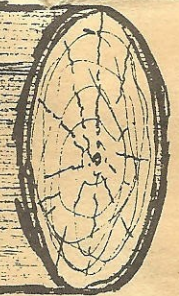


# Wood-Burning Stoves, Furnaces, and Fireplaces



The increasing costs and limited supplies of fossil fuels are generating interest in burning wood to heat homes. Many homeowners are installing wood-burning stoves, furnaces, or fireplaces as a backup system or in tandem with conventional furnaces.

Wood can be an attractive source of energy for individual households. But there are efficient and inefficient ways of utilizing wood to heat a home because burners differ in their design and effectiveness. Wood heaters must be properly installed and operated for optimum performance, and safety must be a primary consideration.

In addition, wood must be available at a relatively low price. If wood costs as much as conventional fuels, there is no advantage in using it for an energy source.

## Combustion and Efficiency

To understand how different stoves operate and what efficiency means, a practical knowledge of the mechanics and chemistry of combustion is helpful.

Wood is composed almost entirely of cellulose and to a lesser extent lignin. When heated, these compounds break down into a variety of gases, liquid tars, and acids. This process is known as the destructive distillation of wood. Combustion occurs when these gases are mixed with oxygen at temperatures high enough to ignite them.

In order for wood to burn, its temperature must be raised. At around 250 degrees F any moisture in the wood prevents the temperature from rising further. Since most well-seasoned wood contains 10 to 20 percent moisture, it takes energy and time for the combustion process to continue.

After the water has been driven from wood, the temperature will rise to around 380 degrees F when the distillation of gases begins. As the volatile gases combine with oxygen, the temperature continues to rise. Most stoves achieve maximum combustion temperatures of around 1,600 degrees F, although higher temperatures are possible.

When the gas burning phase is completed, charcoal remains, and this is primarily carbon. Charcoal combines with oxygen to produce heat, carbon dioxide, and water. This solid fuel burns slowly and evenly and produces a great deal of heat.

Combustion also produces creosote. Creosote is a mixture of materials known as pyroligneous acid and occurs most often when combustion is incomplete or when the fire is not hot enough to carry this material out of the chimney. It collects on the inside of the chimney and is extremely flammable; therefore, periodic inspection and cleaning of the chimney may be necessary.

Now let's examine how a fire can be designed for max-

**Table 1. Total potential heat content of wood from different species.**

Species of wood	Weight per cubic foot <sup>1</sup> (pounds)	Weight per cord <sup>2</sup> (pounds)	Total heat <sup>3</sup> content per cord (million Btu's)
Osage orange	59.9	4,792	33.5
Black locust	52.4	4,192	29.3
Shagbark hickory	50.9	4,072	28.4
White oak	47.2	3,776	26.4
Red oak	44.2	3,536	24.7
White ash	43.4	3,472	24.2
Hard maple	42.6	3,408	23.8
Green ash	41.2	3,296	23.0
Red elm	37.4	2,992	20.8
Sycamore	35.9	2,872	20.0
American elm	35.9	2,872	20.0
Silver maple	34.4	2,752	19.2
Boxelder	32.1	2,568	18.0
Cottonwood	28.4	2,272	15.9
Basswood	24.8	1,984	13.8

<sup>1</sup> Weight per cubic foot at 20 percent moisture content.

<sup>2</sup> A "cord" is a stack of wood 4 feet by 4 feet by 8 feet or 128 cubic feet of wood and air. It is assumed an average cord contains 80 cubic feet of solid wood.

<sup>3</sup> Total heat content of 20 percent moisture content is approximately 7000 Btu's per pound. One pound of wood at 20 percent moisture content contains .833 pounds of wood and .167 pounds of water (8600 Btu's per pound of dry wood) (0.833) minus (0.167) (1117 Btu's per pound of water) = 6980 Btu's. 1117 Btu's is energy required to vaporize 1 pound of water.

Prepared by Paul H. Wray, extension forester.

