Chapter 16

Energy Conservation

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Chapter 16

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 fuel supplier and their system. 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 the technician must:

- Keep track of new technology—As the pace of new technology increases, technicians need to stay up-to-date.
- Inform customers of new technology advances—Customers trust technicians to offer them valuable advice about potential improvements to their heating system.
- Install and adjust equipment for peak efficiency—Properly adjusted equipment provides safe, reliable, efficient, clean, environmentally friendly and comfortable heat.
- Service the equipment—Take responsibility for the operation of the customer's equipment.
- Measure and record combustion efficiency—Use test instruments to ensure customer's equipment is operating at its peak potential and cleanliness, while producing minimal emissions and carbon monoxide levels.

Combustion efficiency testing

Using instruments to adjust burners is required by all manufacturers because it improves efficiency, ensures minimal smoke and soot, lowers air pollution emissions, and ensures safe operation. It also reduces call backs, improves our image and increases customer satisfaction.

NORA recommends the use of electronic analyzers over "wet kits" because they provide excess air readings, carbon monoxide measurements and a clearer picture of what's happening in the combustion process.

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 (sometimes called Seasonal Efficiency) is the actual heating efficiency of the home for the year. Unfortunately, a technician cannot measure it during a service call. It involves the amount of fuel consumed, the total degree days, the temperature the customer heats their home to and the amount of hot water consumed.

Heat losses

The purpose of a heating system is to transfer heat from the burner flame to the home. No heating system, regardless of the fuel it uses, can operate at 100% efficiency. Some heating energy is lost before it ever reaches the radiators, convectors or supply registers in the house. These losses reduce

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overall system effectiveness and increase fuel use. It is important to understand the many types of heat loss that reduce efficiency. Figure 16-1. Heat can be lost:

- During the burner on cycle
- During the burner off cycle
- Through the jacket
- From piping or ductwork
- Due to air infiltration

The actual efficiency of the system is affected by many factors, including:

Installation factors:
- Selection and sizing of the appliance
- Control strategies
- Integration of domestic water heating system
- Chimney design—height, materials, construction
- Boiler water or furnace air operating temperatures
- Piping or ducting design
- Burner adjustment, including barometric damper setting
- Combustion air source

Service procedures:
- Burner adjustment, including barometric damper setting
- Checking for and sealing air leaks into the appliance
- Cleaning the appliance heat transfer surfaces
- Proper firing rates

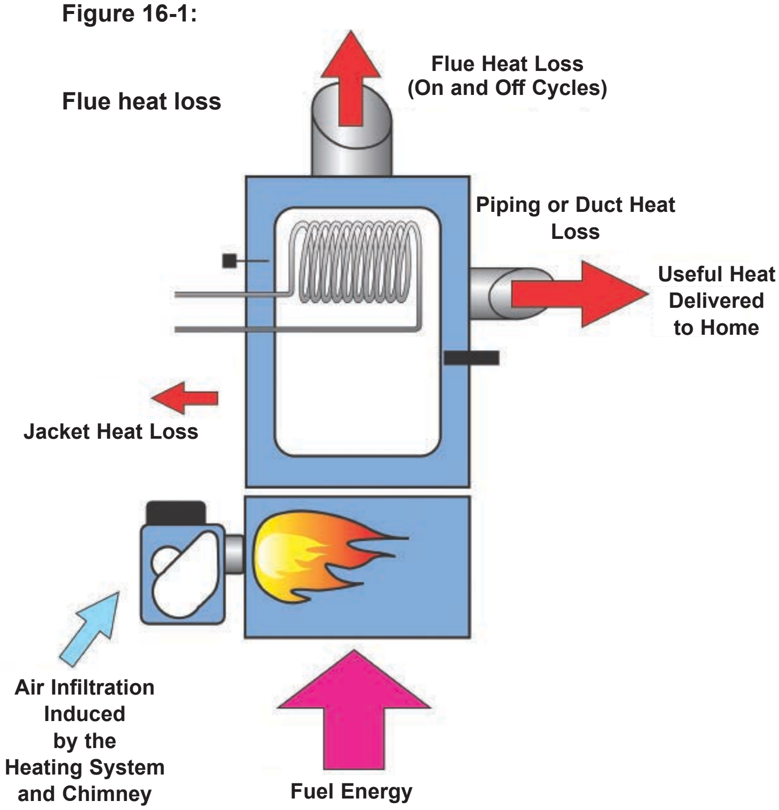
Other factors that affect efficiency:
- Location of unit
- Source of combustion and dilution air
- Burner design
- Zoning of distribution system

Service procedures have a significant effect on appliance 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 appliance is not reached, the efficiency

Combustion test equipment must always be used to adjust the burner for peak efficiency

Figure 16-1:

Flue heat loss



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advantage is reduced. Routine service using standardized procedures, including vacuum cleaning when appropriate and precise burner adjustment, is a vital part of good service.

