Contents

Chapter 12: Heating, Air Conditioning, and Ventilating

"Our climate is warming at a faster rate than ever before recorded."

D. James Baker
NOAA Administrator, 1993–2004

Introduction

The quotes below provide a profound lesson in the need for housing to provide protection from both the heat and cold.

> "France heat wave death toll set at 14,802: The death toll in France from August's blistering heat wave has reached nearly 15,000, according to a government-commissioned report released Thursday, surpassing a prior tally by more than 3,000." *USA Today*, September 25, 2003.

> "In the study of the 1995 Chicago heat wave, those at greatest risk of dying from the heat were people with medical illnesses who were socially isolated and did not have access to air conditioning." Centers for Disease Control and Prevention, *Morbidity and Mortality Weekly Report*, July 4, 2003.

> "3 Deaths tied to cold . . .The bitter cold that gripped the Northeast through the weekend and iced over roads was blamed for at least three deaths, including that of a Philadelphia man found inside a home without heat." *Lexington* [Kentucky] *Herald Leader*, January 12, 2004.

> "In many temperate countries, death rates during the winter season are 10%–25% higher than those in the summer." World Health Organization, Health Evidence Network, November 1, 2004.

This chapter provides a general overview of the heating and cooling of today's homes. Heating and cooling are not merely a matter of comfort, but of survival. Both very cold and very hot temperatures can threaten health. Excessive exposure to heat is referred to as heat stress and excessive exposure to cold is referred to as cold stress.

In a very hot environment, the most serious health risk is heat stroke. Heat stroke requires immediate medical attention and can be fatal or leave permanent damage. Heat stroke fatalities occur every summer. Heat exhaustion and fainting are less serious types of illnesses. Typically they are not fatal, but they do interfere with a person's ability to work.

At very cold temperatures, the most serious concern is the risk for hypothermia or dangerous overcooling of the body. Another serious effect of cold exposure is frostbite or freezing of exposed extremities, such as fingers, toes, nose, and ear lobes. Hypothermia can be fatal if immediate medical attention is not received.

Heat and cold are dangerous because the victims of heat stroke and hypothermia often do not notice the

Definitions of Terms Related to HVAC Systems

Air duct—A formed conduit that carries warm or cold air from the furnace or air-conditioner and back again.

Antiflooding Control—A safety control that shuts off fuel and ignition when excessive fuel oil accumulates in the appliance.

Appliance:

- **High heat—**A unit that operates with flue entrance temperature of combustion products above 1,500°F (820°C).
- **Medium heat—**Same as high-heat, except above 600°F (320°C).
- **Low heat—**same as high-heat, except below 600°F (320°C).

Boiler:

- **High pressure—**A boiler furnishing pressure at 15 psi or more.
- **Low pressure (hot water or steam)—**A boiler furnishing steam at a pressure less than 15 psi or hot water not more than 30 psi.

Burner—A device that mixes fuel, air, and ignition in a combustion chamber.

symptoms. This means that family, neighbors, and friends are essential for early recognition of the onset of the conditions. The affected individual's survival depends on others to identify symptoms and to seek medical help. Family, neighbors, and friends must be particularly diligent during heat or cold waves to check on individuals who live alone.

Although symptoms vary from person to person, the warning signs of heat exhaustion include confusion and profuse and prolonged sweating. The person should be removed from the heat, cooled, and heavily hydrated. Heat stroke signs and symptoms include sudden and severe fatigue, nausea, dizziness, rapid pulse, lightheadedness, confusion, unconsciousness, extremely high temperature, and hot and dry skin surface. An individual who appears disorientated or confused, seems euphoric or unaccountably irritable, or suffers from malaise or flulike symptoms should be moved to a cool location and medical advice should be sought immediately.

Definitions of Terms Related to HVAC Systems

Carbon monoxide (CO) detector—A device used to detect CO (specific gravity of 0.97 vs. 1.00 for oxygen, a colorless odorless gas resulting from combustion of fuel). CO detectors should be placed on each floor of the structure at eye level and should have an audible alarm and, when possible, a digital readout at eye level.

Chimney—A vertical shaft containing one or more passageways.

- **Factory-built chimney**—A tested and accredited flue for venting gas appliances, incinerators and solid or liquid fuel-burning appliances.
- **Masonry chimney**—A field-constructed chimney built of masonry and lined with terra cotta flue or firebrick.
- **Metal chimney**—A field-constructed chimney of metal.

Chimney connector—A pipe or breeching that connects the heating appliance to the chimney.

Clearance—The distance separating the appliance, chimney connector, plenum, and flue from the nearest surface of combustible material.

Central cooling system—An electric or gas-powered system containing an outside compressor, cooling coils, and a ducting system inside the structure designed to supply cool air uniformly throughout the structure.

Central heating system—A flue connected boiler or furnace installed as an integral part of the structure and designed to supply heat adequately for the structure.

Collectors—The key component of active solar systems and are designed to meet the specific temperature requirements and climate conditions for different end uses. Several types of solar collectors exist: flat-plate collectors, evacuated-tube collectors, concentrating collectors, and transpired air collectors.

Controls:

- **High-low limit control**—An automatic control that responds to liquid level changes and will shut down if they are exceeded.
- **Primary safety control**—The automatic safety control intended to prevent abnormal discharge of fuel at the burner in case of ignition failure or flame failure.
- **Combustion safety control**—A primary safety control that responds to flame properties, sensing the presence of flame and causing fuel to be shut off in event of flame failure.

Convector—A radiator that supplies a maximum amount of heat by convection, using many closely spaced metal fins fitted onto pipes that carry hot water or steam and thereby heat the circulating air.

Conversion—A boiler or furnace, flue connected, originally designed for solid fuel but converted for liquid or gas fuel.

Damper—A valve for regulating draft on coal-fired equipment. Generally located on the exhaust side of the combustion chamber, usually in the chimney connector. Dampers are not allowed on oil- and gas-fired equipment.

Draft hood—-A device placed in and made a part of the vent connector (chimney connector or smoke pipe) from an appliance, or in the appliance itself. The hood is designed to a) ensure the ready escape of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft hood; b) prevent backdraft from entering the appliance; and c) neutralize the effect of stack action of the chimney flue upon appliance operation.

Warning signs of hypothermia include nausea, fatigue, dizziness, irritability, or euphoria. Individuals also experience pain in their extremities (e.g., hands, feet, ears) and severe shivering. People who exhibit these symptoms, particularly the elderly and young, should be moved to a heated shelter and medical advice should be sought when appropriate.

The function of a heating, ventilation, and air conditioning (HVAC) system is to provide for more than human health and comfort. The HVAC system produces heat, cool air, and ventilation, and helps control dust and moisture, which can lead to adverse health effects. The variables to be controlled are temperature, air quality, air motion, and relative humidity. Temperature must be maintained uniformly throughout the heated/cooled area. There is a 6°F to 10°F (-14°C to -12°C) variation in room temperature from floor to ceiling. The adequacy of the HVAC system and the air-tightness of the structure or room determine the degree of personal safety and comfort within the dwelling.

Definitions of Terms Related to HVAC Systems

Draft regulator—A device that functions to maintain a desired draft in oil-fired appliances by automatically reducing the chimney draft to the desired value. Sometimes this device is referred to in the field as air-balance, air-stat, or flue velocity control or barometer damper.

Fuel oil—A liquid mixture or compound derived from petroleum that does not emit flammable vapor below a temperature of 125°F (52°C).

Heat—The warming of a building, apartment, or room by a furnace or electrical stove.

Heating plant—The furnace, boiler, or the other heating devices used to generate steam, hot water, or hot air, which then is circulated through a distribution system. It typically uses coal, gas, oil or wood as its source of heat.

Limit control—A thermostatic device installed in the duct system to shut off the supply of heat at a predetermined temperature of the circulated air.

Oil burner—A device for burning oil in heating appliances such as boilers, furnaces, water heaters, and ranges. A burner of this type may be a pressure-atomizing gun type, a horizontal or vertical rotary type, or a mechanical or natural draft-vaporizing type.

Oil stove—A flue-connected, self-contained, self-supporting oil-burning range or room heater equipped with an integral tank not exceeding 10 gallons; it may be designed to be connected to a separate oil tank.

Plenum chamber—An air compartment to which one or more distributing air ducts are connected.

Pump, automatic oil—A device that automatically pumps oil from the supply tank and delivers it in specific quantities to an oil-burning appliance. The pump or device is designed to stop pumping automatically if the oil supply line breaks.

Radiant heat—A method of heating a building by means of electric coils, hot water, or steam pipes installed in the floors, walls, or ceilings.

Register—A grille-covered opening in a floor, ceiling, or wall through which hot or cold air can be introduced into a room. It may or may not be arranged to permit closing the grille.

Room heater—A self-contained, freestanding heating appliance (space heater) intended for installation in the space being heated and not intended for duct connection.

Smoke detector—A device installed in several rooms of the structure to warn of the presence of smoke. It should provide an audible alarm. It can be battery powered or electric, or both. If the unit is battery powered, the batteries should be tested or checked on a routine basis and changed once per year. If the unit is equipped with a 10-year battery, it is not necessary to replace the battery every year.

Tank—A separate tank connected, directly or by pump, to an oil-burning appliance.

Thimble—A metal or terra cotta lining for a chimney or furnace pipe.

Valve (main shut-off valve)—A manually operated valve in an oil line used to turn the oil supply to the burner on or off.

Vent system—The gas vent or chimney and vent connector, if used, assembled to form a continuous, unobstructed passageway from the gas appliance to the outside atmosphere to remove vent gases.

Gas, electricity, oil, coal, wood, and solar energy are the main energy sources for home heating and cooling. Heating systems commonly used are steam, hot water and hot air. A housing inspector should have knowledge of the various heating fuels and systems to be able to determine their adequacy and safety in operation. To cover fully all aspects of the heating and cooling system, the entire area and physical components of the system must be considered.

Heating

Fifty-one percent of the homes in the United States are heated with natural gas, 30% are heated with electricity, and 9% with fuel oil. The remaining 11% are heated with bottled fuel, wood, coal, solar, geothermal, wind, or solar energy [1]. Any home using combustion as a source of heating, cooling, or cooking or that has an attached garage should have appropriately located and maintained carbon monoxide (CO) gas detectors. According to the U.S. Consumer Product Safety Commission (CPSC), from data collected in 2000, CO kills 200 people and sends more than 10,000 to the hospital each year.

