G3.1 HEATING THE HOME
A central heating system may include:

- a means of burning or converting the fuel or energy (gas, oil, coal, electricity) to "heat"
- a furnace or boiler to transfer the heat to the medium (air, water, or steam) that will be used to distribute the heat to various parts of the house
- heat distribution system (ducts or pipes)
- Heat outlets (registers, diffusers, convectors, baseboards)
- controls

Non-central systems or room units are placed within the space to be heated. These include heat pumps, electric resistance heating in the form of baseboards, convectors, panels or embedded cables, or small units that include some of the features of a central system. A heating system may also include cooling features, humidifying equipment, and special air cleaning equipment. Some features are not available on all central or non-central systems.

The operating efficiency of a heating system depends upon the correct design, installation, and operation of the equipment chosen. The real cost of a heating system is not only the cost of the original equipment but also the cost of the fuel to operate the system and the cost of maintenance and replacement of the equipment. A "cheap" heating system will usually cost more over the life of the house than one properly designed and installed.

The construction of the house will also affect the operating efficiency of the heating system. Excessive heat loss through poorly fitted windows and inadequately insulated walls and ceilings will increase heating costs. Storm sash on windows, storm doors, and insulation in the walls, ceilings, and floor or foundation systems will pay for themselves in fuel savings and in added comfort in both winter and summer. (See SHC-BRC publications A1.61, Savings by Insulating Doors and Windows; A1.62, Savings by Insulating Ceilings, Walls, and Foundations; F11.2, Insulating Windows and Screens; F7.0, Chimneys and Fireplaces; and F6.2, Moisture Condensation.

Choice of Systems

The decision as to the type of heating system to use will depend on such factors as:

- initial cost and estimated life
- maintenance costs
- convenience
- design of the house
- personal preference
- adaptability to summer cooling

A number of systems are discussed and illustrated in this publication. In general, any of the systems shown will produce about equal comfort if they are properly designed and installed.

Fuels

The systems described in this circular can use any fuel (natural gas, LP-gas, oil, electrical energy) with the few exceptions noted in the accompanying discussions. The fuel used will depend primarily on its availability and the relative cost when compared to other available fuels. To some degree, the convenience offered by the fuel may affect choice, although most modern fuels offer about equal operating convenience. The equipment selected should be designed for the intended fuel to give the highest operating efficiency.

Controls

The heating systems described in this publication are operated by automatic "controls". These devices include thermostats, fuel valves, safety controls, and switches to operate fans and pumps. They are designed to run the system automatically so that it functions only when heating is needed. This helps to keep the house at the temperature desired, which adds to the comfort of the occupants and reduces the cost of operating the system.

A thermostat is essentially a temperature-sensitive switch that turns the heating system on and off.
The heart of the control system is the thermostat, essentially a temperature-sensitive switch that turns the heating (or cooling) system on and off. Some thermostats are designed so that various stages or parts of the heating system can be turned on or off so that the heat input is "modulated" to match the heat loss of the house. Many thermostats contain small heating elements called anticipators. The anticipator raises the temperature within the thermostat case, giving it a false reading and causing it to turn the system off before the room reaches the desired temperature. The residual heat in the system will then bring the temperature up to the desired point. If there is not sufficient residual heat, the thermostat will turn the system on again. In this way the desired temperature is reached in small steps so that the house is not overheated, with a resultant waste of fuel and occupant discomfort.

In many instances, one thermostat is used to control the temperature in several rooms or the whole house. Actually, it can sense the temperature only in the room where it is located. Therefore, it is important that the thermostat be located where the temperature is representative of the whole house or where temperature control is most important. Locate the thermostat at a height of 3 to 4 feet above the floor. Avoid locations on outside walls, near outside doors, or in bedrooms where windows may be left open. It should not be near heat outlets, behind a door, on walls which receive heat from the sun or fireplace, or on walls that house ducts, heating pipes or chimneys. Probable furniture arrangement must also be taken into account. Lamps, TV sets, or any other heat-producing appliances located near a thermostat will give it false information and result in poor control.

