

Audel™

**HVAC Fundamentals
Volume 3**

**Air-Conditioning, Heat
Pumps, and Distribution
Systems**

All New 4th Edition

James E. Brumbaugh



Wiley Publishing, Inc.

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For Laura, my friend, my daughter.

Introduction

The purpose of this series is to provide the layman with an introduction to the fundamentals of installing, servicing, troubleshooting, and repairing the various types of equipment used in residential and light-commercial heating, ventilating, and air conditioning (HVAC) systems. Consequently, it was written not only for the HVAC technician and others with the required experience and skills to do this type of work but also for the homeowner interested in maintaining an efficient and trouble-free HVAC system. A special effort was made to remain consistent with the terminology, definitions, and practices of the various professional and trade associations involved in the heating, ventilating, and air conditioning fields.

Volume 1 begins with a description of the principles of thermal dynamics and ventilation, and proceeds from there to a general description of the various heating systems used in residences and light-commercial structures. Volume 2 contains descriptions of the working principles of various types of equipment and other components used in these systems. Following a similar format, Volume 3 includes detailed instructions for installing, servicing, and repairing these different types of equipment and components.

The author wishes to acknowledge the cooperation of the many organizations and manufacturers for their assistance in supplying valuable data in the preparation of this series. Every effort was made to give appropriate credit and courtesy lines for materials and illustrations used in each volume.

Special thanks is due to Greg Gyorda and Paul Blanchard (Watts Industries, Inc.), Christi Drum (Lennox Industries,

Inc.), Dave Cheswald and Keith Nelson (Yukon/Eagle), Bob Rathke (ITT Bell & Gossett), John Spuller (ITT Hoffman Specialty), Matt Kleszezynski (Hydrotherm), and Stephanie DePugh (Thermo Pride).

Last, but certainly not least, I would like to thank Katie Feltman, Kathryn Malm, Carol Long, Ken Brown, and Vincent Kunkemueller, my editors at John Wiley & Sons, whose constant support and encouragement made this project possible.

James E. Brumbaugh

About the Author

James E. Brumbaugh is a technical writer with many years of experience working in the HVAC and building construction industries. He is the author of the *Welders Guide*, *The Complete Roofing Guide*, and *The Complete Siding Guide*.

Chapter 1

Radiant Heating

Heat is lost from the human body through radiation, convection, and evaporation. Radiation heat loss represents the transfer of energy by means of electromagnetic waves. The convection loss is the heat carried away by the passage of air over the skin and clothing. The evaporation loss is the heat used up in converting moisture on the surface of the skin into vapor.

Heat transfer, whether by convection or radiation, follows the same physical laws in the radiant heating system as in any other; that is, heat flows from the warmer to the cooler exposure at a rate directly proportional to the existing temperature difference.

The natural tendency of warmed air to rise makes it apparent that this induced air current movement is greater at the cooler floor and exterior walls of the average heated enclosure than at its ceiling. It is through absorption by these air currents that the radiant panel releases the convection component of its heat transfer into the room air.

The average body heat loss is approximately 400 Btu per hour; total radiation and convection account for approximately 300 to 320 Btu of it. Because this is obviously the major portion, the problem of providing comfort is principally concerned with establishing the proper balance between radiation and convection losses.

It is important to understand that bodily comfort is obtained in radiant heating by maintaining a proper balance

between radiation and convection. Thus, if the air becomes cooler and accordingly the amount of heat given off from the body by convection *increases*, then the body can still adjust itself to a sense of comfort if the heat given off from the body by radiation is *decreased*. The amount given off from the body by radiation can be decreased by raising the temperature of the surrounding surfaces, such as the walls, floor, and ceiling. For comfort, the body demands that if the amount of heat given off by convection increases, the heat given off by radiation must decrease, and vice versa.

The principles involved in radiant heating exist in such commonplace sources of heat as the open fireplace, outdoor campfires, electric spot heaters, and similar devices. In each of these examples, no attempt is made to heat the air or enclosing surfaces surrounding the individual. In fact, the temperature of the air and surrounding surfaces may be very low, but the radiant heat from the fireplace or campfire will still produce a sensation of comfort (or even discomfort from excess heat) to those persons within range. This situation can occur even though a conventional thermometer may indicate a temperature well below freezing. Radiant heat rays do not perceptibly heat the atmosphere through which they pass. They move from warm to colder surfaces where a portion of their heat is absorbed.

