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HEATING THE HOME

ISSUED BY THE SMALL HOMES COUNCIL

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HEATING THE HOME
SMALL HOMES COUNCIL G3.1

REQUIREMENTS FOR AN EFFICIENT HEATING SYSTEM

A central heating system includes 1) the fuel burner; 2) the furnace or boiler; 3) heat distributing equipment, such as ducts and pipes; 4) room heating units (registers, radiators, convectors, baseboard units, concealed panels); and 5) controls.

The efficiency of a heating system depends on correct installation and operation of properly chosen equipment. A heating system is expected to produce comfort twenty-four hours a day throughout the heating season. The real cost of a heating system is not just the cost of the original equipment, but is equal to the initial cost plus maintenance and fuel costs. A "cheap" heating system will cost more in the end than one properly designed and correctly installed.

Heating equipment should meet safety and performance standards set up by heating trade associations and technical societies. Be sure the equipment you buy bears their seal of approval.

The installation of the equipment should satisfy requirements of local ordinances.

The construction of the house also affects the efficiency of a heating system. Excessive heat loss can be avoided through good construction. To make your house as easy to heat as possible, use storm sash and storm doors; caulk joints around window frames; insulate ceiling and outside walls. All of these will pay dividends; they will reduce the initial cost of the heating system, reduce fuel bills, and increase comfort both winter and summer. A good chimney is also necessary for efficient operation of any heating system. (See Small Homes Council circulars: F11.2, "Insulating-Windows and Screens"; F6.0, "Insulation"; F7.0, "Chimneys and Fireplaces"; and F6.2, "Moisture Condensation.")

WHAT KIND OF HEATING SYSTEM?

While your decision as to the type of heating system will depend on such factors as cost, performance, maintenance requirements and convenience, it will also be influenced by:

Your preference as to room heating units.

The design of your house. For example, gravity systems (warm-air or hot-water) are not generally suited to basementless houses, nor are steam systems usually used.

The chart below lists 1) room heating units used with the various systems, and 2) systems for basement and basementless construction.

	ROOM HEATING UNITS	HOUSE TYPE
HOT-WATER SYSTEMS		
Forced	Baseboard units Convectors Radiators Panels (coils of pipes concealed in panel)	For either: House with basement or Basementless house
Gravity	Baseboard units Convectors Radiators	Seldom used in basementless houses or in new construction
STEAM SYSTEMS		
One-Pipe	Convectors Radiators	Not for basementless houses
Two-Pipe	Baseboard units Convectors Radiators	Not common in new construction
WARM-AIR SYSTEMS		
Forced	Registers* and diffusers**	For either: House with basement or Basementless house
Gravity	Registers	For compact house with basement Not for basementless house

* Register delivers air in a concentrated pattern

** Diffuser delivers air in a fan-shaped pattern

Fuels

Any fuel may be used with the heating systems described in this circular. Consult your heating contractor regarding the type of fuel that will best meet your requirements. Remember that equipment specifically designed for the fuel you intend to use will give the highest efficiency. (See Small Homes Council circular G3.5, "Fuels and Burners.")

Domestic Hot-Water

With some systems, the boiler can be used to heat water the year-round. Such an installation eliminates the need for a separate water heater and often is the most economical way of securing an adequate supply of hot water for household use. (See Small Homes Council circular G5.0, "Plumbing.")

Controls

Controls may be added to any of the heating systems described. These devices — room thermostats, combustion controls, operating controls (for forced circulation systems only), and safety controls — are designed to "run" your furnace or boiler automatically and to keep your house at an even temperature. They add to your comfort and save money by eliminating overheating. (See Small Homes Council circular, G3.2, "Controls for Central Heating Systems.")

INSTALLATION

In building a house, consider the heating plant in its relation to the total house construction before any actual work is started. Cooperation between the general or carpentry contractor and the heating contractor will usually result in savings. If the placement of pipes or ducts is planned ahead of time, they can be located in such a way that little cutting of framing members is necessary; thus, the structural frame of the house is not weakened.

Your heating contractor should supply 1) engineered layouts, 2) written guarantees on equipment, and 3) service agreements. If plumbing or electrical connections are necessary in the installation of a heating plant, obtain a statement from the heating contractor as to how much of this work is included in his estimate.

Warm-air systems should be designed and installed in accordance with manuals of instructions issued by the *National Warm Air Heating and Air Conditioning Association, 640 Engineers Building, Cleveland 14, Ohio.*

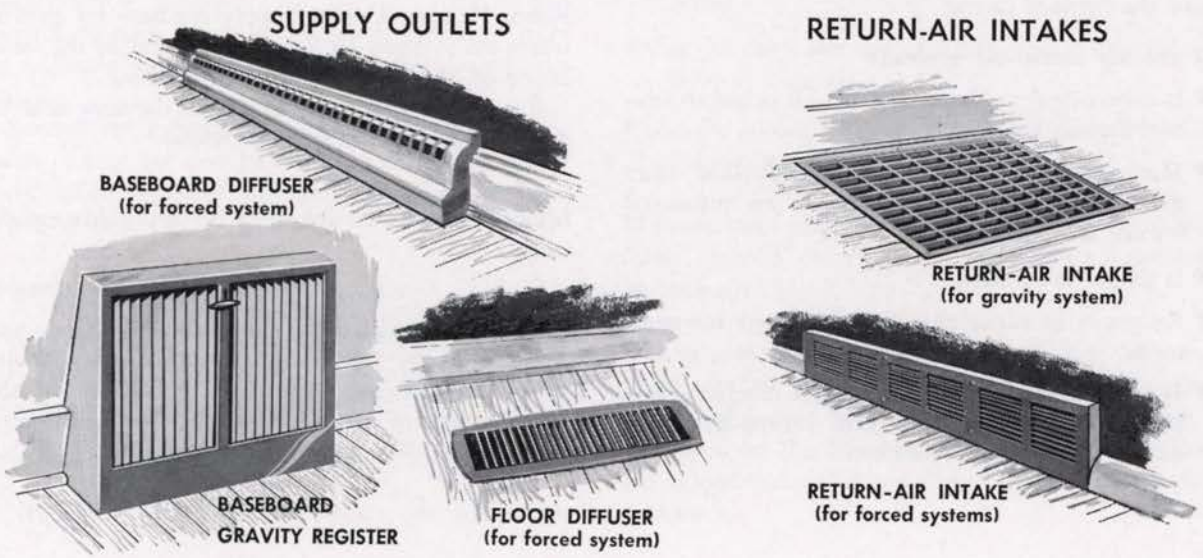
Hot-water and steam systems should be designed and installed in accordance with installation guides issued by the *Institute of Boiler and Radiator Manufacturers, 608 Fifth Avenue, New York 20, New York.*

The manuals and installation guides are based on research conducted at the University of Illinois.