The standard fuels for heating are discussed below.

Standard Fuels

Gas

More than 50% of American homes use gas fuel. Gas fuels are colorless gases. Some have a characteristic pungent odor; others are odorless and cannot be detected by smell. Although gas fuels are easily handled in heating equipment, their presence in air in appreciable quantities becomes a serious health hazard. Gases diffuse readily in the air, making explosive mixtures possible. A proportion of combustible gas and air that is ignited burns with such a high velocity that an explosive force is created. Because of these characteristics of gas fuels, precautions must be taken to prevent leaks, and care must be exercised when gas-fired equipment is lit.

Gas is broadly classified as natural or manufactured.

- **Natural gas—**This gas is a mixture of several combustible and inert gases. It is one of the richest gases and is obtained from wells ordinarily located in petroleum-producing areas. The heat content may vary from 700 to 1,300 British thermal units (BTUs) per cubic foot, with a generally accepted average figure of 1,000 BTUs per cubic foot. Natural gases are distributed through pipelines to the point of use and are often mixed with manufactured gas to maintain a guaranteed BTU content.

- **Manufactured gas—**This gas, as distributed, is usually a combination of certain proportions of gases produced from coke, coal, and petroleum. Its BTU value per cubic foot is generally closely regulated, and costs are determined on a guaranteed BTU basis, usually 520 to 540 BTUs per cubic foot.

- **Liquefied petroleum gas—**Principal products of liquefied petroleum gas are butane and propane. Butane and propane are derived from natural gas or petroleum refinery gas and are chemically classified as hydrocarbon gases. Specifically, butane and propane are on the borderline between a liquid and a gaseous state. At ordinary atmospheric pressure, butane is a gas above 33°F (0.6°C) and propane a gas at -42°F (-41°C). These gases are mixed to produce commercial gas suitable for various climatic conditions. Butane and propane are heavier than air. The heat content of butane is 3,274 BTUs per cubic foot, whereas that of propane is 2,519 BTUs per cubic foot.

Gas burners should be equipped with an automatic shutoff in case the flame fails. Shutoff valves should be located within 1 foot of the burner connection and on the output side of the meter.

Caution: Liquefied petroleum gas is heavier than air; therefore, the gas will accumulate at the bottom of confined areas. If a leak develops, care should be taken to ventilate the appliance before lighting it.

Electricity

Electricity has gained popularity for heating in many regions, particularly where costs are competitive with other sources of heat energy, with usage increasing from 2% in 1960 to 30% in 2000. With an electric system, the housing inspector should rely mainly on the electrical inspector to determine proper installation. There are a few items, however, to be concerned with to ensure safe use of the equipment. Check to see that the units are approved by an accredited testing agency and installed according to the manufacturer's specifications. Most convector-type units must be installed at least 2 inches above the floor level, not only to ensure that proper convection currents are established through the unit, but also to allow sufficient air insulation from any combustible flooring material. The housing inspector should check for curtains that extend too close to the unit or loose, long-pile rugs that are too close. A distance of 6 inches on the floor and 12 inches on the walls should separate rugs or curtains from the appliance.

Heat pumps are air conditioners that contain a valve that allows switching between air conditioner and heater. When the valve is switched one way, the heat pump acts like an air conditioner; when it is switched the other way, it reverses the flow of refrigerants and acts like a heater. Cold is the absence of energy or calories of heat. To cool something, the heat must be removed; to warm something, energy or calories of heat must be provided. Heat pumps do both.

A heat pump has a few additions beyond the typical air conditioner: a reversing valve, two thermal expansion valves, and two bypass valves. The reversing valve allows the unit to provide both cooling and heating. Figure 12.1 shows a heat pump in cooling mode. The unit operates as follows:

- The compressor compacts the refrigerant vapor and pumps it to the reversing valve.
- The reversing valve directs the compressed vapor to flow to the outside heat exchanger (condenser), where the refrigerant is cooled and condensed to a liquid.
- The air blowing through the condenser coil removes heat from the refrigerant.
- The liquid refrigerant bypasses the first thermal expansion valve and flows to the second thermal expansion valve at the inside heat exchanger (evaporator) where it expands into the evaporator and becomes vapor.
- The refrigerant picks up heat energy from the air blowing across the evaporator coil and cool air comes out at the other side of the coil. The cool air is ducted to the occupied space as air-conditioned air.

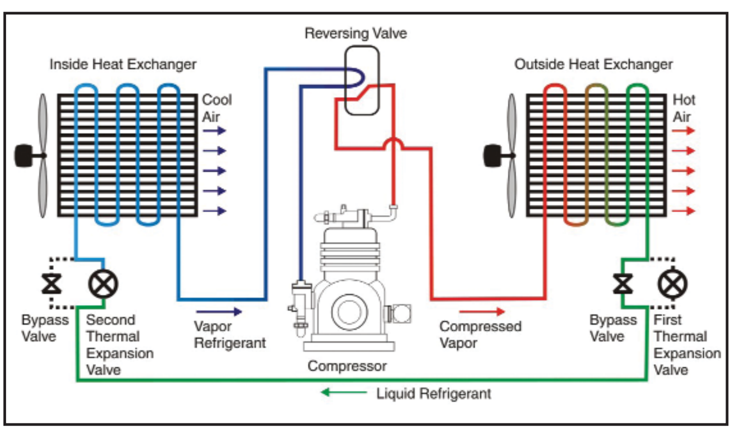


Figure 12.1. Heat Pump in Cooling Mode [2]

- The refrigerant vapor then goes back to the reversing valve to be directed to the compressor to start the refrigeration cycle all over again.

Heat pumps [3] are quite efficient in their use of energy. However, heat pumps often freeze up; that is, the coils in the outside air collect ice. The heat pump has to melt this ice periodically, so it switches itself back to air conditioner mode to heat up the coils. To avoid pumping cold air into the house in air conditioner mode, the heat pump also uses electric strip heaters to heat the cold air that the air conditioner is pumping out. Once the ice is melted, the heat pump switches back to heating mode and turns off the burners.

Radiant heat warms objects directly with longwave electromagnetic energy. The heating panels diffuse heating energy rays in a 160° arc, distributing warmth evenly. The goal is to achieve no more than a 4°F (-16°C) difference in temperature between floor level and ceiling level. When properly installed, radiant heat warms a room sooner and at lower temperature settings than do other kinds of heat. Extreme care must be taken to protect against fire hazards from objects in close proximity to the infrared radiation reflectors. Inspectors dealing with this heat source should have specialized training. Radiant heating is plastered into the ceiling or wall in some homes or in the brick or ceramic floors of bathrooms. If wires are bare in the plaster, they should be treated as open and exposed wiring. The inspector should be knowledgeable about these systems, which are technical and relatively new.

Fuel Oil

Fuel oils are derived from petroleum, which consists primarily of compounds of hydrogen and carbon (hydrocarbons) and smaller amounts of nitrogen and sulfur. Domestic fuel oils are controlled by rigid specifications. Six grades of fuel oil—numbered 1 through 6—are generally used in heating systems; the lighter two grades are used primarily for domestic heating:

- **Grade Number 1**—a volatile, distillate oil for use in burners that prepare fuel for burning solely by vaporization (oil-fired space heaters).
- **Grade Number 2**—a moderate weight, volatile, distillate oil used for burners that prepare oil for burning by a combination of vaporization and atomization. This grade of oil is commonly used in domestic heating furnaces.

Heating values of oil vary from approximately 152,000 BTU per gallon for number 6 oil to 136,000 BTU per gallon for number 1 oil. Oil is more widely used today than coal and provides a more automatic source of heat and comfort. It also requires more complicated systems and controls. If the oil supply is in the basement or cellar area, certain code regulations must be followed (Figure 12.2) [4–7]. No more than two 275-gallon tanks may be installed above ground in the lowest story of any one building. The IRC recommends a maximum fuel oil storage of 660 gallons. The tank shall not be closer than 7 feet horizontally to any boiler, furnace, stove, or exposed flame(s).

Fuel oil lines should be embedded in a concrete or cement floor or protected against damage if they run across the floor. Each tank must have a shutoff valve that will stop the flow if a leak develops in the line to or in the burner itself. A leak-tight liner or pan should be installed under tanks and lines located above the floor. They contain potential leaks so the oil does not spread over the floor, creating a fire hazard.

The tank or tanks must be vented to the outside, and a gauge showing the quantity of oil in the tank or tanks must be tight and operative. Steel tanks constructed before 1985 had a life expectancy of 12–20 years. Tanks must be off the floor and on a stable base to prevent settlement or movement that may rupture the connections. Figure 12.3 shows a buried outside tank installation. In 1985, federal legislation was passed requiring that the exterior components of underground storage tanks (USTs) installed after 1985 resist the effects of pressure, vibration, and movement. Federal regulations for USTs exclude the following: farm and residential tanks of 1,100 gallons (420 liters) or less capacity; tanks storing heating oil used on the premises; tanks on or above the floor of basements; septic tanks; flow-through process tanks; all tanks with capacity of 110 gallons or less; and emergency spill and overfill tanks [8]. A review of local and state regulations should be completed before installing underground tanks because many jurisdictions do not allow burial of gas or oil tanks.

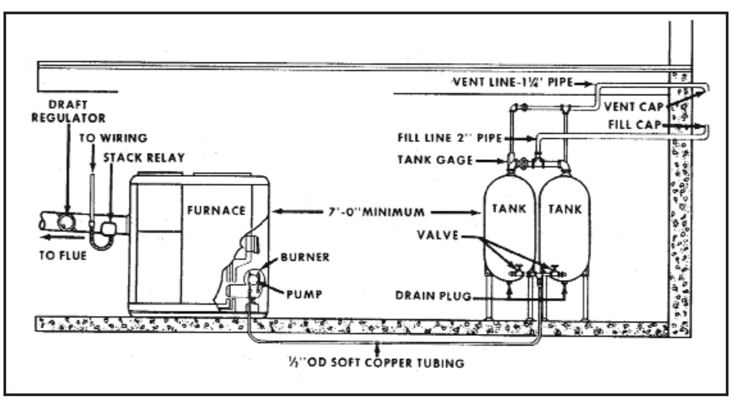


Figure 12.2. Piping Hookup for Inside Tank Installation [4]

Coal

The four types of coal are anthracite, bituminous, subbituminous, and lignite. Coal is prepared in many sizes and combinations of sizes. The combustible portions of the coal are fixed carbons, volatile matter (hydrocarbons), and small amounts of sulfur. In combination with these are noncombustible elements composed of moisture and impurities that form ash. The various types differ in heat content. Heat content is determined by analysis and is expressed in British thermal units per pound.

