4101

CENTRAL FORCED AIR HEATING SYSTEMS

FACTSHEET

WASHINGTON ENERGY EXTENSION SERVICE April 1988

INTRODUCTION

There are two basic ways to take control of your home heating bill. One is to make the building itself as energy efficient as possible and the other is to make the heating system more efficient. Typically, the first course of action is to address the building since many low cost opportunities for saving energy can be found there. For example, caulking and weatherstripping, insulation, and storm windows all reduce the amount of heat needed to keep the building warm. Most utilities offer free energy audits that can help identify cost-effective weatherization measures.

Once basic steps have been taken to weatherize the building, consideration can be given to making the heating system as energy efficient as possible. This factsheet will address gas, oil, and electric central forced air heating systems. It serves as an overview of ways to make sure that you are getting the best return on your heating energy dollars. A typical system consists of the furnace itself where heat is produced, duct work and fan (or blower) for circulating air, and a thermostat to control operation. Oil and gas furnaces also contain a burner and a flue where combustion takes place and gases can escape, respectively. For information on other types of heating systems, refer to WEES publications listed at the end of this document.

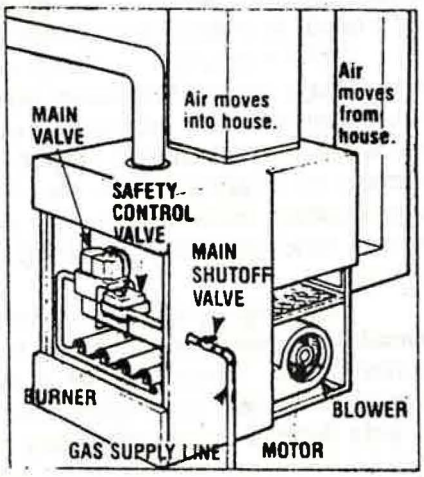

Figure 1. Typical Gas Furnace

Information is organized into three sections:

Existing Systems -- A review of modification options to improve the efficiency of existing forced air heating systems and a discussion of fuel conversions.

New Systems -- A look at new high efficiency furnaces, definitions of efficiency, and how to select a system that's best for you.

Efficient Operation -- A list of operation & maintenance items for efficient and reliable performance, and a discussion of thermostats.

EXISTING SYSTEMS

Whether your existing furnace is oil, gas, or electric, it may not be working at peak efficiency for several reasons. Perhaps your home has been remodeled or weatherized since the furnace was originally installed. Or maybe your family has changed size. Since residential structures and occupant activities often change, so do heating requirements. It is important that your heating system match as closely as possible your present heating needs for both improved comfort and efficiency. Even if properly designed, a heating system can be wasting energy due to lack of maintenance. Regular tune-ups will typically pay for themselves through increased savings on your heating bill as well as offer peace-of-mind. To find out if your present heating system is correctly sized and running in top condition, schedule a service visit from a qualified firm. Options for improving forced air heating system efficiency in the home are further discussed below.

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Modifications

If your furnace is in generally good condition it is usually possible to increase its efficiency by making certain modifications. For oil furnaces there are derated nozzles and flame retention burners. For gas furnaces there is electronic ignition. These modifications are covered in detail below. Automatic flue dampers can be used on both systems, but savings are more difficult to predict. They are most cost effective on boilers and furnaces located in heated spaces and that have large off-cycle stack losses. For many types of modern burners that already restrict stack losses, adding an automatic flue damper would not be cost effective.

Since electric furnaces utilize resistance heating (no burner or flue) the possibilities for improved efficiency are limited to the air distribution system and maintenance concerns. However, efficiency is typically high to begin with.

A significant improvement for any forced air heating system is reducing heat losses from any duct work passing through unheated spaces such as basements, crawlspaces and attics. If you can't remember when the ducts were last inspected, it's a good idea to do so whether they are insulated or not. All leaks and joints should be sealed using duct tape and then insulated. Excessive air leakage can also cause inefficient air distribution and possible fan overloading.

If your furnace is very old and will soon require replacement, it is probably better to let it go without major modification until you can replace it with a new efficient heating system. Rather, invest a little time and money in home weatherization measures or an automatic thermostat. These efforts will also result in energy savings but offer much faster paybacks.