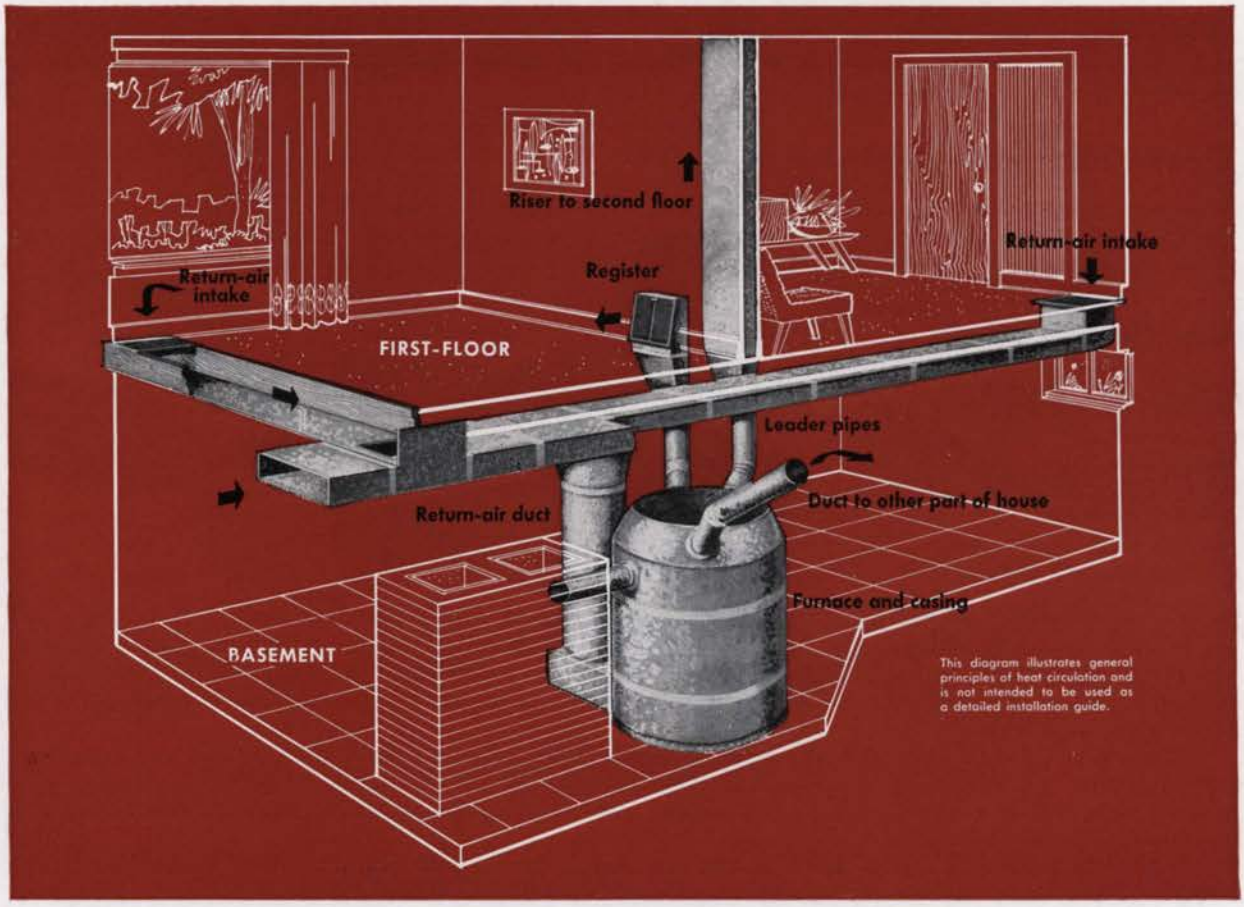
ROOM HEATING UNITS FOR WARM-AIR SYSTEMS

Forced and gravity warm-air systems require supply outlets to deliver the warm air from the supply ducts into the room. For the purpose of this circular, the supply outlets are sometimes referred to as room heating units.

Return-air intakes are necessary to return the room air back to the furnace, to be reheated and redistributed to the supply outlets. Some of the various types of supply outlets and return-air intakes are shown here.



GRAVITY WARM-AIR HEATING SYSTEM



Air circulation in a gravity warm-air system results from the fact that heated air flows upward and cool air flows downward. Air is warmed as it comes into contact with heated surfaces of the furnace. As the air becomes warmer, it rises and flows through leader pipes (and risers if the house has more than one story) to the warm-air supply registers in the rooms. The cooler air in the rooms flows downward and is drawn through return-air intakes (usually located in first-floor rooms) to return-air ducts, and then to the space between the furnace and the furnace casing.

A gravity warm-air system:

- Is economical to install and is well suited to low-cost homes.
- Has no motors or electrical connections other than those required if controls or an automatic burner are used.
- Is simple to operate.
- Responds to rapid changes in outdoor temperatures.
- Is best adapted to a house with a compact floor plan since leader pipes and return-air ducts should be as short as possible.
- Requires a centrally located furnace, and either horizontal or inclined leader pipes. (The inclined pipes reduce the amount of usable basement head room.)
- Is not suitable for basementless houses or for heating basement rooms since the furnace must be below the level of the rooms to be heated.
- Permits air to be humidified.

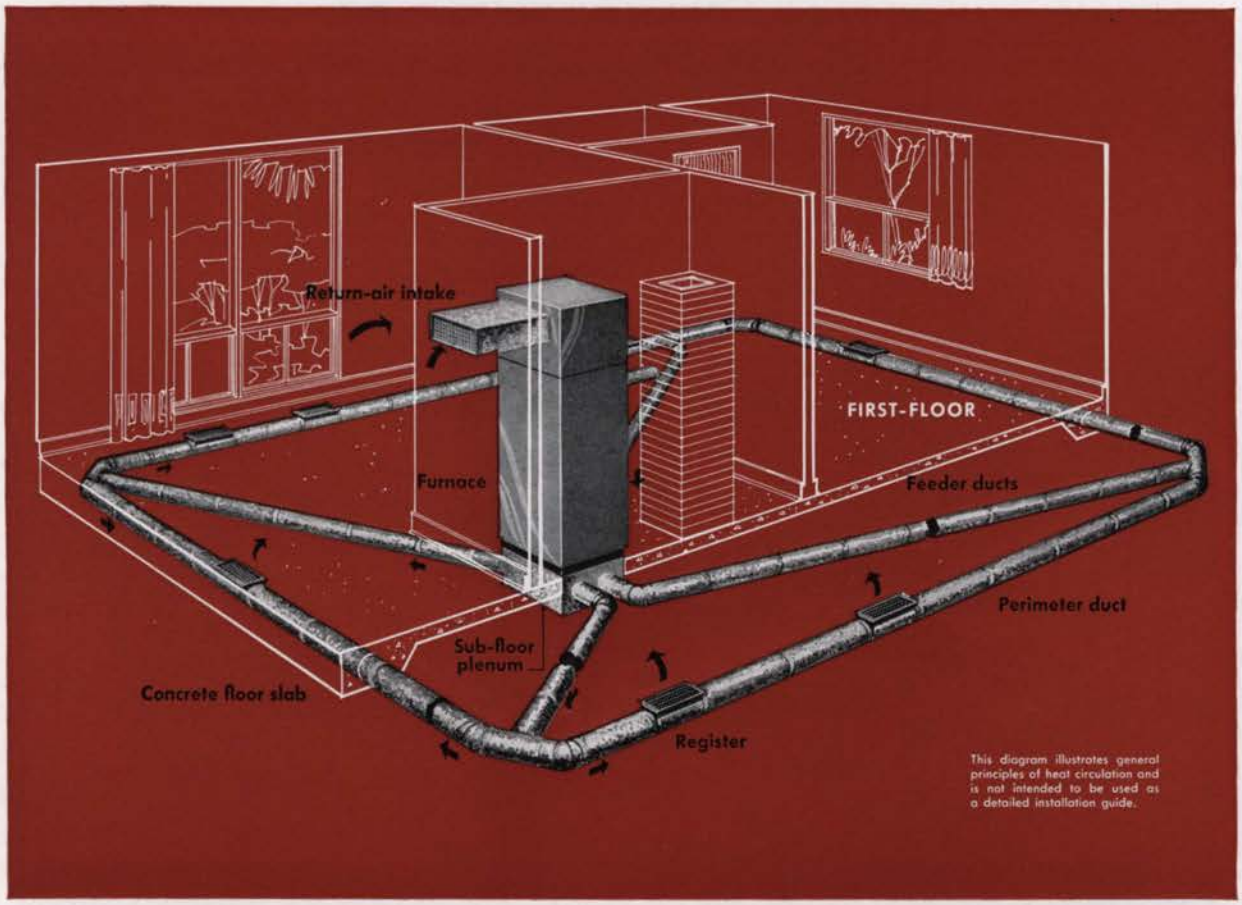
Room Heating Units: Supply registers for gravity warm-air systems are usually installed in the baseboard on the inside walls or in the floor.

Return-air intakes are placed in the floor near an outside wall, usually below windows.

Maintenance: Furnace must be inspected periodically.

Design and Installation: Use Manual 5, "Code and Manual for the Design and Installation of Gravity Warm-Air Heating Systems," published by the National Warm Air Heating and Air Conditioning Association. (See page 3 for address.)

WARM-AIR PERIMETER-LOOP SYSTEM



Perimeter-loop heating with a down-flow furnace is intended for basementless houses built on a concrete floor slab. The warm air from the furnace is circulated through a duct system which is embedded in the concrete slab. This duct system encircles the slab at its outer edge and is connected to the furnace by feeder ducts.

The warm air in the ducts is discharged into the room through outlets — either floor diffusers or baseboard diffusers placed on the outside walls, usually below windows. Air is taken back to the furnace through return-air intakes at locations either on an inside wall or in a hallway ceiling close to the furnace.

Several arrangements of perimeter ducts and feeder ducts are possible. These ducts can be of sheet metal, vitrified tile, concrete pipe or other precast forms.

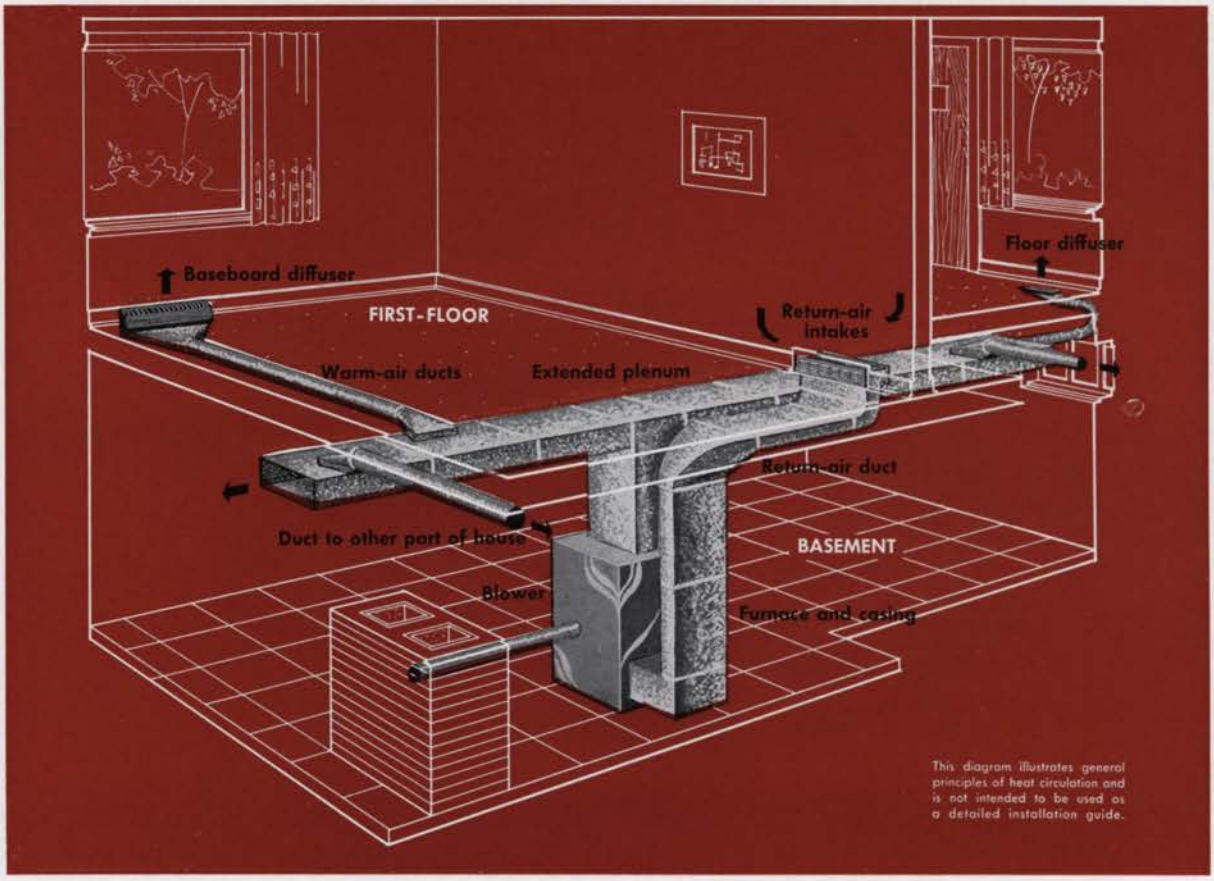
A perimeter-loop heating system:

- Is designed to eliminate cold floors and retain all the advantages of a forced warm air heating system.
- Is economical to install.
- Needs very little floor area since a down-flow-type furnace has been designed for basementless installations. These furnaces may be placed in closets, alcoves, or utility rooms, but provisions must be made to supply air to the furnace for combustion purposes.
- Requires a well-constructed concrete slab which is laid on suitable porous fill and which has a waterproof membrane and edge insulation.
- Is well adapted to conventional thermostatic controls.
- Can, through the use of filters and a humidifier, condition room air.
- Can be adapted to summer air conditioning with the addition of cooling equipment.

Maintenance: Motor and blower must be oiled, filters cleaned or replaced, and furnace inspected periodically.

Design and Installation: Use Manual 4, "Warm-Air Perimeter Heating" and Manual 6, "Adjusting Air Conditioning Systems for Maximum Comfort," published by the National Warm Air Heating and Air Conditioning Association. (See page 3 for address.)

FORCED WARM-AIR EXTENDED-PLENUM SYSTEM



Air circulation in a forced warm-air system is maintained by a blower (fan) in the furnace. The air is warmed by the heated surfaces of the furnace and then distributed 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 intakes and return ducts to be reheated and filtered. After the room air has been heated and filtered it is redistributed to the rooms.

A forced warm-air system:

- Responds rapidly to changes in outdoor temperature.
- Is economical to install.
- Is adapted to basementless houses and large structures, and to the heating of basement rooms since air circulation is maintained by the blower.
- Requires less space for the furnace and ducts than a gravity system. The furnace does not need to be centrally located and all the ducts are smaller.
- Can through the use of filters and a humidifier condition room air.
- Can be adapted to summer air conditioning with the addition of cooling equipment.
- Can provide controlled outdoor ventilation through the duct system.

Room Heating Units: Adjustable registers and diffusers located on the outside wall at the floor level, preferably below windows, are recommended for heating. The supply outlets so installed will curtain the cold outside wall with warm air and will not discharge directly on the occupants.

For small houses a single central return-air intake may be sufficient. In larger structures multiple return-air intakes may be necessary. The return-air intakes are usually located on inside walls, or in the ceilings of hallways.

Maintenance: Motor and blower must be oiled, filters cleaned or replaced, and the furnace inspected periodically.

Design and Installation: Use Manual 4, "Warm-Air Perimeter Heating" and Manual 6, "Adjusting Air Conditioning Systems for Maximum Comfort," published by the National Warm Air Heating and Air Conditioning Association. (See page 3 for address.)

ROOM HEATING UNITS
FOR HOT-WATER OR STEAM SYSTEMS

Radiators, convectors and baseboard units are devices for transferring heat from the water or the steam to the air of rooms. They are referred to in this circular as room heating units.

Radiators, Cast iron

Conventional radiators are composed of vertical tubes through which water or steam passes. In the newer radiators, the tubes are small so that the unit may be recessed in any wall construction if desired. If a radiator is recessed, the wall behind it should be insulated with a minimum of one inch of insulation board, or the equivalent.

Preferred location for a radiator is under a window. Radiators may be partially or fully enclosed in a cabinet.

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 or steam 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.

Convectors may be installed against an outside wall, or they may be recessed in the wall with only the air openings exposed. Preferred location for a convector is under a window.

Baseboard Units

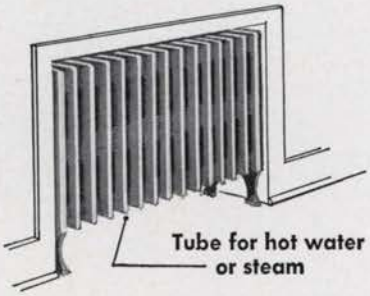
Baseboard heating units can be used with hot-water systems or with two-pipe steam systems.

These units resemble conventional baseboards and are installed along the outside walls of each room in place of the usual wood baseboard. Hot water or steam circulating through the sections transmits heat to the room.

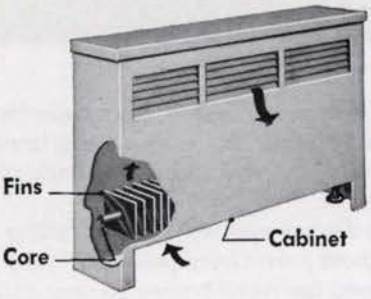
Baseboard units are made of 1) hollow sections either cast iron or steel, or 2) finned tube placed behind a sheet-metal enclosure.

Baseboard heating units achieve even temperatures throughout the room because the units distribute the heat near the floor which normally is the coolest part of a 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.

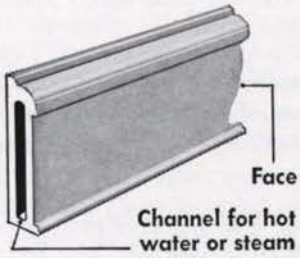
RECESSED RADIATOR

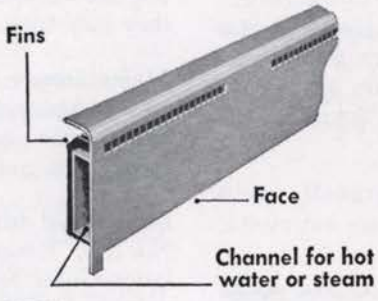


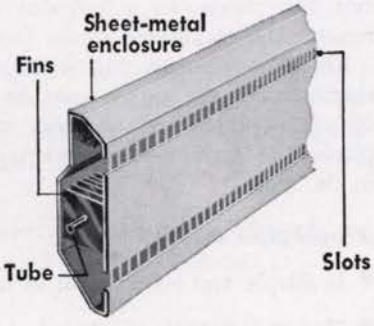
CONVECTOR



BASEBOARD UNITS







HOLLOW-TYPE

TYPE "R" (full radiant)

Water or steam flows directly behind the baseboard face. Heat from this surface is transmitted to the room.

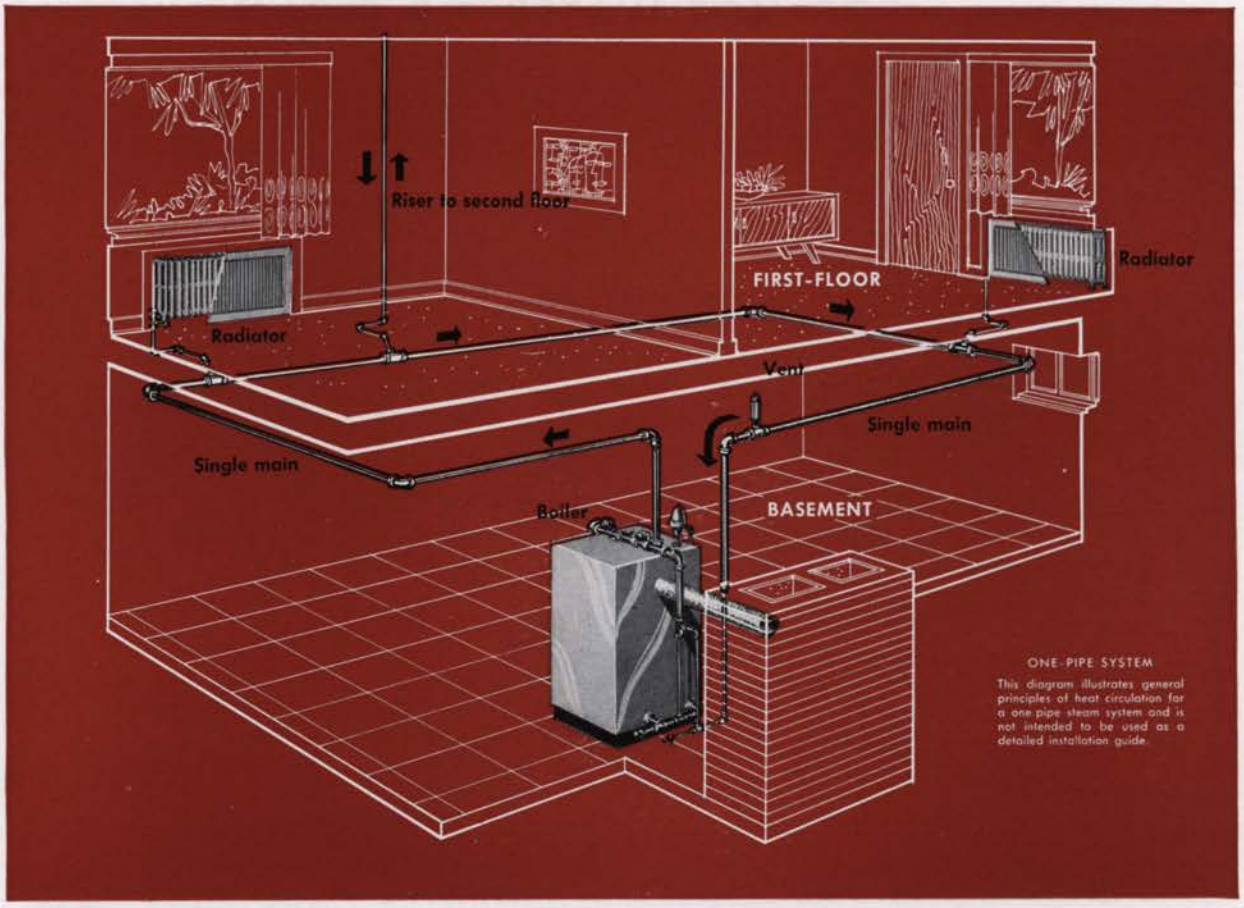
TYPE "RC" (radiant convector)

Operation is similar to Type "R" except that additional heat is supplied to the room by air passing over the fins.

FINNED-TUBE

Hot water or steam passing through tubes heats the tubes and the fins, and the air passing over them. The heated air is delivered to the room through the slots.

STEAM HEATING SYSTEM



In a steam system, the steam is generated in the boiler and rises to the room heating units. Here it condenses and forms water which is returned to the boiler.

Steam systems may be either one-pipe (shown above) or two-pipe.* The latter is not generally used for small homes because of its cost.

One-Pipe System

In the one-pipe steam system, the pipe which carries the steam to a radiator or convector also returns the condensed steam (water) to the boiler.

Since both steam and water are present in the single main, the pipes must be larger than those of other boiler systems and must be accurately pitched to avoid water pockets and "hammering" in the main.

A one-pipe steam system:

- Is simple and economical to install.
- Has no motors or electrical connections other than those required if controls or an automatic burner are used.
- Heats domestic water the year-round if heating coils are installed in the boiler, and an automatic fuel burner is used.
- Offers difficulty in control as radiator temperature cannot be varied. The radiator valve must be either **entirely on or off** in order to prevent the convectors or radiators from filling with water. (In the two-pipe system, the heat input rate to rooms can be controlled.)
- Is not recommended for basementless houses or for heating basement rooms since the boiler must be below the level of the room heating units.

Room Heating Units: Either radiators or convectors may be used. Baseboard units are not generally recommended for the one-pipe steam system; they may be used with the two-pipe.

Maintenance: The water level in the boiler should be checked regularly, as should the operation of boiler safety controls and the air vents on each radiator or convector.

Design and Installation: Use I-B-R Piping Guide No. 700, "Residential Heating Systems," and Installation Guide No. 800, "Hydronic Heating Systems," published by the Institute of Boiler and Radiator Manufacturers. (See page 3 for address.)

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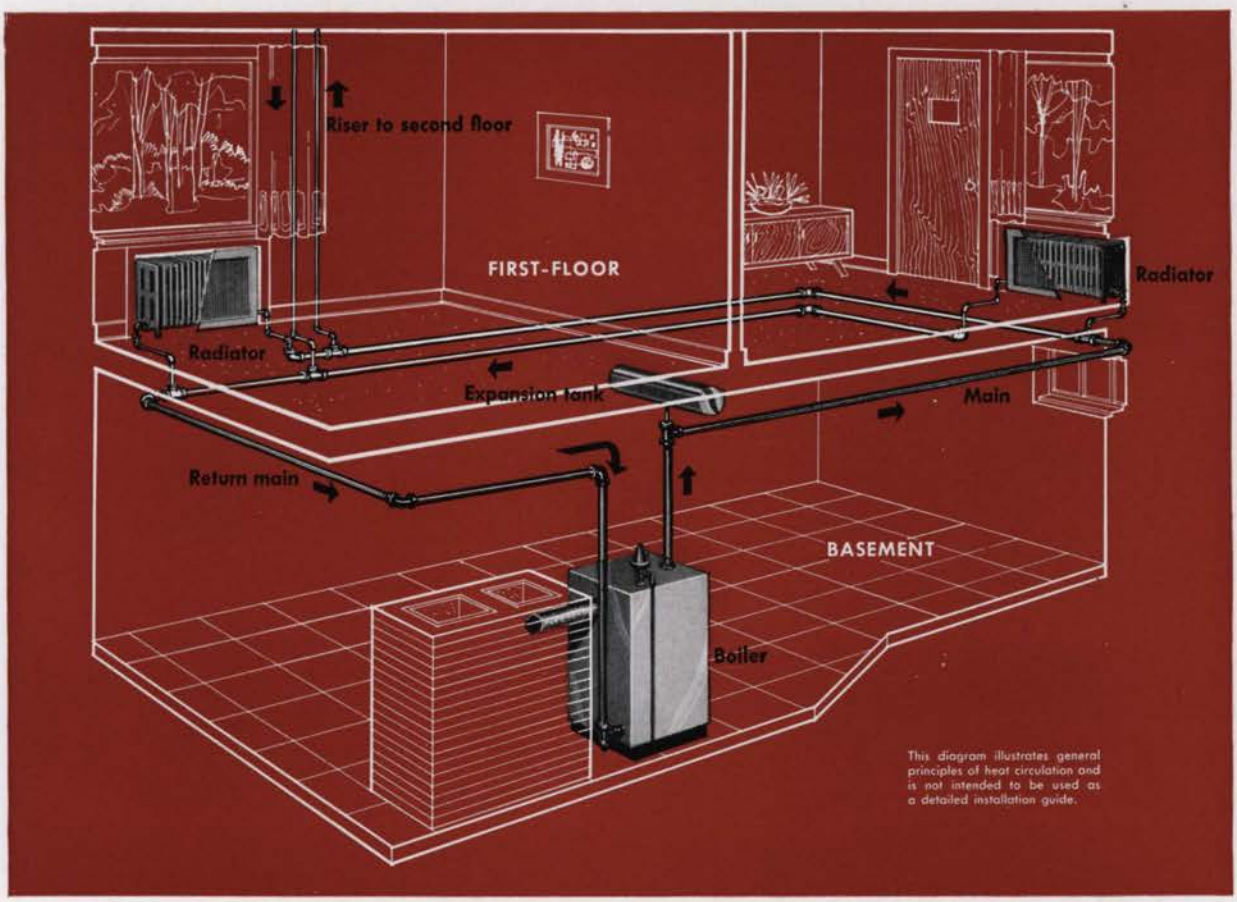
* In the two-pipe system (not illustrated), the steam rises through a supply main and risers to the room heating units. Air in the system and the condensed steam (water) are forced through thermostatic traps at the outlets of the radiators into the return main. An air eliminator in the return main expels the air through a vent and allows the water to return to the boiler.

The system can be adapted to basementless structures if a condensation pump or a vacuum pump is added.

GRAVITY HOT-WATER HEATING SYSTEM



Circulation in a gravity hot-water system results from the fact that heated water flows to the top and cool water to the bottom of a container. Water is heated in the boiler and as it becomes warmer, it rises and flows out through supply pipes (mains and risers) to the room heating units (radiators, convectors or baseboards); the cooled water flows downward through the return pipes (risers and mains) to the bottom of the boiler.

This system may be operated either as a *closed* or as an *open* system.

In the closed, or pressure, system (shown above), the expansion tank is usually located near the boiler. As the heated water expands, the air in the tank is compressed. Since an increase in pressure raises the boiling point of the water, higher temperatures can be maintained in the closed system than in the open system without having steam form in the room heating units. These higher temperatures permit the use of smaller heating units than those needed for the open system.

In the open system, the expansion tank is located above the highest radiator, and the water is "open" or exposed to the air.

A gravity hot-water system:

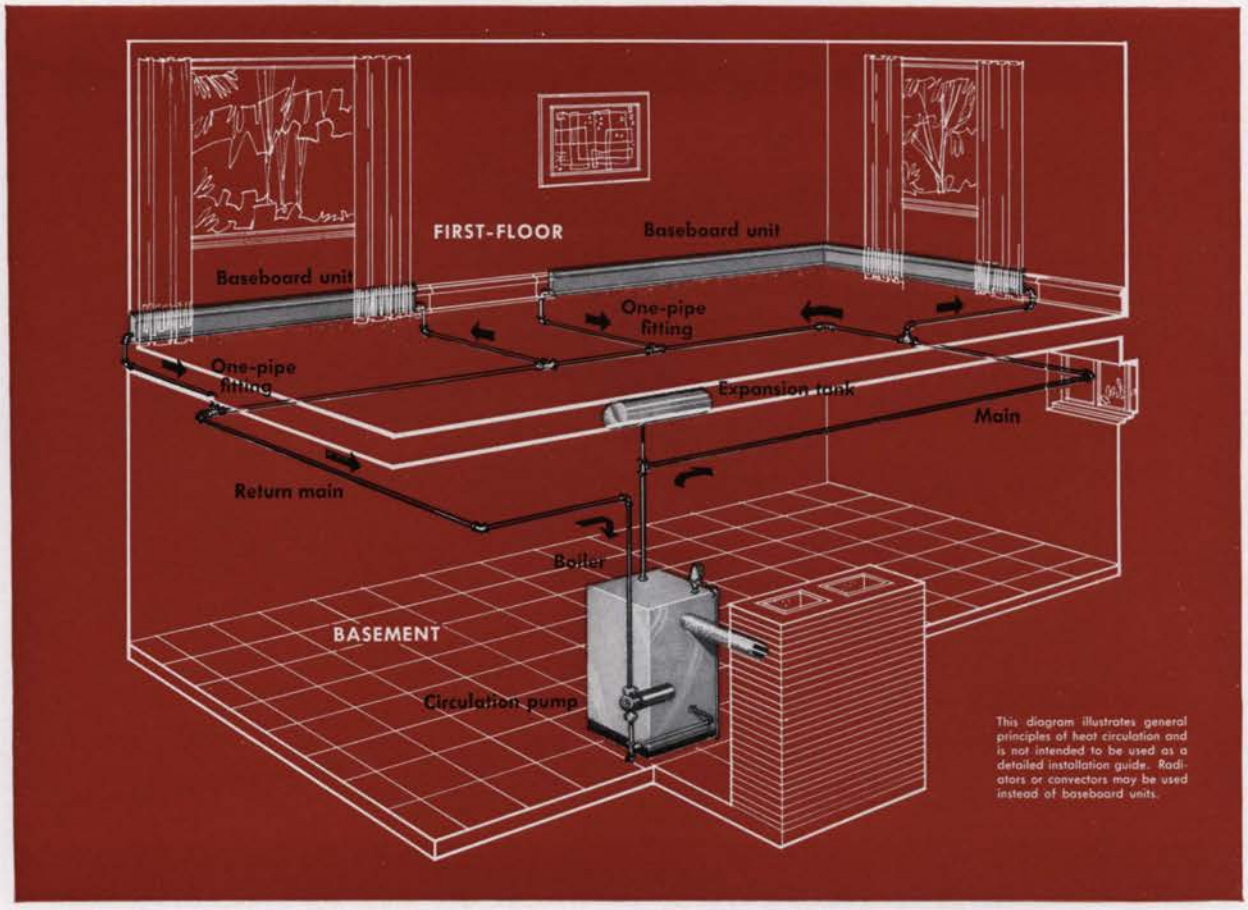
- Is economical to install as it requires a minimum of special fittings or devices.
- Has no motors or electrical connections other than those required if controls or an automatic burner are used.
- Is not generally recommended for basementless houses or for the heating of basement rooms since the boiler should be at a lower level than the room heating units.
- Requires large supply and return mains in order to reduce friction since circulation of the water is by gravity action.
- Has a slower response to temperature changes than a forced hot-water system because of the larger amount of water retained in pipes and room heating units.

Room Heating Units: Radiators, baseboards or convectors may be used with this system.

Maintenance: Water pressure (altitude) in system must be checked, and room heating units vented regularly unless automatic air vents are used.

Design and Installation: The design and installation of this system should be the work of competent men experienced in gravity hot-water heating.

FORCED HOT-WATER HEATING SYSTEM



In a forced hot-water system, the water is heated in the boiler and is forced through the pipes (mains and risers) to the room heating units. The circulation of water is produced by the action of a circulating pump at the boiler. The pump is motor driven and requires electrical connections.

Two basic types of piping layout are common:

The one-pipe system (shown above) — This 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 — This 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:

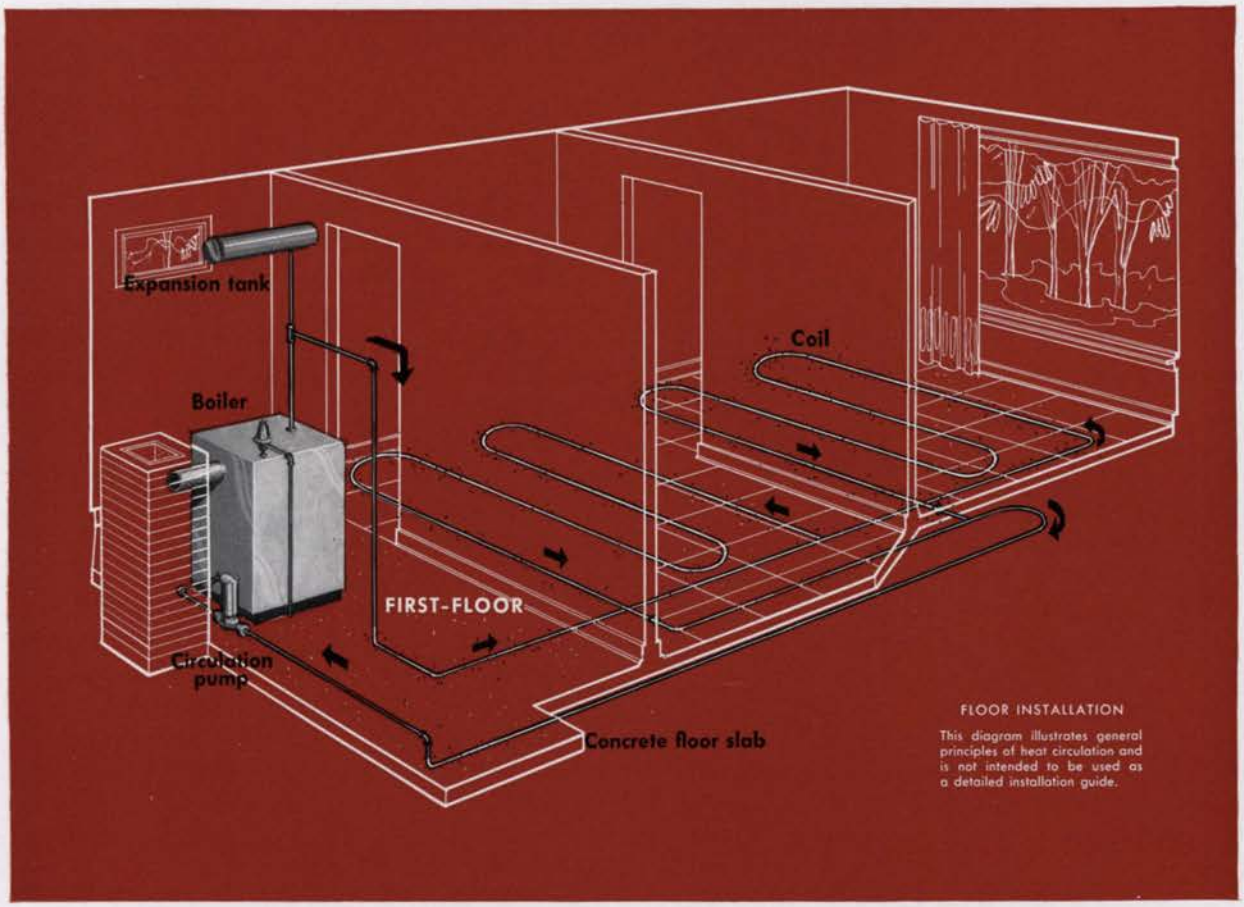
- Responds rapidly to changes in outside temperature. Temperature of the room heating unit can be varied in accordance with changing weather so that uniform room air temperatures are maintained.
- Can be used to heat domestic water the year-round when heating coils are installed with the boiler and an automatic fuel burner is used.
- Is adapted to basementless houses and to the heating of basement rooms. Circulation of water by means of the pump makes it possible to locate radiators, baseboard units or convectors either above or below the level of the boiler.
- Makes possible a large amount of usable basement space since small pipes can be used for the mains and risers. (The pump is capable of circulating water against high friction heads, making large pipes unnecessary.)
- May cost more to install than a gravity hot-water system due to the need for the circulating pump and, for one-pipe systems, special fittings. Frequently the reduction in pipe size results in lower labor and material costs which partially offset the cost of the pump and one-pipe fittings.

Room Heating Units: Radiators, convectors or baseboard units may be used.

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

Design and Installation: For one-pipe systems which use radiators or convectors use I-B-R Piping Guide No. 700, "Residential Heating Systems," and Installation Guide No. 800, "Hydronic Heating Systems," published by the Institute of Boiler and Radiator Manufacturers. (See page 3 for address.)

HOT-WATER PANEL INSTALLATION



In a hot-water panel heating installation, the water which is heated in the boiler is circulated through pipe coils (tube) concealed in sections of the floor, wall, or ceiling. These are, in effect, the room heating units. No radiators, convectors or baseboard units are necessary. The panels are indistinguishable in appearance from other sections of the floor, wall or ceiling.

The heat from the water is transmitted through the pipe to the surface of the floor, wall or ceiling where it is transmitted to the room by radiation (heat rays) and convection (air currents).

A forced circulation heating system is required for use with a hot-water panel installation. Steam systems can sometimes be used for panel installations, but their use is not practical for homes. The boiler should have an automatic fuel burner and controls.

Panel heating is still in the development stage. Whether the floor, the ceiling or the wall is the best surface in which to embed the coils is still a matter of controversy. A floor installation is illustrated.

A hot-water panel system:

- Requires planning in the early stages of the house design since the system is usually a structural part of the house.
- Can be used in houses with or without basements.
- Is well adapted to conventional thermostatic controls, but may be subject to overheating or underheating. This is particularly true in houses having large glass areas which are subject to rapid temperature changes due to variations in sun intensity.
- Has definite limitations on temperatures of panels. Floor surface temperatures should not be more than 85°F. for comfort; surface temperatures of wall or ceiling panels may be as high as 115°-120°F.
- Requires adequate insulation on the back of the panels to prevent heat loss and, consequently, excessive fuel costs. When installation is made in a floor slab, the slab should be insulated.

Maintenance: Motor and pump must be oiled, and boiler inspected periodically.

Design and Installation: Use I-B-R Installation Guide No. 6, "Panel Heating for Small Structures," published by the Institute of Boiler and Radiator Manufacturers. (See page 3 for address.)

HEATING WITH ELECTRICITY

Heating with electricity is not new, but it is only within recent years that it has become popular in the residential field.

Electricity may be thought of as a "fuel" much the same as coal, oil, or gas. If it is used to "fire" a furnace or boiler then heating with electricity is basically the same as with any other fuel.

Resistance heating

Electric baseboards are similar to the baseboards described on page 7 of this circular except that instead of having hot water or steam passing through the baseboard they are manufactured with an electric heating element very similar to the element used on an electric range. 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.

Electric ceiling cable may be compared to the hot-water panel system shown on page 11 of this circular. For this type of heating system, electric resistance wires are either attached to the ceiling lath and then embedded in plaster, or sandwiched between layers of drywall. The temperature of the ceiling panel is maintained at approximately 100°-105°F. The air temperature in each room or area is controlled by a separate thermostat.

Lightweight or insulating plasters cannot be used over the cables. Care must be taken during installation so that the cable is not broken or that nails are not driven into the cable. Installation costs of electric ceiling cable will usually be somewhat less than baseboard resistance heating.

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.

Other resistance-type heaters are available in the form of panels of glass or metal that are mounted on the wall; units that have a small fan which circulates the heated air; and hot-water baseboards in which the water is heated in the baseboard by electrically heated 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.

Considerable development work is now in progress on conductive films that do not contain resistance wires and therefore are not subject to the usual installation damages or to future short circuits.

Electric heat pump

The electric heat pump is effectively 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 dissipated 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, generally by means of a typical duct system as described under warm air heating systems. The process is controlled by one or more thermostats located inside the house.

Installation costs are higher than for resistance-type heating but are comparable to the cost of installing separate systems for heating and cooling. In general, heat pumps are less expensive to operate than resistance heaters.

When outdoor temperatures are low, heat pumps using the outside air or the ground as heat sources operate at reduced efficiencies and supplemental resistance heaters, usually installed in the duct work, are required. In northern climates, heat pumps are usually sized for the cooling load, and added resistance heaters are necessary to care for the heavier winter heating loads.

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 duct work, piping, boiler or furnace, or chimney. They also offer the advantage of complete room-by-room control of temperature. Heat pumps offer the advantage of all-year climate control in one unit.

Heating with electricity has its disadvantages, too. Operating costs will generally be higher than with other fuels except where electric energy is available at favorable rates. More insulation will generally 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 men. Most power suppliers will, upon request, give advice to those people interested in heating with electricity.