Burner on-cycle heat loss

The venting of exhaust gases while the burner is operating results in a significant heat loss, 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 350 and 600°F. Heat loss can be reduced by proper burner adjustment, clean heat exchanger surfaces or an upgrade to more efficient appliances.

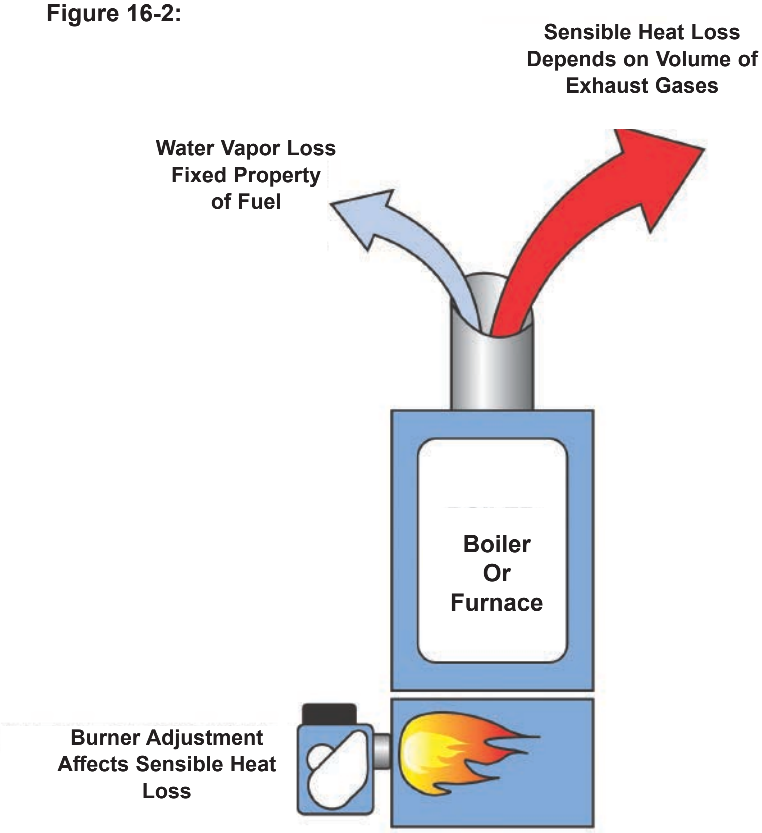
On-cycle loss consists of two components: latent heat loss and sensible heat loss, which varies with burner adjustment, equipment design and servicing.

Latent heat loss, also referred to as "water vapor" loss, is a result of the water vapor contained in the combustion gases. Water produced during the combustion process, 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 the fuel. This loss 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 appliances 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

Figure 16-2:



need to be 350°F or more. The 350° 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. Properly setting excess combustion air keeps sensible heat losses to a minimum.

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FLUE HEAT LOSS DURING BURNER OPERATION
(Percent of Total Heat Content of #2 Fuel)

	Average	Typical Range	Comb. Eff.
Old Heating Units	28	20 - 35	72%
New Heating Units	13	11 - 19	86%

New 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 lower temperatures.

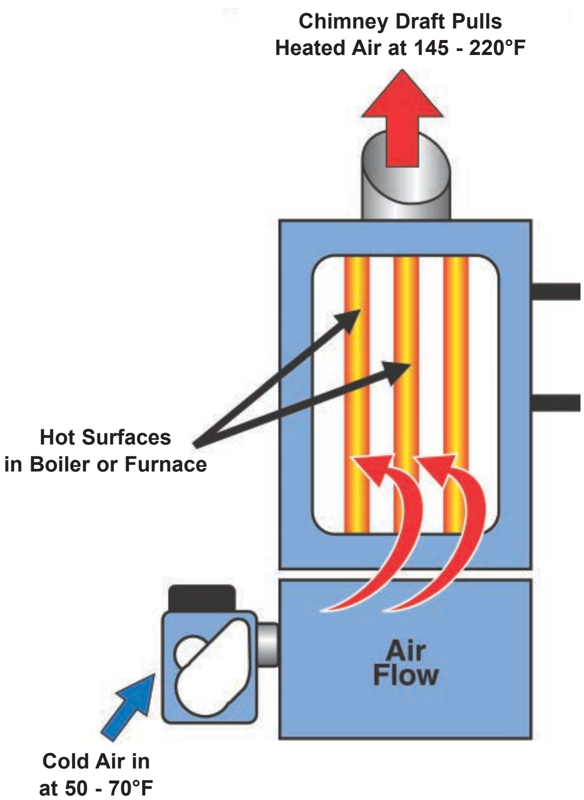
Off-cycle heat loss

Burners cycle on and off, they do not operate continuously. A typical burner will run approximately 15-20% of the time during the heating season and stay idle for the remainder.

