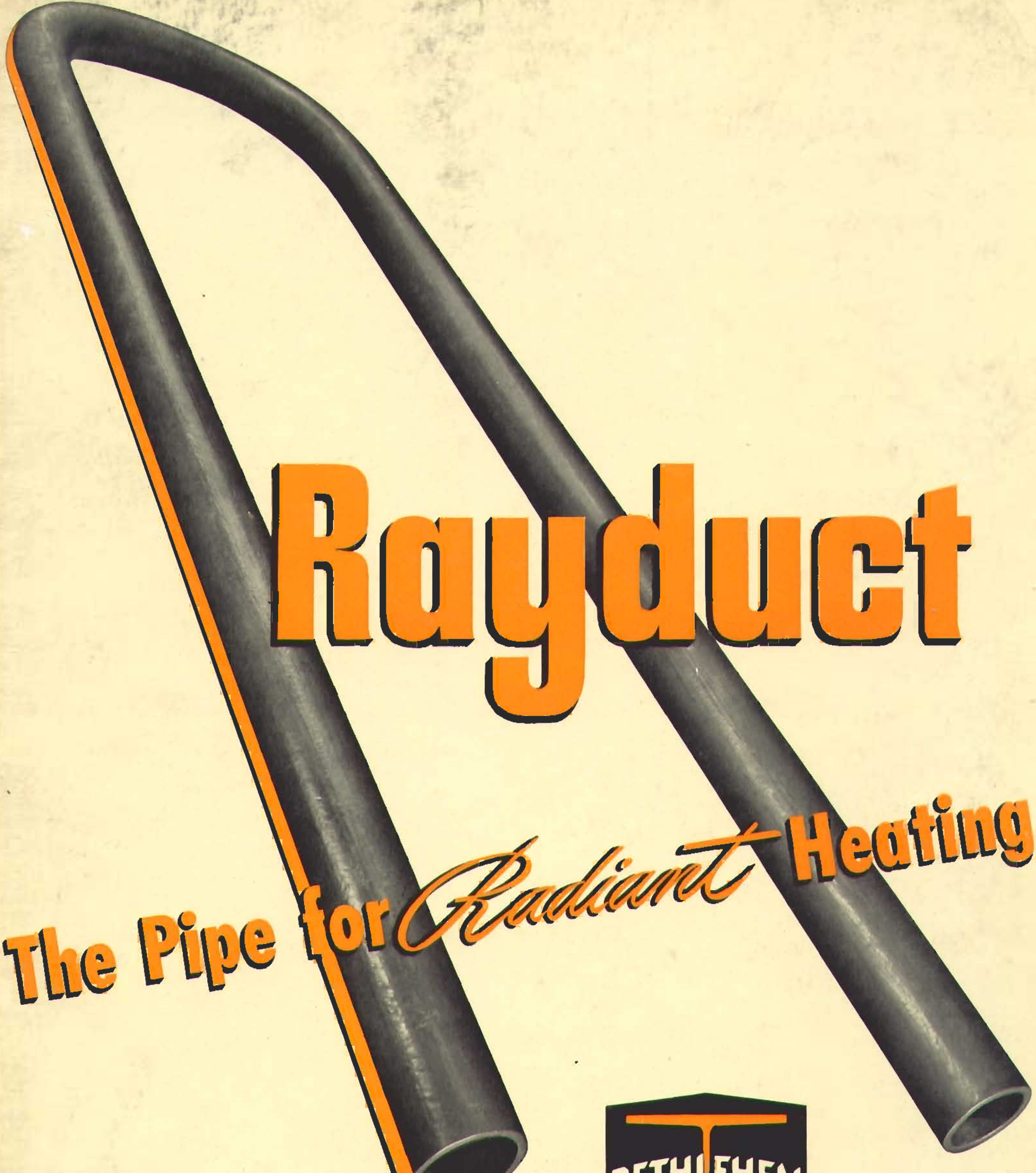
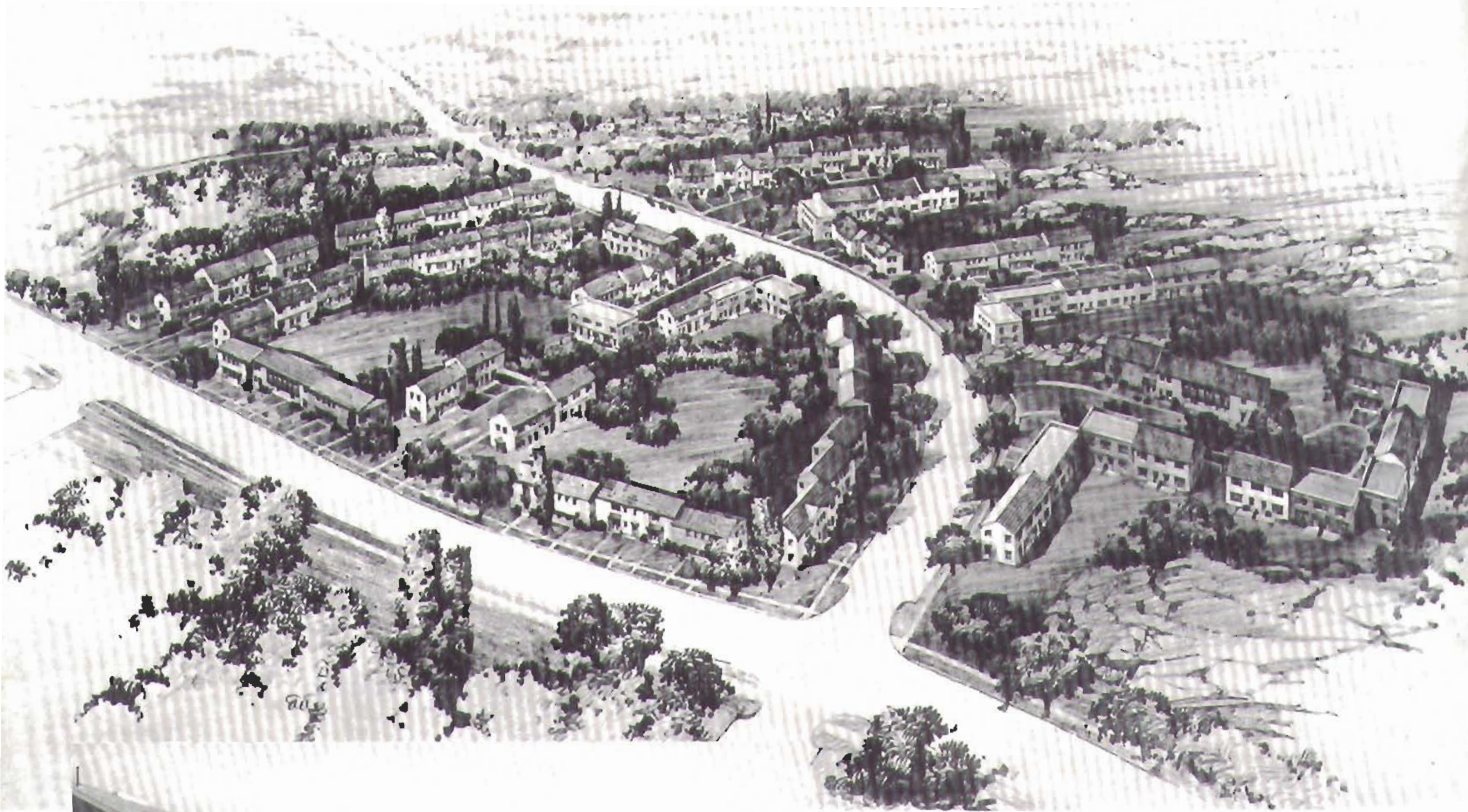
Rayduct

The Pipe for *Radiant* Heating



BETHLEHEM STEEL

BOOKLET 225-A



RAYDUCT FLOOR COILS USED IN HANCOCK VILLAGE

Hancock Village, a new apartment project at West Roxbury and Brookline, Mass., is owned and operated by the John Hancock Mutual Life Insurance Co., of Boston. It consists of 789 two-story units, of varying architectural designs. Each home is heated by means of Rayduct floor coils, carrying warm water from gas-fired boilers. Shown here are: (top) architect's rendering of project, (bottom) homes under construction, with Rayduct coils in place in foreground, and (center) a section showing buildings completed.

Rayduct

THE PIPE FOR RADIANT HEATING

Information on Radiant Heating prepared especially for this book by
RAYMOND VINER HALL, R.A., A.I.A., Lynn Hall, Port Allegany, Pa.
Radiant Heating Consultant

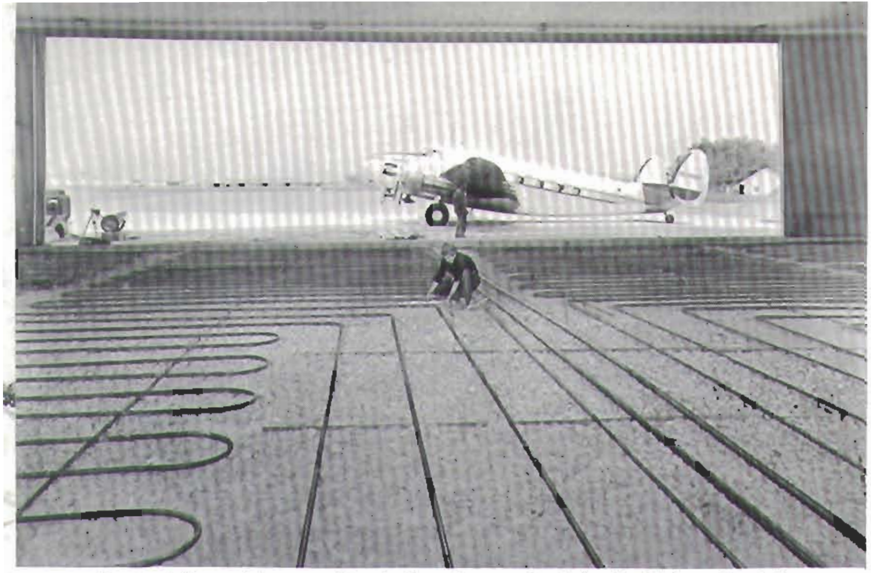
RADIANT HEATING is today one of the most widely discussed subjects among people interested in the heating of homes and other buildings. However, because the idea of heating interiors by means of pipe coils embedded in concrete or plaster, in floors, walls, or ceilings, is still relatively new in this country, there are comparatively few people who are in position to know all, or for that matter, even the majority of the answers to radiant-heating problems.

In fact, while a recent poll taken among heating contractors disclosed an intense interest in this form of heating, practically all those interviewed stated that they had little or no practical experience with radiant-heating installations.

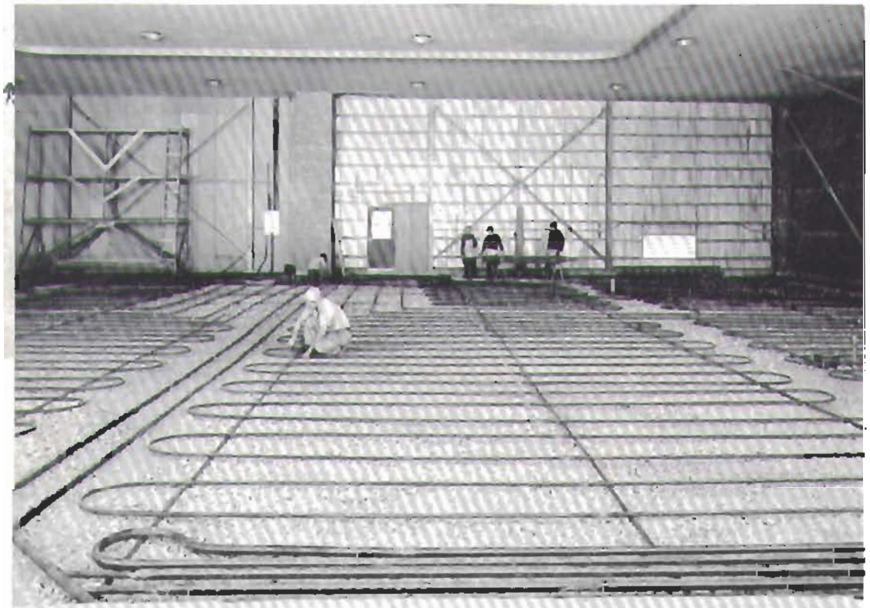
While making no attempt to advocate any particular type of heating, this manual is presented in an effort to throw some light on the principal problems encountered in the design of a radiant-heating system. At the same time it will be pointed out how Rayduct, the steel pipe of extra-high ductility made by Bethlehem for use in installations of this type, offers practical and economic advantages in the fabrication of the extensive coil assemblies which form a major part of a radiant-heating system.

Rayduct is made by the continuous-weld process from a low-carbon open-hearth steel of extra-low metalloid content. Due to this special analysis and the method of manufacture, Rayduct is extremely tough and ductile, and highly uniform in physical properties and dimensions.

BETHLEHEM STEEL COMPANY BETHLEHEM STEEL BETHLEHEM, PA.



Rayduct floor piping used in airplane hangar built for Bethlehem Steel Company at Allentown-Bethlehem Airport, Pa.



Another view of radiant-heating system in airplane hangar. Note concentration of pipes (*foreground*), to compensate for heat loss when doors are opened.

Warm water, circulating through Rayduct piping buried in concrete under hangar doors, keeps ice from forming, and makes doors easy to open.

Some Facts about Rayduct

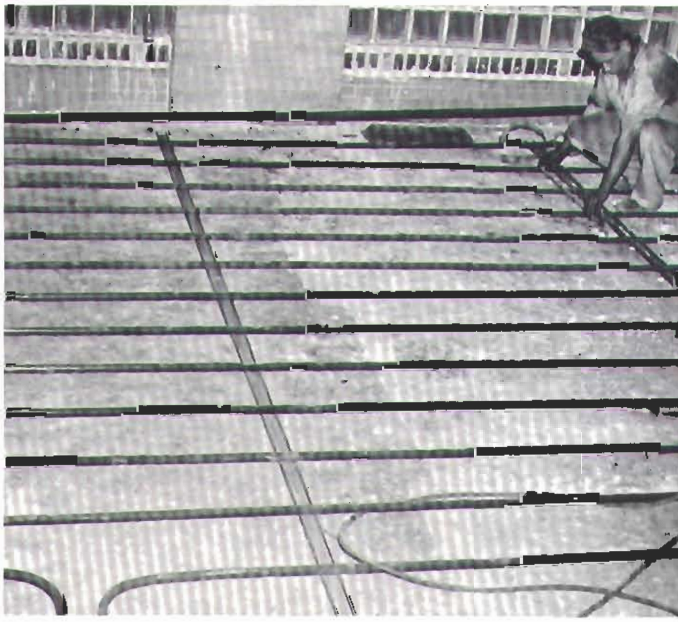
Fabrication

Rayduct is so ductile that it can be bent cold and close-coiled with minimum effort, and without any need of filler. As no annealing is required, this cold-bending may be carried out in the field, without elaborate equipment. The cold bends are as tough and strong as hot bends made with regular steel pipe of the same dimensions.

Welding

Besides ease of fabrication, good welding properties are a prime requisite in pipe used in radiant-heating systems. Here again Rayduct stands out. It can be readily welded by all commonly used methods, and any workman with ordinary welding experience can make tight, sound welds, free from pinholes.

Type of floor piping used in the office building on the opposite pa



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Corrosion

Heating experts generally agree that in a properly designed radiant-heating installation, corrosion is of little or no consequence. In the first place, the water circulated is not as hot as in regular domestic hot-water systems, and corrosion is very much less at lower temperatures. Second, and what is still more important, the heating system is closed, that is, the same water remains in the pipes year after year, except for the small amount of make-up water needed from time to time. Any corrosive action caused by the original water, which, incidentally, is negligible even in the worst cases, is completed in the early life of the installation.

Furthermore, Rayduct has stood the test of time effectively in applications where corrosion is far more of a problem than in radiant heating, such as in piping for ice-skating rinks, with brine being used as the refrigerant, and in train-line piping for air and steam.

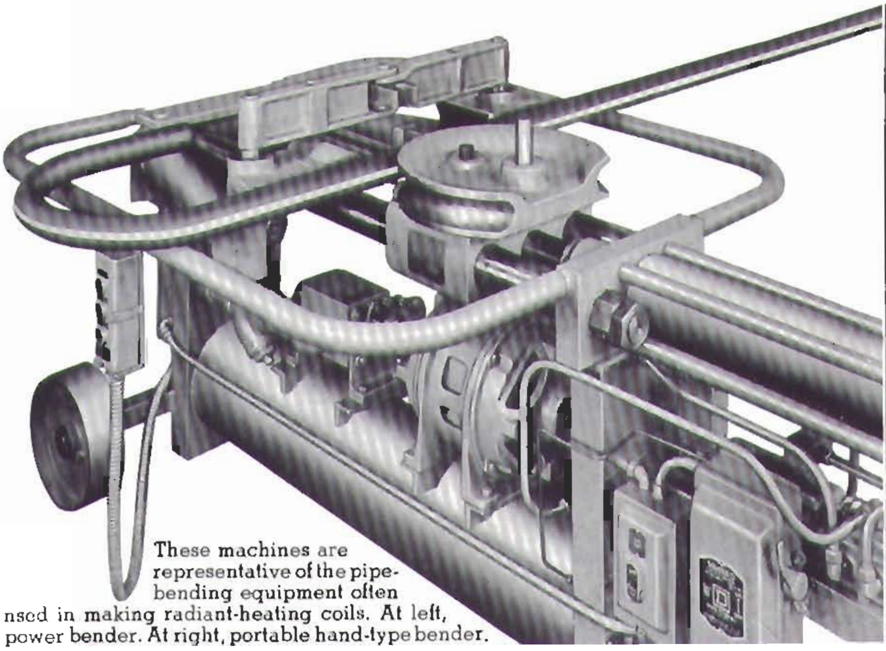
Expansion

Concern is sometimes expressed about the effect of thermal expansion when a pipe carrying hot water is embedded in concrete or plaster. This should not create any serious problem, due to the fact that Rayduct, like all other ferrous materials, has practically the same coefficient of expansion as concrete and plaster. No trouble from uneven expansion or contraction may thus be expected, when the pipe coils are embedded in floors, walls, or ceilings.