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**Table 2. Available heat from wood compared with equivalent amounts of other fuels.**

Species of wood	Available heat <sup>1</sup> (million Btu's)	Heat equivalents of other fuels				
		lowa coal <sup>2</sup> (tons)	No. 2 fuel oil <sup>3</sup> (gallons)	Natural gas <sup>4</sup> (100 cu. ft.)	LP gas <sup>5</sup> (gallons)	Electricity <sup>6</sup> (kilowatt hrs)
Osage orange	16.8	1.68	185	224	249	4,924
Black locust	14.6	1.46	161	195	217	4,288
Shagbark hickory	14.2	1.42	156	189	211	4,165
White oak	13.2	1.32	145	176	195	3,862
Red oak	12.3	1.23	136	165	183	3,617
White ash	12.1	1.21	133	162	180	3,551
Hard maple	11.9	1.19	131	159	176	3,486
Green ash	11.5	1.15	126	153	170	3,371
Red elm	10.4	1.04	115	139	155	3,060
Sycamore	10.0	1.00	110	134	148	2,937
American elm	10.0	1.00	110	134	148	2,937
Silver maple	9.6	0.96	106	128	142	2,815
Boxelder	9.0	0.90	99	120	133	2,638
Cottonwood	7.9	0.79	87	106	117	2,324
Basswood	6.9	0.69	76	92	103	2,029

<sup>1</sup> Available heat is defined as total heat potential (table 1) times the efficiency factor of the stove; 50 percent efficiency of wood burner is assumed.

<sup>2</sup> Iowa coal has total heat content of 10,000 Btu's per pound; 50 percent efficiency of hand-fired coal burners yields 5,000 Btu's per pound.

<sup>3</sup> Total heat content is 140,000 Btu's per gallon burned at 65 percent efficiency yields 91,000 Btu's per gallon.

<sup>4</sup> Total heat content is 100,000 Btu's per 100 cu. ft. burned at 75 percent efficiency yields 75,000 Btu's per 100 cu. ft.

<sup>5</sup> Total heat content is 90,000 Btu's per gallon, burned at 75 percent efficiency yields 67,500 Btu's per gallon.

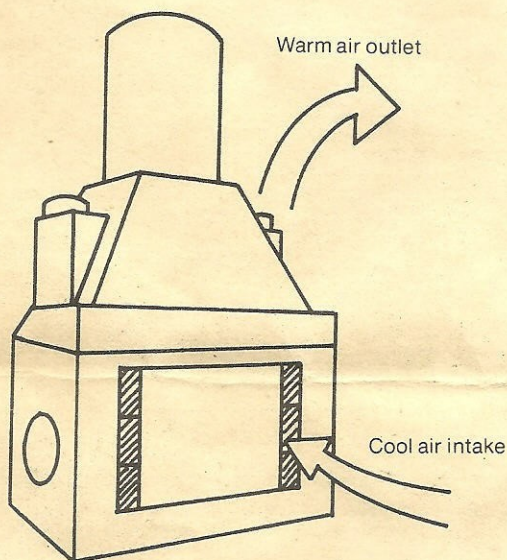
<sup>6</sup> Total heat is 3412 Btu's per kilowatt hour at 100 percent efficiency.

imum efficiency. We are not so much interested in getting the heat out of the wood, as in getting the heat into the house.

