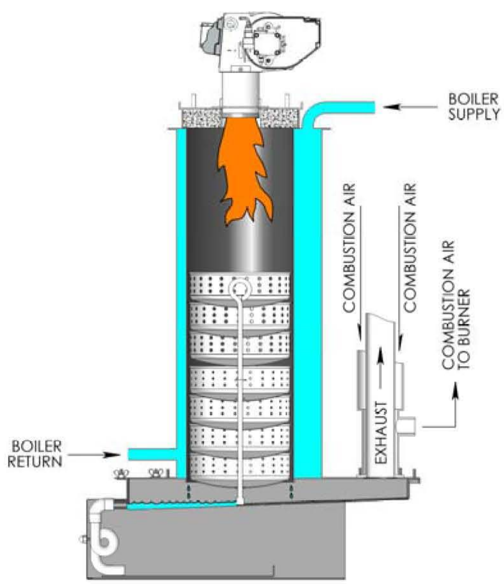


Figure 23 New condensing boiler design

The boiler has a large drain pan in its base to collect condensate. The condensate is drained from the pan through a 3/4-inch Schedule 40 pipe. A condensate trap is required to prevent combustion gases from exiting through the condensate piping. After that, a condensate neutralizer before the drain is recommended.

The boiler uses a concentric vent/air inlet pipe; the vent pipe is made of polypropylene. This piping is used extensively in Europe for venting of both natural gas and oil-fired appliances. This material has a maximum operating temperature of about 250ºF. The boiler is also only available for direct vent, sealed combustion operation. It cannot be vented into a chimney however, an existing chimney can be used as a chase to vertically vent the boiler.

Field Results

The pre-production prototype was installed during the second half of the heating season in a house located on Long Island, NY. During the following summer a team consisting of BNL staff, the boiler manufacturer and one oil burner manufacturer visited the test site to do a post heating season inspection and cleaning. The boiler showed minimal corrosion on average. The point of highest corrosion was located near the return flow connection where condensing is occurring as expected. A simple water wash procedure was used to effect cleaning and this worked well. BNL took samples of the deposits for iron and sulfate analysis. Figure 24, below, indicates the boiler surface condition before cleaning (left) and after (right). The cleaning was done with a garden hose with an ordinary spray nozzle and the rinse was flushed down the walls and out the condensate drain.

Figure 24 Condensing boiler before and after cleaning by water wash

The deposits were light and sooty and indicated that the burner had not been adjusted with the correct air to fuel ratio towards the end of the heating season. A substitute burner having been tested recently caused this condition. In fact the smoke upon arrival at the test site was well above a number four on the ASTM smoke scale. The next series of photos (Figure 25) indicate the condition of the lower "jet" assembly both before and after it was cleaned using a water spray only. The deposits at the bottom were "sticky" in comparison to the light fluffy condition of the deposits at the top. The upper "jet was somewhat cleaner but was in similar condition as the lower assembly.

Figure 25 Upper "jet" before (left) and after cleaning

Boiler fouling deposits taken from the boiler were also analyzed for iron and sulfate concentrations and the results are shown in Table 3.

Table 3 Condensing Boiler Deposit Analysis

Condensing Boiler Deposit Analysis (Long Island)

#	Sample Location	Sulfate Concentration Determined	Iron Concentration Determined	% Sulfate by Weight	% Iron by Weight
1	Top, Upper Jet	10 mg./liter	2.49 mg./liter	6.8 %	1.7 %
2	Bottom, Upper Jet	33 mg./liter	2.99 mg./liter	21.2 %	1.9 %
3	Top, Lower Jet	26 mg./liter	>3.3 mg./liter	18.4 %	> 2.4 %
4	Bottom, Lower Jet	27 mg./liter	> 3.3 mg. liter	21.4 %	> 2.6 %

In part, based on the successful BNL/DOE field evaluation of this high efficiency prototype boiler, the manufacturer did decide to take the design, tool it up and produce this product line for the US oilheating industry.

Conclusions

Condensing boilers and furnaces offer the potential for a significant step increase in the efficiency of oil heated homes. To achieve condensing operation the appliance heat transfer surfaces must be below the water vapor dewpoint and this is easier to achieve with a furnace than with a boiler due to the lower return air temperatures. In the case of boilers the return water temperature is a strong function of the type of distribution system and the controls used. In some field installations studied during this project condensing is impossible because of high return water temperatures and the boilers are operating with high efficiency, but no latent heat recovery is occurring. While condensing boilers are clearly technically feasible and are entering the market, greater attention should be paid to the application and the controls.

Heat exchanger corrosion rates are certainly higher with condensing than conventional heat exchangers. However, the corrosion and fouling rates observed during this project appear to be reasonable, considering the time period of operation. Clearly longer term experience is required. Sulfur plays a major role in corrosion and future, lower sulfur, fuels are expected to lead to longer lives for condensing appliances.

References

ASHRAE. 1993. *ASHRAE Standard 103-1993, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*. Atlanta: American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.

Butcher, T. 2004 BNL--73314-2004-IR, Hydronic Baseboard Thermal Distribution System With Outdoor Reset Control To Enable The Use Of A Condensing Boiler*,* October 2004.

Butcher, T. 2006. Condensing boilers and baseboard hydronic distribution systems. ASHRAE Transactions, Vol. 112, part 1.

Butcher, T. 2006. The performance of integrated hydronic heating systems. Proceedings of the 5th Aachener Ölwärme-Kolloquium, Aachen, Germany, Sept. 13-14, 2006.

Locklin, D. and Hazard, H.R., 1980. Technology for the Development of High-Efficiency Oil-Fired Residential Heating Equipment, BNL Report 51325, prepared for BNL by Battelle Columbus Laboratories.

Mori, G. and Zitter, H., 2004, Material requirements for heat exchangers in oil condensing boilers, presentation and paper from: "Will Oil Condensing Boilers Become Standard?" , A European Conference within the OPET Program, Vienna, 28th January, 2004.

Weber, C., Gebhardt, B., Fahl, U., Market transformation for energy efficient technologies – success factors and emperical evidence for gas condensing boilers. Energy, Vol. 27, pp. 287-315, 2002.