Same Price as Regular Steel Pipe

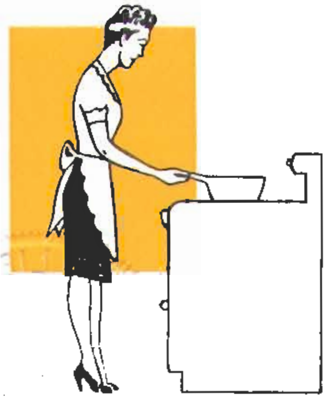
Rayduct is furnished in uniform 21-ft lengths, plus or minus 1 in., in diameters from ½ in. to 3 in., standard weight and extra-strong. In spite of its marked advantages in radiant-heating installations, Rayduct is inexpensive. It sells for the same price as regular merchant steel pipe.

Rayduct is used in the floor-type radiant-heating system in this office building at Columbia, S. C.




These machines are representative of the pipe-bending equipment often nsed in making radiant-heating coils. At left, power bender. At right, portable hand-type bender.

What is Radiant Heating?



CONDUCTION

To reach the water in which potatoes are boiling, heat from the burner passes through the metal walls of the sauce-pan by conduction—one of the three ways in which heat is transmitted.

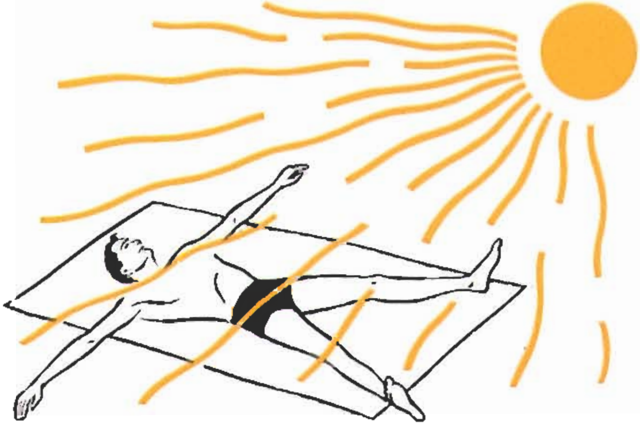
Heat is conveyed in three principal ways: by conduction, by convection, and by radiation.

When water is heated on a stove, the heat from the burner of the stove passes through the metal bottom of the cooking utensil by conduction. Convection occurs, for example, when hot air from a furnace is carried to the rooms of a house by natural draft or by a fan. The heat from the sun passing through space reaches the earth purely by radiation.

All surfaces at a temperature above absolute zero radiate heat. Invisible radiation of heat from an object like a radiator or a heated panel differs from solar radiation in one important respect: it has much longer wave length. Otherwise it follows the same physical laws. All heat waves travel at the same speed and radiate from the heat source in all directions. What happens when they strike an object depends on the nature of the material; they may be transmitted, or reflected, or absorbed or all three.

The bodily processes of living generate an amount of excess heat in the human body which must be given off if body temperature is to be maintained at an even level. This excess heat may be dissipated in several ways. One is the loss of heat from the skin by convection, that is, by cooler air passing over the skin, and by radiation to the colder surroundings. At the same time the body is also receiving heat from the sun as well as from nearby objects of higher temperature than the body. As soon as the net loss of heat from the body exceeds the heat that must be dissipated we begin to "feel cold."

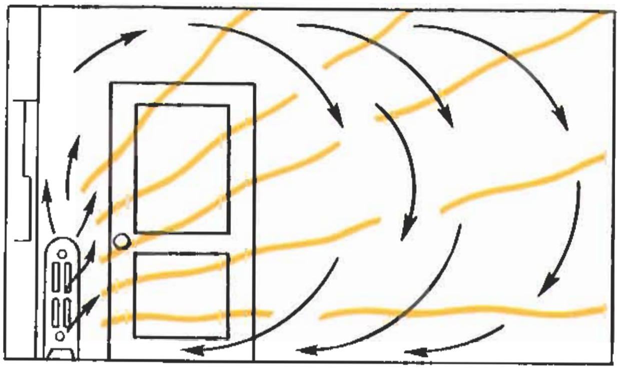
Heating systems are designed for conveying heat either by convection, conduction or radiation or by a combination. In the case of a steam or hot-water



RADIATION

Radiated heat is transmitted from the heat source (the sun, in the sketch above) to an object (the sun-bather) by means of radiant heat waves, without appreciably heating the intervening medium (the air). The yellow arrows indicate radiant heat.

radiator, for example, the major portion of the heat is given off by conduction from the hot radiator surfaces to the air, thence by convection. In addition, however, the radiator gives off a good deal of heat by radiation which can be sensed by the feeling of warmth.



CONVECTION
The radiator warms the air surrounding it, and the lighter heated air moves upward, establishing a current, as shown by the black arrows. When heat is transmitted in this way we call it Convection. In addition, a portion of the heat from the radiator warms objects in the room by radiation (yellow lines).

What Radiant Heating Is

"Radiant Heating" denotes a system which heats a room by use of the floor, ceiling or walls as heating panels to radiate heat to the interior. Most contemporary radiant-heating systems have extensive pipe coils in the floor structure or in the walls and ceiling if these are to be used as heating panels. When a concrete floor slab is used, the

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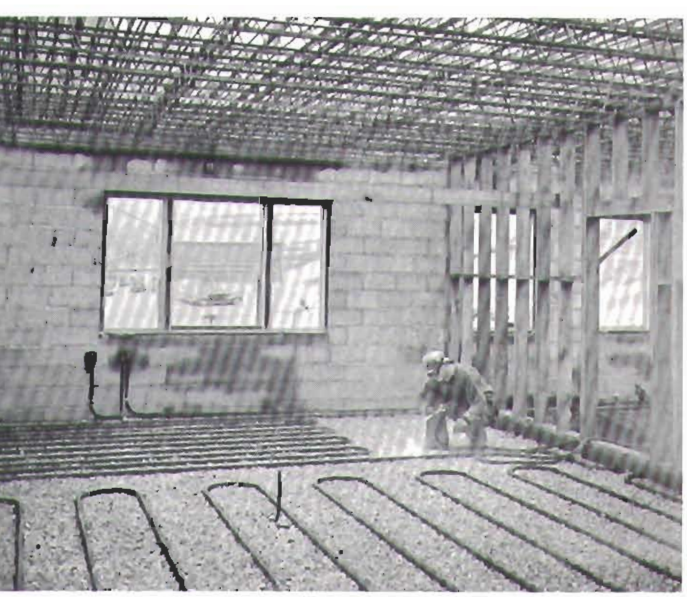
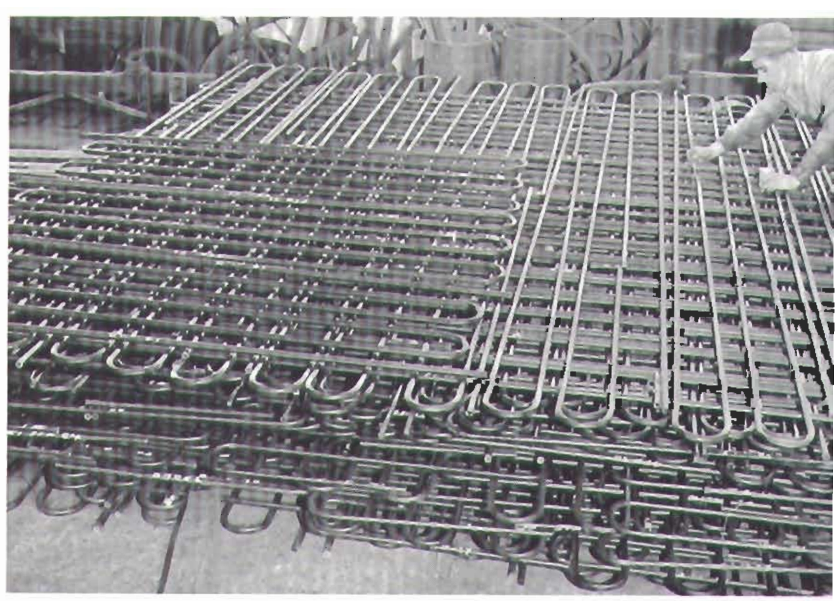
pipe coils are often embedded in the concrete, or they may be run between the floor joists.

The heating medium, generally water, is circulated through these pipe coils. It will be apparent that, due to the very large heating surfaces, the temperature of the source of heat can be kept a good deal lower than in conventional radiator systems, except in the case of pipes in joist spaces. As the term radiant heating implies, the heat is conveyed mainly by radiation. The amount of heat transmitted by convection, that is, by first heating the surrounding air, varies with the placement of the heated panel, but is generally of secondary importance.

In conventional heating systems, where the heat is distributed through the room mainly by convection, relatively high air temperatures must be maintained to insure bodily comfort. Convection currents, caused by the tendency of hot air to rise and cold air to sink, necessarily cause drafts and uneven temperatures from wall to wall and from floor to ceiling. Furthermore, the greatest heat is concentrated where it is not needed and does

Ground floor piping in office building, showing Rayduct being welded. Rayduct floor coils are also used in heating the second floor of this structure. Right: Pile of prefabricated Rayduct coils ready for shipment to project in Metropolitan area.

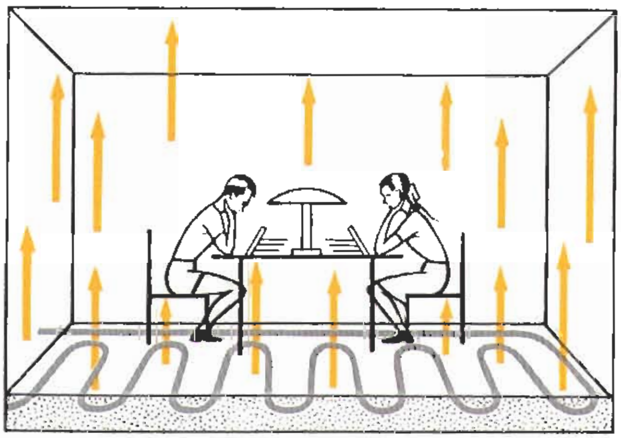




HEAT-LOSS TABULATION

SURFACE	FACTOR	ROOM #1	REPEAT FOR EACH ROOM
Ceiling, Roof or Floor*	Factor = Btu/sq ft U x $(T_1 - T_2)$ = Factor	Area x Factor = Btu	
Int. Wall (to unheated rooms)	x =	x =	
Ext. Glass	x =	x =	
Ext. Doors	x =	x =	
Ext. Wall	x =	x =	
Infiltration**	.018 x $(T_1 - T_2)$ = Factor	Volume x Factor = Btu	
Total Btu			
Btu/sq ft heated surface = $\left(\frac{\text{Total Btu}}{\text{Area heated surface}}\right)$			
Btu Loss from heated surface to exterior (Obtained from Figure 1, 9, or 14)			
TOTAL Btu LOSS***			

*Loss through unheated surfaces only. Allowance for this factor has been made in Figures 1, 9 and 14.
**Volume of fresh air to be heated.
***For use in sizing take-offs, mains, circulators and boilers.



RADIANT-HEATED ROOM—FLOOR TYPE

Warm water circulating through pipes embedded in the concrete floor slab heats the floor, the entire floor thus becoming a huge low-temperature radiator from which heat is radiated (yellow arrows) to objects in the room.

little good, at interior walls and in the upper levels of the room.

A radiant-heating system is designed to raise the temperature of as large a proportion of the interior surfaces as possible. The large, low-temperature panels employed by this method provide a uniform heating effect throughout the room. In a well-designed radiant-heating system the temperature of the radiating panels is so low that the direct effect, if detectable, is a comfortable sensation. The air is warmed up somewhat by contact with the radiant surfaces, although it very seldom reaches the average temperature of the room surfaces.

Variations in air temperature throughout a room are remarkably low in radiant-heating systems, and as a result convection currents and drafts are almost entirely absent; a condition which promotes the comfort of the occupant and reduces dust deposits and heat streaks on interior surfaces.

Comfort

Advocates of radiant heating emphasize the degree of comfort attained. Breathing the cooler air in a room equipped with radiant heating creates, they claim, a stimulating, invigorating feeling, somewhat like that enjoyed on a brisk, sunny spring day.

In most small buildings equipped with radiant heating no special provisions are made for adding moisture to the air. Due to the somewhat lower air temperature, the relative humidity in such installations is somewhat higher than that generally found in houses heated by radiators, or which use warm air with no moisture added.

There is indisputable evidence that as air passes over hot surfaces the moisture in the air combines chemically with dust particles to produce hydrocarbons and other compounds which may harm the membranes of the nose and throat. There is no chance for this to happen in a radiant-heating system, because the rooms are heated by large, low-temperature panels, and the air never comes in contact with hot surfaces. A resulting lower rate of sinus and respiratory ailments, among those living in buildings with radiant heating, is a further advantage claimed by radiant-heating advocates.

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Principal Features
in the design of a
Radiant-Heating Installation

Due to several uncontrollable variables, the heating of buildings can not yet be called an exact science. But over a period of years many of the factors involved in the designs of heating systems have been studied and, from experience, certain empirical values worked out, making it possible to reach a reasonably accurate estimate of requirements without elaborate calculations.

In a large structure, such as an office building or a multi-story apartment house, accuracy of design is a practical and economic necessity and a thorough design analysis calls for the study of all conditions of air and surface temperatures, heat flow through each surface, behavior of each medium, etc. But in a small structure such as the average residence where a slight inaccuracy would have only a minor effect on cost, design becomes a comparatively simple matter.

Selection of Method

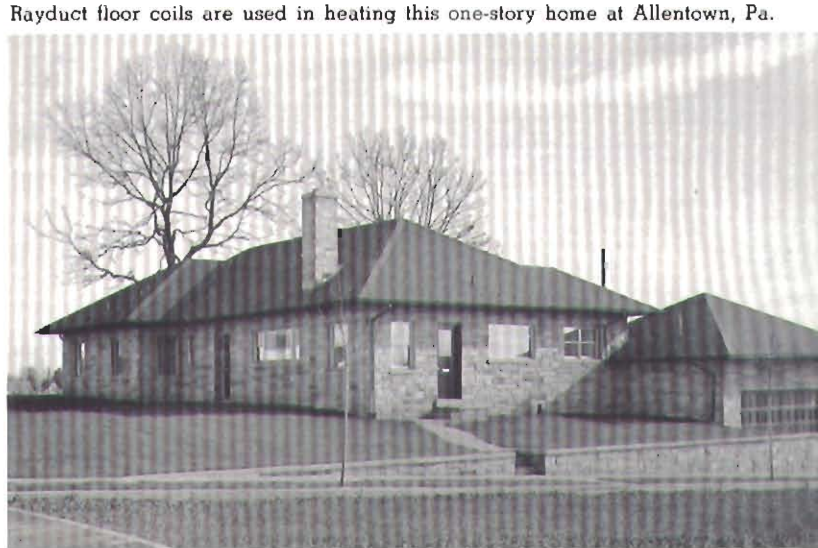
Since we are dealing primarily with radiant heat rays, which behave like light in that they flow freely in any direction until they reach an obstruction, there is no particular preference as to the location of the heated surface as far as radiant energy is concerned.

As to the heating medium used in radiant heating, some limited use has been made of warm air circulating in continuous ducts, although this method involves structural complications. In general, however, the use of warm water under forced circulation through pipes embedded in the structure is the accepted method of distributing heat in radiant-heating systems. This method is favored because of its ease of installation, flexibility, adaptability to any type of building construction, and its moderate cost.

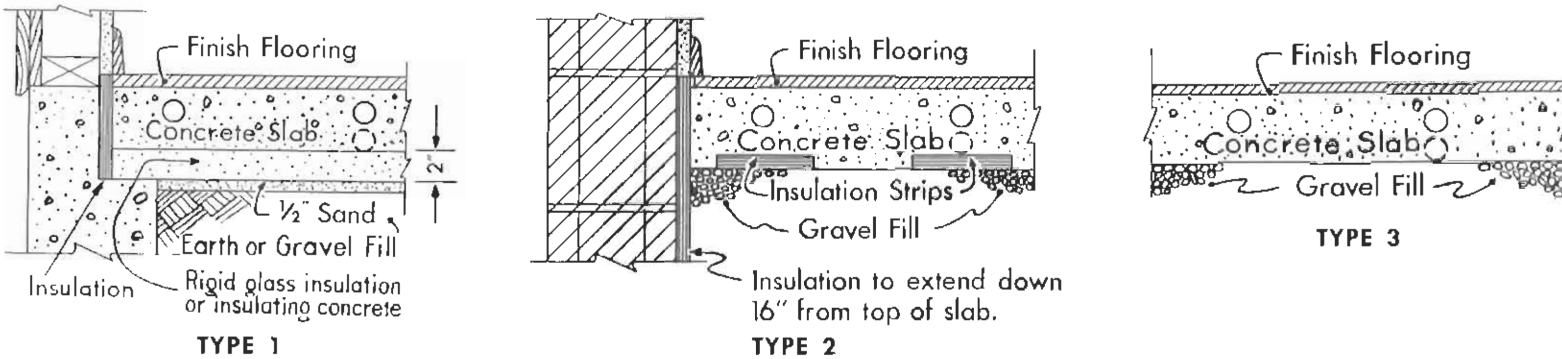
The use of the entire floor as a low-temperature radiating panel is the method which has been most commonly used. This is particularly advantageous in one-story buildings. In addition to the practical benefits gained from economical construction and fuel cost, supplying maximum warmth at the occupant's feet and minimum warmth at his head has been found beneficial to health and comfort. Lower temperatures maintained within the room make these advantages possible.