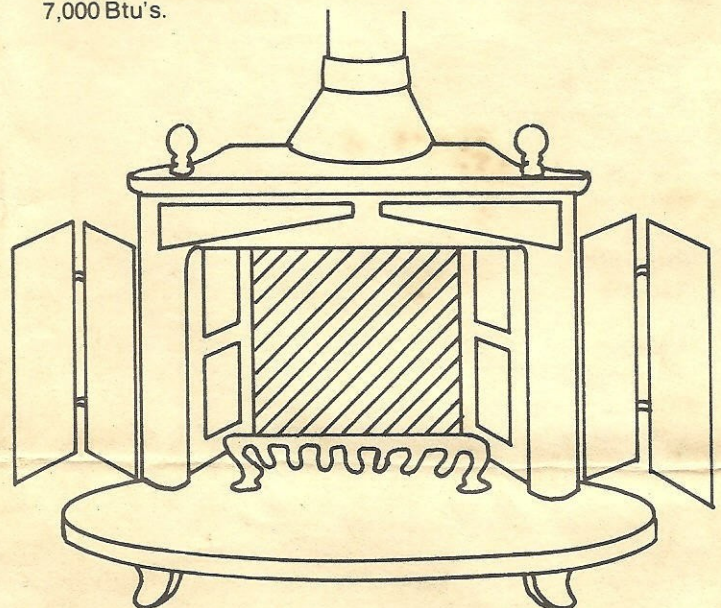
All wood has a certain heat potential which must be released before its combustion is completed (table 1). The object is to get as much burning done as possible before the heat goes up the chimney. If complete combustion could be achieved, the only gases going up the chimney would be water vapor, carbon dioxide, and a small amount of carbon monoxide. The most efficient wood stoves are only about

50-70 percent efficient—one-third to one-half of the energy goes up the chimney and the rest stays in the structure (table 2).

The energy released when a pound of bone-dry wood is burned completely is called its fuel value—about 8,600 Btu's. Air-dried wood may contain nearly 20 percent water by weight, and the heat liberated by burning is less—about 7,000 Btu's.



**Fig. 1. Heat circulating fireplaces are more efficient than conventional types.**



**Fig. 2. Franklin fireplaces are available in a variety of sizes and models. They combine some of the aspects of a fireplace and a cast iron stove.**

## Types of Wood Heating Units

There are many decisions to make in selecting a home wood heating unit. One of the most critical choices is the type of unit. There are three general types of home heating units: fireplaces, stoves, and central heating systems. Each type should be evaluated with respect to advantages, disadvantages, and design differences.

### Fireplaces

Fireplaces are not suitable for the entire heating job; only stoves and furnaces have this potential. Fireplaces are inefficient. With conventional fireplaces, about 90 to 95 percent of the heat generated from the wood goes up the chimney. In fact, many fireplaces represent a net loss to the home heating budget.

Years ago, many homes were heated with fireplaces, but these required several times the amount of wood to heat the home compared with a more efficient stove. In addition, a moderate sized home required three or four fireplaces to maintain comfortable temperatures.

The advantage of a fireplace is primarily the aesthetic appeal of an open flame. However, for those who want an open flame, there are a number of ways to improve its efficiency. The amount of heat from a fireplace can be increased by making it shallower (reducing the distance from the front to the back) and by sloping the rear wall forward. On existing fireplaces, efficiency can be improved through the use of heat-tempered glass doors which can be mounted over the front of a fireplace opening. You can expect well-fitted doors to almost double the efficiency (from perhaps 5 to 10 percent), but only if the fireplace is located on an inside wall. If the fireplace is on an outside wall, about all that can be accomplished with doors is to heat the masonry outside your house. Adding glass doors will let you shut off excess drafts when the fireplace is not in use, but they should be left open when a fire is burning.

Fireplaces fall into four different structural categories: masonry, metal built-in or zero clearance units, free-standing fireplaces and the Franklin type units.

Certain models of metal built-in units are equipped with heat circulating ducts for increased efficiency. The circulated hot air can be conveniently carried to any part of the house by using relatively inexpensive double wall ductwork. Fans to increase the rate of circulation are also available (fig. 1).