Improper coal furnace operation can result in an extremely hazardous and unhealthy home. Ventilation of the area surrounding the furnace is very important to prevent heat buildup and to supply air for combustion.

Solar Energy

Solar energy has gained popularity in the last 25 years as the cost of installation of solar panels and battery storage has decreased. Improved technology with panels, installation of panels, piping, and batteries has created a much larger market. Solar energy largely has been used to heat water. Today, there are more than a million solar water-heating systems in the United States. Solar water heaters use direct sun to heat either water or a heat-transfer fluid in collectors [3]. That water is then stored for use as needed, with a conventional system providing any necessary additional heating. A typical system will reduce the need for conventional water heating by about two-thirds, minimizing the cost of electricity or the use of fossil fuel and thus the environmental impact associated

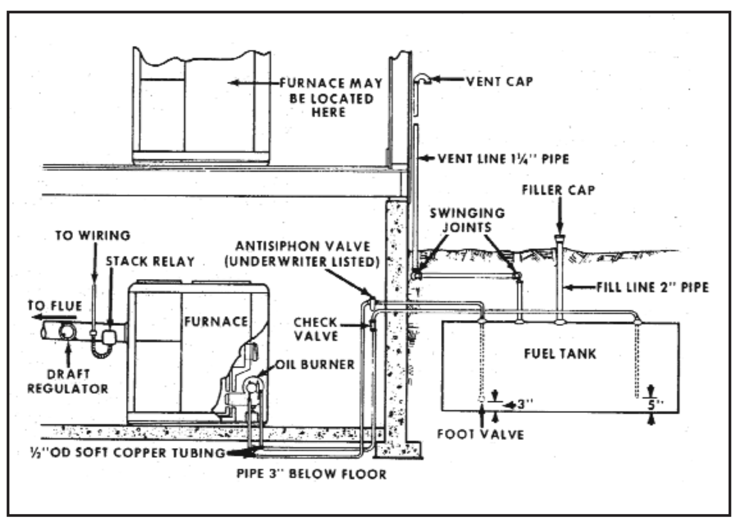


Figure 12.3. Piping Hookup for Buried Outside Tank [4]

with their use. The U.S. Department of Housing and Urban Development and the U.S. Department of Energy (DOE) have instituted initiatives to deploy new solar technologies in the next generation of American housing [3]. For example, DOE has the Million Solar Roofs Initiative begun in 1997 to install solar energy systems in more than 1 million U.S. buildings by 2010.

Central Heating Units

The boiler should be placed in a separate room whenever possible, which is usually required in new construction. In most housing inspections, however, the inspector is dealing with existing conditions and must adapt the situation as closely as possible to acceptable safety standards. In many old buildings, the furnace is located in the center of the cellar or basement. This location does not lend itself to practical conversion to a boiler room.

Consider the physical requirements for a boiler or furnace.

- **Ventilation**—More circulating air is required for the boiler room than for a habitable room, to reduce the heat buildup caused by the boiler or furnace and to supply oxygen for combustion.
- **Fire protection rating**—As specified by various codes (fire code, building code, and insurance underwriters), the fire regulations must be strictly adhered to in areas surrounding the boiler or furnace. This minimum clearance for a boiler or furnace from a wall or ceiling is shown in Figures 12.4 and 12.5.

Asbestos was used in numerous places on furnaces to protect buildings from fire and to prevent lost heat. Figure 12.6 shows asbestos-coated heating ducts, for example. Where asbestos insulation is found, it must be

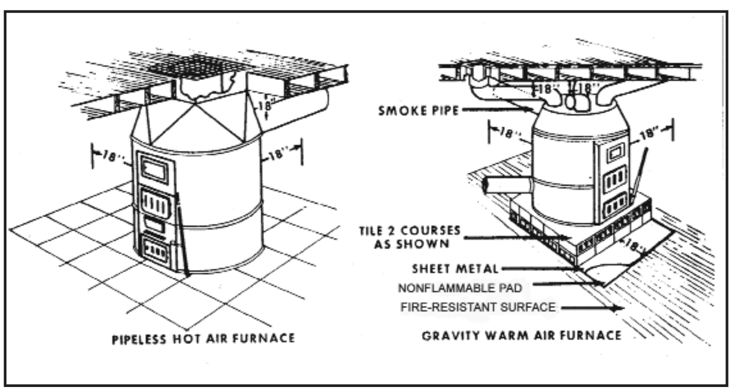


Figure 12.4. Minimum Clearance for Pipeless Hot Air and Gravity Warm Air Furnace [4]

handled with care (breathing protection and protective clothing) and care must be taken to prevent or contain release into the air [10].

The furnace or boiler makes it difficult to supply air and ventilation for the room. Where codes and local authority permit, it may be more practical to place the furnace or boiler in an open area. The ceiling above the furnace should be protected to a distance of 3 feet beyond all furnace or boiler appurtenances, and this area should be free of all storage material. The furnace or boiler should be on a firm foundation of concrete if located in the cellar or basement. If codes permit furnace installations on the first floor, then they must be consulted for proper setting and location.

Heating Boilers

The term boiler is applied to the single heat source that can supply either steam or hot water (a boiler is often called a heater).

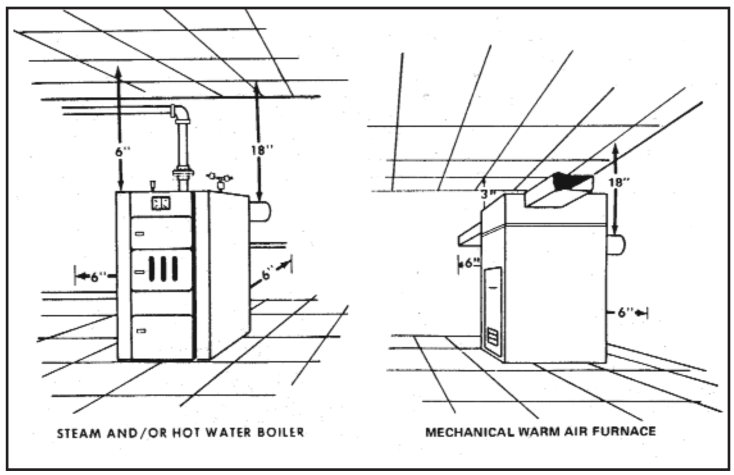


Figure 12.5. Minimum Clearance for Steam or Hot Water Boiler and Mechanical Warm-air Furnace [4]

Figure 12.6. Heating Ducts Covered With Asbestos Insulation

Boilers may be classified according to several kinds of characteristics. They are typically made from cast iron or steel. Their construction design may be sectional, portable, fire-tube, water-tube, or special. Domestic heating boilers are generally of low-pressure type with a maximum working pressure of 15 pounds per square inch (psi) for steam and 30 psi for hot water. All boilers have a combustion chamber for burning fuel. Automatic fuel-firing devices help supply the fuel and control the combustion. Hand firing is accomplished by the provision of a grate, ash pit, and controllable drafts to admit air under the fuel bed and over it through slots in the firing door. A check draft is required at the smoke pipe connection to control chimney draft. The gas passes from the combustion chamber to the flue passages (smoke pipe) designed for maximum possible transfer of heat from the gas. Provisions must be made for cleaning flue passages.

Cast-iron boilers are usually shipped in sections and assembled at the site. They are generally classified as

- square or rectangular boilers with vertical sections; and
- round, square, or rectangular boilers with horizontal pancake sections.

Most steel boilers are assembled units with welded steel construction and are called portable boilers. Large boilers are installed in refractory brick settings on the site. Above the combustion chamber, a group of tubes is suspended, usually horizontally, between two headers. If flue gases pass through the tubes and water surrounds them, the boiler is designated as the fire-tube type. When water flows through the tubes, it is termed water-tube. Fire-tube is the predominant type.

Heating Furnaces

Heating furnaces are the heat sources used when air is the heat-carrying medium. When air circulates because of the different densities of the heated and cooled air, the furnace is a gravity type. A fan may be included for the air circulation; this type is called a mechanical warm-air furnace. Furnaces may be of cast iron or steel and burn various types of fuel.

Some new furnaces are as fuel efficient as 95%. Furnaces with an efficiency of 90% or greater use two heat exchangers instead of one. Energy savings come not only from the increased efficiency, but also from improved comfort at lower thermostat settings.

Fuel-burning Furnaces

Some localities throughout the United States still use coal as a heating fuel, including residences, schools, colleges and universities, small manufacturing facilities, and other facilities located near coal sources.

In many older furnaces, the coal is stoked or fed into the firebox by hand. The single-retort, underfeed-type bituminous coal stoker is the most commonly used domestic automatic-stoking steam or hot-water boiler (Figure 12.7). The stoker consists of a coal hopper, a screw for conveying coal from hopper to retort, a fan that supplies air for combustion, a transmission for driving coal feed and fan, and an electric motor for supplying power. The air for combustion is admitted to the fuel through tuyeres (air inlets) at the top of the retort. The stoker feeds coal to the furnace intermittently in accordance with temperature or pressure demands.

Oil burners are broadly designated as distillate, domestic, and commercial or industrial. Distillate burners are usually found in oil-fired space heaters. Domestic oil burners are usually power driven and are used in domestic heating plants. Commercial or industrial burners are used in larger central-heating plants for steam or power generation.

Domestic oil burners vaporize and atomize the oil and deliver a predetermined quantity of oil and air to the combustion chambers. Domestic oil burners operate automatically to maintain a desired temperature.

Gun-type burners atomize the oil either by oil pressure or by low-pressure air forced through a nozzle. The oil system pressure-atomizing burner consists of a strainer, pump, pressure-regulating valve, shutoff valve and atomizing nozzle. The air system consists of a power-driven fan and an air tube that surrounds the nozzle and electrode assembly.