Oil Furnaces -- Many older oil furnaces were typically oversized and recent weatherization trends have resulted in homes with significantly lower heating loads. For these reasons, the simplest and most cost effective oil furnace modification is to derate (or down size) the burner nozzle. Operation is most efficient when heat output better matches heating load. By reducing the firing rate, the burner will remain on slightly longer but the amount of heat lost up the flue, during both on and off cycles, is significantly reduced. Overall savings are about 4 to 6 percent. Since nozzles are normally replaced with a tune-up, cost is minimal. Have a trained technician determine whether your oil burner can be derated.

For higher efficiency, you will need to invest in a flame retention burner. Also called a high speed or retention head burner, the design provides a more efficient mixing of oil and air, and a smaller, hotter flame. Since less air is used, less heat is lost up the flue while the burner is on. Most flame retention burners also restrict draft losses while the burner is off. Savings on your heating bill will largely depend on the efficiency of your existing system. The lower it is, the greater your gains will be. For an older oil furnace with a steady state efficiency of 70 percent, upgrading to a flame retention burner will reduce your bill by about 20 percent or more. Costs including installation vary from $550 - $650. As you might suspect, savings are greater and paybacks shorter for households with larger heating bills. If you do decide to upgrade your burner, be sure the service technician is well qualified for this work, since proper selection, installation and adjustments can be critical. Call the Oil Heat Institute (OHI) for recommended contractors nearest you at (206) 623-8730 in Seattle or (509) 624-1641 in Spokane.

Gas Furnaces -- Many gas furnaces, and most with atmospheric burners, have standing pilot lights that constantly burn a small amount of gas even when the burner is off. To eliminate this needless waste, the pilot light can be replaced with an electronic ignition, also called an intermittent ignition device, that creates a spark only when the burner is called upon to heat up the furnace. The cost for this installation is about $150 but savings are from 5 to 7 percent, so paybacks can be as low as 4 years.

Conversions

Many people wonder if converting from one fuel to another will save them money. Although savings are often possible, remember that fuel prices can fluctuate significantly from year to year and are not easy to predict. When oil prices rose steeply in the late 70s and early 80s, a great number of people converted from oil to natural gas. In recent years both oil and gas prices have stabilized. It is important to note that fuel price is only one factor in how much you pay for heat. The other factors are how well your house keeps heat in, how long the system is on, and how efficiently it runs. These factors are more easily controlled by you and should be a higher priority. To compare fuel costs, however, WEES Technote TN1204 provides a handy table for simplifying the calculations.

In general, if the fuel costs are only marginally different, the cost of conversion will probably not justify the savings. It costs from $800 - $1,000 to install a power gas burner on an existing oil furnace although this cost can often be deferred by inexpensive leasing arrangements (about $5 per month) from local gas utilities. For oil users not near a gas main, hookup costs can add significantly to the total cost of conversion. Another concern is the condition of your chimney. If not in very good condition and clean prior to gas conversion, moisture condensation from cooler stack temperatures can cause soot to loosen and fall, leading to possible restrictions of flue passages and fouling of heat exchanger surfaces. Chimney concerns aside, gas furnaces generally burn more cleanly and require less maintenance. If you own a gas furnace it is not possible to switch to oil without replacing the entire furnace.

The best time to consider fuel conversion is when your existing heating system is in need of major repair or replacement. Since you will need to spend some money anyway, it simply comes down to a question of which system is best for your needs. Information on selecting new forced air heating systems is given in the next section. Remember that other types of heating systems offer distinct benefits as well. Refer to related WEES publications on heat pumps, zone heating, and wood heaters. Selecting the ideal heating system can be difficult. In the final analysis you may find that concerns such as comfort, aesthetics or air quality matter just as much, or more, than dollars spent.

NEW SYSTEMS

One of the first decisions to make when selecting a heating system is fuel type. As mentioned above, the choice between gas, oil, or electricity is often one of personal preference, assuming that all three fuels are available to the home. To best compare the long term economics of different systems requires life cycle costing methods outside the scope of this document. (See the WEES Factsheet on Economics, FS-1001.) Perhaps more important to consider than fuel type is efficiency and unit size. These are discussed below.

Efficiency

What is efficiency? Simply stated, efficiency tells us how much energy is used for actually heating the home and how much is lost up the flue. For example, a furnace that is 80 percent efficient provides 80 cents of heat for every dollar spent on fuel. So we see that our heating bill depends not only on the unit cost of fuel but on how efficiently the fuel is used.

