

UI Extension Forestry Information Series

Wood-Burning Stoves

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Wood-burning stoves are regaining popularity because of rising energy costs and energy conservation concerns. However, anyone considering burning wood for fuel must consider several factors when selecting which wood burner to buy:

- What is the size and the arrangement of the area to be heated?
- Is the wood burner to be used as a main source (perhaps the only source) of heat or just used occasionally?
- Is the cooking or heating of food desired?
- Is the unit to be strictly a functional heat source or are the aesthetics of wood burning of primary importance?
- What burning efficiency is desired when considering the time, effort, and expense of obtaining wood, and the time demanding chores inherent with safe, satisfactory wood burning?
- What amount of money is available to invest in the initial purchase and operation, maintenance, and possible replacement of the wood burner?
- Are the satisfactions of wood burning worth the responsibilities and the risks that go with it?

Wood-Burning Efficiency. The satisfaction achieved from any heating method depends upon it providing the highest level of comfort with the lowest expenditure of money and time. While wood burning is inherently time consuming, it can be made more satisfactory by improving the thermal efficiency of the area to be heated. Suggestions for improving thermal efficiency are to make sure that insulation, weather-stripping, caulking, storm doors and storm windows are adequate, and to minimize the opening and closing of outside doors and of doors to unheated areas of the house. A wood stove might comfortably heat several

rooms, but to attempt heating the entire house might produce unsatisfactory heating levels in all rooms.

The burning efficiency or the combustion efficiency of a wood stove refers to the percentage of total heat content in the wood that can be extracted and used. If wood has an energy content of 7,000 British Thermal Units (BTU's) per pound and 3,500 BTU's can be discharged as heat into the air around the stove, the combustion efficiency is 3,500 divided by 7,000 or 50%.

Combustion efficiencies for wood stoves range from under 20% for a poorly-designed stove (which allows 80 to 90% of heat generated to go up the chimney) to over 50% for a well-designed, efficient draft-controlled stove. Efficiency depends primarily on the:

- design of stove (its draft control and heat extraction characteristics);
- design and condition of the chimney;
- type and condition of the wood used for fuel; and
- skill of operator

As a rough estimate, assuming air-dry wood as the fuel source, the following combustion efficiencies can be expected for different stove types and standard fireplaces:

• Standard fireplace	up to 10%
• Simple box	20 to 30 %
• Air-tight box	40 to 50%
• Base-burning	40 to 60%
• Down-draft	50 to 65%
• Front-end combustion	50 to 60%

All air-tight stoves are characterized by seamless or gasketed fireboxes, precision made draft controls, and carefully fitted, sealing doors.

To understand wood stove efficiency, we must first understand the three phases of wood burning. First, the wood is heated to evaporate and drive off moisture, this occurs under 500°F. Above 500°F, the wood starts to break down chemically and volatile matter is vaporized. These vapors contain 50 to 60% of the heat value in the wood. The third phase of wood burning occurs above 1,100°F when these vapors and the remaining material (charcoal) burn. This high temperature must be maintained for maximum combustion efficiency.

All three phases of burning may and usually do occur at or about the same time. For efficient burning, the volatiles must be mixed with air and kept at 1,100°F or higher to burn completely within the stove. Wood burns with a long, yellow flame. By providing a long flame path within the stove, heat from these burning gases can be used before it escapes up the chimney. The flame path is lengthened in more efficient stoves in one of the following ways: by using an interior baffle which causes the gases to travel in an “S” pattern rather than a straight line, by using a gas combustion chamber from near the base of the fire for base-burning or down-draft stoves, or by using a secondary combustion chamber mounted at the top of the stove.

We must also understand the methods of heat transfer accomplished by stoves of different designs (Figure 1). Heat moves in three ways: by *conduction*, where the

heat energy moves through a material by migration; by *radiation*, where energy waves from a hot surface move in a straight line until they are absorbed by something and converted to heat energy; and by *convection*, where a fluid (air) expands and rises when heated, eventually traveling around the enclosure until its heat is lost or diluted.

Heat moves through the walls of the firebox by conduction. Heavy metal stoves and firebrick linings take longer for the heat to move through. Hence they provide usable heat more slowly but maintain a more even temperature over a longer period of time.