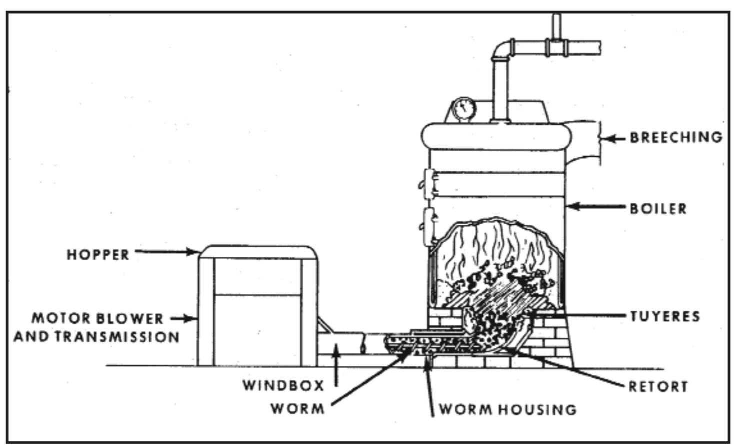


Figure 12.7. Typical Underfeed Coal Stoker Installation in Small Boilers [4]

The fan and oil pump are generally connected directly to the motor. Oil pressures normally used are about 100 psi, but pressures considerably in excess of this are sometimes used.

The form and parts of low-pressure, air-atomizing burners are similar to high-pressure atomizing (gun) burners (Figure 12.8) except for addition of a small air pump and a different way of delivering air and oil to the nozzle or orifice.

The atomizing type burner, sometimes known as a radiant or suspended flame burner, atomizes oil by throwing it from the circumference of a rapidly rotating motor-driven cup. The burner is installed so that the driving parts are protected from the heat of the flame by a hearth of refractory material at about the grate elevation. Oil is fed by pump or gravity; the draft is mechanical or a combination of natural and mechanical.

Horizontal rotary burners were originally designed for commercial and industrial use but are available in sizes suitable for domestic use. In this burner, fuel oil being thrown in a conical spray from a rapidly rotating cup is atomized. Horizontal rotary burners use electric gas or gas-pilot ignition and operate with a wide range of fuels, primarily Numbers 1 and 2 fuel oil. Primary safety controls for burner operation are necessary. An antiflooding device must be a part of the system to stop oil flow if ignition in the burner should fail. Likewise, a stack control is necessary to shut off the burner if the stack temperatures are exceeded, thus cutting off all power to the burner. This button must be reset before starting can be attempted. The newer models now use electric eye-type control on the burner itself.

On the basis of the method used to ignite fuels, burners are divided into five groups:

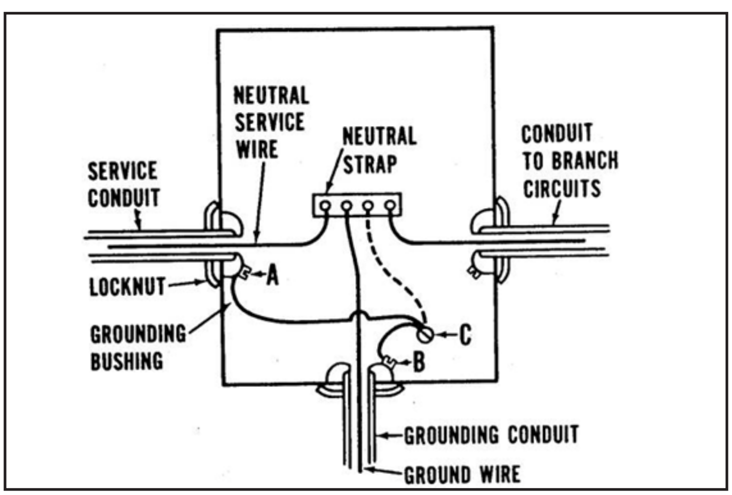


Figure 12.8. Cutaway View of Typical High-pressure Gun Burner [4]

- **Electric**—A high-voltage electric spark in the path of an oil and air mixture causes ignition. This electric spark may be continuous or may operate only long enough to ignite the oil. Electric ignition is almost universally used. Electrodes are located near the nozzles, but not in the path of the oil spray.

- **Gas pilot**—A small gas pilot light that burns continuously is frequently used. Gas pilots usually have expanded gas valves that automatically increase flame size when a motor circuit starts. After a fixed interval, the flame reverts to normal size (Figure 12.9).

- **Electric gas**—An electric spark ignites a gas jet, which in turn ignites the oil-air mixture.

- **Oil pilot**—A small oil flame is used.

- **Manual**—A burning wick or torch is placed in the combustion space through peepholes and thus ignites the charge. The operator should stand to one side of the fire door to guard against injury from chance explosion.

The refractory lining or material should be an insulating fireproof bricklike substance, never ordinary firebrick. The insulating brick should be set on end to build a 2½-inch-thick wall from furnace to furnace. The size and shape of the refractory pot vary from furnace to furnace.

Figure 12.9. Gas-fired Boiler
Source: HUD

The shape can be either round or square, whichever is more convenient to build. It is more important to use a special cement having properties similar to that of the insulating refractory-type brick.

Steam Heating Systems

Steam heating systems are classified according to the pipe arrangement, accessories used, method of returning the condensate to the boiler, method of expelling air from the system, or the type of control used. The successful operation of a steam heating system consists of generating steam in sufficient quantity to equalize building heat loss at maximum efficiency, expelling entrapped air, and returning all condensate to the boiler rapidly. Steam cannot enter a space filled with air or water at pressure equal to the steam pressure. It is important, therefore, to eliminate air and remove water from the distribution system. All hot pipelines exposed to contact by residents must be properly insulated or guarded. Steam heating systems use the following methods to return the condensate to the boiler:

- **Gravity one-pipe air-vent system**—One of the earliest types used, this method returns condensate to the boiler by gravity. This system is generally found in one-building-type heating systems. The steam is supplied by the boiler and carried through a single system or pipe to radiators, as shown in Figure 12.10. Return of the condensate is dependent on hydrostatic head. Therefore, the end of the stream main, where it attaches to the boiler, must be full of water (termed a wet return) for a distance above the boiler line to create a pressure drop balance between the boiler and the stream main.

  Radiators are equipped with an inlet valve and an air valve. The air valve permits venting of air from the radiator and its displacement by steam. Condensate is drained from the radiator through the same pipe that supplies steam.

- **Two-pipe steam vapor system with return trap**—The two-pipe vapor system with boiler return trap and air eliminator is an improvement of the one-pipe system. The return connection of the radiator has a thermostatic trap that permits flow of condensate and air only from the radiator and prevents steam from leaving the radiator. Because the return main is at atmospheric pressure or less, a boiler return trap is installed to equalize condensate return pressure with boiler pressure.

Water Heating Systems

All water heating systems are similar in design and operating principle. The one-pipe gravity water heating system is the most elementary of the gravity systems and is shown in Figure 12.10. Water is heated at the lowest point in the system. It rises through a single main because of a difference in density between hot and cold water. The supply rise or radiator branch takes off from the top of the main to supply water to the radiators. After the water gives up heat in the radiator, it goes back to the same main through return piping from the radiator. This cooler return water mixes with water in the supply main and causes the water to cool a little. As a result, the next radiator on the system has a lower emission rate and must be larger.

Note in Figure 12.11 that the high points of the hot water system are vented and the low points are drained. In this case, the radiators are the high points and the heater is the low point.

- **One-pipe forced-feed system**—If a pump or circulator is introduced in the main near the heater of the one-pipe system, it becomes a forced system that can be used for much larger applications than can the gravity type. This system can operate at higher water temperatures than the gravity system can. When the water is moving faster and at higher temperatures, it makes a more responsive system, with smaller temperature drops and smaller radiators for the same heating load.

- **Two-pipe gravity system**—A one-pipe gravity system may become a two-pipe system if the return radiator branch connects to a second main that returns water to the heater (Figure 12.12). Water temperature is practically the same in the entire radiator.

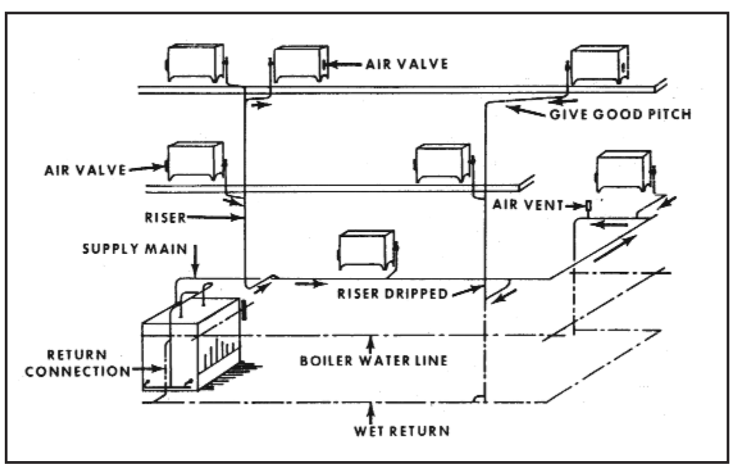


Figure 12.10. Typical Gravity One-pipe Heating System [4]

- **Two-pipe forced-circulation system**—This system is similar to a one-pipe forced-circulation system except that it uses the same piping arrangement found in the two-pipe gravity system.

- **Expansion tanks**—When water is heated, it tends to expand. Therefore, an expansion tank is necessary in a hot water system. The expansion tank, either open or closed, must be of sufficient size to permit a change in water volume within the heating system. If the expansion tank is open, it must be placed at least 3 feet above the highest point of the system. It will require a vent and an overflow. The open tank is usually in an attic, where it needs protection from freezing.

  The closed expansion tank is found in modern installations. An air cushion in the tank compresses and expands according to the change of volume and pressure in the system. Closed tanks are usually at the low point in the system and close to the heater. They can, however, be placed at almost any location within the heating system.

Air Heating Systems

Gravity Warm-air Heating Systems. These operate because of the difference in specific gravity of warm air and cold air. Warm air is lighter than cold air and rises if cold air is available to replace it (Figure 12.13).