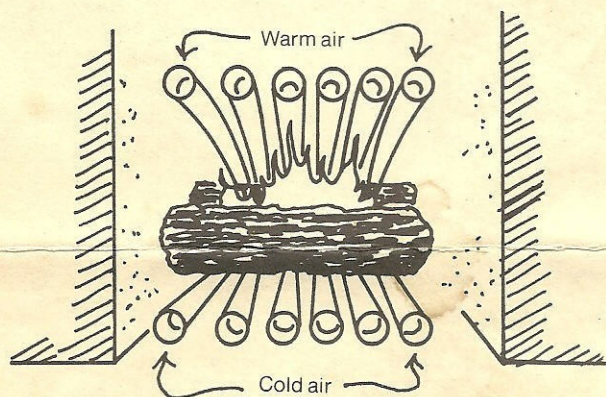


Fig. 3. Attachments to a fireplace such as this circulating grate can increase efficiency.

The Franklin type is a compromise between the beauty of an open fire and the higher efficiency of a wood stove. Closing the doors substantially reduces the amount of warm air drawn out of the room and up the chimney and increases the efficiency of combustion. But Franklin fireplaces are not as efficient as a well-designed stove (fig. 2).

Specially designed fireplace grates made of hollow pipes are available. When these pipes are heated, a small amount of warm air circulation is generated in the room. These can be equipped with an electric fan for greater efficiency. But sometimes these units can be uncomfortable because a blast of hot air is not as pleasant as radiant warmth (fig. 3).

A fireplace must draw air for combustion, and it will use much more air than a stove. If air can be inducted directly from outside the house, the fireplace will not be pulling cold drafts under doors and over floors.

### Stoves

There are several items to be considered in selecting a stove for home heating. Decide before you buy what you want in light of your needs. There are at least six main things you should consider: function, durability, safety, cost, effectiveness, and appearance.

**Function** basically means what the stove will do. A *cookstove* will serve as a heater, but its main function is cooking. Heating stoves are divided into two types according to the type of heating. The *radiant* stove simply radiates heat directly to people and objects around it. Radiant heaters are better for large open spaces and where comfort is desired at lower air temperatures. A *convective* stove is usually a radiant inner stove surrounded by a cabinet; the air rising between the stove and the cabinet is heated. Convection heaters are most useful where more heat is wanted on the floor above.

**Durability** primarily relates to how long the unit will last and is often correlated with price. However, there are some exceptions to this rule. Stoves are produced from cast iron or from steel, and a debate rages over which is best. Both have advantages and disadvantages. The durability of cast

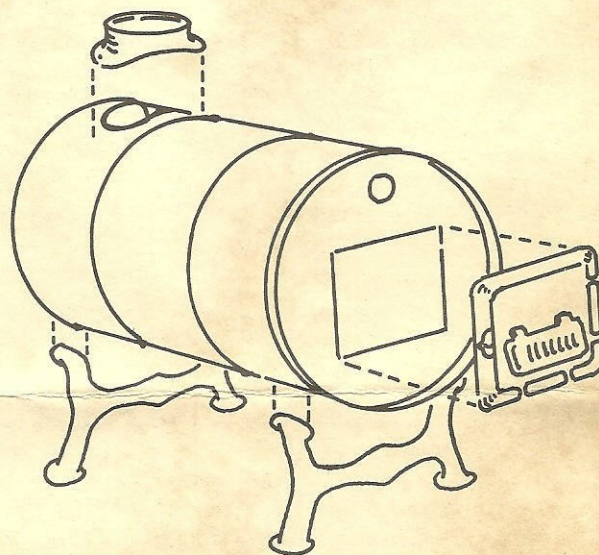


Fig. 4. Kits are available for converting a 55-gallon steel barrel into a wood heater suitable for occasional use such as heating a garage or a summer cabin.

iron is derived from its resistance to deterioration or deforming under intense firebox heat. But it tends to be brittle and may crack under rapid temperature change or from a sharp blow such as a log tossed into the firebox with excessive vigor. Steel, on the other hand, will not crack like cast iron, but it has a tendency to deform and break down under intense heat. In general, the best stoves of either type are lined with firebrick, but there are exceptions to this general rule.