Radiation is increased by stoves which have higher exterior surface temperatures and larger surface areas. The straight line aspect of heat radiation causes people to experience the campfire phenomena of being too hot on the side next to the heat and too cold on the other side.

The mixing action of convected air provides the most comfortable heat. Stoves with an outer jacket and with an air space between the jacket and the firebox maximize convection heat transfer. They also have lower surface temperatures which substantially reduce the likelihood of igniting nearby combustibles and causing burns if touched. Convection-type stoves often use electric fans to provide positive air movement around the firebox.

A typical wood-burning stove will provide substantial amounts of both radiant and convective heat to the room in which it is located. Increasing the area of hot stove surfaces exposed to the air increases both radiation and convection and improves burning efficiency. It also lowers the temperature of escaping flue gases. The cooler flue gases become, the more likely creosote will be deposited on chimney surfaces. Any wood-burning system should be cleaned periodically to reduce the likelihood of chimney fires.

Air Supply. Adequate amounts of air must be available to achieve the most efficient burning. For any established fire, only 20% of the total available air is needed at the surface of the burning wood (Figure 2). The remaining 80% is necessary for the combustion of gases that are given off. For this reason, more efficient

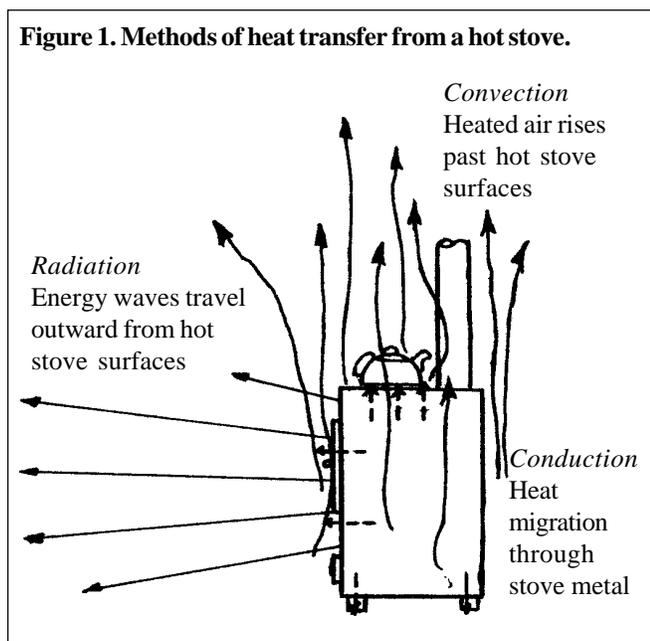
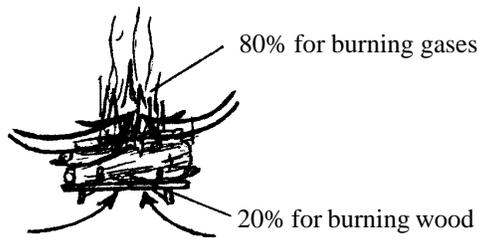


Figure 2. Air supply distribution.



stoves have dual draft systems with a primary air supply for the wood and a secondary air supply for the gases. Pre-heating channels are often provided for one or both of these air supplies. These channels increase air temperatures before the air reaches combustion zones.

Since wood burning requires such large amounts of air and since many homes are now tightly weather-proofed, a supplemental air source should be provided to the stove (Figure 3). This air can be supplied through a duct from a crawl space or directly from outside of the house. The duct should have an outlet as near to the stove as possible. The size of the duct should be roughly the same as that of the stove flue. A damper should be installed on the duct to adjust air flow and to close it completely when the stove is not in use. If no ducts are provided, you may need to open a nearby window slightly in order for the chimney to draw properly and the fire to burn most efficiently.