- **Operation**—Satisfactory operation of a gravity warm-air heating system depends on three factors: size of warm air and cold air ducts, heat loss of the building, and heat available from the furnace.

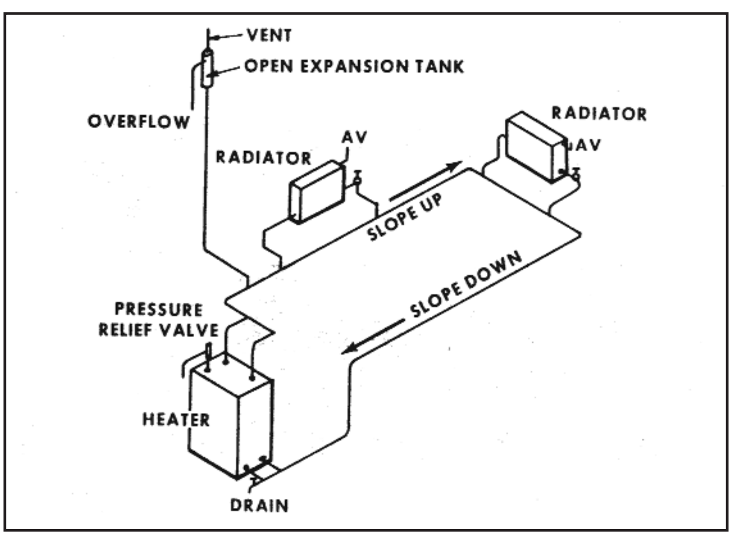


Figure 12.11. One-pipe Gravity Water Heating System [4]

- **Heat distribution**—The most common source of trouble in these systems is insufficient pipe area, usually in the return or cold air duct. The total cross-section area of the cold duct or ducts must be at least equal to the total cross-section area of all warm ducts.

- **Pipeless furnaces**—The pipeless hot-air furnace is the simplest type of hot-air furnace and is suitable for small homes where all rooms can be grouped about a single large register. Other pipeless gravity furnaces are often installed at floor level. These are really oversized jacketed space heaters. The most common difficulty experienced with this type of furnace is supplying a return air opening of sufficient size on the floor.

Forced-Warm-Air Heating Systems. The mechanical warm-air furnace is the most modern type of warm-air equipment (Figures 12.13 and 12.14). It is the safest type because it operates at low temperatures. The principle of a

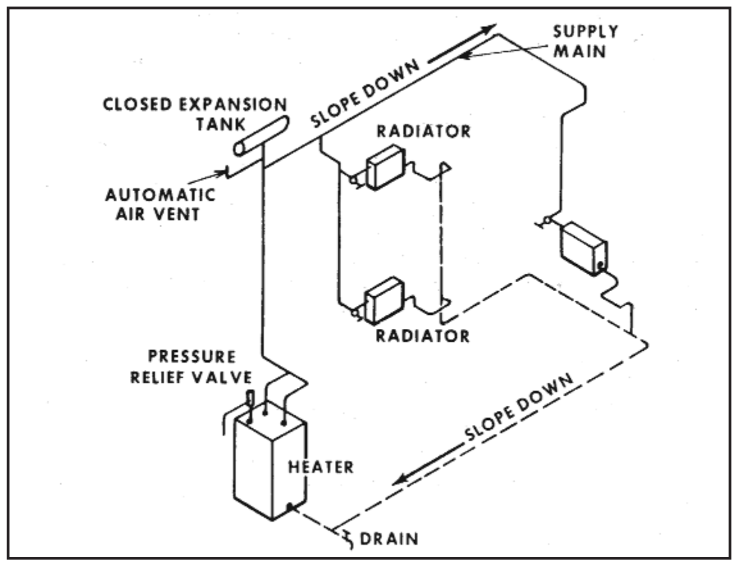


Figure 12.12. Two-pipe Gravity Water Heating System [4]

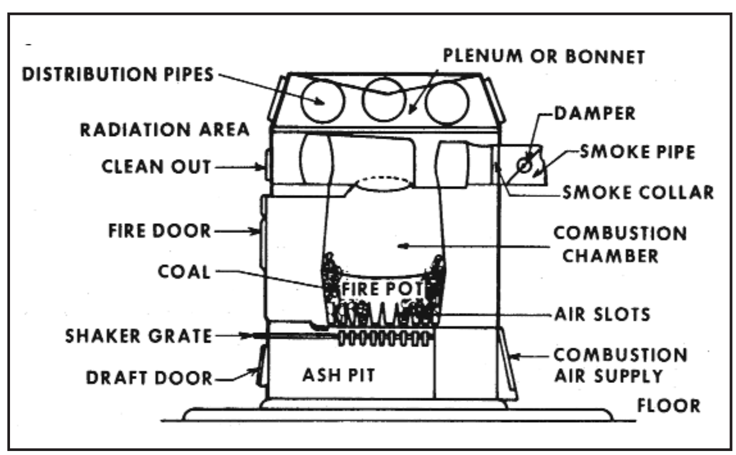


Figure 12.13. Warm-air Convection Furnace [4]

forced-warm-air heating system is very similar to that of the gravity system, except that a fan or blower is added to increase air movement. Because of the assistance of the fan or blower, the pitch of the ducts or leaders can be disregarded; therefore, it is practical to deliver heated air in the most convenient places.

- **Operation—**In a forced-air system, operation of the fan or blower must be controlled by air temperature in a bonnet or by a blower control furnace stat. The blower control starts the fan or blower when the temperature reaches a certain point and turns the fan or blower off when the temperature drops to a predetermined point.

- **Heat distribution—**Dampers in the various warm-air ducts control distribution of warm air either at the branch takeoff or at the warm-air outlet. Humidifiers are often mounted in the supply bonnet to regulate the humidity within the residence.

Space Heaters

Space heaters are the least desirable type of heating from the viewpoint of fire safety and housing inspection. A space heater is a self-contained, free-standing air-heating appliance intended for installation in the space being heated and not intended for duct connection. According to the CPSC, consumers are not using care when purchasing and using space heaters. Approximately 21,800 residential fires are caused by space heaters a year, and 300 people die in these fires. An estimated 6,000 persons receive hospital emergency room care for burn injuries associated with contacting hot surfaces of space heaters, mostly in nonfire situations.

Individuals using space heaters should use the heaters in accordance with the following precautions:

- Read and follow the manufacturer's operating instructions. A good practice is to read aloud the instructions and warning labels to all members of the household to be certain that everyone understands how to operate the heater safely. Keep the owner's manual in a convenient place to refer to when needed.

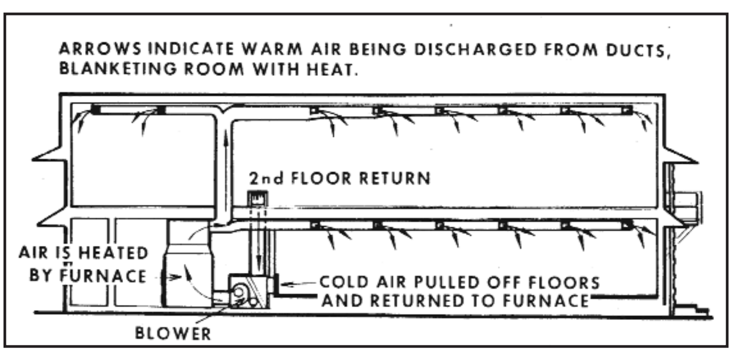


Figure 12.14. Cross-sectional View of Building Showing Forced warm-air Heating System [4]

- Choose a space heater that has been tested and certified by a nationally recognized testing laboratory. These heaters meet specific safety standards.

- Buy a heater that is the correct size for the area you want to heat. The wrong size heater could produce more pollutants and may not be an efficient use of energy.

- Choose models that have automatic safety switches that turn off the unit if it is tipped over accidentally.

- Select a space heater with a guard around the flame area or heating element. Place the heater on a level, hard, nonflammable surface, not on rugs or carpets or near bedding or drapes. Keep the heater at least 3 feet from bedding, drapes, furniture, or other flammable materials.

- Keep doors open to the rest of the house if you are using an unvented fuel-burning space heater. This helps prevent pollutant build-up and promotes proper combustion. Follow the manufacturer's instructions for oil heaters to provide sufficient combustion air to prevent CO production.

- Never leave a space heater on when you go to sleep. Never place a space heater close to any sleeping person.

- Turn the space heater off if you leave the area. Keep children and pets away from space heaters. Children should not be permitted to either adjust the controls or move the heater.

- Keep any portable heater as least 3 feet away from curtains, newspapers, or anything that might burn.

- Have a smoke detector with fresh batteries on each level of the house and a CO detector outside the sleeping area. Install a CO monitor near oil space heaters at the height recommended by the manufacturer.

- Be aware that mobile homes require specially designed heating equipment. Only electric or vented fuel-fired heaters should be used.

- Have gas and kerosene space heaters inspected annually.

- Do not hang items to dry above or on the heater.

- Keep all heaters out of exit and high-traffic areas.

- Keep portable electric heaters away from sinks, tubs, and other wet or damp places to avoid deadly electric shocks.

- Never use or store flammable liquids (such as gasoline) around a space heater. The flammable vapors can flow from one part of the room to another and be ignited by the open flame or by an electrical spark.

Coal-fired Space Heaters (Cannon Stove)

A coal stove is made entirely of cast iron. Coal on the grates receives primary air for combustion through the grates from the ash-door draft intake. Combustible gases driven from the coal by heat burn in the barrel of the stove, where they receive additional or secondary air through the feed door. The side and top of the stove absorb the heat of combustion and radiate it to the surrounding space. Coal stoves must be vented to the flue.

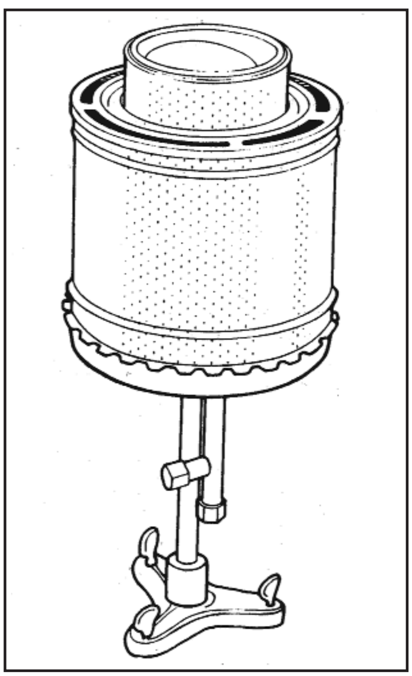


Figure 12.15. Perforated-sleeve Burner

Oil-fired Space Heaters

Oil-fired space heaters have atmospheric vaporizing-type burners. The burners require a light grade of fuel oil that vaporizes easily and in comparatively low temperatures. In addition, the oil must be such that it leaves only a small amount of carbon residue and ash within the heater. Oil stoves must be vented.