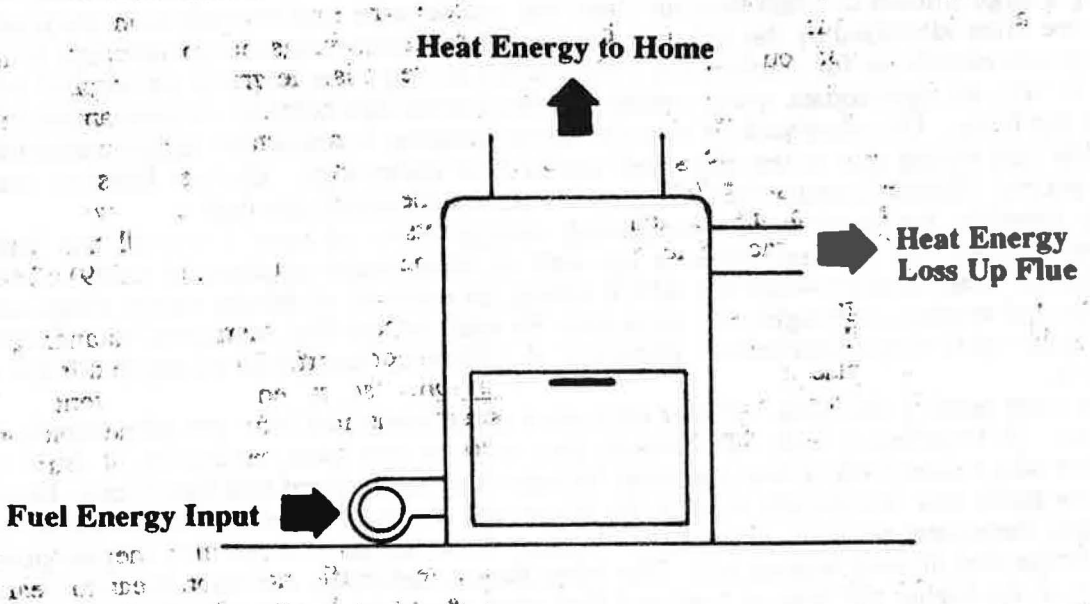
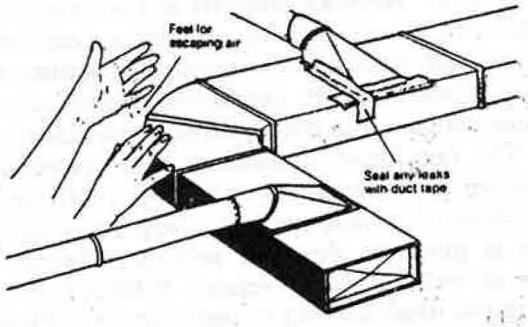


Figure 2. Understanding Furnace Efficiency

Like automobile mileage ratings, furnace efficiency ratings are a good tool for comparing different models. One must be careful when comparing efficiencies, however, since several different types of efficiencies may be used. The two most common are Steady State Efficiency and Annual Fuel Utilization Efficiency (AFUE). Steady state efficiency refers to how well the unit performs once it is warmed up and running. The AFUE, sometimes called seasonal efficiency, takes into consideration the fact that a furnace cycles on and off, and accounts for the fuel used to repeatedly heat up the furnace itself. The AFUE will always be lower than steady state efficiency. It is important to remember that furnace efficiency ratings exclude heat losses from ductwork as well as electricity to run fans. In severe cases, where uninsulated and loosely connected or damaged ductwork run through unheated spaces, system efficiency can be reduced by over 30 percent. The following table provides a guideline for furnace AFUE efficiencies.

Figure 3. Leaking Ducts Can Cost You Plenty



Older Gas or Oil	60 - 75%
Current Efficiency Gas or Oil	75 - 85%
Super Efficient Gas or Oil	85 - 95%
Electric	100%

Most current gas units utilize a power burner or an induced draft system to regulate the flow of combustion air. Oil units in the same range have flame retention burners and improved heat exchangers. The result of this technology is a smaller, hotter flame and a reduction in the amount of hot exhaust gas escaping up the flue. Super efficient furnaces recover further heat from flue gases by condensing water vapor containing a large amount of latent heat, and may use two or more heat exchangers in the process. These furnaces are often identified by the lack of a traditional flue using a smaller plastic pipe instead. In addition, some use outside air for combustion, a significant saving when furnaces are located within heated spaces. In very air tight homes, using outside combustion air also helps to maintain balanced air pressures inside the home. One drawback of super-efficient furnaces is potentially higher maintenance costs for cleaning and tuning due to the increased use of new technology. Electric furnaces are all considered 100 percent efficient because the electricity is entirely converted into heat.