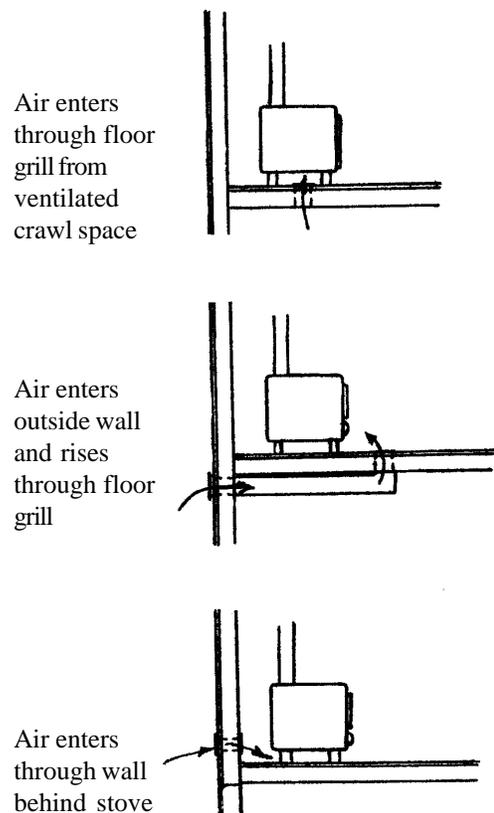
Wood stove designs.

- *Box or chunk stoves* are the simplest and most common types available. They come in many forms including kitchen, Franklin, pot belly, and parlor stoves (Figure 4). These generally do not have very positive draft control and consequently burn excessive amounts of wood. Most introduce air under the fire. Some introduce additional air over the fire to help provide needed oxygen to burn escaping volatile gases. Unburned gases can carry large percentages of potential heat up the chimney.
- *Air-tight box stoves* (Figure 5) have controlled-draft damper systems, some with automatic thermostats, to give more positive control of both primary and secondary combustion air. Most introduce air below and above the fire. Some designs preheat incoming air. Others incorporate

thermostatically-controlled heat exchangers to recapture heat for space heating.

- *Base-burning air-tight stoves* take the principles of the controlled-draft box stove one step further and add a second chamber for better combustion of the gases. These stoves bring secondary air through a pre-heating channel so it will not significantly cool the volatile gases. In addition, the flue outlet is located at the base of the fire box, forcing all exhaust products to pass by the hottest part of the fire before leaving the stove. Under proper conditions, these stoves can be fairly efficient but still need frequent tending.
- *Down-draft air-tight stoves* are relatively simple in design. Air is drawn down through air ports in the stove top, producing a blow torch effect. Volatile gases from fresh fuel are driven through the glowing coals. In some down-draft models, primary air enters above the fire but below the main load of wood. This primary draft flows down and outward through the glowing bed of coals,

Figure 3. Outside air supply for wood-burning stoves.



pulling volatile gases with it. Secondary air is introduced under the coals where it can oxidize these superheated gases. Gases continue to burn in the secondary chamber. This draft pattern prevents the heat of the fire from rising up through the fresh wood load (isolating it from the fire) until wood has dropped down into proper burning position. Thus, even a full load of fresh fuelwood will not cool the fire below. Volatile gases from the new fuelwood are also released more slowly for more efficient burning. Some down-draft stoves use a thermostatically controlled fan to circulate hot air through heat exchange chambers. This arrangement takes advantage of heat otherwise lost up the chimney.