Burner off-cycle heat loss, also called “idle” or “standby loss”, is caused by air flowing through the hot appliance when the burner is off. The draft of the chimney creates negative pressure in the heat exchanger. It pulls cold air into the heat exchanger through the burner air inlet and air leaks in the appliance. This air is heated as it travels through the combustion chamber and flue passages and carries the heat out of the appliance through the chimney.

The size of this loss varies with appliance design, control strategy, chimney draft and the operating temperature of the appliance. It is an important cause of inefficiency, especially for older and oversized units, as well as for boilers maintaining temperature for domestic hot water coils or other reasons. Furnaces will have lower idle losses than boilers because the typical fan control will lower the appliance temperature to 100°F or less before stopping the fan. Most boilers don’t use this control strategy and leave the appliance hot at the end of a cycle, increasing idle loss. Boilers with tankless coils maintain temperature and will have high idle losses. Low mass

Figure 16-3:
Off-cycle heat loss



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and cold start boilers will have lower idle losses. Oversized and/or overfired appliances have shorter on periods and longer off periods so the off-cycle loss will be higher. An appliance that is properly sized for the building's heating requirements, will provide the lowest off-cycle heat loss and highest efficiency. Figure 16-3 shows off-cycle loss.

Air leaks

Air leaks into the heat exchanger provide a path for off-cycle airflow.

Some common locations for air leaks 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, 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 setting is reached, but heat that remains in the furnace is lost during the off period. The low limit set point often is adjustable and setting to the furnace manufacturers recommendation can limit unnecessary heat loss. Boiler water temperature settings have the same effect and maintaining excessive boiler temperatures increases off-cycle losses.

Excessive firing rates

Firing rates that are too large for the heating requirement of the house increase both on and off-cycle loss. Heat loss varies with the off-period time and large firing rates produce long burner-off times. The solution to this problem is to reduce the firing rate, provided that the burner will perform well with the lower firing rate. With fixed head burners, it may be necessary to change the combustion head when drastically reducing the firing rate. Selecting the correct nozzle size and pressure are important parts of proper service procedures.

Older units have high stand-by losses

Reducing firing rates on very old 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 350°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.

Replacement of old, oversized, outdated units is often the best option for homeowners. Several design features of old units promote heat loss, including:

- Open burner head designs that allow air to flow during the 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 exchanger passages that are less restrictive than modern units, allowing larger off-cycle airflows
- Steam boilers operate at higher temperatures than hot water systems and off-cycle heat losses for old units can be more than 20%

Jacket heat loss

Useful heat is lost through the walls of the boiler or furnace. This is referred to as

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"jacket" 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 escapes through the jacket to the surrounding area. Generally, wet-base boilers have the lowest losses and dry-base units have the highest.

Distribution (pipe & duct) heat loss

The heat from a boiler or furnace is transported throughout 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 the size of the distribution system, the amount of thermal insulation and the location of the pipes and ducts within the building.

Hot water or steam piping that is not insulated adequately causes additional heat loss. The water in pipes leading to the heat emitters is generally between 180°F and 200°F. These pipes are often 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 heat emitters in the house. More fuel must be consumed to compensate for these heat losses.