To help simplify the process of determining energy costs of new furnaces, the federal government now requires that all new furnaces (as well as other major appliances) carry a yellow *Energy Guide Label*. This label provides the AFUE rating, an estimate of annual energy costs, and a comparison of the unit to others of roughly the same size. In addition, the Gas Appliance Manufacturers Association (GAMA), publishes a Consumers' Directory of Efficiency Ratings for a long list of gas and oil furnace models.

You may soon reach a dilemma. Higher efficiency units lower fuel bills yet they usually cost more to purchase. It becomes a trade off between pay now or pay later. Actually, it isn't very complicated if you take a close look at two important factors - heating load and unit fuel prices. Heating load refers to how much heat is typically used in the home and depends on the size of the home, how well it is insulated, thermostat settings, and outside climate. You can get a rough idea of your present heating load from the size of your heating bill. The other factor, fuel price, can vary from one area to another. In general, the higher the heating load and fuel price, the more you can justify investing in a high-efficiency furnace.

It is sometimes useful to estimate the payback of investments in efficiency. For example, you may be faced with two gas furnaces. The first unit costs $1,800 at 75 percent AFUE efficiency, while the second costs $2,400 at 86 percent AFUE efficiency. Is the more efficient unit worth the extra investment? To calculate payback, the following equation is used.

$$\text{Payback (in years)} = \frac{\text{Extra Cost (\$)}}{\text{Annual Savings (\$/year)}}$$

Of course, savings depend on the size of your heating load and utility prices as mentioned above. Assuming an annual bill of $800 at 75 percent efficiency, the bill could be reduced to $698 at 86 percent efficiency ($800 x .75/.86). Thus one could save about $102 each year, assuming no differences in maintenance costs. The payback in this case would be just under 6 years ($600/$102 per year = 5.9 years). Note that if fuel prices rise, then paybacks will be shorter. WEES Technote TN1204 provides further information and a calculation sheet for estimating home heating costs.

Sizing

The other important issue to consider when purchasing a new furnace is the size of the unit. Like automobile mileage, the actual efficiency of a furnace depends on how it is run. An oversized unit wastes energy by excessive cycling on and off resulting in greater stack losses. Naturally it is critical that a furnace not be undersized to avoid possible discomfort during very cold weather. Too often, however, units are oversized due to unrealistic climate assumptions or failure to consider insulation and other thermal improvements to the building. By properly matching the size of the furnace to the heating load of the building, you thus save in two ways. The unit operates more efficiently and you don't pay for a larger unit than you need.

The best way to insure a properly sized unit is to actually calculate the building's heating load (Btu/hour). The calculation is fairly simple but lengthy, and involves determining the area and insulation level of each building component in the home (floor, ceiling, exterior walls, and windows) in addition to estimating infiltration. The WEES Factsheet titled "Heat Loss Calculations" goes into detail on how to perform a heating load analysis.

If calculating heating load is not something you feel comfortable with, most furnace dealers or energy consultants should be able to do this for you. In fact, many personal computer programs are now available that can quickly analyze heating loads for a wide variety of building and temperature inputs. Sizing furnaces by rule of thumb is not recommended.

New Duct Systems

Along with furnace efficiency and sizing it is important to install an efficient air distribution system (duct work). No matter how well the furnace works it will be of little use if the hot air produced is lost or cooled down before it reaches the living spaces. The duct work should ideally be located inside the heated space to minimize conductive heat losses. Avoid putting ducts in unheated crawlspaces and attics. The duct work should also be designed to insure proper air flows throughout the entire system. After installation, make sure all duct work joints are sealed with duct tape to prevent air leakage. Insulate any duct work that cannot be located inside the heated space. Careful attention to the design and installation of duct work will have a major impact on the overall heating system efficiency.