This chapter is primarily concerned with a description of radiant panel heating, which can be defined as a form of radiant heating in which large surfaces are used to radiate heat at relatively low temperatures. The principal emphasis will be on hydronic and electric radiant floor heating.

Types of Radiant Panel Heating Systems

Radiant panel heating systems use water-filled tubing or electric heating mats or rolls installed in the floors, walls, and ceilings to distribute the heat. Radiant floor heating is by far the most popular installation method in residential and light-commercial construction.

Note

The word *panel* is used to indicate a complete system of tubing loops in a single room or space in a structure. It may also be used to indicate a premanufactured radiant floor heating panel.

Floor Panel Systems

Floor panels are usually easier to install than either ceiling or wall panels. Using floor panels is the most effective method of eliminating cold floors in slab construction. Another advantage of heating with floor panels is that much of the radiated heat is delivered to the lower portions of the walls. The principal disadvantage of using floor panels is that furniture and other objects block portions of the heat emission.

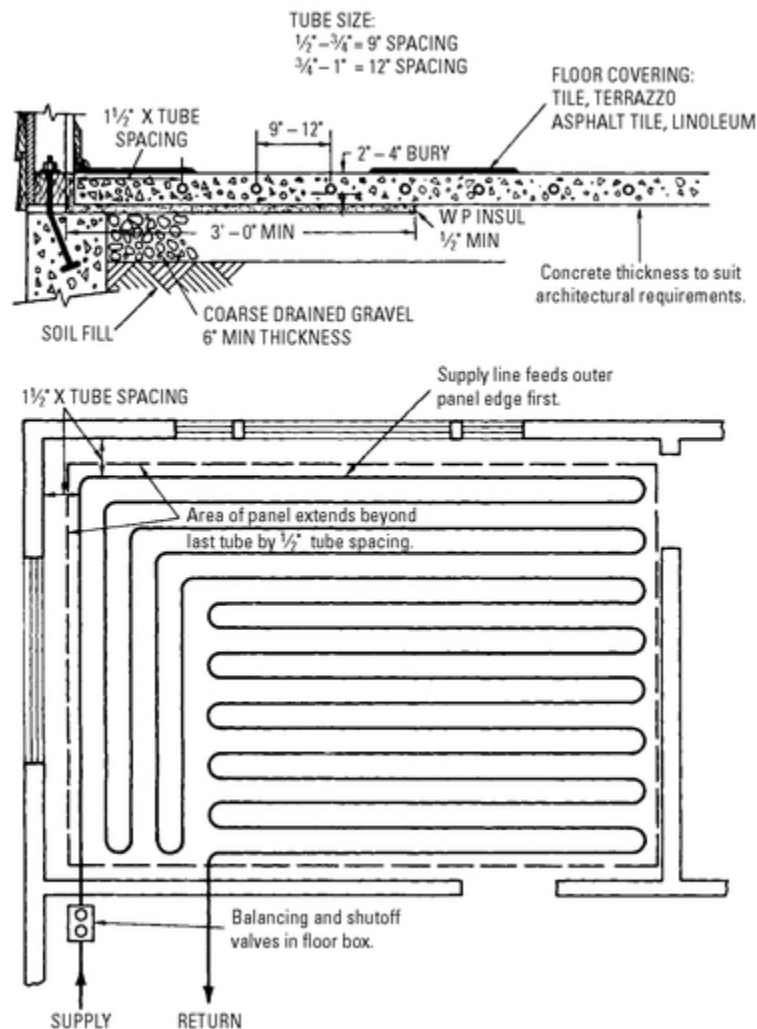
Floor panels are recommended for living or working areas constructed directly on the ground, particularly one-story structures. Partial ceiling or wall treatment may be used as a supplement wherever large glass or door exposures are encountered. A typical floor installation is shown in [Figure 1-1](#).

Ceiling Panel Systems

The advantage of a ceiling panel is that its heat emissions are not affected by drapes or furniture. As a result, the

entire ceiling area can be used as a heating panel. Ceiling panels are recommended for rooms or space with 7-foot ceilings or higher. A ceiling panel should never be installed in a room with a low ceiling (under 7 feet) because it may produce an undesirable heating effect on the head.