A radiant-heating system, with Rayduct steel pipe, is one of the features of this new residence at Litchfield, Conn.

Rayduct floor coils are used in heating this one-story home at Allentown, Pa.



TYPES OF FLOOR CONSTRUCTION



Ceiling locations theoretically produce the smallest possible variation of air temperature with a minimum amount of convection currents. However, this is not always true in actual practice and certain disadvantages do arise on occasion. These include excessive heat losses through the roof structure in a one-story building; and a tendency to produce a sensation of greater warmth about the head and shoulders than at the feet and ankles (when the floor is placed on grade).

Wall locations are to be avoided except for supplementary heat sources or where it is definitely desired to set up convection currents. For instance, a wall coil under a large "picture" window will tend to neutralize the downward draft naturally occurring at that point. This same result may be obtained by developing a warmer band of floor adjoining the glass area or exterior wall.

Heat Losses

As a first step in the design method discussed below, it is necessary to determine the heat loss from all exposed surfaces, except, of course, those to be used as radiating panels. And it is necessary to know the amount of heat required to raise incoming fresh air to 70 deg F. This step may be readily determined by following the usual Btu method as described in the American Society of Heating and Ventilating Engineers Guide, and other heating manuals. (The temperature of the outside air to be used is of course that generally assumed for the given locality.) With such a wealth of material available, it is considered unnecessary to review this subject here.

It has been found convenient to set up a heat-loss table similar to that on page 6, using a work sheet large enough to permit a separate column listing for each room. After determining the Btu per hour to be delivered to each room, we may proceed with the design of a radiant-heating system for the specific type of building.

Note that the Btu per hour per sq ft of heated surface is shown in the table on page 6. This information is needed to insure that allowable limits for the various types of panels are not exceeded. It is also used in connection with the design charts.

Specific Problems

As this method of radiant-heating design has been developed for greatest simplicity it naturally involves certain inaccuracies and limitations. The inaccuracies, however, are all on the side of safety, and do not sufficiently affect the installation cost of the average small job to warrant a complete design analysis by an expert. Of course, large projects always justify the services of an engineer.

The limitations of this simplified method arise from the fact that no one method can possibly cover every kind of situation. The design of a radiant-heating system should be accompanied by experienced judgment and calculation in cases where there are long, narrow rooms with severe exposures; rooms exposed on more than two sides; in "solar" types of homes; in homes where there are intensive ventilating requirements; and in poorly-insulated structures.

Therefore, application of the following method is limited to the average well-built small structure. For simplicity, this method is based on three common building types using the most common construction methods. By combining these types and methods the reader will be able to deal with a wide variety of conditions.

One-Story Structure with Concrete Floor Slab on the ground

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This type of building is rapidly gaining acceptance as a low-cost and practical method of construction. In such buildings radiant heating is often chosen as the solution to the problem of cold floors in winter. Obviously, the proper location of the heating coils is in the floor slab.

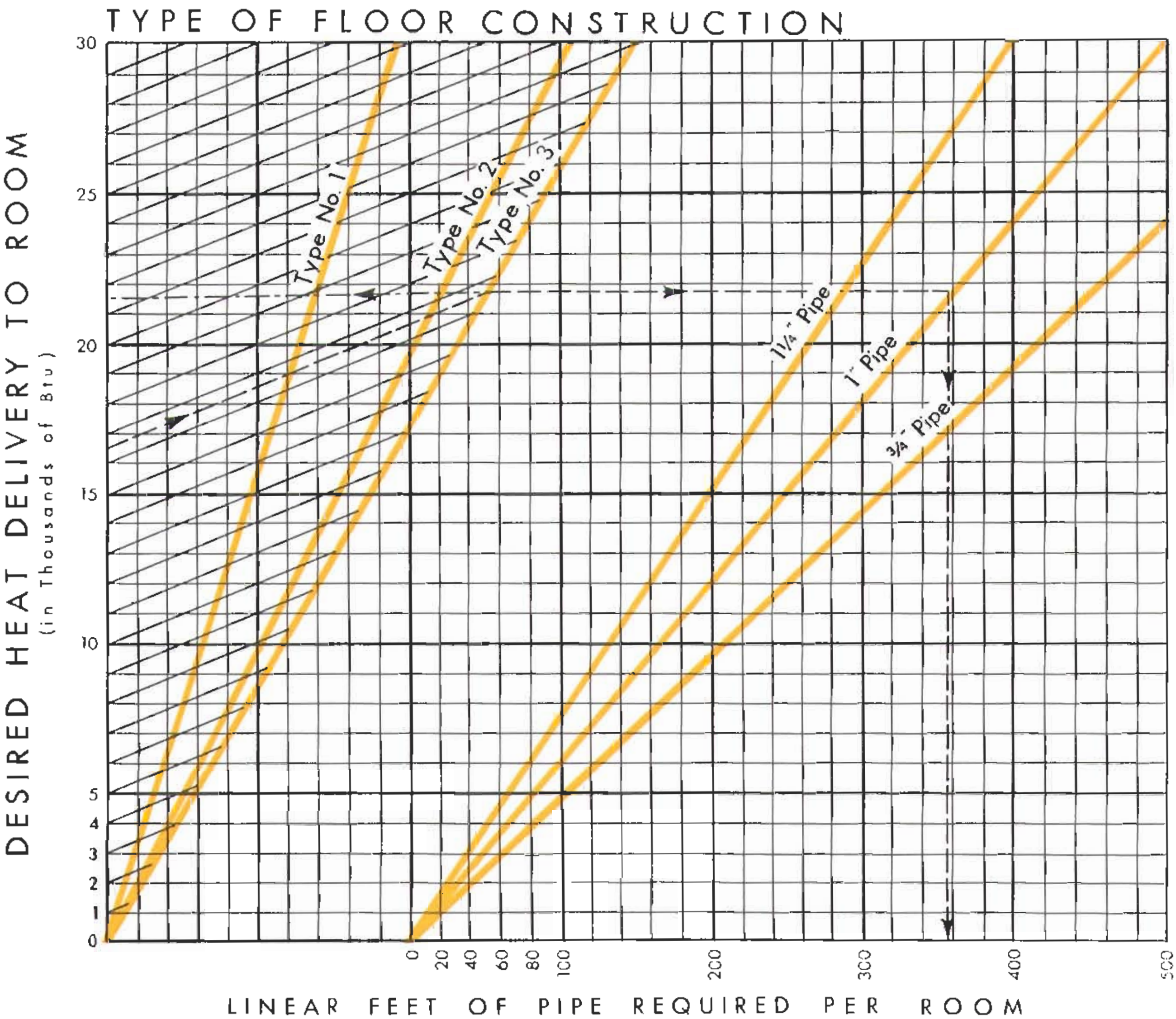


FIGURE 1

Note: In this Figure allowance is made for the following alternate floor coverings:

- Tempered hard-board, applied to slab with adhesive.
- Wood Block, ¾-in. thick, applied to slab with adhesive.
- Resilient flooring, i.e., rubber tile, linoleum, asphalt tile, etc.
- Rug or carpet on concrete.

Determining Pipe Requirements

Having tabulated the Btu losses per hour for each surface, the amount and size of pipe needed for each room can be quickly determined by using Fig. 1, page 9. The hypothetical dash line is an example of how the chart works. Entering the left side of the graph at the correct number of Btu, follow the diagonal line to the point where it intersects the appropriate curve for the floor construction. See Types 1, 2, and 3, page 8. From this point, continue horizontally to the diagonal line of the selected pipe size, then descend vertically and read the required pipe footage on the horizontal scale at the bottom of the chart. This chart includes allowances for heat losses to the ground for whichever type of insulation is chosen.

Heating Limitations

In the average small structure where floors are warm enough to deliver more than 50 Btu per sq ft to the room, some slight discomfort may be felt where the occupant's feet remain in one spot for an extended period of time.

Where it is necessary to supply more than 50 Btu per sq ft to an area, place pipes for a delivery of 50 Btu per sq ft under the greater portion of the floor and decrease pipe spacing under a 2- or 3-ft-wide band at the exterior walls to provide the excess Btu required. In the event that heat requirements exceed the maximum figure per sq ft, use Fig. 14, page 19, to determine: (a) total footage of pipe required to supply 50 Btu per sq ft (50 Btu x room area = hypothetical delivery) and (b) total footage required for total heat supply.

The difference between (a) and (b) will be the footage of additional pipe required, which may be installed by spacing the pipe closer than normally in the exterior band. A practical limitation sometimes arises here, in that efficiency of pipe spaced closer than one-and-one-half times the slab thickness drops off appreciably. In the event that the spacing in the exterior band becomes closer than this figure, it is recommended that supplementary ceiling panels, wall coils, or other sources be used. Design of ceiling panels and wall coils will be dealt with separately in the section devoted to the two-story type of building. In the case of an unusually well-insulated structure it would be well to consider 40 Btu per sq ft as a maximum for the principal floor area.

Residence at Orinda, Calif., has Rayduct pipe coils.

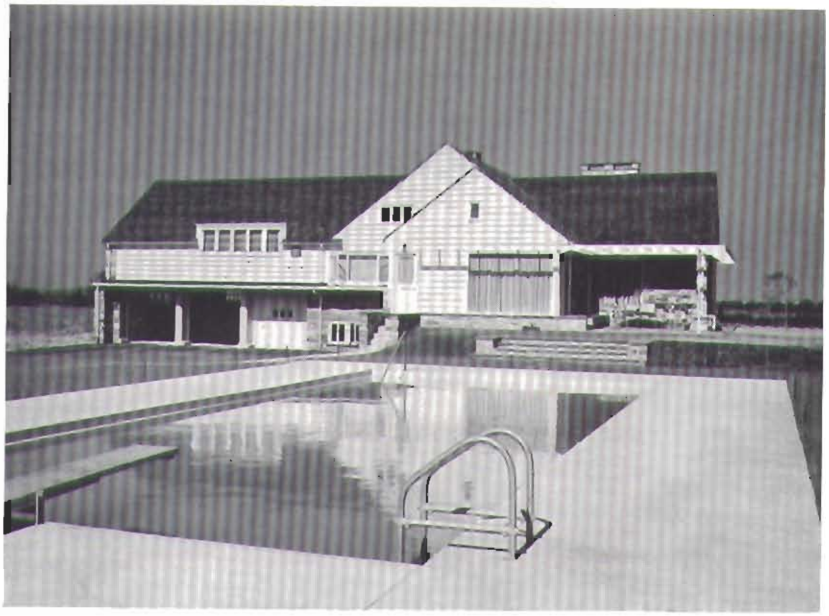
Designing the Pipe System

Indicated in Fig. 2, page 11, is the main-floor plan and piping layout for a modern residence using a typical forced-circulation water radiant-heating system. The structure, built in an open area, is a combination one- and two-story home with large picture windows and concrete floors.

Heat losses for each room are calculated in the usual manner, based on a zero exterior temperature. Variations in air temperatures and slab surfacing necessitate a comparatively wide range of pipe spacing. Differing Btu per sq ft demands are met by:

1. *Varying "blank spots" in rooms at end of coils.*
2. *Increasing spacing of return lines.*
3. *Doubling up of perimeter supply mains with decreased spacing between.*

Note: Where equipment is available for making but a limited number of sizes of standard bends, and it is desired to increase or decrease the heat input per sq ft by using the available sizes of bends, the coils may either be spread or squeezed. In general, it is well to select a pipe size which will allow a normal spacing of between 12 in. and 16 in. Closer spacing tends to reduce the efficiency of the pipe, and wider spacing tends to produce an uneven surface temperature gradient between and over the pipes. However, in garages, storerooms, etc., the latter condition is not of great importance.



Rayduct floor coils are used in this one- and two-story residence at Emmaus, Pa. Installation plan shown below.

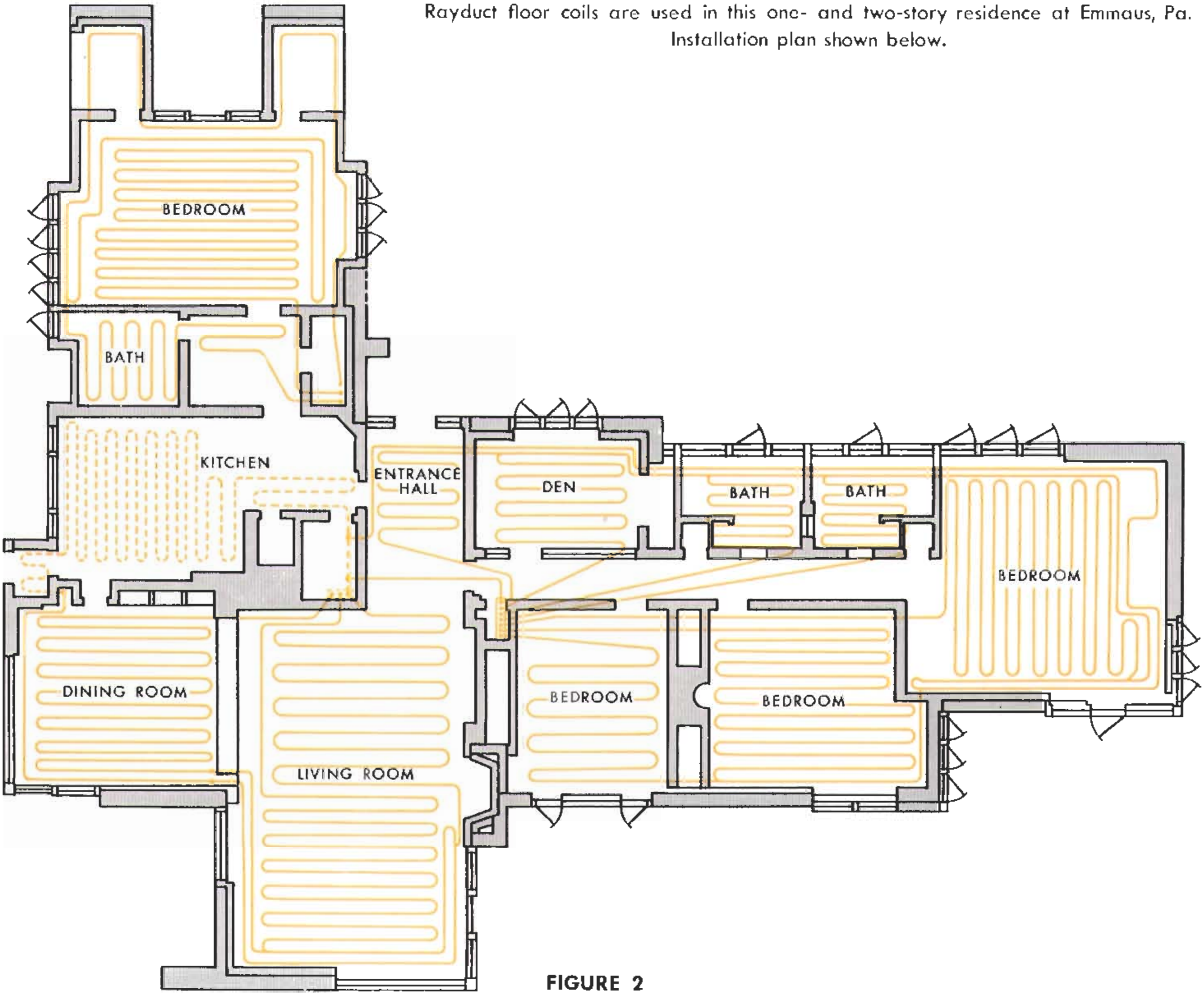
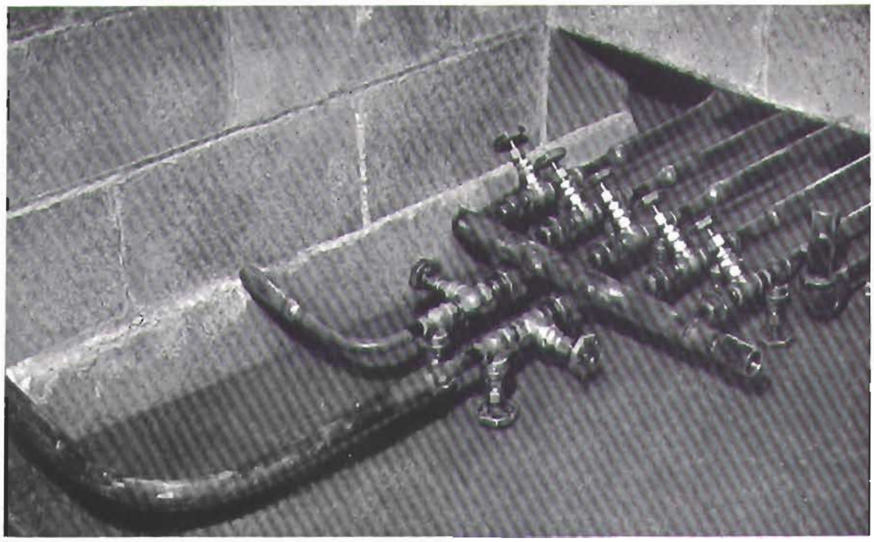


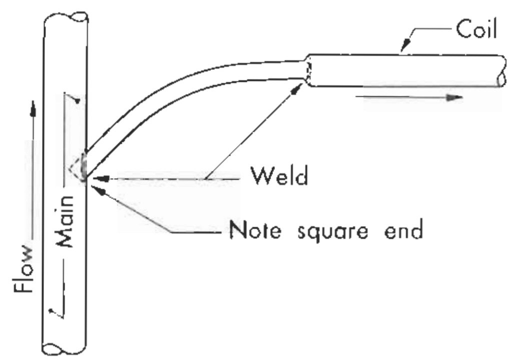
FIGURE 2

Installation of radiant heating, with Rayduct steel pipe, was one feature of extensive renovation in this residence at Washington, Conn.