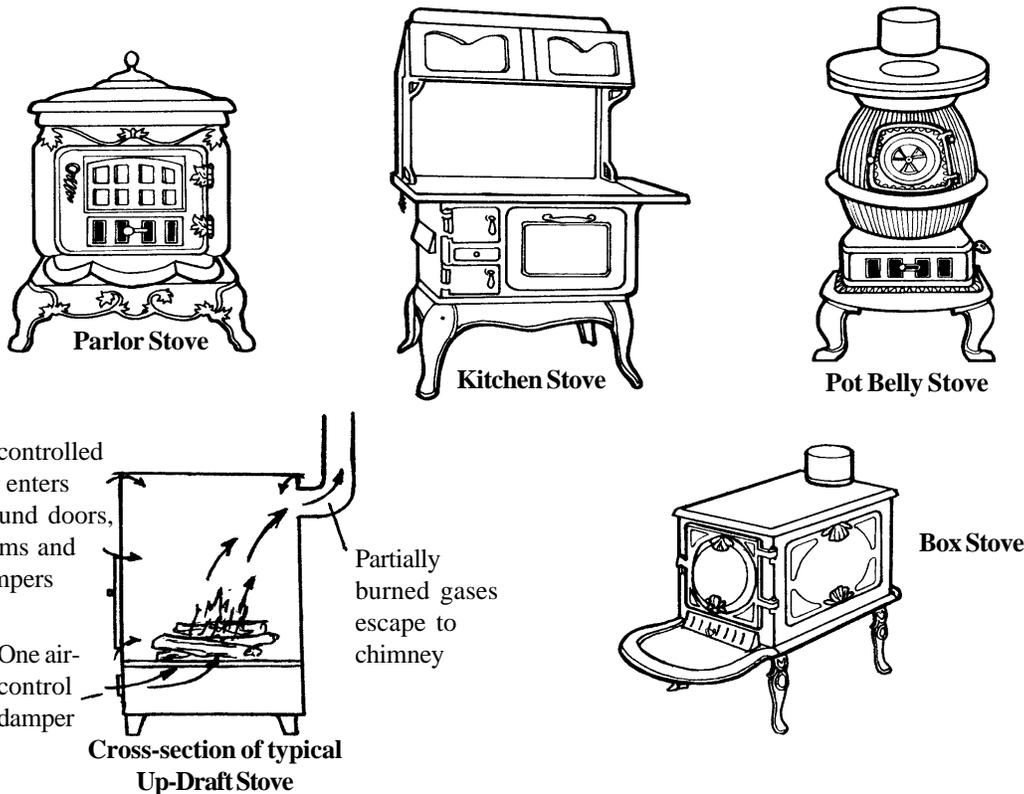
- *Front-burning air-tight stoves* characterize the Scandinavian approach to efficient wood burning. Primary air is directed into the coals, forcing the volatile gases into the burning area. Secondary air is introduced above the fire for burning of escaping gases in a baffled secondary chamber. Since oxygen is consumed near the front, burning toward

the back is delayed.

Stove Construction. Wood stoves are constructed from sheet metal, plate steel, cast iron, or combinations of these metals. Generally, the heavier the stove, the better the heat-holding and spreading capabilities.

- *Sheet metal stoves* are relatively thin gauge. They are inexpensive and have a shorter life than plate steel or cast iron stoves. They will heat a room quickly, but they also cool rapidly as the fire burns down. Thin-wall stoves should never be heated red hot as they tend to warp and burn through. They should have several inches of dirt or sand in the firebox to prevent burnout by hot coals. These stoves need to be examined frequently for thin spots.
- *Plate steel stoves* 1/8 inch thick or thicker hold heat longer than sheet metal stoves. Many are lined with firebrick to provide more uniform heating and to protect the metal from deteriorating and warping from repeated overheating. Historically, steel

Figure 4. Non air-tight stoves.