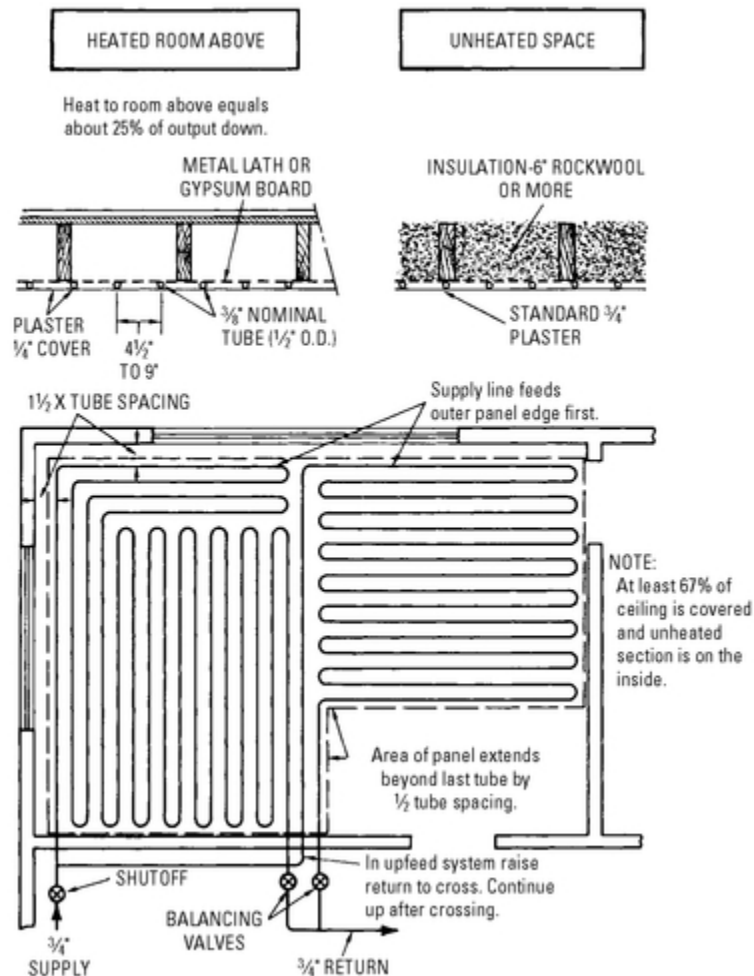
Figure 1-1 Diagram of a typical radiant floor heating installation.



In multiple-story construction, the use of ceiling panels appears to be more desirable from both the standpoint of physical comfort and overall economy. The designed

utilization of the upward heat transmission from ceiling panels to the floor of the area immediately above will generally produce moderately tempered floors. Supplementing this with automatically controlled ceiling panels will result in a very efficient radiant heating system. Except directly below roofs or other unheated areas, this design eliminates the need for the intermediate floor insulation sometimes used to restrict the heat transfer from a ceiling panel exclusively to the area immediately below. It must be remembered, however, that when intermediate floor insulations are omitted, the space above a heated ceiling will not be entirely independent with respect to temperature control but will necessarily be influenced by the conditions in the space below. A typical ceiling installation is shown in [Figure 1-2](#).

[Figure 1-2](#) Diagram of a typical radiant ceiling heating panel.



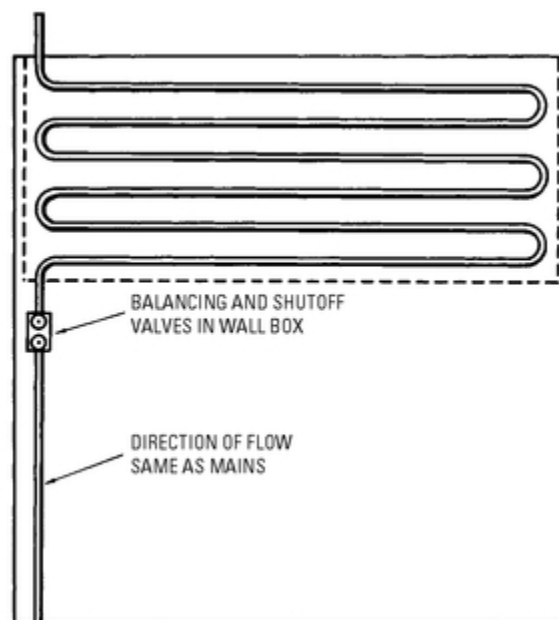
Apartment buildings and many office and commercial structures should find the ceiling panel method of radiant heating most desirable. In offices and stores, the highly variable and changeable furnishings, fixtures, and equipment favor the construction of ceiling panels, to say nothing of the advantage of being able to make as many partition alterations as desired without affecting the efficiency of the heating system.