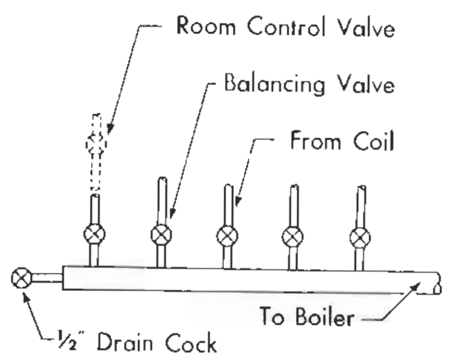
Control center for radiant-heating system in a residence at Port Allegany, Pa.

Two-story fire house and service building at the Steelton, Pa., plant of Bethlehem Steel Company, equipped with a Rayduct radiant-heating system in both stories.



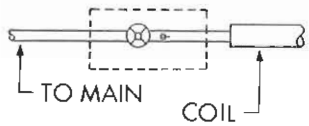
TYPICAL COIL TAKE-OFF

FIGURE 3

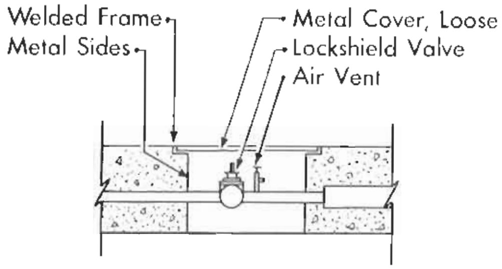


RETURN HEADER

FIGURE 4



NOTE: Place valve in tilted position when necessary for clearance.



VALVE BOX DETAILS

FIGURE 5

Supply mains are run along outside walls so that the hottest water is delivered in these areas. It should be remembered that supply and return lines are actually part of the system not merely additional elements.

Where convenient, supply mains should be looped back to form reversed returns. Obviously an attempt to equalize the pressure drop in each circuit is desirable, even though balancing valves are provided for the purpose. Mains are sized in the usual manner, with close attention toward keeping the head as low as practicable—generally 4 ft to 6 ft of water. As coil length is a factor which should always be considered, the heads are sometimes unavoidably higher.

Higher slab temperatures are provided at exterior wall lines by placing supply mains close to these areas and by designing the coil arrangement so that the water temperature drops as the water nears the center of the rooms.

The purpose of maintaining higher slab temperatures close to exposures is threefold:

1. *To neutralize the tendency toward the formation of cold downward convection currents at these points.*
2. *To produce slightly greater radiant warmth here, so that the increased cooling effect of the colder exterior wall or glass may be neutralized.*
3. *To keep glass surfaces clear of moisture. (Formation of moisture on window glass is particularly undesirable in the case of a large, single-glazed picture window.)*

A sinuous coil arrangement is used here because in most localities it costs far less to bend the pipe than to use a grid-type arrangement with many welded connections. Where grids are used, great care should be taken to equalize the frictional losses of the many paths. Otherwise, unequal heating of laterals may occur, greatly reducing the efficiency of the pipe as a heat-transfer element.

Coil Connections

Fig. 3 on page 12 indicates a recommended method of connecting coils to mains. Size of nipples is based on the Btu requirement of the coil served. Note that a square end of the nipple extends into the main to form a "scoop," giving a more positive deflection of water than can be afforded simply by differences in pressure.

Coil Controls

In a home in which the owner required separate room control only in the bedrooms, kitchen, garage and shop for every-day operation, valves for this purpose were placed in recesses similar to Fig. 5, on page 12, and located inside closets. In some installations these valves are placed under built-in cabinets; in corners or along walls of rooms (covered with flush floor plate); or at the return header near the boiler. Valve location is, of course, largely a matter of convenience and owner preference.

Returns and Return Headers

The return from each coil is run to a common header at the boiler location. Such an arrangement is highly desirable, as it is possible to use balancing valves in each return where it enters the header. This is convenient and it allows complete control of the relative flow in each of the coil circuits. Errors in pipe sizing, unavoidable variations in frictional resistance of circuits due to varying lengths, a partial blockage due to faulty welding, errors in design calculation between rooms all these can easily be corrected from one point.

It is recognized that breaks in floor levels or other conditions may make it impractical to extend returns from individual coils to a common point. In such cases it is well to place balancing valves at one end of each coil, located at the most desirable points, considering the eventual arrangement of furniture and rugs.

In some radiant-heating installations room-control valves have served the dual purpose of balancing the system. This has not proved a very satisfactory solution where there is a noticeably unbalanced flow, because the occupant can hardly be expected to turn the valve to the correct balancing position each time he regulates it.

One-Story Building with Wood-Joist Construction

Referring to Fig. 8, page 15, we have a conventional "development-type" house designed as a one-floor layout with wood joists over a "crawl space," without a basement. If a basement were used, it would have little effect on the coil system, because the principal problem with wood-floor construction is to force heat through wood finish and sub-floors. These elements are naturally good resistors, and necessitate unusually good insulation beneath the coils to prevent excessive downward losses. The unavoidable resistance of the flooring material rapidly raises air temperature in the joist spaces as the Btu delivery of the floor is raised. This results in a comparatively low maximum delivery if pipe economy and practical water temperatures are considered.

Determining Pipe Requirements

With heat losses for each room calculated from Fig. 1, page 9, and the floor construction selected from Figs. 6 or 7 shown below, the size and number of pipes per 16-in. joist space may be read directly on Fig. 9, page 16, which includes allowances for downward heat losses.

Fig. 9 allows for automatically holding the Btu radiation per sq ft of floor within safe limits. To increase the heat delivery much beyond the figures shown would require inordinate pipe sizes or impractical circulating-water temperatures. Where additional heat is required for comfort, supplementary wall or ceiling heating panels must be used.

Layout of Pipe System

A study of Fig. 8, page 15, shows that the structural limitations of a wood-joist floor do not provide all of the desirable features found in the extremely flexible concrete-slab system. Also, the pipe requirements are comparatively greater with wood-joist construction. However, the system as designed will work very well when modified to fit any similar job.

Design Factors

In this example outside and inside temperatures are selected in the usual manner. Here it is assumed that excessive heat losses occurring in the kitchen will require a small supplementary ceiling panel as shown on the drawing, Fig. 8, page 15.

Installation Problems

When pipes are installed as shown in Figs. 6 and 7, the structure is not appreciably weakened because all notching of the joists is done at or near wall bearings. In most cases it will be possible to run all pipes dead level, as has been done here. Where pipe crossings are required, or where breaks occur in floor level, it may be necessary to run some supply or return lines below the joists. In this event, if there is no basement, it is obvious that such lines should be insulated and proper provision should be made for drainage.

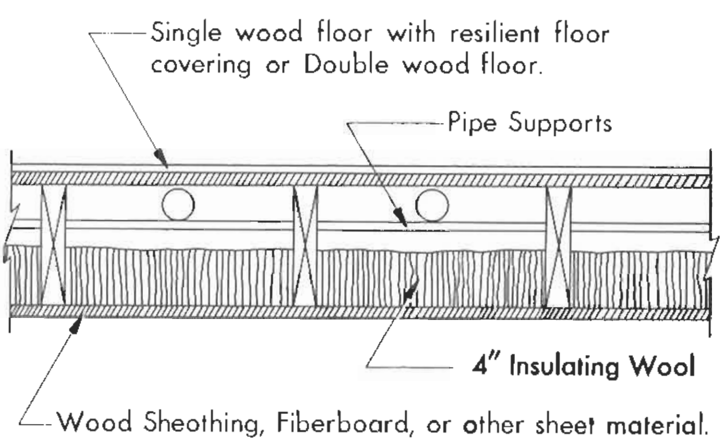


FIGURE 6

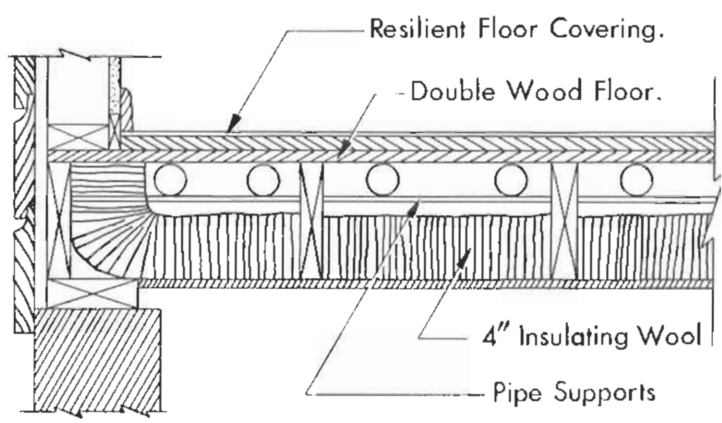
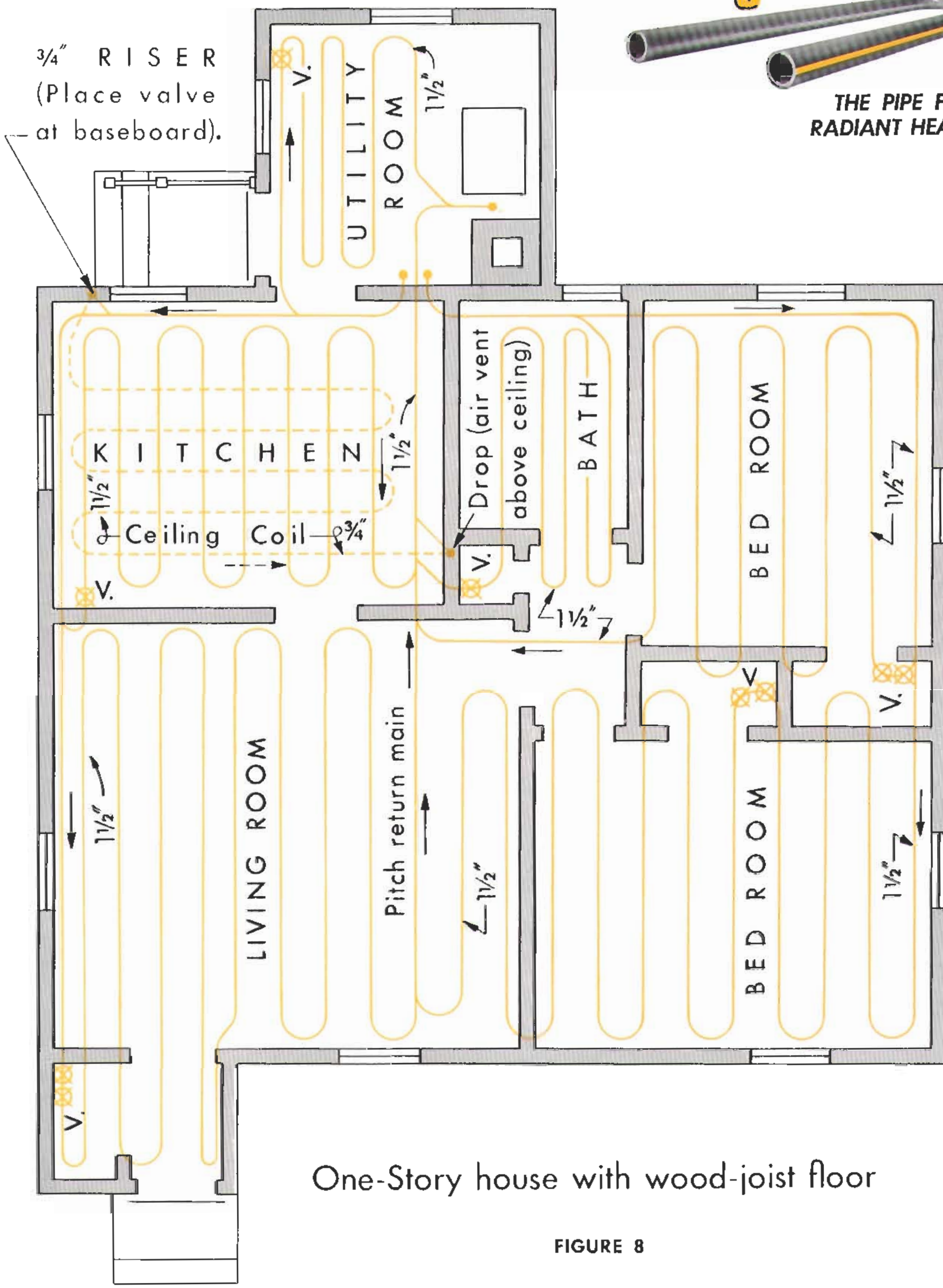


FIGURE 7

BETHLEHEM STEEL

Rayduct

THE PIPE FOR RADIANT HEATING



One-Story house with wood-joist floor

FIGURE 8

This building at Columbia, S. C., housing an office, garage and showroom, is equipped with Rayduct floor coils.

The Pipe System

It will be noted that desirable features of the concrete-slab system have been retained wherever possible. Supply mains follow the exterior wall, typical coil connections are used, and additional pipe is used in joist spaces adjoining the outside wall.

For purposes of illustration, it is assumed that notching of joists should be reduced to the minimum. Therefore, balancing valves are shown on each coil at the coil-control valve locations, rather than continuing each return to a common header.

Sizing of mains and valves are based on common practice for forced-circulation hot-water systems, again considering the length of coil as part of the maximum circuit length and sizing for comparatively low friction heads.

PIPE SIZING AND SPACING

Desired heat delivery to room in Btu per sq ft	Pct allowed for loss down	Type of floor construction	Size and number of pipes to be used in 16 in. joist space					
			½"	¾"	1"	1¼"	1½"	2"
20	33%	Fig. No. 6	1	—	—	—	—	—
	36%	Fig. No. 7	1	—	—	—	—	—
25	26%	Fig. No. 6	2	1	—	—	—	—
	33%	Fig. No. 7	2	2	2	1	—	—
30	25%	Fig. No. 6	2	2	2	1	—	—
	31%	Fig. No. 7	—	—	—	2	2	2
35	24%	Fig. No. 6	—	2	2	2	2	1
	30%	Fig. No. 7	—	—	—	—	—	3

FIGURE 9

Two-Story Wood-Frame Structure with Basement

BETHLEHEM STEEL

Rayduct

THE PIPE FOR RADIANT HEATING

Figs. 10 and 11, page 18, represent the floor arrangements of a fairly common type of house for which a ceiling installation is considered the logical solution because:

1. *Heat losses upward from the ceiling panels provide some of the second-floor bedroom requirements.*
2. *Piping arrangement for supply of supplementary heat to second-floor rooms is somewhat simplified.*
3. *The danger of a cold first-floor surface is reduced by both the radiant effect from the ceiling, and by the presence of a basement partially warmed by heat from the boiler and exposed piping. Incidentally, the saving in cost by eliminating pipe insulation, which is often a substantial item, should be applied against cost of the radiant-heating installation.*

Determining Pipe Requirements

Pipe requirements per sq ft of panel surface may be determined from Fig. 14, page 19, which is used in a manner similar to that described for Fig. 1, page 9, under "One-Story Structure, with Concrete Floor Slab on the Ground."

The remarks concerning piping arrangement, spacing, circuiting, etc., under that heading also apply in the case of ceiling coils.

Heating Limitations

In all types of radiant-heating systems, maximum benefit to the occupant is gained by maintaining a radiating surface as large and as cool as possible, consistent with bodily comfort.

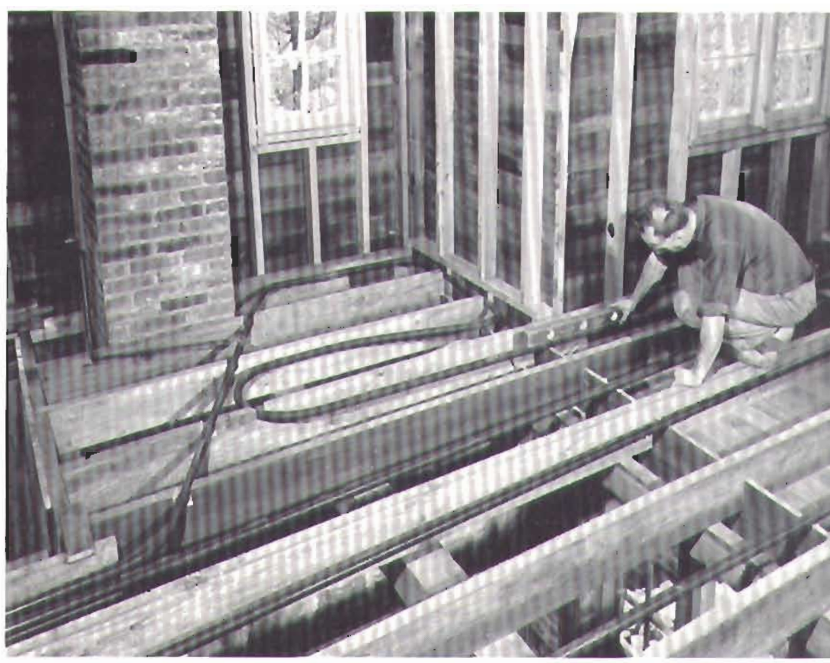
In the case of ceiling installations, excessive temperatures may produce an unpleasant sensation of warmth about the head and shoulders. Therefore, it is recommended that supplementary wall and/or floor coils be used to supply any heat required in excess of 50 Btu per sq ft of panel surface, except in minor rooms.

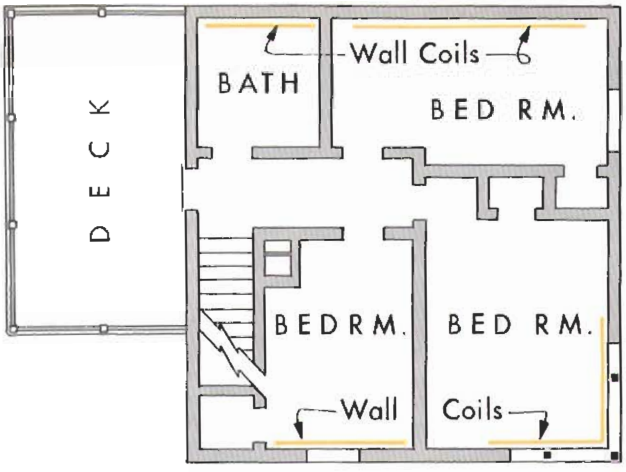
Since the intensity of radiant effect, like light, varies in inverse algebraic proportion to the distance from the source, the use of ceiling radiant sources is not recommended in rooms with relatively high or extremely low ceilings.

Layout of Pipe System

Figs. 10 and 11, page 18, indicate that a circuiting arrangement is employed. An additional feature is the method of connecting second-floor wall radiation by using short stub risers. Since coil control valves are most conveniently operated when located in the wall within arm's reach, either separate risers or return drops are necessary. In this case, it is considered advisable to run a main-supply riser and to place coil control valves in the individual return drops, just above the baseboards. (The valves are placed in wall recesses with flush cover plates. A key-type cover for a standard electrical box will serve satisfactorily.) The individual returns are connected to a common return main at basement ceiling, with balancing valves at that point.

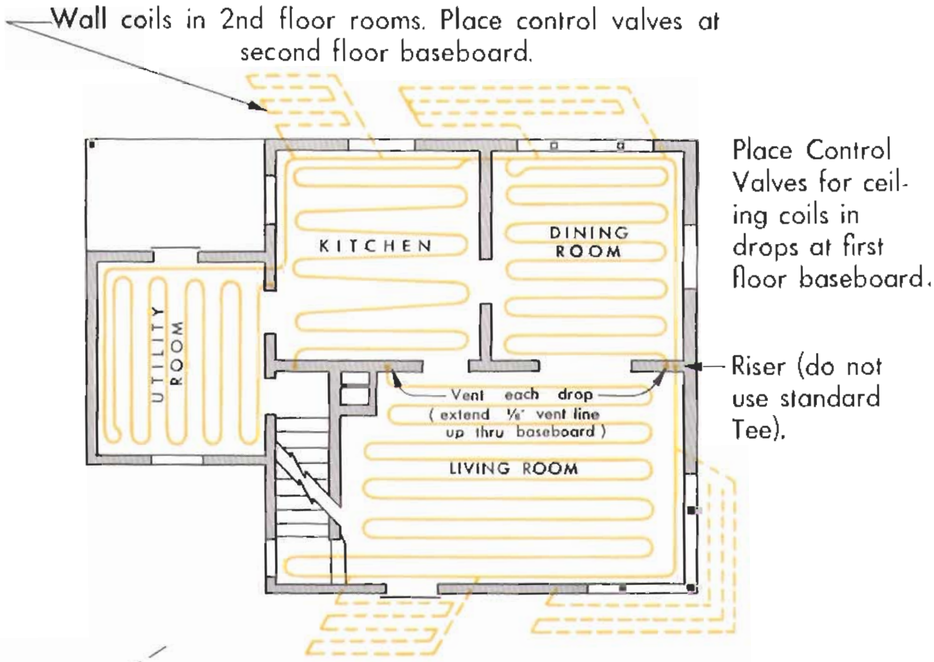
Rayduct floor piping in the second story of a dwelling at Lancaster, Pa.





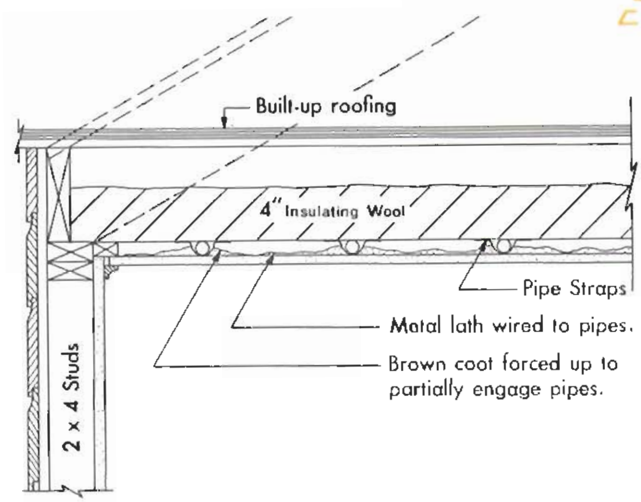
SECOND FLOOR PLAN

FIGURE 10



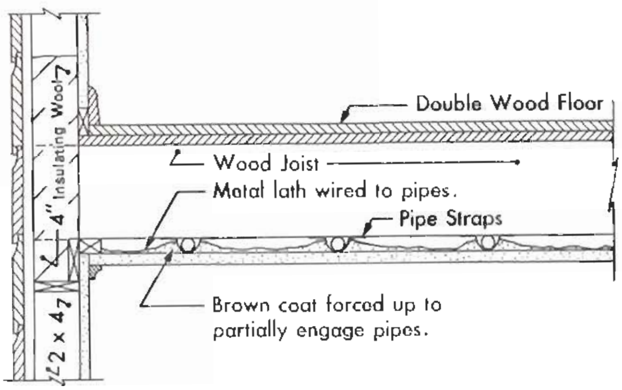
FIRST FLOOR PLAN

FIGURE 11



Ceiling panel with flat or pitched roof above.

FIGURE 12



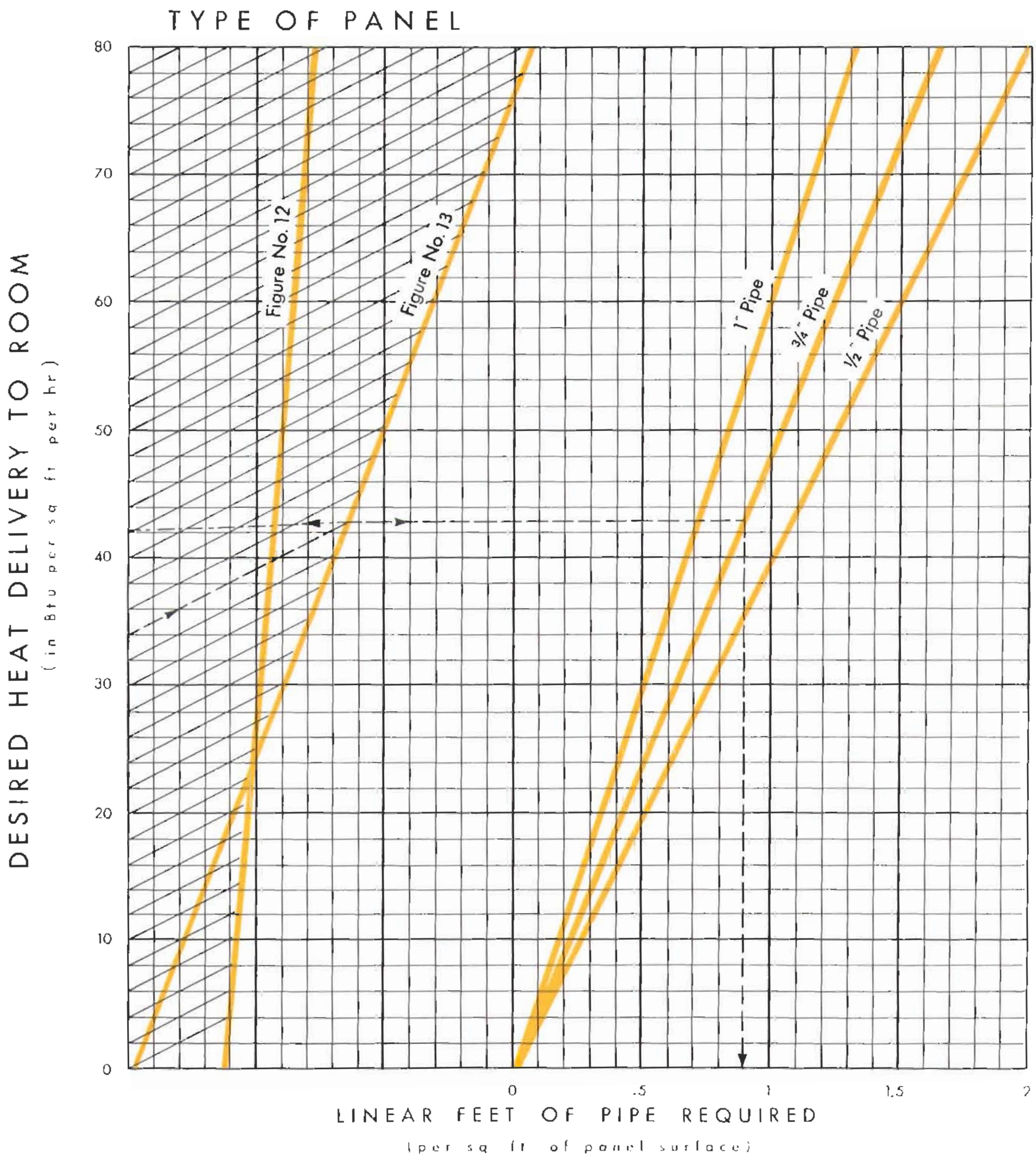
Ceiling panel with room above.

FIGURE 13

BETHLEHEM STEEL

Rayduct

THE PIPE FOR RADIANT HEATING



WALL AND CEILING PANEL PIPE REQUIREMENT

FIGURE 14

Typical Installc

Left: Fifteen-story apartment building, New York.

Dutch Maid Tourist

Left: Transmitter for Radio Station WKDK, Newberry, S.

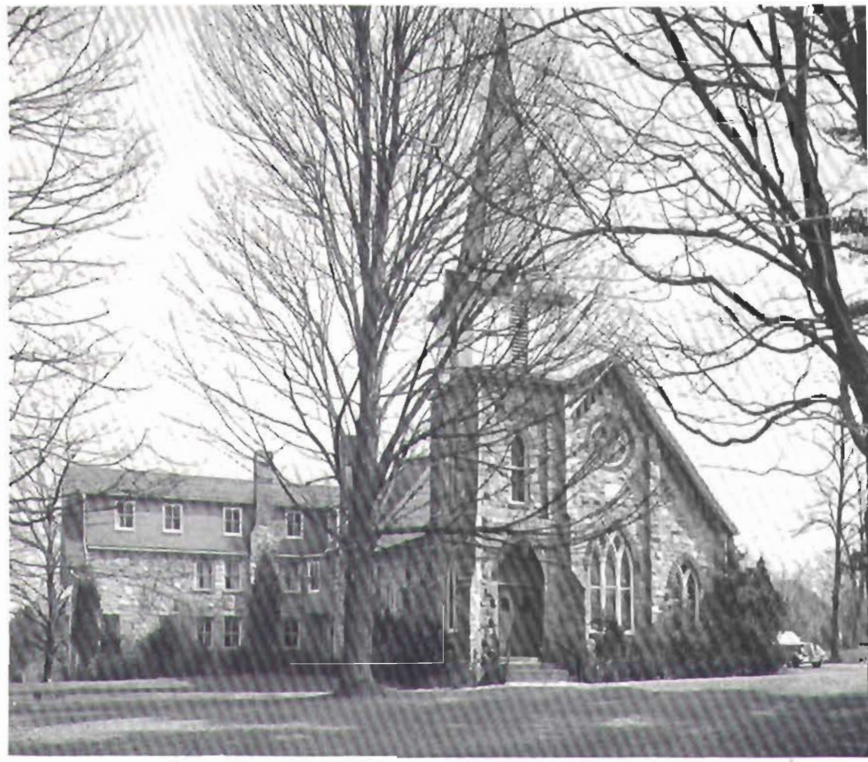
Super Market at Washington, N. J.

Residence at Port Allegany, Pa.

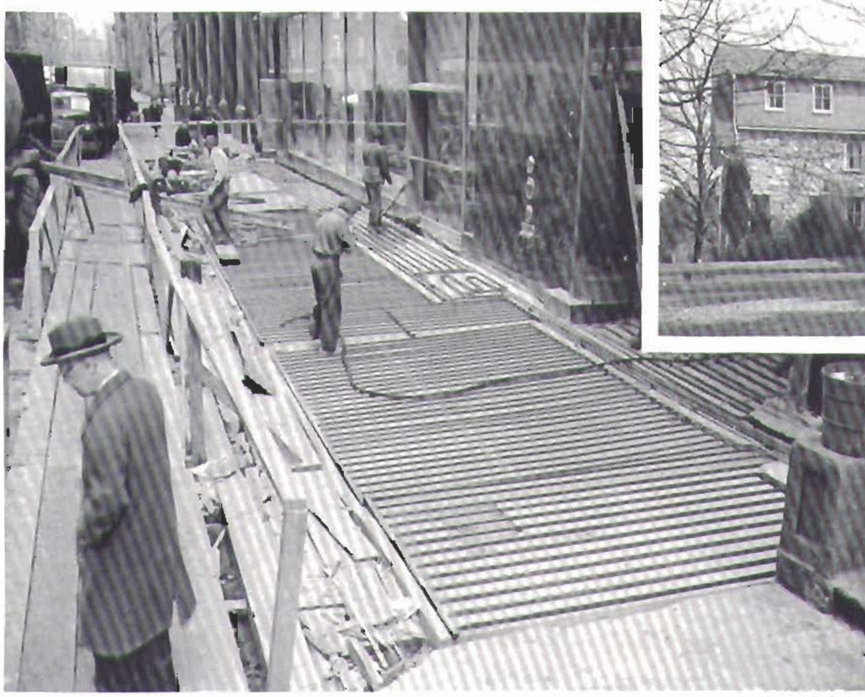
Left: Office building at Olyphant, Pa.

ons using Rayduct

U. S. Route 1, near Newark, N. J.



Presbyterian Church at Falls Church, Va.



Left: Sidewalk installation, New York.

Hunterdon County Veterinary Hospital, Whitehouse, N. J.

Right: Service station, Still Valley, N. J.

New residence near Easton, Pa., has Rayduct ceiling coils.

Right: Rayduct ceiling coils in place in the home shown at left.

Second-Floor Heating

Multiply the Btu per sq ft supplied upward from the ceiling panel below, as found on Fig. 14, page 19, by the area of the room under consideration. Subtract this quantity from the total heat requirement of the second-floor room to determine the number of Btu required from additional surfaces. It is practicable to use small conventional radiators or convectors, second-floor ceiling coils, or wall coils for this purpose.

Since the design of wall coils has not yet been described, it is assumed that they will be used for supplying the additional heat to the second-floor rooms. As they will deliver somewhat more heat than an equivalent ceiling panel, a slight additional safety factor is introduced by sizing both on the same basis. Therefore, pipe size and length for both wall and ceiling panels are obtained by use of Fig. 14, page 19 as indicated by the dotted line. Wall-coil piping should be arranged for a minimum spacing of 6 in. for ½-in. pipe, 9 in. for ¾-in. pipe, and 12 in. for 1-in. pipe. In general, small pipe is used to reduce furring problems and to keep plaster thickness at a minimum.

In the event that other means of second-floor delivery are employed, radiators may be sized in the usual manner, based on 130 Btu per ft of radiation, or second-floor ceiling panels may be installed as described above and as shown on Fig. 12, page 18.

Installation Problems

Installation of supply and return mains should offer no design problems other than those previously mentioned. Some provision should be made for expansion of the plaster by keeping the edges of heated panels free to move. A wood molding at the juncture of walls and ceiling serves to hide the necessary expansion joint. A similar treatment of any small wall coil located in only part of a given plane may be employed.

Welding feed line in store installation, Allentown, Pa. System is designed to accommodate super market, with food counters to be placed over wide, pipe-free areas.

Final check before the floor is poured in garage and shop building at Allentown, Pa. Spaced on 16 in. centers, Rayduct rests on insulating material.

Basic Design of Radiant Heating

BETHLEHEM STEEL

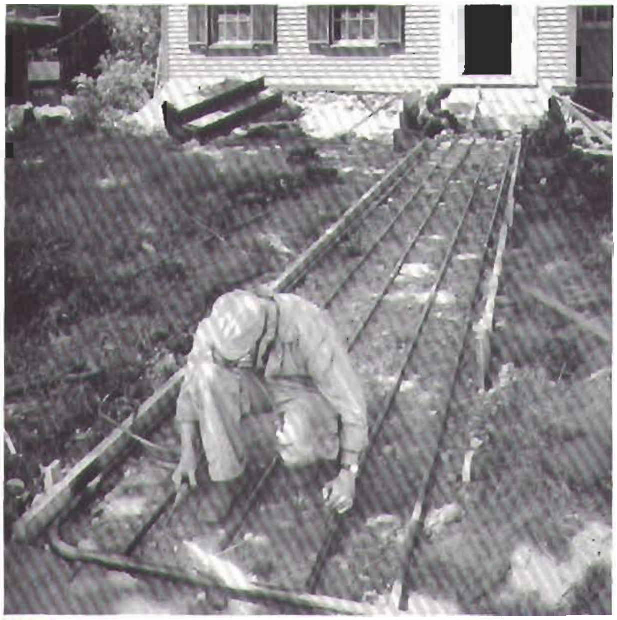
THE PIPE FOR RADIANT HEATING

Attention is again called to the limitations of the foregoing design method. It should be understood that this method is not a "cure-all," nor will it do away with the need for a thorough design analysis in large or unusual buildings. It has been developed solely to help the man who is unfamiliar with radiant-heating theory to install a workable system at reasonable cost, without elaborate calculations.

Anyone wishing to become active in radiant-heating design should thoroughly acquaint himself with both basic theory and a practical, accurate, and complete design method. The following outline indicates the highlights of the design procedure recommended:

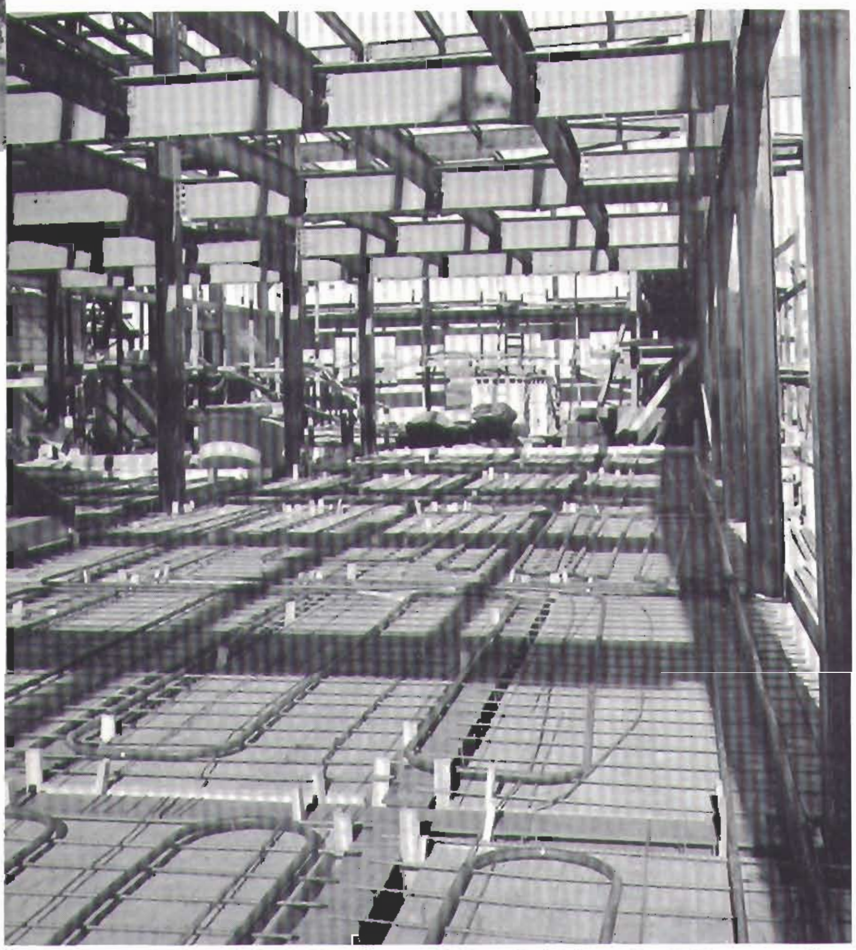
1. *Assume an inside air temperature, and establish the size and location of the radiating panel.*
2. *Calculate Btu losses due to air infiltration and through unheated surfaces.*
3. *Find the average radiant temperature of the unheated surfaces.*
4. *Determine the radiating panel surface temperature required to deliver sufficient heat to the room to balance losses figured under Step 2, above.*
5. *Find the average radiant temperature of all interior surfaces, including the radiating panel.*
6. *The combined effect of air temperature, Mean Room Temperature, and other assumed factors on comfort is known as Effective Temperature. If the foregoing assumptions produce an Effective Temperature too low or too high to maintain a maximum of bodily comfort for the type of physical activity in the building, assume a higher or lower air temperature, repeating Steps 1, 2, 3, 4, and 5.*
7. *After determining the size, surface temperature, location, and physical construction of the radiating panel, the remainder of the problem is a matter of delivering enough heat under sufficient pressure to maintain the surface temperature of the panel. Present methods for doing this, while largely based on experience, are accurate enough to produce excellent results.*

It is far beyond the scope of this book to attempt a complete discussion of the many design factors peculiar to radiant heating. For a more detailed account of the major points involved the reader is referred to books on radiant heating available from public libraries, and also to Chapter 45 of the 1945 issue of the American Society of Heating and Ventilating Engineers Guide.



Goodbye to snow shoveling! This Rayduct installation at West Newton, Mass., keeps sidewalk free from snow and ice.

General Considerations in Planning a Radiant-Heating System



Radiant-heating system being installed in Bethlehem Steel Company office building, Cambridge, Mass.

In completed building, employees work in comfortable surroundings.

Selection of Pipe

The selection of the kind of pipe for radiant heating is based on these factors:

1. *Ductility, for ease of bending.*
2. *Welding qualities.*
3. *Length of life, under the conditions of the proposed service.*
4. *Efficiency, as a heat-transfer medium.*
5. *Material cost.*
6. *Cost in place.*

Although all commonly-available materials have been tried, steel pipe, with welded joints, has been adopted in the majority of radiant-heating installations both here and in Europe. In the selection of pipe, the importance of ductility and welding quality in relation to cost is evident.

There is no marked difference in life expectancy of the various pipe materials when used in a closed water system, except from exterior causes. When pipes are embedded in concrete, the danger of damage from exterior causes is minimized, and the overall rate of heat transfer is almost the same for all pipe materials. Material and installation costs vary widely, but installation costs can be kept down considerably by the use of an easy-bending pipe such as Bethlehem Rayduct.

Pipe Bending and Welding

Pipe bending may be done easily in either shop or field. Several small, inexpensive pipe benders are now on the market. Some heating contractors choose to cold-bend the pipe on a wooden "wheel," by hand. Although the use of such crude equipment produces some flattening and a slightly uneven bend, the finished work is quite acceptable. To take advantage of the increased demand for radiant-heating systems, fabricators throughout the

BETHLEHEM STEEL

THE PIPE FOR RADIANT HEATING

country are now preparing for volume production of standard bends and for shop fabrication of custom-sized coils.

There are no particular welding problems peculiar to radiant-heating installations. Workmanship of the highest quality is desirable, just as in any type of piping system. Many contractors prefer

Rayduct floor coils are used in this recapping and tire accessory shop, Allentown, Pa.

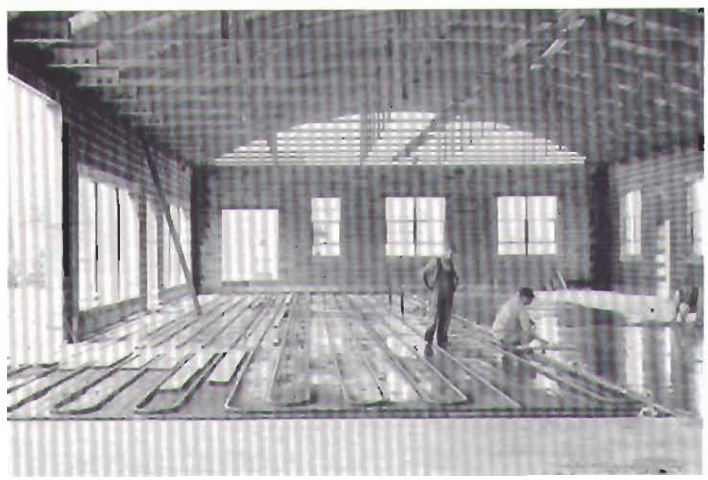
to fabricate coils in the shop to reduce the number of position welds required under field conditions.

Placing Piping

The preceding text, together with the accompanying illustrations, should serve to suggest several possible methods of installing the necessary piping. It is naturally important to follow standards of good piping practice, so as to avoid the difficulty and expense involved in repair or correction operations.

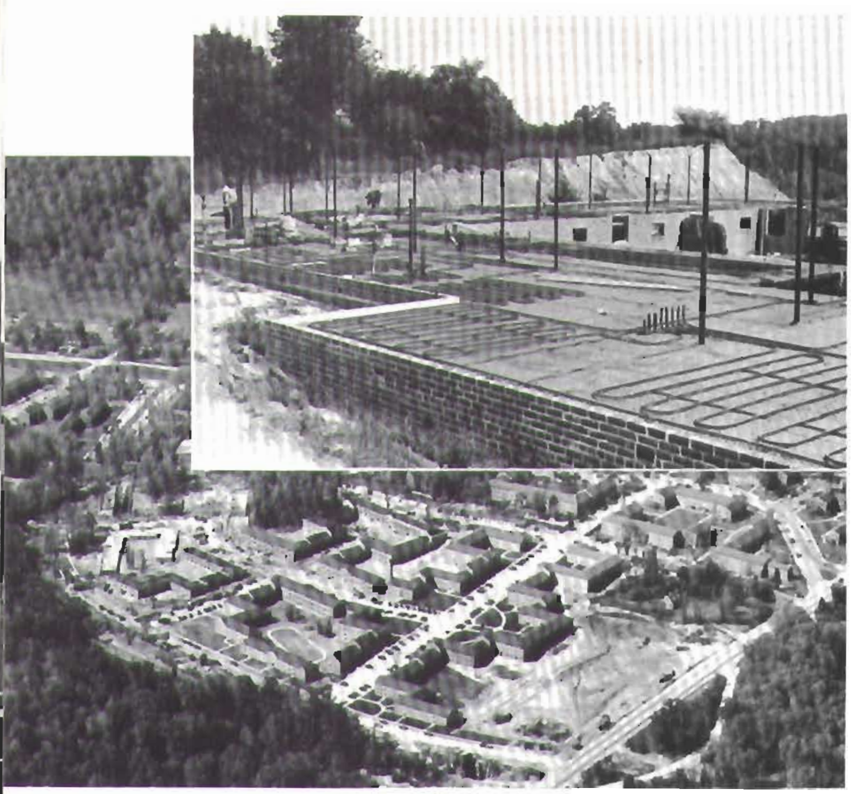
When working in wood construction, any of the customary methods of pipe support may be used. Coils placed in concrete are usually braced by small transverse channels or bars, welded or wired on, or by temporary wood 2 in. x 4 in., wired on, and removed while the concrete is being poured. Coil supports facilitate delivery from shop to field, and simplify proper leveling and grading in the field, and they prevent individual pipes from being accidentally moved from vertical alignment during construction.

Every care should be taken during construction to prevent vertical displacement of piping. In slab work, coils may be supported in the proper vertical position by spot-grouting, by the use of suitable blocking or by wire bar-supports like those used in placing concrete-reinforcing steel.



In building shown at top of page, Rayduct rests on 4-in. slab over 7-in. stone fill, and is covered with a 3-in. slab of concrete.

Rayduct floor coils and a beneath-the-window grid, shown in place in hosiery shop at Bethlehem, Pa.



The two pictures above show Barcroft Apartments, Arlington, Va. This project uses 54 miles of Rayduct.

Another construction view (*below*) of Barcroft Apartments with Rayduct stockpile in foreground.

Radiant-heating system in this salesroom in eastern Pennsylvania is designed to compensate for heat loss through large windows. Rayduct used throughout.

Grading and Venting

There is a considerable difference of opinion as to the necessity for grading pipes for drainage. When installed in a concrete slab, the danger of freezing due to boiler shut-downs even over a period of several days is remote because of the relatively high thermal content of the concrete. This danger is much more apparent where the pipes are covered only with plaster or where a wood-joist enclosure is used.

In some installations, including a few of the smaller ones designed for slab installation, and some where comparatively large pipe sizes are used, the coils are run dead level. Partial drainage may be obtained by running the circulating pump, or by blowing out the system with compressed air. Either arrangement will provide adequate protection against pipe damage from freezing, provided that no pocket-forming "dips" in piping have occurred from faulty placement or from structural settlements.

Proper grading to make complete emptying of the system possible is highly recommended where structural conditions permit.

Air vents should be placed at all high points of the system, and where shown in Figs. 15 and 16, page 27.

Expansion

When pipe is installed without being embedded in surrounding material, all customary provisions for expansion should be made. No special provision need be made, however, for the portion of piping enclosed in plaster or concrete except at structural expansion joints occurring in large concrete floor slabs. In such cases, it is the usual practice to use a typical horizontal expansion loop, wrapped in a resilient covering to prevent binding by the concrete slab.

It has been found that the coefficient of expansion of Rayduct approximates that of concrete and that shear stresses set up during warm-up periods fall safely within the bond limits of the enclosing materials.

Testing

All piping should be given a thorough pressure test before being enclosed in any manner. The following test is recommended:

1. *Completely fill the system with cold water under a pressure of 125 psi.*
2. *Sharply rap each weld with a hammer.*
3. *Keep the system under pressure for four hours, without drop.*

Boiler Equipment

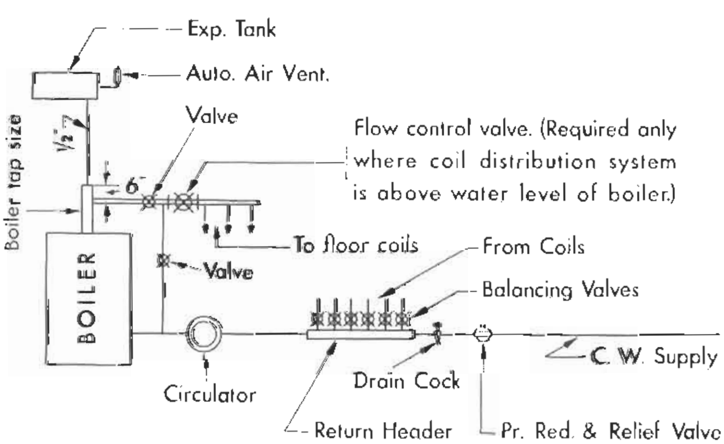
Any good hot-water boiler with typical accessories and trim may be used. To figure the number of Btu required at the boiler nozzle, add the calculated heat losses for each room (from the heat loss table on page 6), and add conventional allowances for pick-up. The Btu losses from heated panels to exterior are obtained from Figs. 1, 9 and 14 on pages 9, 16 and 19 - by the given percentage figure on Fig. 9, page 16, and by reading the difference between the point of entry and intersection with first diagonal line on the vertical Btu scale in the case of Fig. 1 or 14. In the case of ceiling coils with heated rooms overhead, the flow upward is ignored as far as boiler sizing is concerned, as this heat is included in second-floor loss calculation.

Boiler capacity for radiant heating theoretically may be reduced as much as 30 pct below that required for a conventional radiator system designed for a comparable building. But in view of the limited possible saving on a small job, and the desirability of excess capacity for more rapid pick-up during a sharp drop in outside temperature, it is recommended that boiler sizes be based on standard heating practice.

Any fuel may be used, including hand-fired coal. However, the difficulty of properly controlling a hand-fired coal job is not eliminated by the use of radiant heating. In fact, the problem is increased by the tendency of the system to "lag," a factor discussed more fully on page 34.

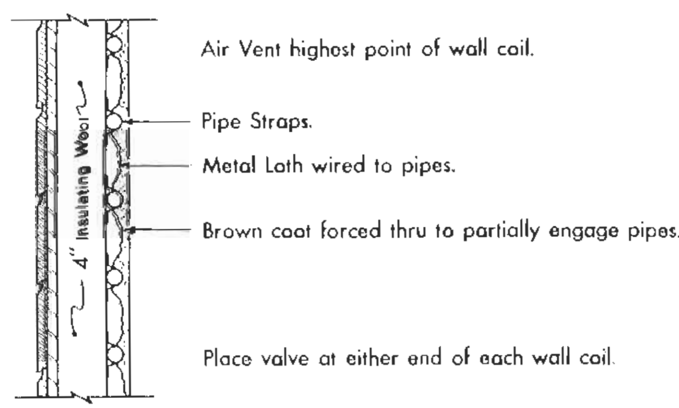
A typical boiler hook-up is shown in Fig. 15, below, which closely follows a conventional forced-circulating water arrangement. Note the provision of an automatic air vent at expansion-tank location, and the use of an oversized vertical extension of boiler supply tapping. It is important to provide for positive air elimination at this point, in order to prevent air from entering the coil system.

The valved cross-connection between supply and return is an optional feature for use when the boiler provides domestic hot water by means of an indirect coil heater. In this case the boiler-water temperature will be higher than that needed for ceiling or



TYPICAL BOILER HOOK-UP DIAGRAM

FIGURE 15

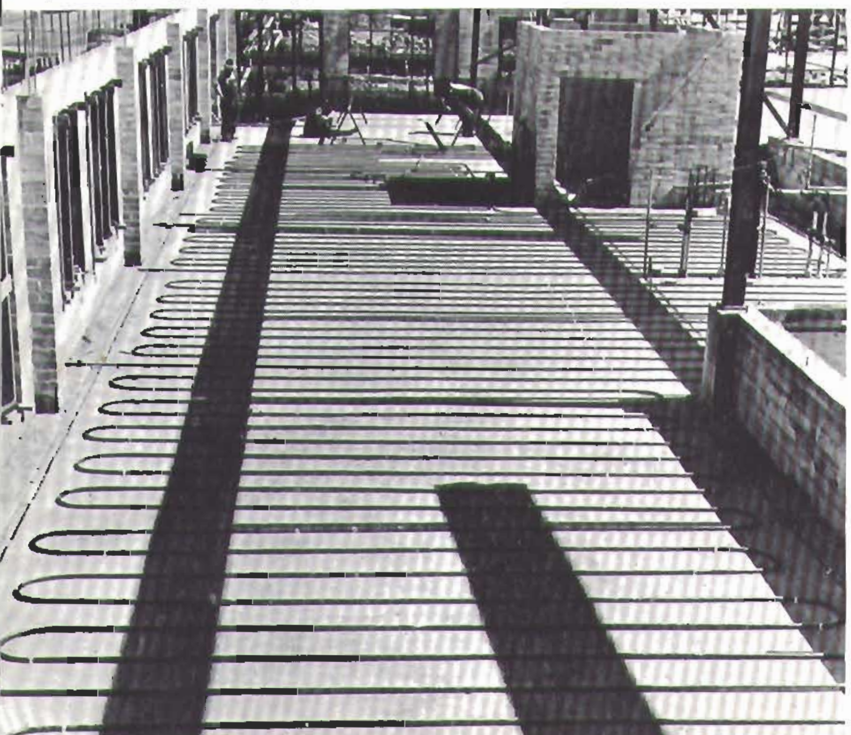


WALL COIL

FIGURE 16

Rug showroom on busy Route 29, at Springfield, N. J., has floor-type radiant heating, using Rayduct. *Below:* Interior view of showroom shown above.

Rayduct floor coils installed in new office and shop building erected for plumbing supply company, Oakland, Calif.



wall coils and for floor coils in concrete. The valve allows circulating water to be controlled as required.

Circulator

Any good standard booster may be used. Due to the wide variation in head found in radiaut-heating systems, it is important to size the circulator on the basis of gallons per minute required against a calculated head. This procedure is too well known to require repetition here. As a basis for these calculations, the table on page 6 gives the total Btu to be supplied to each room and to the entire building. Equivalent length of circuit is figured directly from the piping layout in the usual manner.

Controls

For the average small radiant-heating system, it is customary to control the circulating pumps with a conventional room thermostat. This method, while convenient, may of course be considered incorrect from the theoretical standpoint for a radiant-heated home, because it attempts to regulate comfort conditions on a basis of air temperature. Further, the ordinary room thermostat has a tolerance of at least two degrees, and it is located indoors where it is affected by outside weather changes only after a considerable time lag. But in spite of theoretical objection, ordinary room thermostats have been widely and satisfactorily used in radiant-heating systems. That they have been able to maintain satisfactory comfort conditions is largely due to the fact that in small enclosures air temperatures tend to more nearly approach average surface temperatures than is the case in large rooms, so that air temperatures in the small installation are more nearly an index of comfort.

When surface temperature is the leading factor in heating, physical comfort is retained over a comparatively wide range of effective temperature which may be defined as the net result of all variables affecting thermal balance; i.e., environmental surface temperatures, ambient air temperatures, air movement, etc.

An improvement over the conventional room thermostat, which requires no increase in installation costs, is a special-type thermal switch designed for accuracy within one-tenth of one degree, and unusually sensitive to radiant-heat effects.

Another type of interior control device is essentially an air thermostat enclosed in a metal ball, designed to accurately measure the combined effects of air and surface temperatures.

The outdoor-type instrument designed to properly

modulate the temperature of the continuously-circulating water to exactly balance heat losses from the structure at any given moment is the best method of control yet devised. Unfortunately the installation cost of this control system is often excessive in a small project. Where funds are available for this equipment, its use should be carefully considered.

Operation of the System

To start and balance a radiant-heating system, place the boiler in operation, start the circulating pump, and open all coil-control and balancing valves. When the water in the system has warmed appreciably, adjust the balancing valves to produce equal temperatures of water in each coil return. After operating for a few days during cold weather, it may be necessary to readjust the balancing valves to correct over-heating or under-heating of any room or zone. After the system has finally been balanced with these valves, further local room control by the occupant is attained by means of the individual room-control valves.

There are no other operating problems peculiar to a radiant-heating system. Maintenance of boiler equipment, circulator, etc., is of course required here just as in any other type of system.

Installation Costs

There is no good reason why the cost of a radiant-heating system should ever be excessive. Installation costs of hundreds of radiant forced-circulation systems installed in concrete slab have been in reasonable ratio to the overall cost of each building.

Except in cases where coils are installed between wood joists, the additional insulation recommended is optional, and should not be considered a part of the heating-system cost. Present-day practice demands a structure as well insulated as possible, regardless of the heating method used.

In this connection, it may be useful to briefly review a little-understood but important reason for using a maximum of insulation in the exposed surfaces of a building. It should be understood that in radiant heating we are first concerned with surface temperatures, and it is clear that good insulation not only reduces heat flow through the outer walls, but also sets up an important chain of events:

1. *Higher thermal resistance causes a higher interior surface temperature with any given indoor-outdoor temperature variation,*
2. *Causing an automatic raise in the average temperature of interior surfaces,*
3. *Making it possible to maintain comfort at a lower interior air temperature,*
4. *Thereby reducing the temperature differential between indoor and outdoor air,*
5. *Which brings about a further appreciable reduction in Btu loss from the building, with a resulting reduction in fuel cost.*

Fuel Costs

Radiant-heating advocates say that for most structures fuel costs with radiant heating are theoretically about 30 pct less than with other heating methods. In a twelve-room European school building, with one wing radiant-heated and the opposite identical wing heated by a different method, this saving is said to have been verified by accurate measurement of heat input under extended operation.

Tests reported in this country indicate that the fuel savings are somewhat less than 30 pct, due to the tendency of the system to over-run during a sharp rise in outdoor temperature.

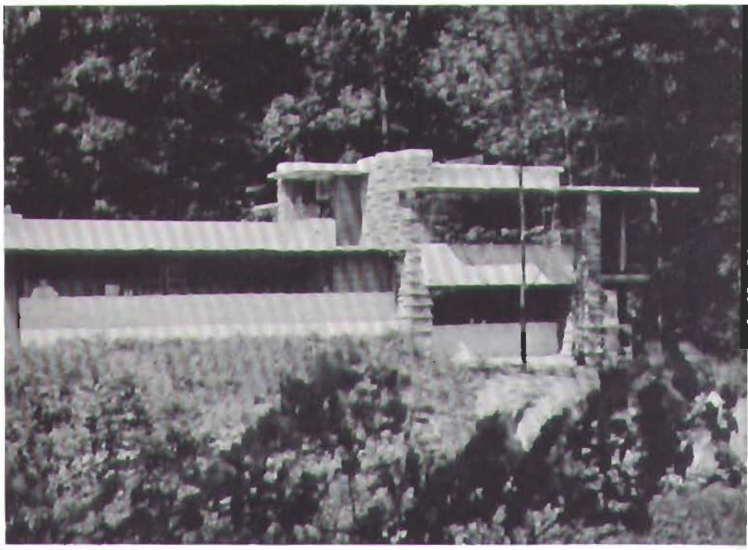
There is an almost unanimous opinion among owners of radiant-heating systems that important fuel savings do result. In the rare cases where fuel costs seem abnormally high for the size of the structure, poor insulation or incorrect installation may be considered basic causes.

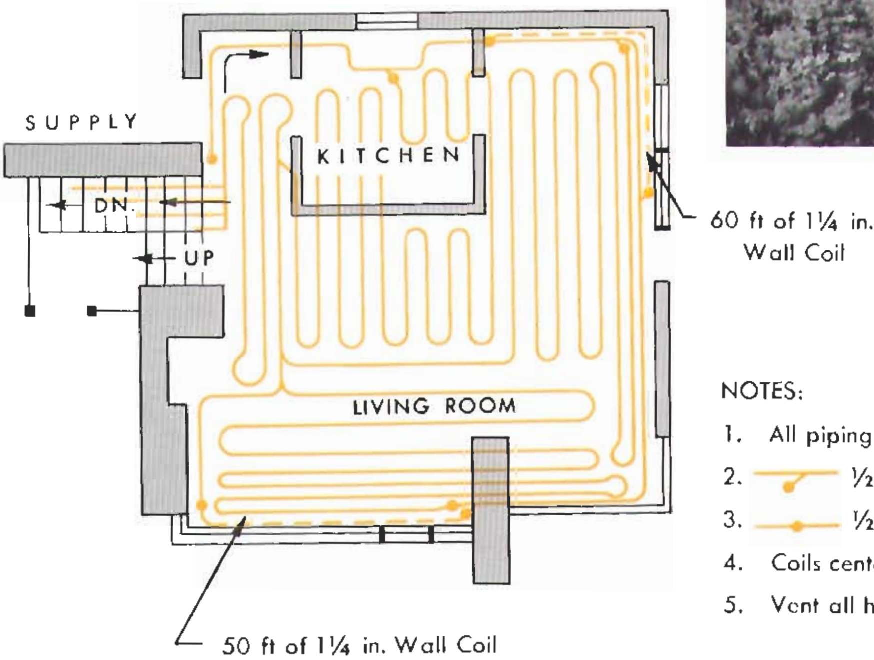
Pipe Leaks

The normal care applied to any first-class piping job will assure a water-tight radiant-heating system. Thereafter, the pipe may conceivably fail as a result of either mechanical injury or corrosion. However, mechanical injury is unlikely, and in the case of the concrete or plaster-jacketed pipe the possibility is so remote that it should not be a cause of concern.

In spite of widespread belief to the contrary,

PLAN FEATURING RADIANT-HEATING INSTALLATION IN MODERNISTIC RESIDENCE ITHACA, N. Y.



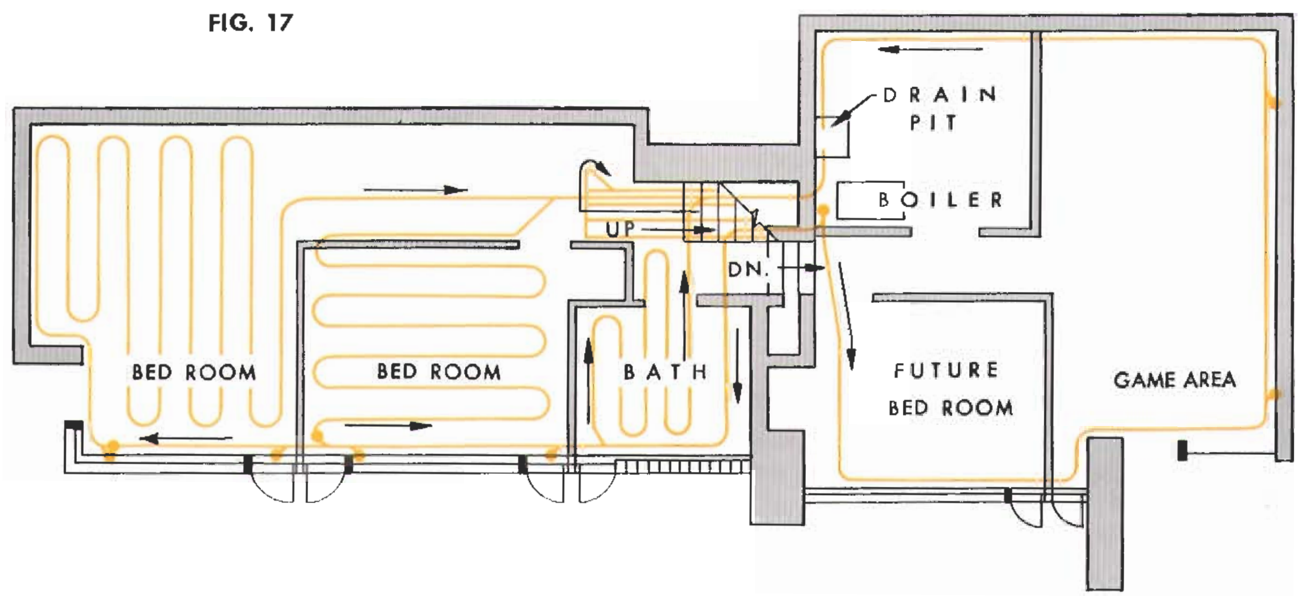


NOTES:

1. All piping 1 in. except as marked
2. ½ in. valve and take-offs
3. ½ in. stubs for wall coils—future unless marked
4. Coils centered in suspended slabs. Grade 1 in.
5. Vent all high points in system

ENTRANCE FLOOR LEVEL

FIG. 17



BEDROOM & BASEMENT LEVEL

FIGURE 18

internal corrosion is not a problem in designing a closed water system.

Corrosion is caused principally by alternate wetting and drying and by the attack of water-borne chemicals. When the system is filled with fresh water, the active elements attack the pipe and are quickly neutralized. Even in the most severe cases the amount of active material in drinking water is comparatively small. After the initial filling, the active materials are introduced at a negligible rate by the entrance of small quantities of make-up water, or by the ill-advised but common practice of draining the system "once a year." In a closed system very little internal exposure to air occurs, since such air bubbles as are carried by the make-up water are frequently vented out. Thus there is little likelihood of "alternate wetting and drying" and therefore a minimum danger of corrosion.

In light of the foregoing, it is evident that the worst possible water conditions which after two or three years might possibly cause pipe failure in a line through which the water flows continually, will produce only a fraction of that corrosion in a lifetime, in a closed water-heating system.

Pipe Stoppage

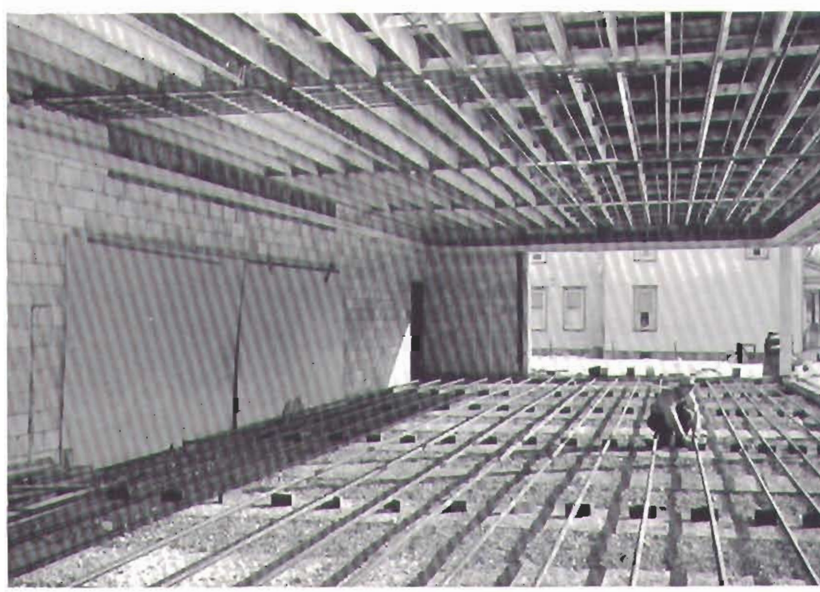
In some localities, the type of available water causes trouble in the form of precipitation of solids on the inner walls of constant-flow lines, reducing free area, and in some cases restricting the flow to a trickle. Preliminary corrective treatment of the water is the only solution to this problem. But in the case of the properly operated closed water-heating system, as in radiant heating, the problem does not exist because very little fresh water is admitted to the system.

Effect on Structure

A heat-distribution system composed of hot-water pipes is not a fire hazard, nor are there any known injurious effects on other building materials where the principles of good construction are followed.

The matter of providing for thermal expansion of plaster and concrete has been mentioned. In rein-

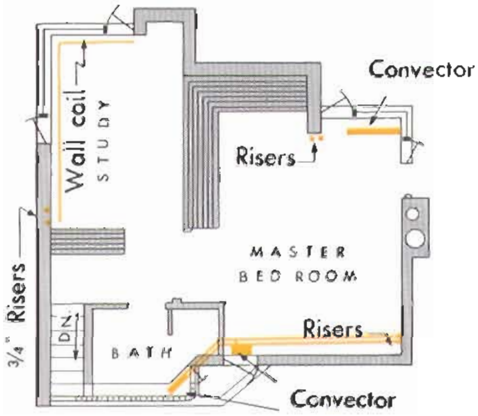
Automobile showroom and service building at Bethlehem, Pa., has radiant heating in floor and ceiling. *Below:* Rayduct coils in ceiling, and grid in floor, in showroom shown above.



PLAN FOR RADIANT-HEATING INSTALLATION IN RESIDENCE AT STATE COLLEGE, PA.