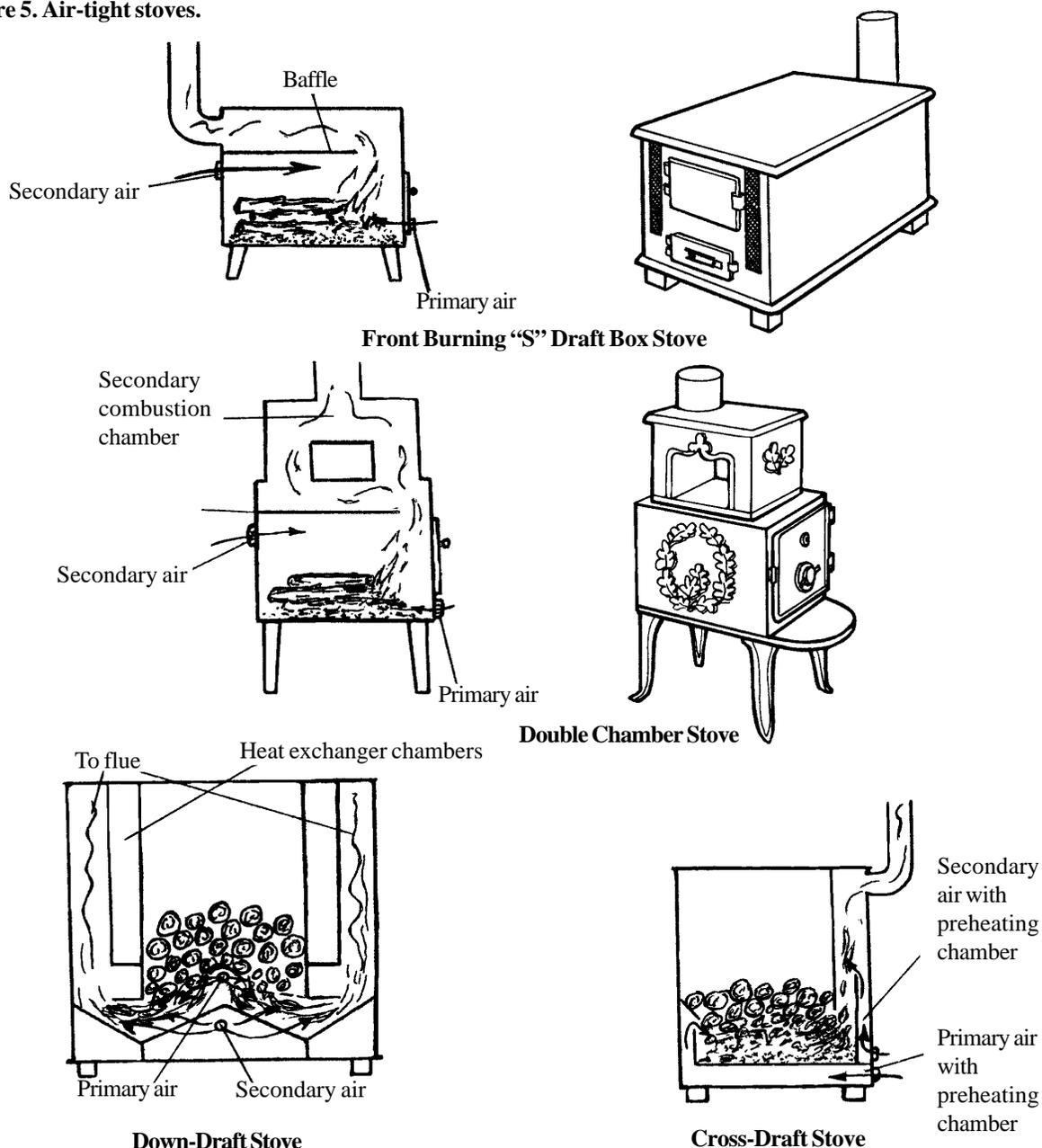
stoves have been bolted together rather than welded in order to reduce warpage problems. In many cases, cast iron doors, door frames, and cast iron or firebrick firebox liners have been used to extend the life of the steel stove.

- *Cast iron* has long been considered the best material for wood stoves. Cast iron stoves warm up slowly and have good heat-holding capability. Designs and texture cast into plates can increase radiating surface by up to 25%. Cast iron holds up well under heat, has a long life, spreads heat away

from hot spots in the fire and generally does not warp.

The characteristics of a good cast iron stove are heavy, smooth castings, fully ground and fitted plates, tightly sealed seams, and tight-fitting doors with positive latches, internal baffles and side liners, tight and easily-adjusted draft controls and smooth, pit-free enamel finishes. Care should be used in handling cast iron because it cracks easily. In the long run, a finely cast, hand-fitted, well-designed

Figure 5. Air-tight stoves.



air-tight cast iron stove is a good investment. Lower quality cast iron stoves increase the likelihood of warping or breaking and in some cases may allow gases to seep through pores in the iron.

Other quality features include door and damper handles made of coiled metal so they don't get so hot, nickel plating on handles and trim, porcelain or tiled finishes if something other than bare metal surfaces that provides increased radiating surface as well as decoration.

General Considerations. All wood stoves should have sturdy legs, providing at least 4 inches, and preferably 8 to 10 inches, of air space between stove bottom and floor. Glass windows in wood stoves should be special safety glass designed to withstand thermal shock.

A stove designed to burn wood only should not be used to burn coal. Some stoves are designed to burn either. The excessive heat of coal will soon burn out the grate or bottom of a stove designed for wood only. Burn manufactured logs only in an open fireplace – they contain wax that burns dangerously hot.