Wall Panel Systems

Walls are not often used for radiant heating because large sections of the wall area are often interrupted by windows and doors. Furthermore, the heat radiation from heating coils placed in the lower sections of a wall will probably be blocked by furniture. As a result, a radiant wall installation is generally used to supplement ceiling or floor systems, not as a sole source of heat.

Wall heating coils are commonly used as supplementary heating in bathrooms and in rooms in which there are a number of large picture windows. In the latter case, the heating coils are installed in the walls opposite the windows. Wall heating coils will probably not be necessary if the room has good southern exposure. A typical wall installation is shown in [Figure 1-3](#).

[Figure 1-3](#) Typical wall installation. Panel is installed on wall as high as possible.



Hydronic Radiant Floor Heating

Hydronic radiant floor systems heat water in a boiler, heat pump, or water heater and force it through tubing arranged in a pattern of loops located beneath the floor surface. These systems can be classified as being either wet installations or dry installations depending on how the tubing is installed.

In wet installations, the tubing is commonly embedded in a concrete foundation slab or attached to a subfloor and covered with a lightweight concrete slab. Dry installations are so called because the tubing is not embedded in concrete.

System Components

The principal components of a typical hydronic radiant floor heating system can be divided into the following categories:

1. Boilers, water heaters, and heat pumps
2. Tubing and fittings
3. Valves and related controls
4. Circulator
5. Expansion tank
6. Air separator
7. Heat exchanger
8. Thermostat

Boilers, Water Heaters, and Heat Pumps

The boilers used in hot-water radiant heating systems are the same types of heating appliances as those used in hydronic heating systems. Information about the installation, maintenance, service, and repair of hydronic boilers is contained in Chapter 15 of Volume 1.

Gas-fired boilers are the most widely used heat source in hydronic radiant heating systems. Oil-fired boilers are second in popularity and are used most commonly in the northern United States and Canada. Coal-fired boilers are still found in some hydronic radiant heating systems, but their use has steadily declined over the years.

Note

Hydronic radiant floor heating systems operate in an 85-140°F (29-60°C) temperature range. This is much lower than the 130- 160°F (54-71°C) temperature operating range required in other hydronic systems. As a result, the boilers used in floor systems operate at lower boiler temperatures, which results in a much longer service life for the appliance.

The electric boilers used in hydronic radiant floor systems are competitive with other fuels in those areas where electricity costs are low. Their principal advantage is that they are compact appliances that can be installed where space is limited.

Radiant floor systems can also be heated with a geothermal heat pump. In climates where the heating and cooling loads are equal or almost equal in size, a geothermal heat pump will be very cost effective.

Most standard water heaters produce a maximum of 40,000 to 50,000 Btu/h. This is sufficient Btu input to heat a small house or to separately heat a room addition, but it cannot provide the heat required for medium to large houses. As a result, some HVAC manufacturers have developed high-Btu-output dedicated water heaters for radiant heating systems. These water heaters are designed specifically as single heat sources for both the domestic hot water and the space-heating requirements. As is the case with boilers used in hydronic radiant heating systems, they

operate in conjunction with a circulating pump and an expansion tank. See Chapter 4 (“Water Heaters”) for additional information about combination water heaters.

Tubing and Fittings

The tubing in a radiant heating system is divided into the supply and return lines. The *supply line* extends from the discharge opening of a boiler to the manifold. It carries the heated fluid to the loops (circuits) in the floors, walls, or ceilings. A *return line* extends from the return side of a manifold to the boiler. It carries the water from the heating panels back to the boiler where it is reheated.

Hydronic radiant floor heating systems use copper, plastic (PEX or polybutylene tubing), or synthetic-rubber tubing to form the loops. Because of space limitations, only the two most commonly used types are described in this chapter: copper tubing and PEX (plastic) tubing. Information about the other types of tubing used in hydronic heating systems can be found in Chapter 8 (“Pipes, Pipe Fittings, and Piping Details”) of Volume 2.