**Safety** will be discussed later, but a couple of points are mentioned here. Stoves generally do not present as many safety problems as do chimneys. As a rule, the more massive and durable the stove, the safer it is. Also, there is little doubt that a cabinet type stove gives the best protection against accidental burns.

**Cost** is often a difficult decision. A cheap stove may end up costing more in the long run because of maintenance and shorter life than one that has a higher price tag. Remember, the initial cost of a stove is only a small part of the operating costs.

**Effectiveness**—How well will the stove do the job you want it to? How much heat will it deliver? How long will it burn? How efficient is it? These considerations plus others must enter into your decision. Remember, you want a stove that is efficient enough to heat your home, but not one that is oversized.

**Appearance** may be fairly important although it depends on where the stove is located. If it is located in the living room, for example, it becomes permanently placed furniture. But if a stove is located in the basement appearance is less important.

There are at least 200 different types of stoves on the market. Some are very different, while many are very similar. The type of stove you choose depends on what you want to heat. Obviously, you will use a cheaper, less efficient model for occasional garage heating than one designed to heat your entire home.

Let's talk about some of the general types of stoves available for different purposes. Least expensive is the *sheet metal* stove or even a converted oil drum. These are not very durable, but for occasional use they are effective heaters but are not very efficient. Prices for these units start around \$50 (figs. 4 and 5).

*Cast-iron* stoves are more durable and can heat small areas such as a single room. Most are inefficient. American models cost around \$100 to \$150 with the more expensive

European models about \$100 more. In general, the tighter the draft control and the fewer leaks in the design, the more efficient the stove will be. Large models are available for heating several rooms (fig. 6).

*Air-tight (draft control)* stoves are more efficient than sheet metal or cast-iron stoves. But air-tight stoves can present problems with creosote buildup in the chimney. Adding a thermostat to control the draft opening increases efficiency and provides better temperature control. Some have controlled burning rate; others feature a full on/full off thermostat control to increase the burning rate when additional heat is required. The advantage of this mechanism may be less creosote buildup. The more complex stoves with thermostat controls cost \$200 to \$600 or more.

Many stoves feature different draft control systems. Most have a primary draft system with an additional secondary draft system for increased combustion of volatile gases. Some stoves also have baffles which may or may not increase burning efficiency (fig. 7).

Many stoves can be equipped with a heat exchanger. This device forces the hot gases to travel a greater distance and promotes more heat output before the hot gases escape up the chimney. These devices may increase the efficiency of the wood burning unit.

Many different models of stoves are equipped with a cabinet and a system for forced air circulation. A stove with forced air circulation generally has higher wood burning efficiency than a noncirculating type (fig. 8).

### Central Heating Units

Using a wood furnace is another way to heat a home with wood. Like a conventional fireplace, it takes up a lot of room and is probably most conveniently located in a basement adjacent to a fuel storage area.

A wood furnace is like a very large circulating stove. It

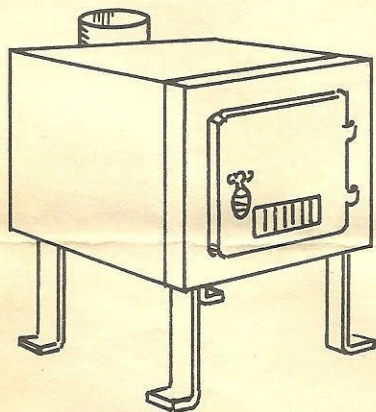


Fig. 5. Sheet metal stoves are manufactured by many different companies.

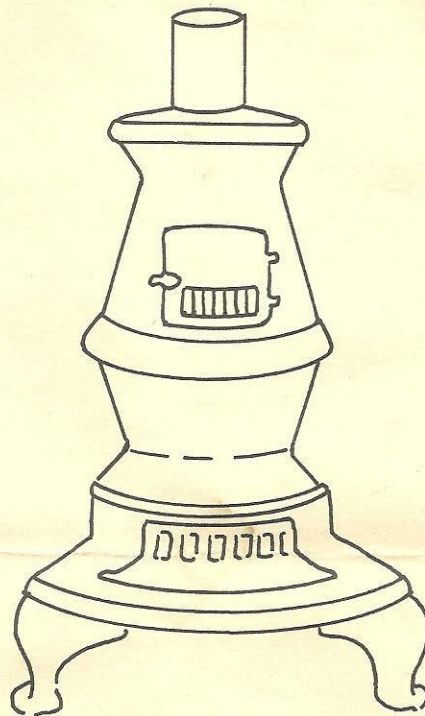


Fig. 6. Cast-iron pot stoves come in a wide variety of sizes and shapes.

has a firebox which operates on the same complete combustion principles as an efficient stove, so that wood is reduced to a minimum amount of ash. Unlike wood stoves, modern wood furnaces can easily be converted to burn oil. Some will switch automatically so that you can have a choice of fuel and can let the furnace run on oil for lengthy periods. When fueled with wood, it will typically require attention about twice a day (fig. 9).

To distribute the heat from a furnace, air is blown around the firebox and circulated through ducts in the house just as in a conventional forced air heating system. Some furnaces can be used with hot water distribution systems. In this case, the firebox is surrounded by water which is then piped into baseboard radiators or radiant floor systems.

A wood furnace is a large investment of \$2,000 to \$4,000. This is equivalent to buying a complete house-heating system. Talk to owners as well as manufacturers before making a purchase. In addition, plan to make wood your primary home heating fuel (not just a supplement) to make the investment worthwhile.

### Stove Location

First, determine where you would like your stove. Although the location you personally prefer may be impractical for one or more reasons, you should consider where you want it located.

Ideally, the best location for heating stoves is in the center of the lowest section of your home. Many early homes were built around fireplaces, but the tendency now is to locate fireplaces on exterior walls. The ideal location is seldom available in an existing house, and compromise may be necessary. But in new construction, the stove can be located for maximum effectiveness and efficiency.

Certain areas of the house such as bedrooms, utility rooms, and pantries can be kept cooler. Areas of more sedentary use such as TV rooms, livingrooms, and bathrooms should be warmer than areas of moderate activity such as kitchens, playrooms, or hallways. If the stove must be located out from the center of the house, place it along the axis of the ridge of the roof, and slightly off center. This will bring the chimney out near the top of the roof, which is desirable.

If you must put a stove at one end of the house (to take advantage of an existing chimney, for example), a metal

shield placed next to the wall will reflect a lot of the radiated heat back into the house.

A small fan directing air past a stove will help even out temperatures in the entire house. The fan of an existing furnace may also be used to circulate heat and maintain a more constant temperature in the house.

In many respects a basement is an ideal location for a wood stove. Since hot air rises, a layer of warm air will develop along the ceiling of the basement. Excellent control over where the heat goes can be maintained by sizing floor grills to correspond to the amount of heat wanted in a particular area. Also locating the stove at the lowest part of the house affords the greatest chimney height, which insures the best possible draft.

### Chimneys

The chimney is an integral part of a wood stove, even though it is not usually provided with the stove. To perform well, a stove must be correctly connected to a good chimney.

The best type of chimney is masonry with a ceramic flue liner. Its main disadvantage is the considerable cost of construction. However, this is not such a major factor if the labor is done by the homeowner.

Prefabricated stainless steel chimneys have increased in popularity. They are fairly easy to install and will meet most codes for safety if installed correctly.

There are several types of prefabricated metal chimneys suitable for use with wood stoves. All have moderately high insulating characteristics. Straight sections are available in various lengths plus all the necessary fittings and hardware.

Remember, wood stoves require high temperatures for best operation. Because of this, one particular kind of prefabricated metal chimney is unsatisfactory for use in some woodstove applications. It is a triple-wall chimney which has no insulation, but uses circulating air for cooling. This system works too well in cooling the chimney. The result may be substantial increase in condensation (creosote) and a reduction in the draft. Therefore, this chimney has been unsatisfactory in some installations.

The least expensive chimney is one already in the

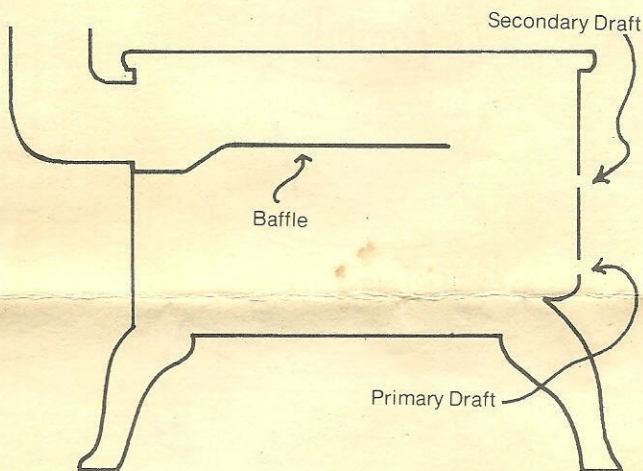


Fig. 7. Outline of a stove showing a type of double draft and baffle system to increase efficiency.

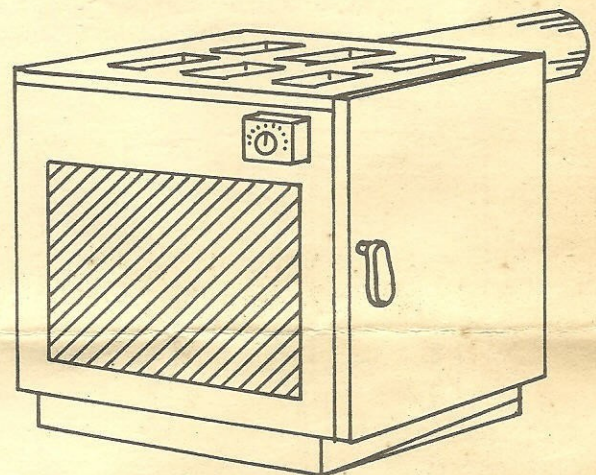


Fig. 8. A circulating stove heats primarily through radiation. The outside of the stove normally does not get hot enough to burn a person's skin.

house. However, it must be suitable for a new stove. An unlined chimney, or one in which the lining is badly cracked, should not be used unless the chimney can be repaired or a new lining installed.

Remember these points when selecting or using an existing chimney. The ideal chimney should prevent combustion gases from losing any of the temperature at which they enter the bottom of the chimney until they reach the top. There are two basic reasons for this. The first is to give the best possible draft; the better the draft, the better and more efficient the combustion process.

The second reason for maintaining flue temperatures is to minimize deposits of creosote. A mixture known as pyroigneous acid runs down the walls of the chimney or stovepipe. As its water content evaporates, a solid residue, commonly called creosote, is left as a coating on the wall of the pipe. It is flammable and, if the buildup becomes severe, can ignite and cause a chimney fire which may spread to the rest of the house. Periodic cleaning of the chimney will prevent this dangerous build-up.

Most fires attributed to wood stoves can be traced to a faulty chimney. Therefore, avoid such makeshift chimneys as a stovepipe out the window, or an uninsulated stovepipe running long distances inside the home or along an outside wall.

Do not connect a wood burner to the same chimney as an oil burner or a gas burner. As a general rule, use one chimney for each burning unit.

## Safety

Proper safeguards must be considered in the installation and operation of a home wood heating device. Wood stoves are not dangerous, but people often fail to follow instructions and fail to comply with safety codes in the installation and operation of stoves.

### Safety In Selection of Equipment

**Even though a fireplace or chimney has been used regularly, check to see that: the chimney is clean; the damper is working properly; the chimney, fireplace, and hearth have sound mortar; and neither remodeling of walls nor moving of fixtures has created a fire hazard.**

Check used stoves for cracks or defects such as faulty legs, hinges, or draft openings. Repair small cracks with stove cement. Large cracks should be welded by an expert.

New stoves should be of sturdy materials such as cast iron or steel and should be purchased from a reliable dealer who employs stove experts.

If a safe chimney is not available, install a complete chimney and stovepipe.

The stove must be suitable for the fuel being used. A fireplace or stove must have grates for burning coal.

### Safety in Installation

Coal and wood fires must have a continuous supply of fresh air. Ventilation is essential for proper combustion and safety. Normal air leakage in most dwellings is usually sufficient. A window may need to be left open slightly in well-insulated and weatherstripped houses. On occasion, it may be necessary to pipe in air for the wood stove or furnace. Use exhaust fans judiciously; they may draw smoke and gases from a stove or fireplace into the room.

To be used safely, stoves must be located with adequate clearance from all combustible materials such as untreated wood. Follow installation instructions, and check the local codes for minimum distances from combustible materials and correct installation methods.

The stovepipe connection to the chimney must have an

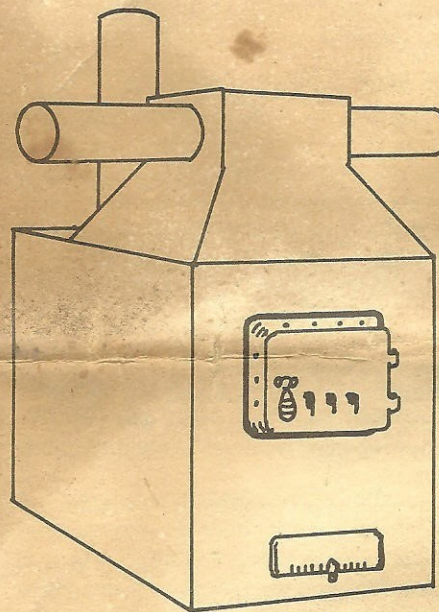


Fig. 9. Central heating units such as this can be an economical way to heat a home even though initial installation costs are high.

internal cross-sectional area not less than that of the flue collar of the stove. The stovepipe should be as straight and short as possible, preferably with not more than one or, at most, two sweeping 90-degree elbows or the equivalent. It should have no sharp turns. The horizontal portion should not be more than 75 percent as long as the vertical portion of the chimney above the point of connection. Connection of the stovepipe to the chimney must also be in accordance with the manufacturer's recommendations and local codes.

### Safe Operation

Safe and satisfactory operation of a wood stove requires the following: a continuous supply of air for combustion, enough fuel burning to heat the chimney and create a draft so that creosote does not collect in the chimney, and proper burning so fuel is not wasted and carbon monoxide does not form. Dry wood burns more efficiently and with less creosote buildup than green wood. The heating value of wood depends on moisture content and also on species. For more information see "How to Use Hardwood Firewood," Iowa State University Cooperative Extension Service publication Pm-662.

Never use a flammable liquid to start or rekindle a fire. Inspect the chimney at least once a year for creosote buildup and chimney defects. Remove creosote buildup with a long-handled flat blade or with a chimney scraper. If you have a chimney fire, call the fire department, and then dump large amounts of coarse salt on the fire in the fireplace or stove to reduce as much as possible the amount of air going up the chimney.

Remember safe operation depends primarily on common sense and continual checking for fire hazards.

### Summary

Iowa homeowners may wish to consider installation of a wood burning unit to at least assist in heating their house. Efficient stoves and furnaces are available for burning wood, but care in installation and operation is essential for safe, dependable performance.

Wood is one available energy resource that is renewable. But an adequate, economical supply of fuel wood should be available before this alternative is considered.

Wood as a fuel can provide completely adequate home heating with the proper burning unit. Consider the advantages and disadvantages of wood compared with other fuels for home heating in new and existing houses.