The burner of an oil-fired space heater consists essentially of a bowl, 8 to 13 inches in diameter, with perforations in the side that admit air for combustion. The upper part of the bowl has a flame ring or collar. Figure 12.15 shows a perforated-sleeve burner. When several space heaters are installed in a building, an oil supply from an outside tank to all heaters is often desirable. Figure 12.16 shows the condition of a burner flame with different rates of fuel flow and indicates the ideal flame height.

Electric Space Heaters

Electric space heaters do not need to be vented.

Gas-fired Space Heaters

The three types of gas-fired space heaters (natural, manufactured, and liquefied petroleum gas) have a similar construction. All gas-fired space heaters must be vented to prevent a dangerous buildup of poisonous gases. Each unit console consists of an enamel steel cabinet with top and bottom circulating grilles or openings, gas burners, heating elements, gas pilot, and a gas valve. The heating element or combustion chamber is usually cast iron.

Caution: All gas-fired space heaters and their connections must be approved by the American Gas Association (AGA). They must be installed in accordance with the recommendations of that organization or the local code.

Venting

Use of proper venting materials and correct installation of venting for gas-fired space heaters is necessary to minimize harmful effects of condensation and to ensure that combustion products are carried off. (Approximately 12 gallons of water are produced in the burning of

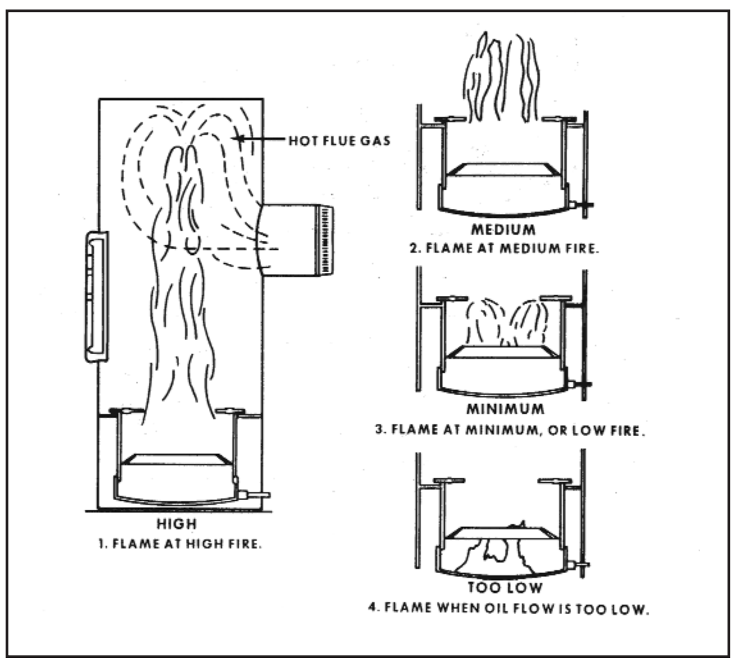


Figure 12.16. Condition of Burner Flame with Different Rates of Fuel Flow [4]

1,000 cubic feet of natural gas. The inner surface of the vent must therefore be heated above the dew point of the combustion products to prevent water from forming in the flue.) A horizontal vent must be given an upward pitch of at least 1 inch per foot of horizontal distance.

When the smoke pipe extends through floors or walls, the metal pipe must be insulated from the floor or wall system by an air space (Figure 12.17). Sharp bends should be avoided. A 9° vent elbow has a resistance to flow equivalent to that of a straight section of pipe with a length 10 times the elbow diameter. Be sure that vents are of rigid construction and resistant to corrosion by flue gas products. Several types of venting material are available such as B-vent and other ceramic-type materials. A chimney lined with firebrick type of terra cotta must be relined with an acceptable vent material if it is to be used for venting gas-fired appliances.

The same size vent pipe should be used throughout its length. A vent should never be smaller than the heater outlet except when two or more vents converge from separate heaters. To determine the size of vents beyond the point of convergence, one-half the area of each vent should be added to the area of the largest heater's vent. Vents should be installed with male ends of inner liner down to ensure condensate is kept within pipes on a cold start. The vertical length of each vent or stack should be at least 2 feet greater than the length between horizontal connection and stack. Remember that the more conductive the unit, the lower the temperature of combustion and the more byproducts of combustion are likely to be produced. These by-products are sometimes referred to as soot and creosote. These by-products will build up in vents, stacks, and chimneys. They are extremely flammable and can result in fire in these units that is hot enough to penetrate the heat shielding and throw burning material onto the roof of the home.

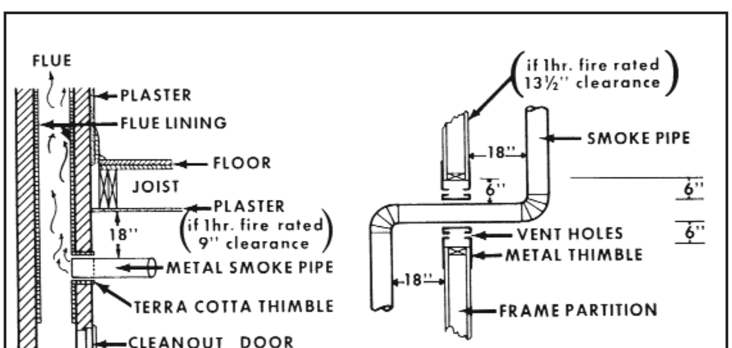
The vent should be run at least 3 feet above any projection within 20 feet of the building to place it above a possible pressure zone due to wind currents (Figure 12.18). A weather cap should prevent entrance of rain and snow. Gas-fired space heaters, as well as gas furnaces and water heaters, must be equipped with a backdraft diverter (Figure 12.19) to protect heaters against downdrafts and excessive updrafts. Only draft diverters approved by the AGA should be used.

The combustion chamber or firebox must be insulated from the floor, usually with airspace of 15 to 18 inches. The firebox is sometimes insulated within the unit and thus allows for lesser clearance firebox combustibles.

Floors should be protected where coal space heaters are located. The floor protection allows hot coals and ashes to cool off if dropped while being removed from the ash chamber. Noncombustible walls and materials should be used when they are exposed to heated surfaces. For space heaters, a top or ceiling clearance of 36 inches, a wall clearance of 18 inches, and a smoke pipe clearance of 18 inches are recommended.

Hydronic Systems

Hydronic (circulating water) systems involving traditional baseboards can be single-pipe or two-pipe. Radiant systems are also an option. All hydronic systems require an expansion tank to compensate for the increase in water volume when it is heated (i.e., the volume of 50°F [10°C] water increases almost 4% when it is heated to 200°F [93°C]). Single-pipe hydronic systems are most commonly used in residences. They use a single pipe with hot water flowing in a series loop from radiator to radiator. Massachusetts has a prototype set of hydronic systems requirements [11].



FLUE CONNECTIONS AND CLEARANCES

PROTECTED CONSTRUCTION MATERIAL (fire rating)	CLEARANCE REDUCTION TOP	CLEARANCE REDUCTION SIDES
20 MINUTES	7/8	5/8
30 MINUTES	3/4	1/2
45 MINUTES	5/8	3/8
60 MINUTES	1/2	1/4

Figure 12.17. Wall and Ceiling Clearance Reduction [4]

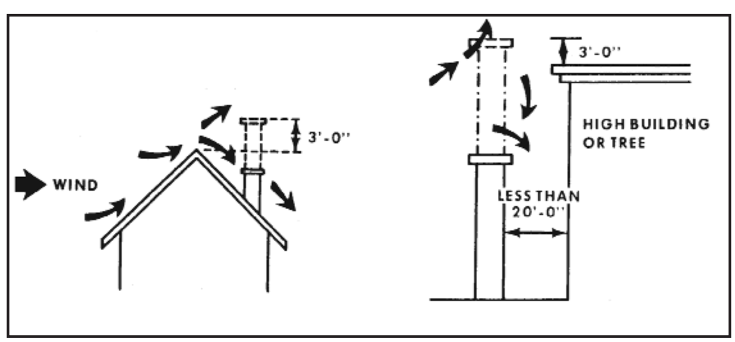


Figure 12.18. Draft Relation to Height of Chimney [4]

The drawback to this arrangement is that the temperature of the water decreases as it moves through each radiator. Thus, larger radiators are needed for those locations downstream in the loop. A common solution to this is multiple loops or zones. Each zone has its own temperature control with circulation provided by a small pump or zone valve in each loop. Two-pipe hydronic systems use a pipe for supplying hot water to the radiators and a second pipe for returning the water from the radiators to the boiler.

There are also direct- and reverse-return arrangements. The direct-return system can be difficult to balance because the pressure drop through the nearest radiator piping can be significantly less than for the farthest radiator. Reverse-return systems take care of the balancing problem, but require the expense of additional piping. Orifice plates at radiator inlets or balancing valves at radiator outlets can also be used to balance the pressure drops in a direct-return system.

Direct Vent Wall Furnaces

Direct vent wall furnaces are specifically designed for areas where flues or chimneys are not available or cannot be used. The furnace is directly vented to the outside and external air is used to support combustion. The air on the inside is warmed as it recirculates around a sealed chamber.

Cooling

Air Conditioning

Many old homes relied on passive cooling-opening windows and doors and using shading devices-during the summer months. Homes were designed with windows on opposite walls to encourage cross ventilation and large shade trees reduced solar heat gains. This approach is still viable, and improved thermal performance (insulating value) windows are available that allow for larger window areas to let in more air in the summer without the heat loss

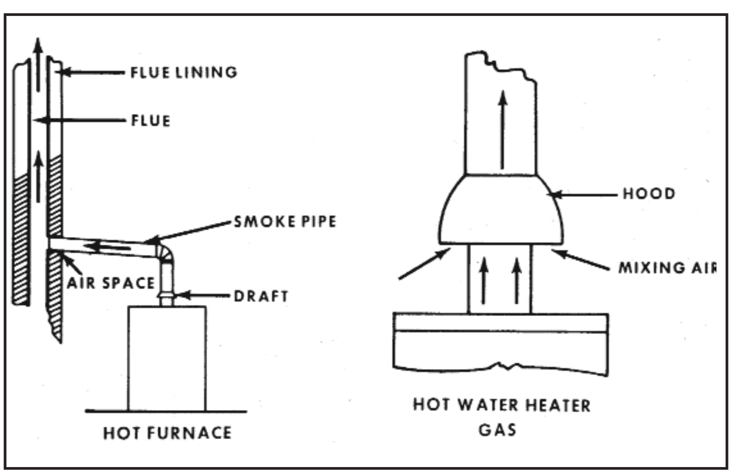


Figure 12.19. Location and Operation of Typical Backdraft Diverter [4]

penalty in the winter. However, increased outdoor noise levels, pollution, and security issues make relying on open windows a less attractive option in some locations today. An air conditioning system of some kind may be installed in the home. It may be a window air conditioner or through-the-wall unit for cooling one or two rooms, or a central split-system air conditioner or heat pump. In any event, the performance of these systems, in terms of providing adequate comfort without excessive energy use, should be investigated. The age of the equipment alone will provide some indication. If the existing system is more than 10 years old, replacement should be considered because it is much less efficient than today's systems and nearing the end of its useful life.

The refrigerant commonly used in today's residential air conditioners is R-22. Because of the suspicion that R-22 depletes the ozone layer, manufacturers will be prohibited from producing units with R-22 in 2010. The leading replacements for R-22 are R-134A and R-410A, and new products are now available with these nonozone-depleting refrigerants.

The performance measure for electric air conditioners with capacities less than 65,000 BTU is the seasonal energy efficiency ratio (SEER). SEER is a rating of cooling performance based on representative residential loads. It is reported in units of BTU of cooling per watt per hour of electric energy consumption. It includes energy used by the unit's compressor, fans, and controls. The higher the SEER, the more efficient the system. However, the highest SEER unit may not provide the most comfort. In humid climates, some of the highest SEER units exhibit poor dehumidification capability because they operate at higher evaporator temperatures to attain the higher efficiency. A SEER of at least 10 is required by the National Appliance Energy Conservation Act of 1987 for conventional central split-system air-cooled systems. The Department of Energy announced a SEER of 13 effective January 2006.

Cooling system options vary widely, depending on the level of control and comfort desired by the homeowner. Fans can increase circulation and reduce cooling loads, but they may be unsatisfactory in hot climates because their cooling capability is directly limited by outdoor conditions. Radiant barriers can reduce cooling loads in very hot climates. Evaporative coolers can be a relatively inexpensive and effective method of cooling in dry climates, such as the Southwest. Electric air conditioning maintains a comfortable indoor temperature and humidity even under the most severe outdoor conditions.

More than 75% of new homes in the United States are equipped with some form of central air conditioning: 50% of the homes in the Northeast, 75% in the Midwest, 95% in the South, and approximately 60% in the West. Electric air conditioning removes moisture from the air and reduces its temperature. It can be a good investment because, in most parts of the country, the payback is significant when the house is sold.

Electric air conditioners that use the vapor-compression, refrigeration cycle are available in a variety of sizes and configurations, ranging from small window units to large central systems. The most common form of central air conditioning is a split-system with a warm air furnace (Figure 12.20). The same ductwork is used for distributing conditioned air during the heating and cooling seasons. Supply air is cooled and dehumidified as it passes over an A-shaped evaporator coil. The liquid refrigerant evaporates inside the coil as it absorbs heat from the air. The refrigerant gas then travels through refrigerant piping to the outdoor unit, where it is pressurized in an electrically driven compressor, raising its temperature and pressure, and returned to a liquid state in the condenser as it releases, or dumps, the heat to the outdoors. A fan draws outdoor air in over the condenser coil. The use of two-speed indoor fans can be advantageous in this type of system because the cooling load often requires higher airflows than the heating load. The lower speed can be used for the heating season and for improved dehumidification performance during the cooling season. The condenser unit for a house air conditioner is shown in Figure 12.21.

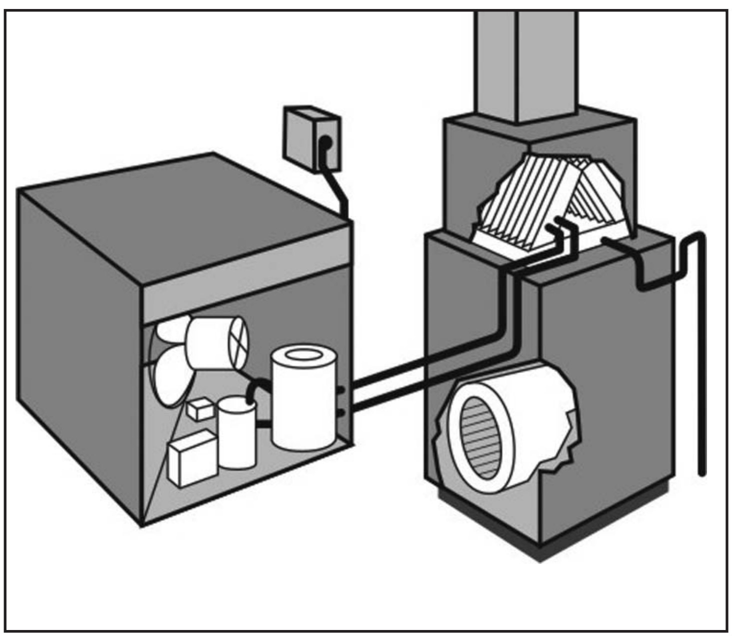


Figure 12.20. Split-system Air Conditioner

Circulation Fans

Air movement can make a person feel comfortable even when dry-bulb temperatures are elevated. A circulation fan (ceiling or portable) that creates an airspeed of 150 to 200 feet per minute can compensate for a 4°F (-16°C) increase in temperature.

Ceiling circulation fans also can be beneficial in the heating season by redistributing warm air that collects along the ceiling, but they can be noisy.

Evaporation Coolers

In dry climates, as in the southwestern United States, an evaporative cooler or "swamp" cooler may provide sufficient cooling. This system cools an airstream by evaporating water into it; the airstream's relative humidity increases while the dry-bulb temperature decreases. A 95°F (35°C), 15% relative humidity airstream can be conditioned to 75°F (24°C), 50% relative humidity. The simplest direct systems are centrally located and use a pump to supply water to a saturated pad over which the supply air is blown. Indirect systems use a heat exchanger between the airstream that is cooled by evaporating water and the supply airstream. The moisture level of the supply airstream is not affected as it is cooled.

Evaporation coolers have lower installation and operating costs than electric air conditioning. No ozone-depleting refrigerant is involved. They provide high levels of ventilation because they typically condition and supply 100% outside air.

The disadvantages are that bacterial contamination can result if not properly maintained and they are only appropriate for dry, hot climates.

Figure 12.21. External Air-conditioning Condenser Unit

Safety

Cooling homes with window air conditioners requires attention to the maintenance requirements of the unit. The filter must be cleaned or replaced as recommended by the manufacturer, and the drip pan should be checked to ensure that proper drainage from the unit is occurring. The pans should be rinsed and disinfected as recommended by the manufacturer. Both bacteria and fungi can establish themselves in these areas and present serious health hazards.

Condensation forms on the cooling coils of central air units inside and outside the home. These units should have a properly installed drip pan and should be drained according to the manufacturer's instructions. They also should receive routine maintenance, flushing, and disinfection. In the spring, before starting the air conditioner, the unit should be checked by a professional or someone familiar with the operation of the system. This is a good time to check drip line(s) for conditions such as plugs, cracks, or bacterial contamination because many of these lines are plastic. The drip pan should be cleaned thoroughly and disinfected if necessary or replaced. A plugged drip line can cause water damage by overflow from the drip pan. In the fall, the heat unit also should be checked before starting the system. Care should be taken with both window air conditioning units and central air systems to use quality air filters that are designed for the specific units and meet the specifications required by the system's manufacturer.

The housing inspector should be on the alert for unvented, open flame heaters. Coil-type, wall-mounted water heaters that do not have safety relief valves are not permitted. Kerosene (portable) units for cooking or heating should be prohibited. Generally, open-flame portable units are not allowed under fire safety regulations.

In oil heating units, other than integral tank units, the oil must be filled and vented outside the building. Filling oil within buildings is prohibited. Cutoff switches should be close to the entry but outside of a boiler room.

Chimneys

Chimneys (Figure 12.22) are often an integral part of a building. Masonry chimneys must be tight and sound; flues should be terra cotta-lined; and, where no linings are installed, the brick should be tight to permit proper draft and elimination of combustion gases.

Chimneys that act as flues for gas-fired equipment must be lined with either B vent or terra cotta. When a portion of the chimney above the roof either loses insulation or the insulation peels back, it indicates potential poisonous gas release or water leakage problems and a need for rebuilding. Exterior deterioration of the chimney, if neglected too long, will permit erosion from within the flues and eventually block the flue opening.
Rusted flashing at the roof level will also contribute to the chimney's deterioration. Efflorescence on the inside wall of the chimney below the roof and on the outside of the chimney, if exposed, will show salt accumulations—a telltale sign of water penetration and flue gas escape and a sign of chimney deterioration. During rainy seasons, if terra cotta chimneys leak, dark areas show the number of flues inside the masonry chimney so they can actually be counted. When this condition occurs, it usually requires 2 or 3 months to dry out. After drying out, the mortar joints are discolored (brown). After a few years of this type of deterioration, the joints can be distinguished whether the chimney is wet or dry. These conditions usually develop when coal is used and become more pronounced 2 to 5 years after conversion to oil or gas.

An unlined chimney can be checked for deterioration below the roofline by looking for residue deposited at the base of the chimney, usually accessible through a cleanout (door or plug) or breaching. Red granular or fine powder showing through coal or oil soot will generally indicate, if in quantity (a handful), that deterioration is excessive and repairs are needed.