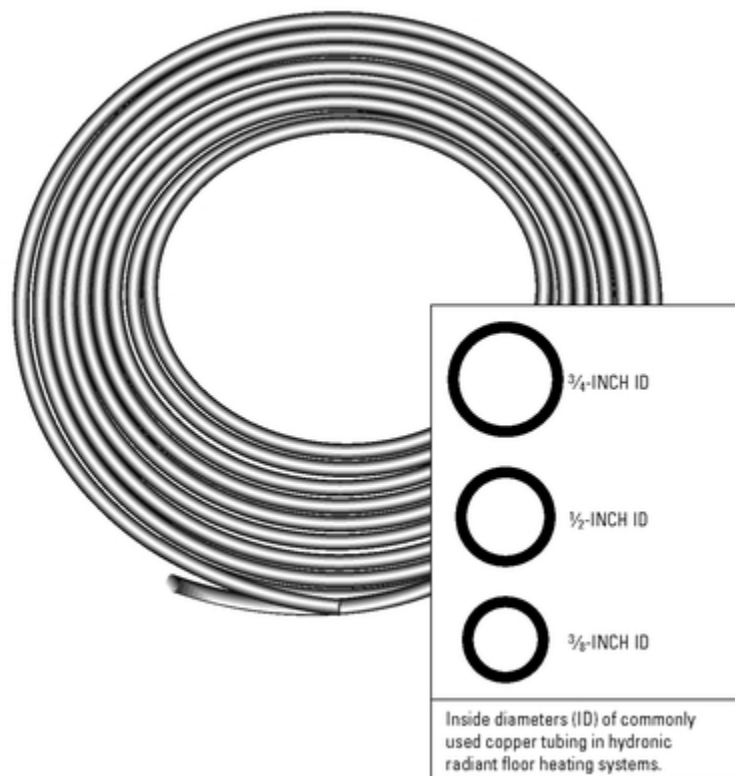
Loops or Circuits

The words *loop* and *circuit* are synonyms for the length of tubing within a zone. Sometimes both are used in the same technical publication. At other times, one or the other is used exclusively. Many loops or circuits of the same length will form a zone. Circuits also refer to the electrical circuit required to operate the heating system.

Copper Tubing

In most modern radiant floor heating systems, the water is circulated through copper or cross-linked polyethylene (PEX) tubing (see [Figure 1-4](#)). The metal coils used in hydronic radiant heating systems commonly are made of copper tubing (both the hard and soft varieties). Steel and wrought-iron pipe also have been used in hydronic floor heating systems, but it is rare to find them in modern residential radiant floor heating systems.

[Figure 1-4](#) Copper tubing.



The soft tempered Type L copper tubing is recommended for hydronic radiant heating panels. Because of the relative ease with which soft copper tubes can be bent and shaped, they are especially well adapted for making connections around furnaces, boilers, oilburning equipment, and other

obstructions. This high workability characteristic of copper tubing also results in reduced installation time and lower installation costs. Copper tubing is produced in diameters ranging from 1/8 inch to 10 inches and in a variety of different wall thicknesses. Both copper and brass fittings are available. Hydronic heating systems use small tube sizes joined by soldering.

The size of the pipes or tubing used in these systems depends on the flow rate of the water and the friction loss in the tubing. The *flow rate* of the water is measured in gallons per minute (gpm), and constant *friction loss* is expressed in thousandths of an inch for each foot of pipe length. For a description of the various types of tubing used in hydronic heating systems, see the appropriate sections of Chapter 8 (“Pipes, Pipe Fittings, and Piping Details”) in Volume 2.

Most of the fittings used in hydronic radiant heating systems are typical plumbing fittings. They include couplings (standard, slip, and reducing couplings), elbows (both 45° and 90° elbows), male and female adapters, unions, and tees (full size and reducing tees) (see [Figure 1-5](#)).

Three special fittings used in hydronic radiant heating systems are the brass adapters, the brass couplings, and the repair couplings. A *brass adapter* is a fitting used to join the end of a length of 3/4-inch diameter copper tubing to the end of a length of plastic polyethylene tubing. A *brass coupling*, on the other hand, is a fitting used to join two pieces of plastic heat exchanger tubing. A *repair coupling* is a brass fitting enclosed in clear vinyl protective sheath to prevent concrete from corroding the metal fitting. The fitting is strengthened by double-clamping it with stainless steel hose clamps.