**Zone control is used to maintain even temperatures in different levels of the house or in sections that have different sun and wind exposures.**

In some cases, it may be desirable to divide the house into two or more zones for heating (or cooling) control. With non-central systems (such as electric resistance baseboard or ceiling cable), this is relatively easy to do. With ducted or piped systems, the distribution lines must be specifically designed for this purpose. Zoning is used to help maintain the same temperature in various parts or levels of the house. Zoning should be considered for multi-level or large houses, or when there are unusual sun or wind exposures.

In a hot water system, a thermostat located in each zone controls a solenoid valve or circulating pump in the line serving that area. The pump and burner are turned on when any zone calls for heat. Although warm air systems can be zoned with motorized dampers in the ducts supplying the separate areas of the house, the use of multiple furnaces for multi-level or large houses is the best way to obtain zone control.

The thermostat should be set at the point at which the occupants are most comfortable and left at that setting except for special circumstances. At very cold outside temperatures, when heating is

**DO NOT SET THERMOSTAT AT 90°**

**SET IT AT TEMPERATURE DESIRED**

Setting the thermostat higher than the desired room temperature will not make the room heat any faster than it would if set correctly.
almost continuous, thermostats equipped with anticpators may have a tendency to "droop" and maintain a temperature a few degrees below the setting. If it does, the thermostat setting will have to be adjusted. A higher setting will not make the temperature rise any faster, and a low setting will not cause the house to cool any faster. The speed with which the temperature in a house will respond to a change in the thermostat setting will depend on the sizing of the heating or cooling system and the construction of the house.

The thermostat setting may be lowered 5 to 10 degrees, either manually or automatically, during sleeping hours, saving up to 10% on the heating bill in poorly insulated houses. The savings will be less in well-insulated houses.

**Installation**

The heating contractor should supply layouts, service agreements, guarantees, and operating instructions for all pieces of equipment. The heating contractor should also indicate in his estimate how much work, such as plumbing and electrical connections, is included. He should state in writing that the system that he will install will maintain a specified interior temperature at specified outdoor temperature and wind conditions.

Warm-air systems should be designed and installed as recommended in the manuals originally issued by the National Warm Air Heating and Air Conditioning Association. Currently, copies of these manuals are available from the Air Conditioning Contractors of America, 1513 16th Street NW, Washington, D.C. 20036.

Hot water systems should be designed and installed as recommended by the Hydronics Institute. Design manuals are available from the Hydronics Institute, 35 Russo Place, Berkeley Heights, New Jersey 07922.

Manuals for the design and installation of electric systems are usually available from local utility companies and from the Edison Electric Institute, 1111 19th Street, NW, Washington, D.C. 20036.

**WARM AIR SYSTEMS**

Warm air systems require an outlet to deliver the heated (or cooled) air to the room or space. The outlets may be floor or wall registers or ceiling diffusers. Return-air intakes are necessary to return the air to the furnace to be reheated, filtered, humidified, and redistributed to the supply outlets. Return air grilles are available with built-in filter racks for use where access to the conventional filters is difficult.

In general, supply outlets should be located at the outside walls, preferably under windows or...
large glass areas, and return-air grilles should be located either high or low on the wall. Ceiling diffusers can be used on the second floor of two-story homes, and on the upper floors of multi-storied buildings as long as there are heated spaces below the floor and there are no large glass areas that can cause drafts across the floor.

Warm-air systems:
- respond rapidly to changes in outdoor temperature.
- are economical to install.
- can provide controlled outdoor ventilation through the duct system.
- can be provided with humidification equipment.
- can include electronic or high-efficiency mechanical air cleaning devices.
- can be adapted to summer air conditioning with the addition of cooling equipment. (Floor registers that can be adjusted to blow the cooled air high into the room toward the ceiling should be used for supply outlets in cold climates. In mild climates, ceiling diffusers should be used. The plenum and ducts should be well-insulated.)

Maintenance: Motor and blower must be lubricated and filters cleaned or replaced. If a burner is used, it must be cleaned and adjusted periodically. Supply outlets and return grilles should be cleaned yearly.


**DOWNFLOW HEATING SYSTEMS**

Heating systems using a down-flow furnace are intended for basementless houses. In a house built on a concrete slab, the warm air from the furnace is circulated through a duct system which is embedded in the concrete. Ducts in or under the slab may be of sheet metal, vitrified tile, concrete pipe, or other precast forms. The warm air in the ducts is discharged into each room through floor or baseboard diffusers located along the outside walls, usually below windows. Air is taken back to the furnace through grilles located either on an inside wall or in a hallway ceiling close to the furnace. Provision must be made to permit the passage of air from all rooms to the return-air intakes.

Several arrangements of perimeter ducts and feeder ducts are possible. A perimeter loop heating system uses a duct that encircles the slab at its outer edge and is connected to the furnace by feeder ducts. A perimeter radial system has a duct from the underfloor plenum to each outlet. It is more economical to install than a perimeter loop system. However, temperatures will not be as uniform as with the loop system.

When a downflow furnace is used in a crawl-space house, an extended plenum, similar to the one shown for basement houses, is usually installed in the crawl space. Ducts extend from the plenum to individual outlets.

A downflow heating system is designed to eliminate cold floors and provide all the advantages of a forced warm air heating system in basementless houses. It needs very little floor area, since downflow-type furnaces have been designed to be placed in closets with minimal clearances. When located in confined areas, provision must be made for supplying combustion air to the furnace burner if gas, oil, or propane is used.

A perimeter radial duct system uses individual ducts connected to each outlet.

A perimeter loop duct system uses outlets connected to a perimeter duct, which is fed from the furnace at several points.
An extended plenum system has a large “trunk duct” with smaller ducts to each outlet. In a crawl-space house, a downflow furnace is connected to the plenum from the top.

Two-story houses are often heated with an extended plenum system on the first floor, with one duct leading to a second plenum and “spider” ducts in the attic, supplying ceiling diffusers in each second-floor room. The ducts in the attic should be covered with at least two inches of insulation.

A horizontal furnace can be installed in the crawl space (as shown) or in the attic, if there is no other space available.

UPFLOW HEATING SYSTEMS

Upflow heating systems are used in basement houses and in slab or crawl-space houses in mild climates. The furnace takes in air near the bottom and discharges heated air into an extended plenum at the top. Ducts are run from the plenum to individual outlets. The extended plenum is located in the basement, or in the attic of houses in mild climates. The latter systems are designed primarily for air conditioning rather than heating.

Air circulation in the extended-plenum system is maintained by a blower (fan) in the furnace. Air is warmed by the furnace and then distributed from the plenum to the various rooms through supply ducts and supply outlets. The blower also draws the room air back to the furnace through the return-air grilles and ducts to be filtered, reheated, and redistributed.

Adjustable registers and diffusers located on the outside wall at floor level, preferably below windows, are recommended for heating. In these locations, they will curtain the cold outside wall with warm air and will not discharge directly on the occupants. Ceiling diffusers may be used in rooms that do not have large glass areas and are located over heated spaces, such as second floor bedrooms, or in mild climates where little heating is needed.

For small houses, where doors to rooms are left open, a central return-air intake may be adequate. In larger structures and in homes where room doors will be kept closed, multiple return-air intakes are usually located on inside walls, or in the ceilings of hallways.

An upflow extended-plenum system is adaptable to large structures, and to the heating of basement rooms.

HORIZONTAL SYSTEMS

Horizontal warm air furnaces take in return air at one end and discharge heated air at the other. They are used in crawl-space or attic locations.
In a forced hot water system, the water is heated in the boiler and is pumped through pipes to radiators, fan-coils, or convectors. Room air circulates over these devices, heating the room.

where there is not enough height available for upflow or downflow units. The operation and advantages are similar. The furnace almost becomes a part of the extended plenum. The disadvantages include difficulty of access for maintenance, and that furnace systems with the highest efficiency are often not available in horizontal models.

HOT WATER SYSTEMS

Hot water or hydronic heating systems use a boiler, fueled by gas, oil, propane, or electricity, to heat water. The hot water is circulated through the house to various devices by a circulating pump. Cabinet-mounted or baseboard convectors and/or fan-coil units are used to transfer heat from the water to the air of the rooms.

Forced Hot Water Heating System

Two basic types of piping layout are common. The one-pipe system has a single pipe or main which supplies the heated water to the baseboard units (or convectors or radiators) and also returns the cooled water from the units to the boiler.

The two-pipe system has two mains. The heated water is supplied to room heating units through a supply main, and the cooled water is returned to the boiler through a separate return main.

A forced hot-water system:
• responds rapidly to changes in outside temperature. Water temperature can be varied in accordance with changing weather so that uniform room air temperatures are maintained.
• is easily adaptable to multi-zone heating through the use of multiple circulating pumps or motorized zone control valves.
• can be used in crawl-space or slab houses and for the heating of basement rooms. Circulation of water by means of the pump makes it possible to locate baseboard units or convectors either above or below the level of the boiler.
• makes possible a large amount of usable basement space, since small (1/2"-1") pipes can be used for the mains and risers.
• can be used to heat domestic water throughout the year with special equipment.
• is not readily adaptable to summer cooling.

Heat Outlets: Convectors, baseboard units, or fan-coil units may be used.

Maintenance: Water pressure in system must be checked, the circulating pump and motor oiled, and room heating units vented unless automatic vents are used.

Design and Installation: Use Hydronics Institute Installation Guide 200, Residential Hydronic Heating Systems, published by the Hydronics Institute. (See Page 4 for address.)
In hot water systems, room air is heated by cabinet convectors, baseboard convectors, or fan-coil units. Baseboard units are the most common in homes, often replacing old-fashioned radiators.

### Cabinet-mounted Convectors

Convectors consist of a core (either a small tube or a hollow cast-iron section) which has a number of thin "fins" or metal plates attached to it. Hot water heats the core and fins which, in turn, warm the air passing over them. The core and fins are enclosed in a cabinet, causing a more effective air flow over the heated surfaces than if they were exposed.

Cabinet convectors may be installed against an outside wall, or they may be recessed into the wall with only the air openings exposed. The preferred location for a convector is under or near a window.

### Baseboard Units

Baseboard heating units are sometimes used with hot-water systems. These units replace conventional baseboards and are installed along the outside walls of each room in place of the usual wood baseboard. Hot water circulating through the sections transmits heat to the room by a combination of radiation and convection.

Baseboard units are made of hollow sections of cast iron or steel, or a finned tube placed behind a sheet-metal enclosure.

Baseboard units achieve even temperatures throughout the room because the units distribute the heat near the floor, which normally is the coolest part of the room. The concentration of heat near the floor makes the units especially desirable for basementless houses. Baseboard units are adaptable to new construction or modernization work.

### Fan-Coil Systems

The fan-coil unit is used primarily when both heating and cooling are to be provided. Water is heated (or chilled) at a central point and then pumped through the pipes to terminal units located throughout the house. They may range in size from a small unit that fits in the toe space of a kitchen cabinet to units equipped with short duct runs that serve several rooms. The fan-coil unit consists of a finned-tube coil and a fan section. The fan section circulates air from the room or from outdoors over the coil section, thus heating or cooling the air. The recirculated air is usually filtered as it is drawn into the enclosure.

The piping system may be a one-pipe system if only heating is to be supplied, or a two-pipe system for heating and cooling. Three- and four-pipe systems can also be used to be able to heat and cool in different rooms at the same time. The temperature in the room may be controlled by valves on the unit or by a thermostat located in the room.

Fan-coil units are not usually used in single-family houses. They are readily adaptable to apartment houses. Since the fan is located in the room, they may be somewhat noisier than other central systems.

**Maintenance:** In addition to the items previously mentioned for hot-water heating systems, the filters at the units must be cleaned or replaced periodically and the fan motors must be lubricated.

**Design and Installation:** Fan-coil heating cooling systems should be designed and installed by professionals.
Domestic Hot Water

With many boiler installations, it is possible to heat water for domestic use. In some cases, a coil of pipe is inserted into the boiler, and the water is heated as it passes through the coil to the faucet. In others, a separate hot water storage tank containing a heat exchanger is used. The heat exchanger operates as one "zone" from the boiler, controlled by the thermostat in the hot water tank. However, it is often more economical to use a separate water heater and operate the boiler at a lower temperature during mild weather.

ELECTRIC HEATING SYSTEMS

Electricity may be thought of as a "fuel" much the same as coal, oil, or gas. Furnaces and boilers that use electricity as a "fuel" operate in the same fashion as other equipment using combustible fuels, with electrical resistance elements replacing the combustion chamber. Heat is distributed as shown elsewhere in this circular.

Resistance Heating

Electric baseboards are similar to the hot water baseboards previously described, except that instead of hot water passing through the baseboard, they contain an electric heating element very similar to the element used on an electric range. Fins are usually attached to the element to increase heat transfer. The units installed in each room or area are controlled by a separate thermostat mounted on the wall or installed as part of the baseboard unit.

An electric resistance baseboard heater functions basically the same as a hot water baseboard, except the heating element is much like an element in an electric range burner that has been straightened and had fins attached. Care must be taken to be sure that air flow over the baseboard is not obstructed by drapes or other decorating items.

Other resistance-type heaters are available in the form of panels of glass or metal that are mounted on the wall or ceiling; resistance cables imbedded in the ceiling; units that have a small fan which circulates the heated air; and liquid-filled baseboards in which the fluid is heated in the baseboard by resistance elements similar to those used in a water heater. Also available are resistance units that may be inserted in the branch supply ducts of a central air duct system.

Electric Heat Pump

The electric heat pump is essentially a reversible refrigeration unit. In the summer it operates as a typical air cooling unit. Heat is extracted from the air inside the house and discharged outside the house. In the winter, the process is reversed. Heat is extracted from the outside air, ground, or well water, and is then distributed in the house, usually by means of a typical duct system as described under warm air heating systems. Council Notes G3.4, Heat Pumps, contains a detailed description of their operation and the various types of installations available.

Advantages and Disadvantages

Heating with resistance heaters has the advantages of lower installation costs, no combustion of fuel in the house and therefore less noise and less maintenance, no space required for fuel storage, and no space required for ductwork, piping, boiler or furnace, or flue. Resistance heaters also offer the advantage of complete room-by-room control of temperature. Heat pumps have the advantage of all-year climate control in one unit.
An electric heat pump provides both heating and cooling through the process of moving, not creating, heat. In the winter, heat is extracted from the outside (either air or ground water sources) and moved indoors. In the summer, the process is reversed and heat is taken from inside the house and transferred outdoors.

Heating with electricity has its disadvantages too. Operating costs will generally be higher than other fuels except where electric energy is available at favorable rates. More insulation will usually be required to keep operating costs from becoming excessive. When power failures occur, heating is not possible. (This is true, however, of most automatic systems.) With resistance-type heaters not employing moving air, control of humidity is difficult. In houses of tight construction, humidistat-operated ventilating fans may be required.

Design and installation of electric heating systems should be done by competent, experienced personnel. Many utility companies will, upon request, give advice to those people interested in heating with electricity.

**Electric Ceiling Cable System**

Electric ceiling-cable systems can provide satisfactory heating. Electric resistance cables are attached to the ceiling lath and embedded in thin-coat plaster, or the cables may be "sandwiched" between two layers of drywall. The panel attains a temperature of about 100 to 120°F.

Heating of the room takes place by the radiant effect of the warm panel and by convection of air moving over the panel and over the floor which is warmed by the radiant panel.

The cable lengths are made up of wire specifically designed for use in panel heating. Heating requirements are met by varying the length and spacing of the cable. The cable assemblies are equipped with non-heating leads, which permit connections to be made at the thermostat without having heated wires in the wall.

When ceiling cable installations are used, the space above the panel is heavily insulated. This prevents excessive heating of the room above, which would make temperature control very difficult. Also, when this system is used in apartments, the use of insulation prevents the heating of upper apartments from the lower floors.