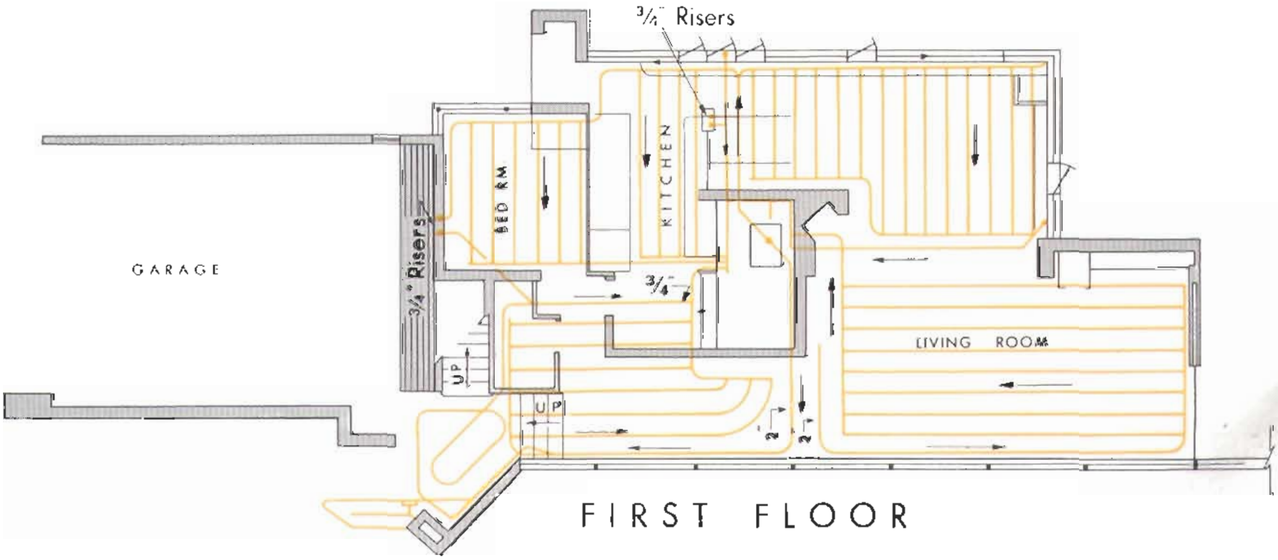
NOTES:

1. All pipes under 1st. floor slab welded
2. All supplies 2 in.—dead level
3. Headers 2 in.—dead level
4. Pipes between headers 1 in.—pitch 1 in.



SECOND FLOOR

FIGURE 19



FIRST FLOOR

FIGURE 20

forced-concrete construction the placement of expansion joints is governed by standard practice. In a small building, the vertical insulation strip shown in Type 2, page 8, automatically provides for expansion.

Effect on Finish Materials

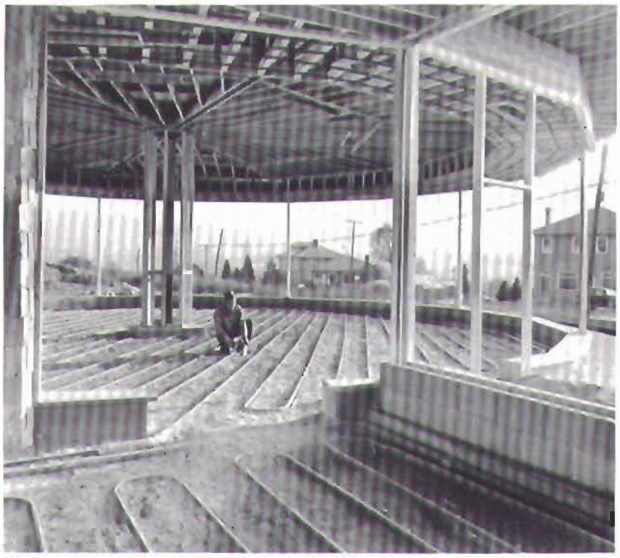
Although there are some minor exceptions, experience shows that no appreciable damage to surface finish materials need be expected. The comparatively low operating temperatures employed are well within the safe limits of the usual decorating materials, paints, paper, etc.

Painted surfaces, instead of being harmed, seem to remain true to color longer probably as a result of the almost total absence of dust-depositing convection currents.

Masonry surfaces are obviously unaffected. Many radiant-heated houses have been built with concrete floor slab simply stained and waxed, or paved with other masonry material. Of the various types of finished floor surfaces these are the most efficient for heating purposes. In no cases have cracks developed or discoloration occurred as a result of a radiant-heating system.

Linoleum covering laid on both concrete and wooden floors has been used quite often with no noticeable damage to the material. In the case of asphalt tile, however, it is well to remember that this material softens appreciably at fairly low temperatures, and its use over radiant-heated floors may sometimes encourage excessive indentation by the legs of furniture or by sharp, pointed heels.

Wood blocks or pressed-hard-board paving applied to a concrete floor slab with adhesive are recommended, provided that the customary provisions for expansion are made. Where wood flooring is used, good construction practice demands that it be thoroughly dried, and kept dry. Factory-



Rayduct used in both floor and ceiling of circular showroom shown in building below.

This garage and automobile salesroom, located in Emmaus, Pa., is heated by means of a radiant-heating system, using Rayduct.

Other Applications

Although this book has concerned itself primarily with radiant panel heating as applied to residential and small commercial structures, the same principle has been successfully used in a great variety of buildings. Over a period of forty years, a rapidly increasing number of European structures have been so heated and the experience gained has been of value in applying the principle to similar buildings in this country. Due however to the important differences in climate and construction methods, new techniques were developed, and thousands of installations now serve to prove new advantages; to provide solutions for new problems; and to open up a wide field of specialized applications.

Multi-Story Buildings

The initial installations of radiant-heated floor- and ceiling-panels in large multi-story buildings in this country have indicated that, while the advantages of radiant-heating are retained, incorporation of a new element within the basic structural system requires a careful restudy and integration of all components if construction speed and economy are to be realized. The time element is important, and may be solved by sensible planning and the use of well-known similar construction methods.

The positioning of coils in, under, or over structural slabs is a matter to be determined by the architect working in conjunction with his structural and heating engineers, and advised by practical builders.

In either the popular flat slab, or slab-and-beam construction, coils and reinforcement may be designed to fit one another in a simple pattern. In this connection it is well to remember that a two- or three-day period for coil installation in the first floor is not cumulative, since it is common practice to work on several floors at one time. Thus, one might reasonably expect an increased elapsed time for basic construction of only a few days in a 15- or 20-story building, and, with the heating coils in place at the end of this stage, the building is much nearer final completion than would be the case if an exposed convector system was to be installed. If, for some reason, this reassignment of construction time is unacceptable, and temporary heat

These two apartment buildings, erected in New York by the (*left*) 15 East Ninety-First Street Corporation, and (*right*) the 47 East Forty-Eighth Street Corporation, both subsidiaries of City Investing Company, are the first major multi-storied buildings in the United States to use radiant heating. Bethlehem Rayduct is used throughout each building.

during finishing operations is not considered important, the coils may be placed under or over the structural slab. That is, the structural slab is completed, leaving openings or sleeves for the pipe mains similar to provisions for a regular type of hot water or steam heating job, and the radiant-heating coils installed later. They can then be plastered in, on the ceiling or sidewalls, or laid on top of the structural slab and embedded in a finished concrete floor, a mastic-type flooring, or covered with conventional wood flooring.

The use of floor or ceiling coils at interior locations has been greatly overdone. Heat losses from rooms in multi-story buildings are generally confined to one exterior wall and exhausted air. A properly designed radiant-heating coil layout for a building of this type places a large portion of the pipe near or adjacent to exterior walls. Such a system is more responsive, provides more even heating effects, and reduces the cost to a point well below that of a conventional convector job. In one large radiant-heated office building, conventional fenestration left sufficient solid exterior wall for the application of heating pipes thereon, and the results are reported to be excellent. In this case, as is possible in many multi-storied buildings, heating coils in the floor slabs were completely eliminated thus dispensing with any integration or interference with the basic structural or floor-slab construction.

BETHLEHEM STEEL

THE PIPE FOR RADIANT HEATING

Under rationally and practicably controlled conditions, radiant heating is economically and structurally feasible in buildings of any height.

Specialized Applications

The fact that controlled radiant energy can economically compensate for wide variation in other comfort-affecting conditions makes possible a variety of specialized industrial applications.

Where processes or activities must take place in the presence of either cold conditions or heat-producing equipment, the worker's efficiency and comfort may be increased by appropriately placed and controlled heating or cooling panels.

For example, commercial candy sorting and packing operations must be performed under room conditions generally too cool for comfort. A restricted radiant floor panel may be installed directly under worker positions, and thus produce

These prefabricated two-story homes, all with Rayduct ceiling coils, are part of a large housing project erected at Nashua, N. H. Closeup of representative home shown in inset.

In addition to apron piping, Rayduct is used in both stories of this automotive building at Quakertown, Pa.

This attractive administration building at Wheeling, W. Va., has Rayduct floor piping in both first and second stories.

comfort conditions at this point without introducing excessive heat gain into the room.

Although excessive fuel costs prevent wide usage of the idea, several "open air" schools have been built. Sufficient radiating surfaces have been provided in these structures to maintain comfort in near freezing weather with the exterior walls, which are made of sliding glass panels, completely open. While definite health advantages are claimed for this arrangement, the cold air obviously tends to cool the heated surfaces rapidly, and an uneconomical amount of heat is required to maintain the necessary surface temperatures.

A similar application where fuel economy is of secondary importance is the sleeping terrace provided in several sanatariums located at cold, mountainous sites. In these places, the patient breathes fresh, unwarmed outdoor air. His comfort is maintained by means of a hot radiating panel of about the same size and shape as his bed, and located directly above it.

Unusual and extreme applications such as these have led to superior solutions for other problems of comfort control which are of less critical nature but of wider application.

Textile Mills

In textile mills certain industrial processes require moderate temperature conditions, and are adversely affected by dust, drafts, and temperature fluctuations ordinarily encountered in convection-type heating. In hosiery knitting mills, for example, floor-type radiant systems have produced moderate, even temperature conditions which minimize the serious problem of needle expansion and thread dropping. In addition, draftless heat reduces dust deposits on materials, and humidity remains within reasonable limits. Radiant heating is not a cure-all, however, and extreme climatic or atmospheric conditions may require additional provisions for air cleaning and humidity control.

Brooder Houses

One of the most remarkable applications is the provision of a radiant-heated concrete floor covered with regular litter in brooder houses, eliminating the time-honored hover, or canopy-type, brooder. Poultry men acclaim this type of chicken brooding as the most revolutionary advancement in poultry production since the discovery of the artificial

Wintry blasts should not interfere with the comfort of the occupants of this residence-apartment house at Bethlehem, Pa. Structure is heated by means of Rayduct floor coils.

Uniform operating temperature, so important to hosiery manufacturers, was one reason for installing radiant heating in this hosiery mill at Kulpsville, Pa.

Young chicks thrive in radiant-heated brooder coop.

incubator. Drafts and dampness the principal contributors to chick discomfort and disease causing poor growth and high mortality rates are positively eliminated. Temperatures are gradually varied from the optimum for day-old chicks to that required by full-feathered birds ready for market or range. It is reported that extended tests under full operating conditions have produced phenomenal results in comparison to conventional type brooding. In one case, peat moss floor litter, regularly changed every two weeks, had to be replaced only once in three months. Fuel costs alone, with an automatically-fired boiler, were reduced $1,650.00 in comparison with the hand-fired hover stoves previously used in producing 25,000 broilers annually. The most spectacular results, however, are these: mortality rates decreased to about 1 pct instead of the average loss of about 15 pct, and the weight of 12-week old birds ready for the broiler trade increased from an average of 3½ lb to 4½ lb each or an approximate 30 pct increase in weight! Results such as these are more than interesting to large-scale operators and definitely prove the system economically justifiable.

De-Icing

The convenience and economy of snow removal by radiant means for both residential and commercial applications has gained widespread acceptance. However, a specific treatment of this principle is noteworthy. The Hudson Coal Company, Scranton, Pa., maintains large trackage for railroad car storage at their Olyphant Colliery. Not only were they confronted by the usual ice and snow common in any switching yard, but in addition they had the problem in clear winter weather of water dripping from the washed coal and freezing cars to the rails. To overcome this a system was devised using Rayduct pipe attached in such fashion as to be in direct contact with the rail-head and switches and using waste steam as the heating element.

Since this system was installed in 1945, it has proved its ability in not only keeping the rails and switches free of ice and snow from normal precipitation, but has prevented the freezing of cars to rails. Older de-icing methods using steam for thawing, and the burning of petroleum products on the switches have been eliminated, thus improving the visibility and safety of the men who work the cars through the yards.

* * * * * *

A great many heating coil systems have been incorporated in concrete slabs poured directly on the ground. This widespread practice gave rise to a popular misconception that radiant heating requires such a construction. The popularity of this method arises from the basic economy of slab-on-ground construction, plus the fact that a radiant-heating floor system is the only practicable method of producing comfort in such buildings when built in climates requiring heat. In other words, a floor-type radiant-heating system makes slab-on-ground construction habitable: but radiant heating, properly designed, can be economically used with any type of building construction.

This brief reference to a few specialized applications is intended to indicate the wide variety of heating problems currently being met and solved by radiant means. The interested reader may find reports of many such projects in current technical and trade publications.

Rayduct, covered with a metal plate after being fastened under heads of rails, keeps tracks free of ice and snow in coal-company storage yard at Olyphant, Pa.

RAYDUCT

DIMENSIONS, WEIGHTS AND BUNDLING TABLE

(Standard Weight Pipe in Uniform 21-ft lengths)

		NOMINAL SIZE							
		½	¾	1	1¼	1½	2	2½	3
Weight per foot	lb	.85	1.13	1.68	2.27	2.72	3.65	5.79	7.58
Thickness	in.	.109	.113	.133	.140	.145	.154	.203	.216
Approx feet per ton	ft	2353	1770	1192	881	736	548	346	264
Pieces per bundle	pc	12	7	5	3	3			
Approx feet per bundle	ft	252	147	105	63	63	Rayduct in sizes 2 in. and larger shipped loose		
Average weight per bundle	lb	214	166	176	144	172			

PHYSICAL CHARACTERISTICS

		NOMINAL SIZE							
		½	¾	1	1¼	1½	2	2½	3
Outside diameter	in.	.840	1.050	1.315	1.660	1.900	2.375	2.875	3.500
Inside diameter	in.	.622	.824	1.049	1.380	1.610	2.067	2.469	3.068
Outside circumference	in.	2.639	3.299	4.131	5.215	5.969	7.461	9.032	10.996
Inside circumference	in.	1.954	2.589	3.296	4.335	5.058	6.494	7.757	9.638
Outside surface per foot	sq in.	31.667	39.584	49.574	62.581	71.628	89.535	108.38	131.95
Inside surface per foot	sq in.	23.449	31.064	39.546	52.025	60.696	77.924	93.079	115.66
Length per sq ft Outside surface	ft	4.547	3.638	2.905	2.301	2.010	1.608	1.329	1.091
Length per sq ft Inside surface	ft	6.141	4.636	3.641	2.768	2.373	1.848	1.547	1.245
Outside surface per foot	sq ft	.220	.275	.344	.435	.498	.622	.753	.916
Capacity, internal, per ft	cu in.	3.646	6.399	10.371	17.949	24.430	40.267	57.453	88.712
Capacity, internal, per ft	US gal	.0158	.0277	.0449	.0777	.1058	.1743	.2487	.3840
Length, pipe containing 1 cu ft	ft	473.91	270.03	166.62	96.275	70.733	42.913	30.077	19.479
*Displacement or volume, external	cu ft	.0038	.0060	.0094	.0150	.0197	.0308	.0451	.0668
Displacement or volume, external	US gal	.0288	.0450	.0706	.1124	.1473	.2301	.3372	.4998

*Also equals transverse area (outside dia) of pipe in sq ft

RELATIVE DISCHARGE CAPACITY

(Number of small size pipes approximating equal discharge of a larger pipe)

PIPE SIZE	PIPE SIZE							
	½	¾	1	1¼	1½	2	2½	3
½	1							
¾	2	1						
1	3.7	1.8	1					
1¼	7.3	3.6	2	1				
1½	11	5.3	2.9	1.5	1			
2	20	10	5.5	2.7	1.9	1		
2½	31	16	8.5	4.3	2.9	1.6	1	
3	54	27	15	7.4	5.0	2.7	1.7	1

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Rolled in a complete range of sizes and sections.

Bethlehem Light Sections

Light in weight for their depth, these solid-web wide-flange sections are especially suitable for upper tier work and for use as purlins in roofs of industrial buildings.

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For reinforcing all types of concrete construction Bethlehem makes a complete line of deformed bars in sizes conforming to the Simplified Practice Recommendation of the U. S. Department of Commerce. These bars are made exclusively of new-billet steel and are marked with the diameter.

Bethlehem maintains strategically located warehouses that cut and bend bars to specifications.

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Open-Web Steel Studs

Light weight, expanded columns 3 in., 4 in., and 6 in. wide.

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With Bethlehem Adjustable Steel Forms contractors can produce round columns of accurate contours. These forms are available on a lease-and-erection basis.

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Bethlehem makes a complete line of wire bar supports and spacers for accurate and economical setting of reinforcing steel.

Column Spirals

Welded Units for Concrete Reinforcement.

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For economical forming of concrete slabs. Available on a lease-and-erection basis.

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