A decoiler bending device or jig should be used to bend metal tubing into the desired coil pattern. Only soft copper

tubing can be easily bent by hand. It is recommended that a tube bender of this type be made for each of the different center-to-center spacing needed for the various panel coils in the installation.

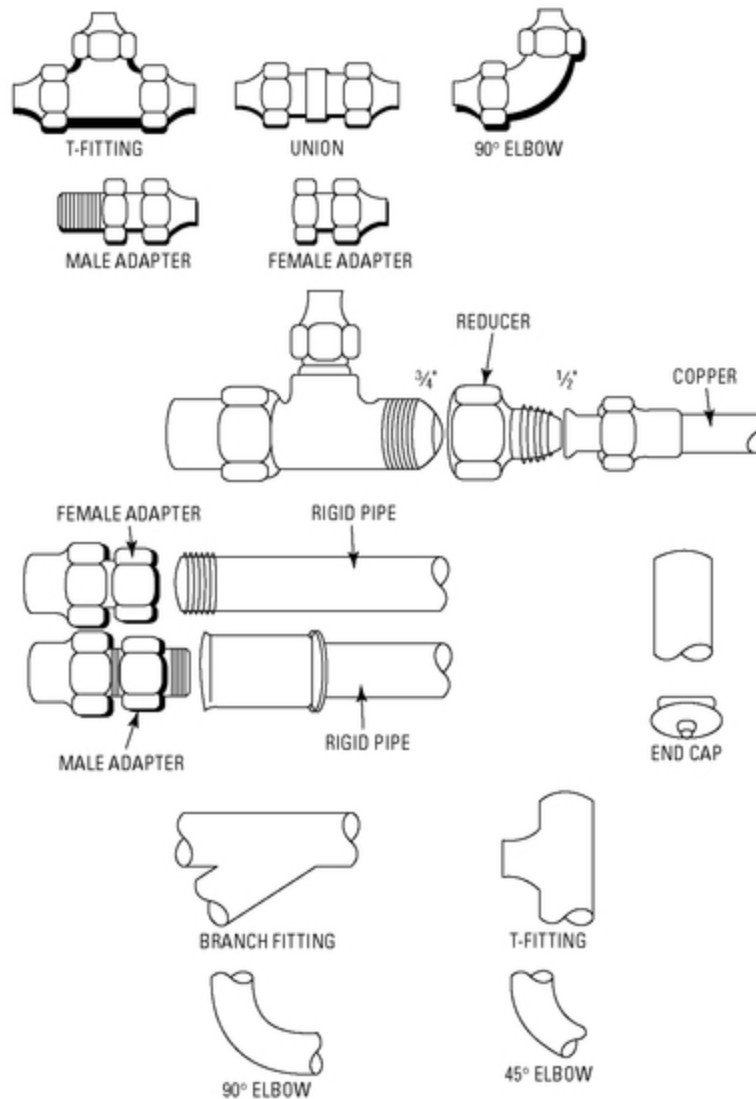
Soft copper tubing is commonly available in coil lengths of 40 feet, 60 feet, and 100 feet. When the tubing is uncoiled, it should be straightened in the trough of a straightener jig. For convenience of handling, the straightener should not be more than 10 feet long.

Note

Most copper tubing leaks will occur at bends or U-turns in the floor loops. These leaks are caused by water or fluids under high pressure flowing through the weakened sections of tubing. The weakened metal is commonly caused by improper bending techniques.

Whenever possible, continuous lengths of tubing should be used with as few fitting connections as possible. Coils of 60 feet or 100 feet are best for this purpose and are generally preferred for floor panels. The spacing between the tubing should be uniform and restricted to 12 inches or less. Use soldered joints to make connections between sections of tubing or pipe.

Figure 1-5 Some examples of copper tubing fittings.



Cross-Linked Polyethylene (PEX) Tubing

Cross-linked polyethylene (PEX) tubing is commonly used indoors in hydronic radiant heating panels or outdoors embedded beneath the surface of driveways, sidewalks, and patios to melt snow and ice. It is made of a high-density polyethylene plastic that has been subjected to a cross-linking process (see [Figures 1-6](#), [1-7](#), and [1-8](#)). It is flexible, durable, and easy to install. There are two types of PEX tubing: