Chapter 16
ENERGY CONSERVATION

IN THIS CHAPTER

• The technician’s role in increasing equipment sales

• Steady state versus seasonal efficiency

• How oil-fired heating systems lose heat and efficiency: on-cycle losses, off-cycle losses, jacket losses, piping and duct losses, and air infiltration

• Equipment upgrades and replacements to improve efficiency

• How to persuade your customers to invest in energy conservation
The technician as an energy expert
A service technician must ensure that the customer’s heating system is operating as efficiently as possible. Efficient equipment is more reliable and cleaner burning. Customers with efficient heating equipment are more satisfied with their oil dealer and with Oilheat. In this chapter, we will examine what constitutes an efficient system, how heating systems waste energy, and what we can do to be sure our customers are getting the most comfort for their energy dollar.

As an energy expert you must:
- Inform customers of new technology advances—Customers trust technicians; therefore, we can supply valuable advice to customers.
- Install and adjust equipment for peak efficiency—Properly adjusted Oilheat equipment is the safest, most reliable, most efficient, cleanest, most environmentally friendly and most comfortable heat available.
- Service the equipment—Take responsibility for the operation of your customer’s equipment.
- Keep track of new technology
- Measure and record combustion efficiency—Use test instruments to ensure customer’s equipment is operating at its peak potential and cleanliness while producing minimal air emissions and carbon monoxide levels.

Combustion efficiency tests
Using instruments improves efficiency, ensures minimal smoke and soot, lowers air pollution emissions, and ensures safe operation. It also cuts call backs, improves our image and increases customer satisfaction.

Steady state vs heating system efficiency
Combustion efficiency tests are vital to proper servicing of equipment; however, they only measure the efficiency when the burner is running. Heating System Efficiency is the actual heating efficiency of the home for the year. (It is also sometimes called Seasonal Efficiency.) You cannot measure it on a service call. It involves the amount of fuel consumed, the total degree days for the year, the temperature the customer heated their home to all year, and the amount of hot water consumed. It is the difference between the Btus purchased and Btus used.

Heat losses in oilheating systems
The purpose of an oilheating system is to transfer the heat from the burner flame to the home. No heating system, regardless
The actual efficiency of an oilheating system is affected by many factors, including:

**Installation factors:**
- Selection of burner/boiler or burner/furnace
- Chimney design or upgrades
- Boiler or furnace sizing
- Boiler water or furnace air operating temperatures
- Piping or ducting design
- Burner adjustment
- Isolated combustion air.

**Service procedures:**
- Barometric damper setting
- Sealing air leaks into the boiler or furnace
- Burner adjustment: (excess air and smoke)
- Cleaning boiler or furnace heat transfer surfaces
- Proper nozzle sizing.

**Other factors that affect efficiency:**
- Location of unit
- Chimney Draft—height, materials, construction
- Source of combustion and draft relief air
- Burner design & operating pressure
- Zoning of distribution system

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- Burner design & operating pressure
- Zoning of distribution system
• Integration of domestic water heating system
• Mass of the boiler or furnace

Service procedures have a significant effect on boiler or furnace efficiency. Even the most efficient heating unit will waste fuel if it is not serviced periodically and if it is not adjusted properly. When the full efficiency of the boiler or furnace is not reached, then oilheat’s efficiency advantage is reduced. Routine service using standardized procedures, including vacuum cleaning and precise burner adjustment, are a vital part of good service. Always record efficiency test results.

Burner on-cycle heat loss
One of the biggest heat losses from central heating systems through the flue is the venting of exhaust gases while the burner is operating. See Figure 16-2. Combustion air and fuel enter the burner at room temperature (usually about 65°F) and heated combustion products leave the boiler or furnace, normally between 400 and 700°F. Heat loss can be reduced by better burner adjustment, clean heat exchanger surfaces, or equipment replacement.

Flue heat loss consists of two components; water vapor loss (a fixed property of the fuel) and sensible heat loss (varies with burner adjustment, equipment design and servicing).

The “water vapor” of flue loss is a result of the water vapor contained in the combustion of exhaust gases. Water is produced when oil is burned. This water is transformed to steam and leaves the heating unit. Eight-thousand Btus are lost with each gallon of water that is vented as steam—or about 6.5% of the total energy in fuel oil. This loss is also called “latent heat loss” (it is the energy required to convert water from liquid to vapor).

It is possible to reclaim the heat contained in the water by lowering the exhaust temperature until the water condenses out of the
flue gases. Condensing equipment, which deliberately condenses the water in the combustion gases, is available in some heating appliance lines. These units are designed to handle the water and the acids that are created in this process.

To prevent condensation in conventional heating units, exhaust gas temperatures need to be 350°F or more. The 350°F exhaust gases also produce the chimney draft that is required by conventional systems for normal flue gas venting.

“Sensible heat loss” depends on the temperature of exhaust gases and their total volume. Increased excess air increases the volume of combustion gases, which also increases the velocity of these gases through the heat exchanger. The faster the gases move through the heat exchanger, the less heat can be extracted. This raises stack temperatures and lowers efficiency. Lowering excess combustion air and/or flue gas temperature can reduce sensible flue heat loss.

New oil-powered appliances operate very efficiently, with flue heat losses ranging from 11 to 15%. This is close to the highest value possible for non-condensing systems. Remember that a net stack temperature of about 350°F or more is required to avoid water condensation and to maintain adequate chimney draft. Sidewall vented units can operate with somewhat lower temperatures.

Off-cycle heat loss

Burners in home heating systems do not operate continuously, but cycle on and off. A typical burner will run between 15 to 20% of the time and remain idle for the remaining 80 to 85% of the time.
Burner off-cycle heat loss is caused by air flowing through the heating unit when the burner is idle. The draft of the chimney creates negative pressure in the heat exchanger. It pulls cold air into the boiler or furnace at the burner air inlet and through other leaks in the unit. This air travels across the hot combustion chamber and flue passages where it is heated and carries the heat out of the house through the chimney.

The size of this loss varies with burner design, chimney draft, the operating temperature of the unit and installation. It is an important cause of inefficiency, especially for older and oversized units. Figure 16-3 shows off-cycle loss.

Off-cycle is also affected by the temperature of the boiler or furnace during the burner off-period. The higher the operating temperature, the greater the burner on-period.

Restriction of off-cycle airflow by the burner can reduce heat loss. Generally, older burners were designed with open combustion heads that provide very little restriction to off-cycle airflow. In contrast, high-speed flame retention head burners reduce off-cycle airflow and thereby reduce heat loss. This is a primary reason why oil heating systems have much lower off-cycle losses than typical natural gas heating units.

Natural gas heaters often use open “atmospheric” burners that do not restrict off-cycle airflow through the heating unit. Additionally, traditional gas units have large draft hoods that continuously remove heated air from the home. Oil burners push air into the heat exchanger while atmospheric gas burners depend upon draft to pull air in. This is why oil heat exchangers can be more restrictive than gas, making them more efficient.

Low mass combustion chambers (including ceramic fibers) will store less heat than high-density firebrick materials, so they will have lower losses. Similarly, small low mass boilers or furnaces store less heat than their older heavier counterparts and will have lower off-cycle losses.

Oversized heating units have longer off periods and off-cycle loss will be higher. A heating unit that is closely matched in size to the building’s heating requirements will provide the lowest off-cycle heat loss and highest efficiency.

Proper heating system adjustment and maintenance also affects burner off-cycle heat loss. Three examples are: air leaks into the heating unit, temperature control settings of the boiler or furnace, and fuel firing rate.

**Air leaks**

Air leaks into the heat exchanger should be avoided whenever possible because they provide a path for off-cycle airflow. Initial start-up and annual servicing procedures should include sealing all such leaks before the final burner adjustment.

Some common locations for air intrusion include the space between the burner air tube and the combustion chamber opening, the connection between the combustion chamber area and heat exchanger, the space between sections of cast iron boilers, heat flanges, and loose-fitting clean out and flame inspection doors. Eliminating these unnecessary air leaks will reduce off-cycle airflow and heat loss.
Temperature settings

The water and air temperature controls also affect heat loss. The blower on a furnace operates until the low temperature limit is reached, but heat remains in the furnace and can be lost during the off period. The low limit set point often is adjustable and lower settings can sometimes prevent unnecessary heat loss. Aquastat settings for boilers have the same effect. Maintaining excessive boiler temperatures increases off-cycle losses.

Excessive firing rates

Fuel nozzles that are too large for the heating requirement of the house increase off-cycle loss. Recall that heat loss varies with the off-period time and that large firing rates produce long burner-off times. The solution to this problem is to reduce the nozzle size, provided that the burner will perform well with the smaller firing rate. With fixed head burners, it may be necessary to change the combustion head if you are drastically reducing nozzle size. Selecting the correct nozzle size is an important part of proper service procedures.

Reducing firing rates on older units works because most of them are oversized. The three exceptions to this are: steam boilers, boilers with tankless coils, and any appliance where the steady state stack temperature is less than 400°F. In these three cases, the units should be fired to their maximum rating. New units that are properly sized for the load should be fired to the manufacturers’ recommendations.

Older units have high stand-by losses

Older appliances have larger losses than modern units. Replacement of these outdated units is often the best option for homeowners. Several design features of old units promote heat loss, including:

- Open burner head designs (non-flame-retention) that allow air to flow during off-cycle
- Larger more massive heating units that store (and lose) more heat during the off-period.
- Dense combustion chamber materials that can increase stored heat and off-cycle loss
- Heat exchange passages that are less restrictive than modern units, allowing larger off-cycle airflows.
- Steam boilers that operate at higher
temperatures than hot water systems. The off-cycle heat losses for old units, especially steam boilers may be more than 20%.

**Jacket heat loss**

Useful heat is lost through the walls of the boiler or furnace. This is referred to as "jacket" or "casing" loss and it reduces the amount of heat delivered to heated areas of the home, Figure 16-4. The size of this loss depends on the heating unit design and the location of the boiler or furnace within the house.

Jacket heat loss is largest when the burner is operating and heat from the flame passes through the combustion chamber and out of the unit through its outer jacket. Heat losses through boiler jackets were measured at Brookhaven National Laboratory and ranged from about 1% to 12% of the fuel’s heating value. Generally, wet-base boilers had the lowest losses and dry-base units had the highest. Old boilers, especially coal-conversion units with large firebrick combustion chambers, had the largest jacket heat loss.

**Pipe and duct heat loss**

The heat from a boiler or furnace is transported to the home through hot water (or steam) pipes or warm air ducts. Heat loss that occurs between the heating unit and the living space causes system inefficiency (see Figure 16-5). The level of efficiency depends upon how and where the pipes or ducts are installed, the size of the distribution system, the amount of thermal insulation and the location of the pipes and ducts within the building.

Hot water piping that is not insulated adequately can increase fuel use. The water in pipes leading to the radiators is generally between 180° and 200° Fahrenheit. These pipes often are located in cool basements and in other unheated spaces. If these pipes are not insulated, heat will be lost from the boiler water before it reaches the radiators in the house. More fuel must be consumed to compensate for these heat losses.

Similarly, heat loss from warm air ducting reduces the useful heat output of a furnace. Furnace ducts typically waste more heat than piping losses. There are two reasons for this. First, warm air ducts have a
large surface area through which heat can be lost. Second, warm air can escape directly from leaky joints in the ducting. According to studies by the US Department of Energy, ducting losses can be as high as 40%.

The level of heat loss is different for each system and it depends upon the placement of ducts within the house. Warm air ducts in cold areas such as unheated basements, attics, or crawl spaces must always be insulated and all joints must be sealed.

### Outdoor air infiltration

The air that goes up the chimney must be replaced by cold outdoor air drawn into the building. This cold air must be heated to indoor temperature, Figure 16-6. The amount of heat needed to heat this cold...
Savings For Every $100 Fuel Costs by Increase of Combustion Efficiency
Assuming Constant Radiation and Other Unaccounted-for Losses

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**In summary**

New, highly efficient oilheating units transfer more than 85% of the fuel energy directly to the home. Old units may operate in the 60 to 76% range. See Figure 16-7.

**Equipment modifications to improve efficiency**

New oil boilers and furnaces are often more efficient than their gas counterparts. While older oil boilers and furnaces are less efficient than the newer units, they can be “modernized,” and their operating efficiencies can be improved. Heating system modifications to improve efficiency range from low-cost adjustments such as adjusting for proper combustion and sealing excess air leaks to equipment replacements such as installing new flame retention oilburners or new boilers or furnaces. The table below summarizes the efficiency gains from those improvements.

This next section will identify a number of equipment modifications that save energy. These are:

- Flame retention burners
- Replacement boilers or furnaces
Pipe or duct insulation
Heating systems tune-up
Thermostat set back
Combining equipment modifications

Flame retention burners
The main difference between old non-flame retention and flame retention burners is the way the combustion air and fuel are combined. The flame retention burner has a specially designed burner head (end cone) and a high-pressure fan that produces more recirculation within the flame for better fuel-air mixing. The swirling air pattern increases the contact between the fuel droplets and the air. In addition, a recirculation zone is formed within the flame.

This recirculation pattern draws some of the hot combustion gases back toward the burner head. This helps to vaporize the oil droplets by direct contact with hot gases. Recirculation also provides a longer path length through the flame. This adds to the time available for the fuel and air to react, promoting complete combustion. This swirling and recirculation pattern also reduces smoke formation, requires less excess combustion air, and provides higher efficiency.

The flame is more stable in flame retention burners. It forms a tight shape that is held near the burner head. That’s where the name “flame retention” comes from. Flame retention burners can operate efficiently in heating units where marginal chimney draft or where oversized combustion chambers could cause problems with older burner designs.

With flame retention, the flame is stabilized by the high velocity airflow and it does not need radiant heat reflected back from the combustion chamber for stable operation. This eliminates some of the flame problems experienced by older burner designs. A drawing of non-flame retention and flame retention combustion is shown in Figure 16-8.
Excess air reduces efficiency and flame retention burners operate with less excess air than older burner designs. Flame retention burners require 20 to 30% excess air while older burners need 50 to 100% more to achieve low smoke numbers. The difference in the flue heat loss for these burners is often about 10%.

The second advantage of flame retention burners is reduced off-cycle heat loss. The flow of off-cycle air through the heating unit is reduced by the narrow openings of the air band and the flame retention head. Therefore, off-cycle heat loss is less. This improves the heating system efficiency. See Figure 16-9.

**Installation requirements**

Be sure to check the condition of the combustion chamber before installing a new burner. Many older chambers are not suitable for the flame produced by a flame retention burner. Modification of the combustion chamber may be required. See Chapter 5 for more details about chamber upgrades.

**Be extra careful when installing new burners into dry-base boilers and older furnaces because it may be possible to burn through the base.**

**Important considerations in an installation procedure include:**

- Select the most efficient fuel nozzle size for the job. Many boilers and furnaces are overfired and operate at lowered efficiency. Remember that flame retention burners operate with higher efficiency and a smaller nozzle is usually advisable.
- Inspect the combustion chamber and repair or replace it. Add a high temperature ceramic liner insert if needed.
- Install the new burner. Carefully follow the recommendations of the burner manufacturers.
- Seal all air leaks around the heat exchanger, and the burner air tube. Air leaks can increase both on-cycle and off-cycle heat loss.
- Adjust the burner using combustion test equipment to an efficiency of 80% or higher. Some burners have adjustable head positions. Use the setting recommended by the manufacturer for the installed fuel nozzle size. If a fixed retention head is used, be sure that the head is the correct size. Use the head size that matches the fuel nozzle rating.
- Test all safety controls for proper operation.
- Perform final checks of burner operation.

Installation of flame retention head burners as replacements for older units can be an effective and economic means for...
conserving heating oil if the old boiler or furnace is suitable.

**Expected energy savings**

Most homeowners with older oil burners can reduce their fuel cost substantially, with savings from 15% to as high as 25%. The combination of low burner cost and high fuel savings make retention head burners one of the best conservation investments available to homeowners. Your service department can also benefit. New burners usually require fewer service calls.

**Replacement of boilers or furnaces**

Many older heating units are inefficient and oversized and replacement with a new oil-fired boiler or a furnace is better than any add-on modification. New high efficiency oil boilers and furnaces have Annual Fuel Utilization Efficiencies (AFUE’s) from 82% to 95%. Replacing old and outdated heating units will cut fuel consumption and increase customer satisfaction.

No simple method can evaluate the efficiencies of older units. However, some design features of older systems tend to increase heat loss and lower efficiency.

Some of these are:
- Designs that allow substantial jacket heat loss by:
  - Dry-base combustion chamber
  - Poor or missing jacket insulation
  - Side arm hot water coils
  - Massive combustion chambers constructed of heavy firebrick

- Many older burner designs use “open” end cones that cannot restrict off-cycle airflow. Secondary air openings and leaks increase off-cycle heat loss.

- High stack temperatures increase on-cycle heat loss. This is caused by wide open flue passages without baffling designed for burning coal. If the stack temperature is excessive for a clean unit with the correct firing rate and burner adjustment, then the design of the boiler or furnace is the problem.

  Combustion efficiency testing can help to identify low efficiency boilers and furnaces that need to be replaced.

**Expected energy savings**

Replacement of obsolete boilers and furnaces with modern, highly efficient models can reduce fuel cost more than any other single option available to homeowners, even insulation and storm windows. Field studies show that replacing a boiler or furnace will often save between 18 to 32%, with typical payback periods of 3 to 6 years.

**Pipe and duct insulation**

Hot water pipes and warm air ducts often waste large amounts of energy when not insulated. These losses reduce system efficiency and increase fuel consumption. Pipe and duct loss is avoidable with the use of thermal insulation. All heating system distribution lines that run through unheated spaces should be protected against heat loss.

**Boiler pipes**

The heat loss from this piping system depends upon several factors:

- Temperatures of the hot water or steam within the pipes
• Length of piping system
• Degree of thermal insulation
• Temperature of the air (or other material) surrounding the pipes

Warm air ducts
Ducts that distribute heated air to the house lose heat in two ways.
• Heat flows from the heated duct walls to the colder surroundings
• Heated air escapes from leaky duct joints

Both of these losses reduce the useful heat delivered to the house and increase fuel consumption. Many warm air ducts pass through unheated areas, such as attics or crawl spaces. Because of the cooler surroundings, heat loss into these areas is large. Inspect all warm air ducts for leaks and proper insulation. Use seamless insulated ducts on new installations.

Expected energy savings
Boiler Piping:
Insulating piping may save 5-10 percent.

Warm Air Ducts:
Insulation and sealing leaks may save up to 40 percent.

Heating systems tune-up
Periodic cleaning and adjustment of all heating systems assures the highest level of efficiency, safety, and fewest service calls. Service routines save fuel and prevents equipment breakdowns that are a nuisance to both homeowners and service departments. See Chapter 14 for more details on proper tune-up procedures.

You may wish to develop a checklist to be filled out during each tune-up. Good service procedures involve a number of steps that include (but are not limited to):
• Visually inspecting the entire heating system
• Performing a combustion efficiency test; be sure to check the draft drop through the heat exchanger by comparing the draft over fire and at the breach.
• Vacuum cleaning of all heating surfaces including the boiler or furnace flue passages (when required).
• Checking to be sure the flue pipe and chimney flue are clear and in good condition
• Cleaning all burner parts including the air fan and housing, ignition electrodes, and burner head.
• Replacing fuel and air filters.
• Sealing air leaks around the burner and heat exchanger.
• Using combustion test equipment to measure efficiency.
• Adjusting the burner for high efficiency and low smoke number.
• Modifying system and readjusting until peak efficiency is obtained.
• Recording final combustion efficiency for tuned system.
• Checking all combustion safety controls.

Heating system tune-ups reduce on-cycle flue heat loss and assure good long-term efficiency. Reduced excess combustion air lowers flue heat loss and low smoke settings avoid soot accumulations and
Energy Conservation

If there is a significant bout of severe cold weather, customers using setbacks may not be able to get the house back to a comfortable temperature. Having customers not use the setback or switch to manual in extreme cold is a good idea.

Expected energy savings

Typical savings from a tune-up are about 3% for systems that are regularly adjusted. If a heating system has been infrequently tuned or is out of adjustment due to equipment malfunction, then the fuel savings will be higher. For example, the efficiency of a boiler or furnace with a partially plugged fuel nozzle and sooted heating surfaces can be improved by 10% or more after a tune-up.

Thermostat set-back

The thermostat is the single best device homeowners can use for energy conservation. The greater the difference between indoor and outdoor temperatures, the more energy it takes to maintain it. For every degree you lower the thermostat setting, up to 3% can be saved on the heating bill.

It is possible to save some energy by lowering the thermostat setting if the building is empty for long periods during the day and again at night when all the occupants are sleeping. Set back thermostats are available that do this automatically.

If the set back is too great in sub-freezing conditions, the heating system may be shut off long enough for water or heat pipes in outside walls to freeze up. Additionally, if the setback is too great, it will take a long time to get the home back up to a comfortable temperature. This may require more energy than you saved by setting the temperature back. A maximum of five degree setback is recommended.

Combining equipment modifications

It is difficult to estimate fuel savings when more than one modification is applied to the same heating system. The expected savings cannot be determined by simply adding together the savings for each individual modification as more than one of them may address the same losses. The most economical first cost retrofit is the one that saves the most fuel for the lowest cost.

Steps for advising your customer

- Measure combustion efficiency
- Inspect the heating system
- Evaluate primary equipment upgrades
- Recommend secondary energy saving options
- Present recommendations to customer

Today’s heating equipment is greatly improved over the old equipment. Replacing an old inefficient oversized boiler or furnace is one of the best investments our customers can make.

Where else can they get over a 20% tax free return on investment; abundant hot water; a more comfortable, cleaner, quieter home; help improve the environment;
lower their cost of living; and increase the value of their home? This is such a great deal, the new equipment should be selling itself. Unfortunately, oil burners cannot talk. They need our help.

**Advantages of new equipment**

- **High Efficiency**—saves energy which saves customers money.
- **Clean Operations**—easier to service and better image as clean modern fuel.
- **Low Air Pollution Emissions**—properly adjusted new oil equipment has the lowest emissions.
- **Improved Reliability**—requires less emergency service.
- **Greatly increases customer satisfaction.**

Additionally, if customers invest in new oil-fired equipment, they will not be tempted to switch to gas heat. The new equipment will save them so much money and be so reliable, they will brag about it to their friends. You will keep your old customers and they will help you get new ones.

**How to sell new equipment**

It is vitally important that we install new oil-fired heating equipment in all of our customer’s homes. New equipment makes customers satisfied and insures a bright future for the Oilheat Industry. If your company has equipment sales people or your service manager does the selling, your job is to identify equipment that should be upgraded and recommend the customer speak to your sales people about investing in conservation.

As the one who services their heating equipment, you have established credibility with your customer. By suggesting an upgrade may be in order, you are extending this trust to the sales person and have given them a great running start.

If you recommend that a customer consider new equipment, you must be sure that you tell the sales person about it. When you recommend new equipment you have given your customer a problem. He thought his system was OK, now you are telling him that it is not. Your sales person had better get to the house right away to solve the problem before the customer solves it himself with some other heating contractor or a switch in fuel.

It is vitally important that we install new oil-fired heating equipment in all of our customers’ homes. New equipment makes customers satisfied and insures a bright future for the Oilheat Industry.

If your company does not have sales people and it is your job to sell the equipment, you need to learn all you can about the art of selling. There are many good books, tapes and seminars on selling. Selling is a skill you can learn and, like any skill, it improves with study and practice.

NORA has published a book on this topic titled *Efficient Oilheat, An Energy Conservation Guide*. It is the basis for the NORA Gold Technician Certification Program. The book, as well as all of NORA’s books and tapes, is available at norastore.org.