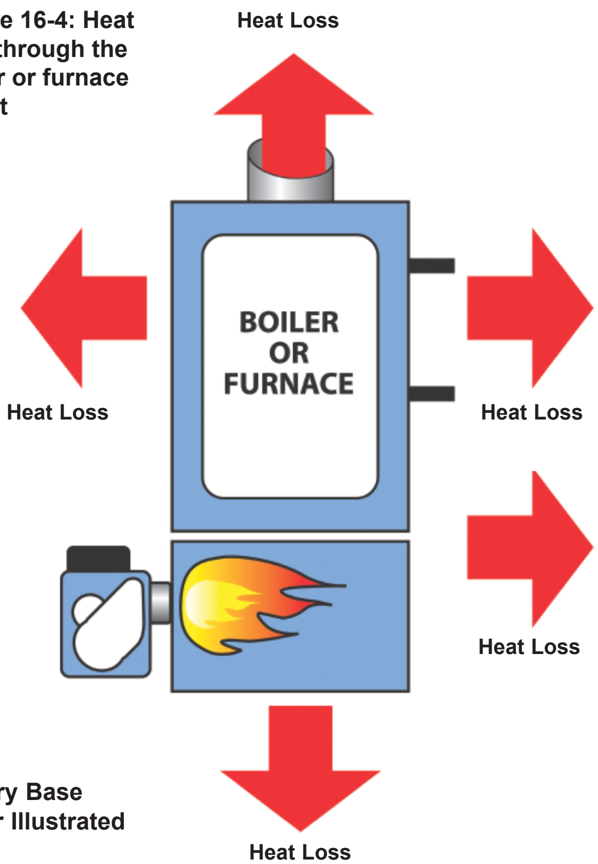
Similarly, heat loss from warm air ducting reduces the amount of heat delivered to the home. Furnace ducts typically waste more heat than piping losses. There are two reasons for this. First, warm air ducts have a large surface area through which heat can be lost. Second, warm air can escape directly 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 (combustion air & dilution air) must be replaced by outdoor air drawn into the building. During the heating season this cold air must be heated to indoor temperature, Figure 16-6. If the appliance is outside or is in a non-heated portion of the home that

Figure 16-4: Heat loss through the boiler or furnace jacket



Dry Base Boiler Illustrated

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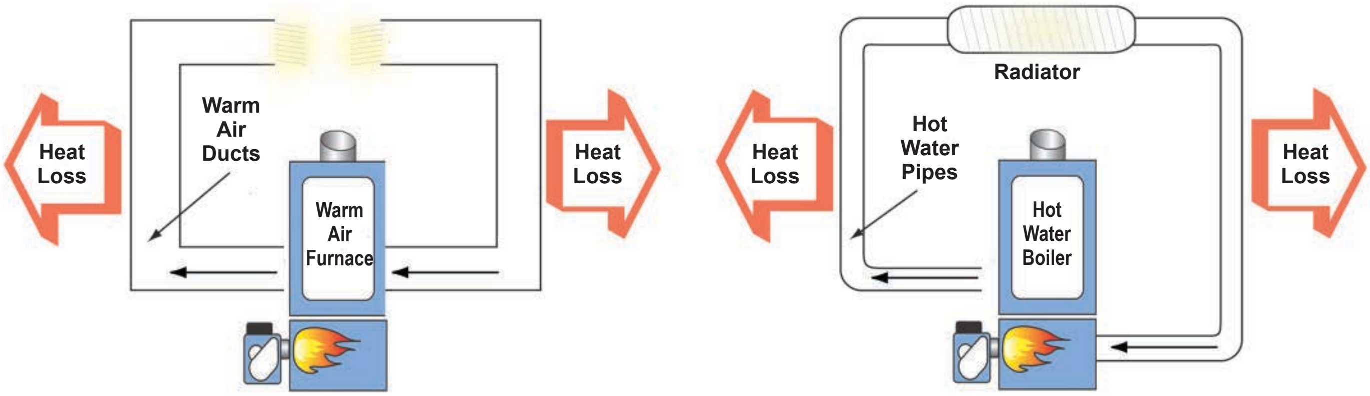
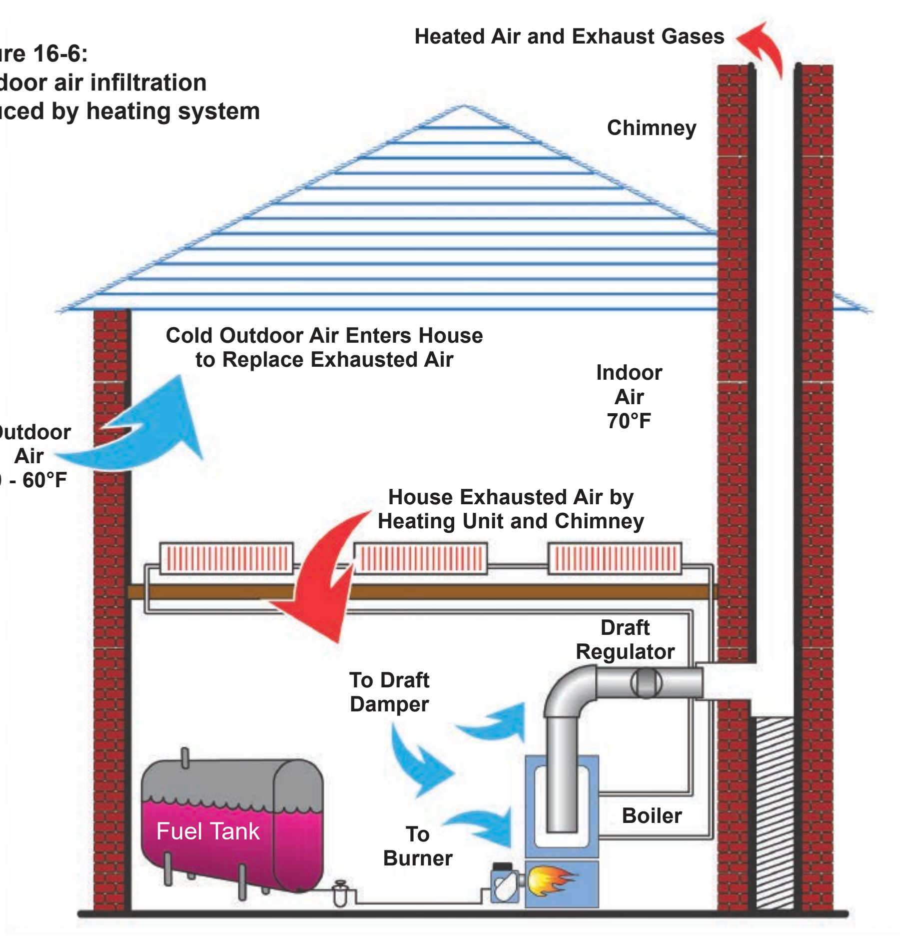
Figure 16-5: Heat loss from warm air ducts and hot water pipes



has plenty of excess air, air infiltration does not affect efficiency. Air infiltration loss is greatest for heating appliances that have large off-cycle airflows or have air leaks into the heat exchanger. Efficient appliance-burner combinations operate with low air infiltration losses.

Air infiltration heat loss for heating systems is usually about 2% of the total fuel energy, but some studies indicate that it can be as high as 12%. The best solution for air infiltration is isolated combustion, whereby outdoor air is piped directly to the burner air intake.

Figure 16-6:
Outdoor air infiltration
induced by heating system



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Equipment modifications to improve efficiency

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 boilers or furnaces.

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

- Replacement of boilers or furnaces
- Pipe or duct insulation
- Heating system tune-ups
- Thermostat set back
- Combining equipment modifications

Replacement of boilers or furnaces

Many older heating units are inefficient and oversized and replacement with a new boiler or a furnace is better than any add-on modification. Replacing old and outdated heating units will cut fuel consumption and increase customer satisfaction.

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 home-owners, 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

Piping and warm air ducts 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 piping systems 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 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%.

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

Heating systems tune-up

Periodic cleaning and adjustment of heating systems assures the highest level of efficiency and safety. Periodic tune-ups save fuel and prevent equipment breakdowns that are a nuisance to both homeowners and service departments.

Many companies 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 complete combustion analysis and recording results
- Vacuum cleaning of all heating surfaces, including the boiler or furnace flue passages (when appropriate)
- 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
- Adjusting the burner for high efficiency and zero smoke
- 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 gradual efficiency loss. The combustion tests give a sound basis for recommending various efficiency modifications.

Service routines save fuel and prevents equipment breakdowns that are a nuisance to both homeowners and service departments.

Expected energy savings

Typical savings from a tune-up are about 3% for systems that are regularly adjusted. If a tuneup is performed on a heating system that 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 a device homeowners can use for energy conservation. The greater the difference between indoor and outdoor temperatures, the more energy it takes to maintain a comfortable setting. For every degree the thermostat setting is lowered, up to 3% can be saved on the heating bill.

It is possible to save some energy by lowering the thermostat setting if the build-

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ing is empty for long periods during the day and again at night when all the occupants are sleeping. Set-back thermostats are available that adjust 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 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 was saved by setting the temperature back. The US EPA suggests a maximum of ten degrees setback.

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 some of them may address the same heat losses.

Steps for advising the customer

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

Remember, replacing an old inefficient oversized boiler or furnace is one of the best investments a customer can make.

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 equipment has the lowest emissions
- Improved Reliability— requires less emergency service
- Greatly increases customer satisfaction

Additionally, if customers invest in new equipment, they will not be tempted to switch to another source of heat.

Chapter 16: Additional Resources

NORA has compiled a library of additional technical resources for your continued education. Scan the QR code or go to the web address. Check back often, as NORA will continually add content as it becomes available..

You will find:

- Videos
- Technical Bulletins
- Instructions
- and More

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