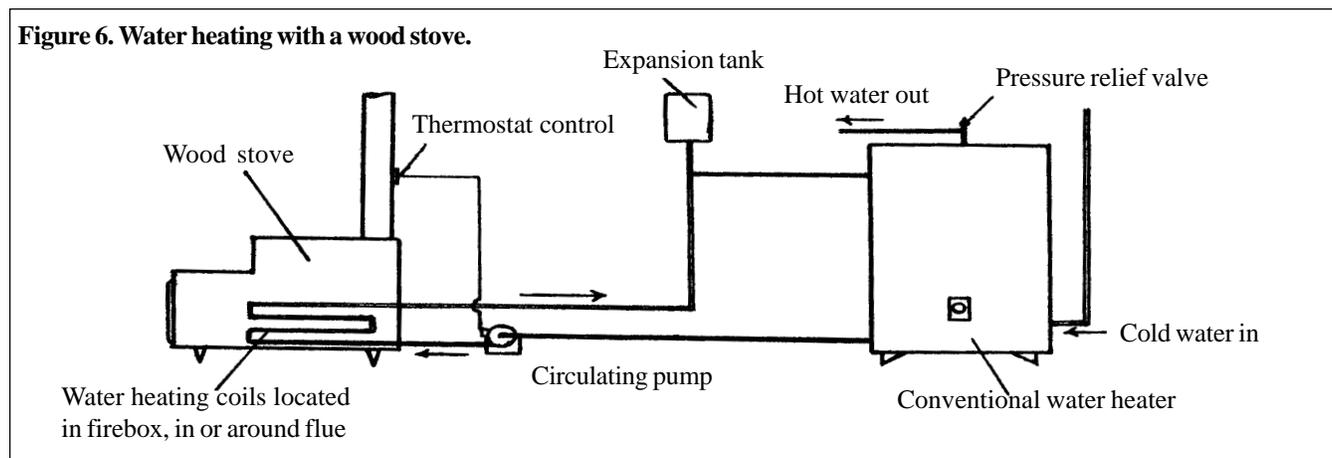
Many manufacturers rate their stoves either by the number of cubic feet or the number of rooms the stove will heat. Any capacity rating must be used judiciously. As a general rule, 2.6 square feet of firebox bottom is required for each 1,000 square feet of room area. Unless the rooms are very open or a forced air duct/system is installed between rooms, attempting to heat more than one room with a stove may well result in uneven temperatures and cold drafts along floors.

When a stove pipe has been installed, perform the tap test. Simply tap the pipe with your fingernail and remember the sound it makes. Repeat this procedure every week during heating season. If the “ting” sound changes to a muffled “thud”, it is time for a creosote inspection. Creosote tends to build up more quickly in efficient air-tight stoves because more heat has been removed from the flue gases and the resulting lower chimney temperature encourages creosote condensation.

Wood Stove Installation. Many people purchase wood stoves without considering the necessary steps or additional costs for installation. Temporary expedencies such as running a single-wall, unventilated stove pipe through walls, ceilings, roofs, or windows, and using stove pipe as chimney do not meet fire codes and may result in a serious fire or cancellation of fire insurance. Install your wood stove in compliance with your local building code or fire department requirements and be safe rather than sorry. Then have your insurance company approve the installation.

Special Considerations. Increasing interest is being shown in home solar heating systems. However, the unpredictability of adequate periods of sunshine during winter months necessitate either an expensive heat storage unit or an auxiliary heating system. A combination of solar and wood heating could provide the benefits of low cost operational expense and total energy independence.

Many people are finding that an additional benefit from a wood stove is the capability to heat domestic water. Figure 6 shows a schematic layout of a stove water



heater supplementing a conventional hot water tank.

Additional heat can be extracted from combustion gases by using some type of flue heat exchanger. Two different kinds are shown in Figure 7. Make sure all flue connections are resealed. Remember that excessive cooling of gases decreases the drawing effect of the chimney and increases the likelihood of creosote deposits on interior surfaces of the flue and chimney. These units need to be cleaned often during the heating season because of the creosote and soot buildup.

Wood stoves can be installed to use a fireplace chimney and to gain improved performance above that of the typical low combustion efficiency of a fireplace

(Figure 8). Some manufacturers make stove units that fit inside existing fireplace openings. These should be carefully installed according to manufacturer recommendation. Other wood-burning stoves can be placed in front of the fireplace opening with their flues either sealed into the existing chimney opening or connected through the front of the chimney above the fireplace mantle.

This information first appeared as CIS 53 and was part of the *Wood as a Fuel Series*.

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