As with any major purchase, it is a good idea to get several bids; however, be sure they cover the same type of system. AFUE efficiencies and sizes should be similar. If new ductwork, thermostats, or electronic filters are desired, have them included in each bid or else priced separately. Only by keeping bids comparable can you get a clear picture of the better investment. Also remember to compare warranties and check the installer's references.

EFFICIENT OPERATION

As mentioned earlier, some of the most cost effective actions for lowering heating bills are weatherization measures such as window treatments, increased insulation, and air leakage reduction. Another important activity for any type of heating system is proper operation and maintenance by you, the owner. In general, a heating system will perform only as well as it is operated and maintained. For many, operation may simply mean turning the thermostat up or down, yet other simple tasks can offer long-term benefits. Below are operation and maintenance recommendations for forced air furnaces that can help insure high and reliable performance, and provide the comfort you want at least cost. A final section discusses new thermostat options.

Operation & Maintenance

Tune-ups -- To keep your furnace running efficiently and to detect possible break downs before they occur, have your unit tuned up periodically by a qualified technician. Older systems and particularly oil systems, can benefit highly from annual servicing.

Housekeeping -- The area surrounding the furnace is generally the source of combustion air so keep it clean. Dirt and dust in this area can cause poor mixing of air and fuel leading to soot formation and heat exchanger fouling.

Air Distribution -- Change air filters as often as necessary (typically twice per year) to insure a clean supply of air to the home. Also, make sure heat supply registers and return air grilles are clean and unobstructed by curtains or furniture. Once a year, vacuum the fan blades and lubricate the motor. Check for duct leaks and seal them with duct tape as required. Before taping, clean the surface with a rag and solvent. If the ductwork has not been professionally vacuumed for several years, it may be a good idea, especially if you have pets or a large household.

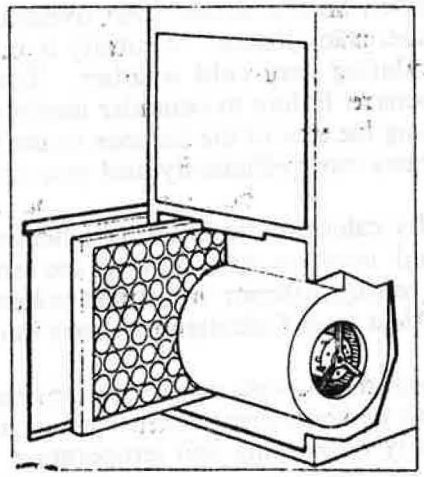


Figure 4. Remove the Fan Door to Change the Filter

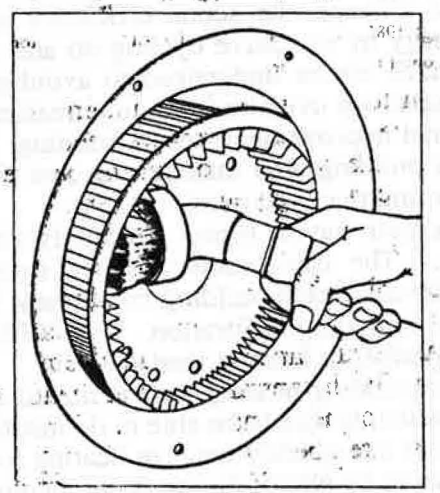


Figure 5. Use A Brush Attachment to Vacuum the Fan Blades

If some rooms overheat while others are cool, you may be inclined to adjust dampers. Although there isn't generally a problem with closing off room registers, be careful not to significantly alter balancing dampers installed in the duct work itself. A minimum amount of air must be circulated to the heat exchanger for good efficiency and to avoid excessive mechanical wear.

Troubleshooting -- Learn to recognize trouble signals such as odors, fuel leaks, soot at the burner, black smoke from the chimney, or any unusual noises.

Thermostats

A thermostat controls furnace operation by sensing temperature and turning the unit on or off accordingly. Therefore, its operation has a direct affect on how much energy you use. If you turn the temperature setting down before going to bed or whenever the home will be unoccupied, you can save considerably on your heating bill without sacrificing comfort. The savings amounts to approximately 1 percent of your heating bill for every degree of setback for an 8 hour period. Thus for a 10 degree setback at night from 11:00 p.m. to 7:00 a.m., you could save 10 percent of your bill or more than $50 per year (depending on the size of your bill).

Although manual setbacks work fine if you remember to make the adjustments, automatic setback thermostats are much more reliable and can quickly pay for their added cost (from $50 - $100 uninstalled). There are two basic kinds of automatic setback thermostats - clock and programmable. Clock thermostats are set manually on the hour and although several daily settings are allowed, the temperature setback is usually fixed.

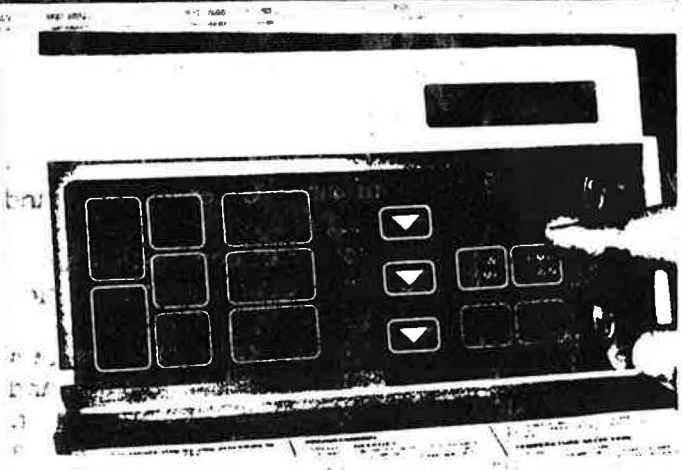


Figure 6. Programmable Thermostats Can Offer Automatic Energy Savings

More modern, programmable thermostats utilize microprocessor circuitry for increased information storage and control functions. Up to six daily settings, with one minute and one degree accuracy are generally possible. On many models, weekends can be programmed differently from weekdays, and on some, seven different daily programs are allowed. Other features to look for are programming instructions that are easy to follow and a battery backup (in case of power failure). Before comparing models, however, be sure the unit is compatible with your existing furnace and installation will not require costly wiring modifications.

No matter what kind of thermostat you use, it is important to check it periodically for accuracy. Compare the thermostat setting to actual room temperature using a thermometer. A one or two degree difference is normal but anything greater suggests your thermostat needs to be calibrated. Check temperatures several times during different outside weather conditions before deciding what correction is needed. Follow any instructions provided for changing your thermostat's readout or else get help form a reliable service company.

SUMMARY

Controlling your home heating bill involves improving the efficiency of both the building and heating system. While low cost weatherization options are generally most cost effective, a well designed and maintained heating system offers the best opportunity for trouble free service and comfort in the home. With central forced air heating systems, the proper care of ductwork and thermostats is just as important as the furnace itself. For information on other heating systems, refer to related WEES publications listed below.

SUGGESTED READING

Consumers Directory of Certified Furnace and Boiler Efficiency Ratings, Gas Appliance Manufacturers Association (GAMA) and ETL Testing Laboratories, Industrial Park, Route 11, Cortland, NY 13045, published twice annually.

"Cut Your Fuel Bills Up to 40%," *Popular Mechanics*, September 1983, The Hearst Corporation, New York, NY.

Analysis of Space Heating and Domestic Hot Water Systems for Energy Efficient Residential Buildings, Dennehy, G., Brookhaven National Laboratory.

"Efficient New Home Heating Systems," *Popular Mechanics*, October 1984, Ibid.

"Fuel Savers -- What the Tests Show," *Popular Science*, February 1984, Times Mirror, New York, NY.

"Fuel Saving Furnaces," *Popular Science*, October 1985, Ibid.

"Heating System Add-Ons," *Popular Science*, October 1984, Ibid.

"High Efficiency Furnaces," *Practical Homeowner*, October 1987, Rodale Press, Emmaus, PA.

"Ten Steps to Upgrade Warm Air Distribution," *Popular Science*, October 1983, Ibid.

"Thinking Thermostats," *Practical Homeowner*, September 1987, Ibid.

WEES PUBLICATIONS

Heat Pumps, FS-1203
Purchasing a Wood Heater, FS-1701
Passive Solar Heating - Residential, FS-1604
Economics of Energy Conservation Investments, FS-1001
Comparing the Cost of Home Heating Fuels, TN1204
Heat Loss Calculations, FS-1201
Energy Saving Thermostats, TN1203
Zone Heating, VD1201.

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