Lightweight, acoustic, or insulating plasters cannot be used over the cables, and caution must be used during construction to protect the cables from damage.
Ceiling-cable systems:
- are usually less expensive to install than other electric-resistance heating systems.
- do not use any floor space.
- are used with thermostatic controls to give room-by-room temperature control.
- do not interfere with furniture location.
- need supplementary heating equipment when there are large glass areas in the room that can cause drafts across the floor.
- limit possible modifications to ceiling and light fixture placement during remodeling.

**Maintenance:** Thermostats should be inspected and cleaned periodically.

**Design and Installation:** Many utility companies will give advice to homeowners interested in heating with electricity.

**Self-Contained Systems**

In addition to the electric self-contained systems, it is possible to install units that use natural or LP-gas or oil for fuel. In appearance, these units look like convectors or fan-coil units. Each unit contains a small furnace that heats the air circulated through the enclosure by a fan section. Air for combustion of the fuel is drawn in from outdoors. The combustion air is never in contact with and cannot mix with the air in the room.

A self-contained system:
- is easy to install in any room. It is particularly convenient to use in room additions when it is not possible to extend the main heating system. It is also convenient for use in rooms that need not be heated all of the time, such as enclosed porches.
- can be used with conventional thermostatic controls, giving individual room control.
- can be used in basement rooms for supplementary heating.

**Maintenance:** Similar to requirements for warm-air furnace.

**Design and Installation:** Heat loss should be estimated from the procedures developed by the National Warm Air Heating and Air Conditioning Association. Equipment should be installed by a competent heating contractor.

![Electric furnace diagram](image1)

Electric furnaces operate in the same way as a gas-fired furnace, except the gas burner is replaced with electric resistance heating elements.

![Combustion air diagram](image2)

In a direct-vent gas heater, the combustion air enters from the outside, provides oxygen for burning the gas, and the gases exit outside. The combustion products never come in contact with the room air.

A gas-fired wall heater is a convenient way to heat a room addition when it cannot easily be connected to the central heating system.
Gravity Warm Air

Air circulation is achieved by the fact that warm air is lighter than cool air. Therefore, warm air rises from the furnace and cool air flows downward into the returns. Gravity systems have no motors or electrical connections other than those required by burner controls, if any. The operation is very simple, but it is only adaptable to compact basement houses. Drafts across floors are common. Gravity systems may be updated by the installation of blower units.

Hot Water Panels

A boiler is used to heat the water circulated through the floor, wall, or ceiling, which acts as a radiant panel. No other radiators or terminal vents are needed. The heat from the water is transferred from the pipes to the panel surface and then heats the room by radiation and convection. The surface temperature of floor panels cannot be maintained above 85°F without discomfort, which can be a limiting factor if the rooms have high heat losses. Wall or ceiling temperatures may be as high as 115-120°F. Control of the panels is difficult in mild weather.

Steam Systems

Steam is generated in a boiler and rises by natural movement to the radiators through risers. The steam cools in the radiators, condenses into water, and returns to the boiler through the same pipes if a one-pipe system is used or through another pipe if a two-pipe system is used. Steam systems are simple and do not require motors or electrical connections except for controls and automatic burners. They can be used to heat domestic water. Temperature control is difficult in the one-pipe systems usually used in residential installations.

Gravity Hot Water

The water in a gravity hot water system circulates as a result of changing density. The warmer water rises and displaces cooler water in the system, forcing it to return to the boiler. Closed systems have expansion tanks located near the boiler and will operate at higher temperatures than open systems without having steam form. The higher temperatures permit the use of smaller radiators. Open systems have an expansion tank located above the highest radiator and the water is "open" or exposed to the air. A gravity system is simple and requires a minimum of fittings. It does not need motors, pumps, or electrical connections except for automatic burners.

SHC-BRC Technical Note 13, Modernization of Hydronic Systems, describes how to convert a two-pipe steam or gravity hot water system to a more modern and efficient forced hot water system.