Unlined chimneys with attached gas units will be devoid of soot, but will usually show similar telltale brick powder and deterioration. Manufactured gas has a greater tendency to dehydrate and decompose brick in chimney flues than does natural gas. For gas installations in older

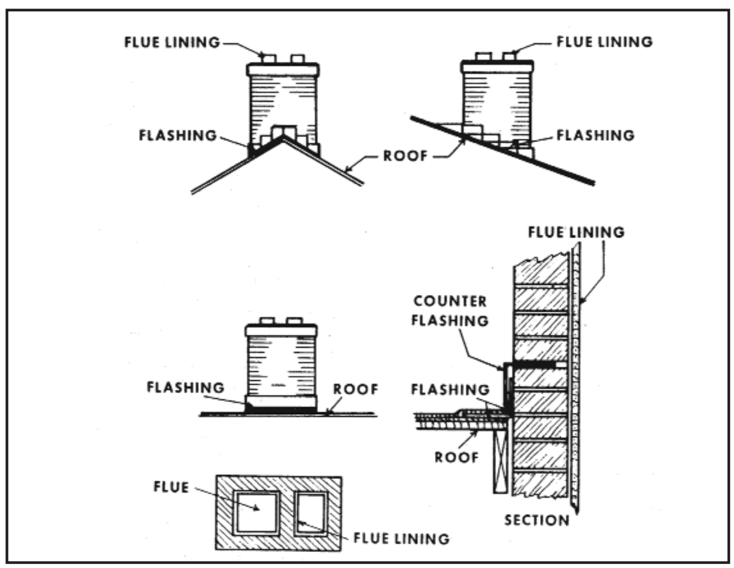


Figure 12.22. Chimney Plan [4]

homes, utility companies usually specify chimney requirements before installlation; therefore, older chimneys may require the installation of terra cotta liners, nonlead-lined copper liners, stainless steel liners, or transit pipe. Black carbon deposits around the top of the chimney usually indicate an oil burner operation using a low air ratio and high oil consumption. Prolonged operation in this burner setting results in long carbon water deposits down the chimney for 4 to 6 feet or more and should indicate to the inspector a possibility of poor burner maintenance. This will accent the need to be more thorough on the next inspection. This type of condition can result from other causes, such as improper chimney height, or exterior obstructions, such as trees or buildings, that will cause downdrafts or insufficient draft or contribute to a faulty heating operation. Rust spots and soot-mold usually occur on deteriorated galvanized smoke pipe.

Fireplaces

Careful attention should be given to construction of the fireplace (Figure 12.23). Improperly built fireplaces are a serious safety and fire hazard. The most common causes of fireplace fires are thin walls, combustible materials such as studding or trim against sides and back of the fireplace, wood mantels, and unsafe hearths.

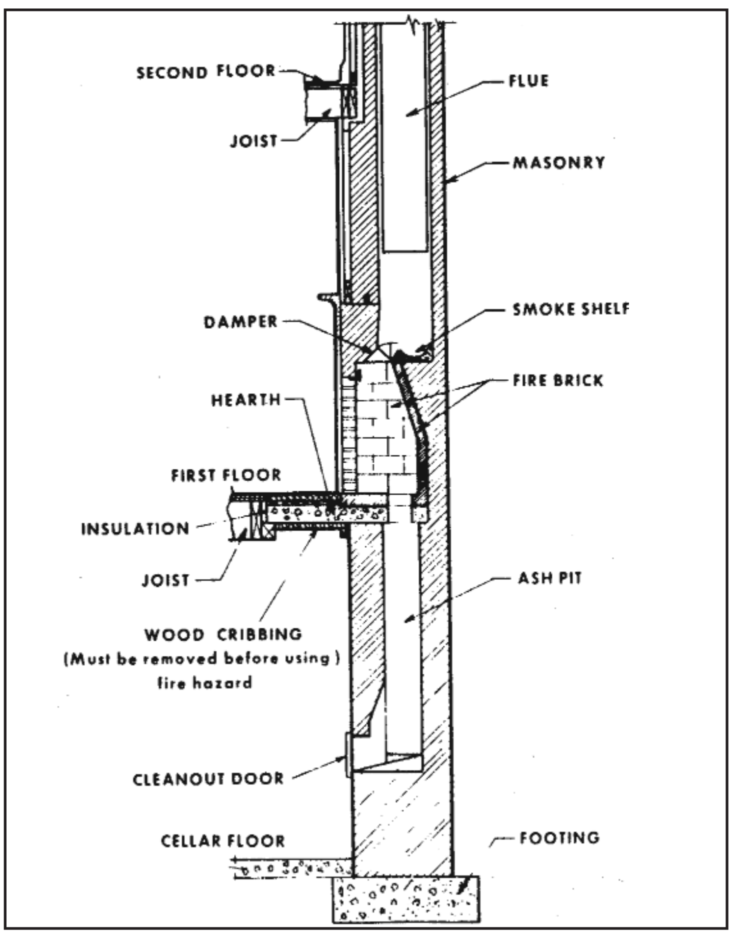


Figure 12.23. Fireplace Construction [4]

Fireplace walls should be no less than 8 inches thick; if built of stone or hollow masonry units, they should be no less than 12 inches thick. The faces of all walls exposed to fire should be lined with firebrick or other suitable fire-resistant material. When the lining consists of 4 inches of firebrick, such lining thickness may be included in the required minimum thickness of the wall.

The fireplace hearth should be constructed of brick, stone, tile, or similar incombustible material and should be supported on a fireproof slab or on a brick arch. The hearth should extend at least 20 inches beyond the chimney breast and no less than 12 inches beyond each side of the fireplace opening along the chimney breast. The combined thickness of the hearth and its supporting construction should be no less than 6 inches at any point. It is important that all wooden beams, joists, and studs are set off from the fireplace and chimney so that there is no less than 2 inches of clearance between the wood members and the sidewalls of the fireplace or chimney and no less than 4 inches of clearance between wood members and the back wall of the fireplace.

A gas-log set is primarily a decorative appliance. It includes a grate holding ceramic logs, simulated embers, a gas burner, and a variable flame controller. These sets can be installed in most existing fireplaces. There are two principal types: vented and unvented. Vented types require a chimney flue for exhausting the gases. They are only 20% to 30% efficient; and most codes require that the flue be welded open, which results in an easy exit path for heated room air. Unvented types operate like the burner on a gas stove and the combustion products are emitted into the room. They are more efficient because no heat is lost up the flue and most are equipped with oxygen-depletion sensors. However, unvented types are banned in some states, including Massachusetts and California. Gas fireplaces incorporate a gas-log set into a complete firebox unit with a glass door. Some have built-in dampers, smoke shelves, and heat-circulating features that allow them to provide both radiant and convective heat. Units can have push-button ignition, remote control, variable heat controls, and thermostats. Gas fireplaces are more efficient than gas logs, with efficiencies of 60% to 80%. Many draw combustion air in from the outside and are direct vented, eliminating the need for a chimney. Some of these units are wall-furnace rated. There are also electric fireplaces that provide the ambience of a fire and, if desired, a small amount of resistance heat. These units have no venting requirements. The advantages are that there are no ashes or flying sparks that occur with wood-burning fireplaces. They are not affected by wood-burning bans imposed in some areas when air quality standards are not met. Direct-vented gas or electric models eliminate the need for a chimney.

The disadvantages are that the cost for equipment and running the gas line can be high.

References

1. US Census Bureau. Rooms, number of bedrooms, and house heating fuel: 2000. Census 2000 Summary File 4 (SF4). Washington, DC: US Census Bureau; 2000. Available from URL: http://factfinder.census.gov [select Data Sets, then select Census 2000 Summary File 4 (SF 4) - Sample Data].

2. National Energy Efficiency Committee. Building: heat pumps; application of heat pumps in Singapore. Singapore: National Environment Agency; 2003. Available from URL: http://www.neec.gov.sg/building/heat_pump.shtm.

3. National Energy Efficiency Committee. Renewables: solar energy. Singapore: National Environment Agency; no date. Available from URL: http://www.neec.gov.sg/renewables/solar.shtm.

4. Center for Disease Control. Basic housing inspection. Atlanta: US Department of Health and Human Services; 1976.

5. Fairfax County. Fuel storage tanks. Fairfax, VA: Fairfax County; 2004. Available from URL: http://www.co.fairfax.va.us/dpwes/construction/fuel_tanks.htm.

6. Wisconsin Department of Commerce. Environmental services—residential fuel oil and gasoline storage tanks. Madison, WI: Wisconsin Department of Commerce; 2004. Available from URL: http://www.commerce.state.wi.us/ER/ER-BST-ResTk.html.

7. Michigan Department of Environmental Quality. FAQ: Home heating oil tanks, Lansing, MI: Michigan Department of Environmental Quality; no date. Available from URL: http://www.michigan.gov/deq/0,1607,7-135-3311_4115_4238-9379--,00.html.

8. US Environmental Protection Agency. Overview of the federal underground storage tank program. Washington, DC: U.S. Environmental Protection Agency; no date. Available from URL: http://www.epa.gov/swerust1/overview.htm.

9. US Department of Housing and Urban Development. Initiatives Programs. Washington, DC: US Department of Housing and Urban Development; 2004. Available from URL: http://www.hud.gov/offices/cpd/energyenviron/energy/initiatives.

10. US Environmental Protection Agency. Sources of indoor air pollution—asbestos. Washington, DC: U.S. Environmental Protection Agency; no date. Available from URL: http://www.epa.gov/iaq/asbestos.html.

11. The Commonwealth of Massachusetts Board of Building Regulations and Standards (BBRS). Hydronic system requirements. Boston: The Commonwealth of Massachusetts Board of Building Regulations and Standards (BBRS); no date. Available from URL: http://www.mass.gov/bbrs/commntry/cmpxhydr.htm.

Additional Sources of Information

McQuiston FC, Parker JD, Spitler JD. Heating, ventilation, and air conditioning: analysis and design. 5th ed. Hoboken, NJ: John Wiley and Sons, Inc.; 2000.

Kittle JL. Home heating and air conditioning systems. New York: McGraw-Hill; 1990.

Pita EG. Air conditioning principles and systems: an energy approach. 4th ed. New York: Prentice Hall; 2001.