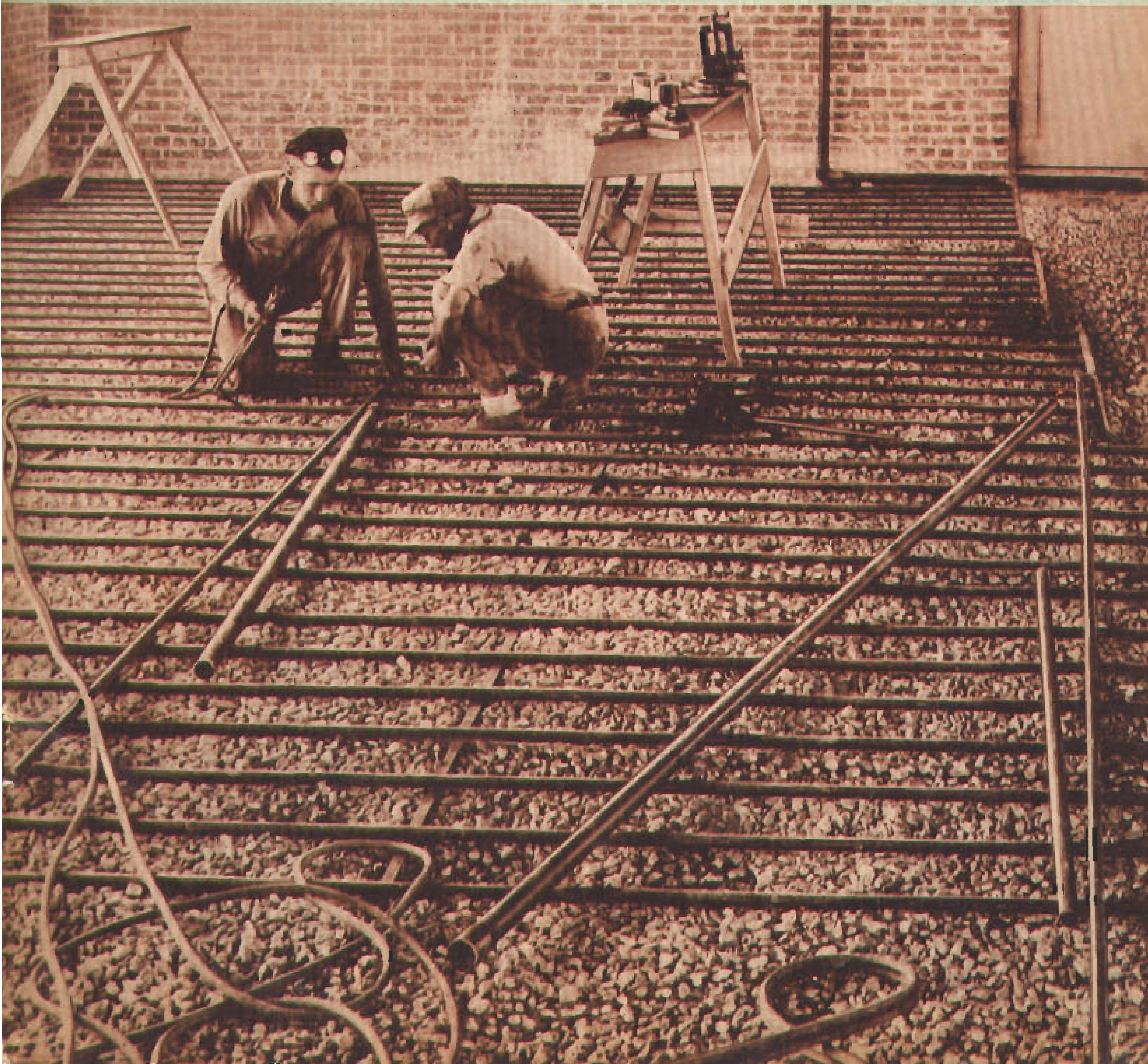
BYERS
Wrought Iron
FOR RADIANT HEATING



The Interest of A. M. Byers Company in Radiant Heating!

As one of the oldest manufacturers of tubular products, A. M. Byers Company has for many years carefully investigated any new development that promised to affect the use of pipe and made the information available to customers as part of a complete engineering service program. The wave of interest which followed the first report on a radiant heating installation in the 1930's indicated that this new system had unusual possibilities, while a study of the practical angles revealed that Byers Wrought Iron combined, in an unusually high degree, the physical, thermal, welding, and corrosion resisting properties necessary in a satisfactory coil material.

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As a help to interested prospects, data on installations in this country and abroad (where the system has been popular for a number of years) was assembled, and engineering information from a number of sources was consolidated into a bulletin, of which this is the latest edition. It is generally conceded throughout the heating industry that this bulletin is the most concise and complete of its kind.

Time has abundantly justified the faith of A. M. Byers Company in radiant heating's possibilities. There is ample reason to believe that as of September 1944 between one and two thousand installations have been made in this country, in all types of structures, since about 1937. Its rapidly expanding use in small homes was temporarily halted by the war, however other applications continued in increasing volume with the result that a broader knowledge of the technique is now available than perhaps would have been the case had development proceeded normally. In one recent industrial installation alone, 19,000 feet of Byers Wrought Iron pipe was used. The strikingly different and pleasant comfort conditions produced, together with the more obvious advantages of complete concealment, give every indication that the era of usefulness of radiant heating is only just beginning.

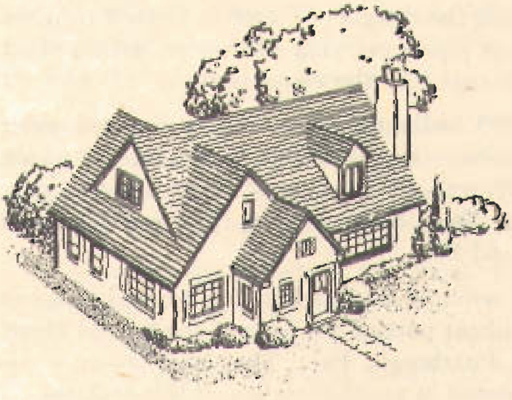
Foreword

It should be understood that the direct interest of A. M. Byers Company in radiant heating is confined to the piping. As explained in detail on the following pages, satisfactory pipe material must have a combination of physical, thermal, welding, and corrosion resisting properties possessed by wrought iron to an exceptionally high degree. During the course of the investigation which led to this conclusion, a considerable amount of additional data was accumulated which did not pertain directly to piping problems but which was of immediate interest to architects and engineers. Purely as a matter of friendly service, this data has also been included in the bulletin.

It is believed that the data presents a cross-section of modern thought on the subject of radiant heating since it has been gathered from recognized authorities. No effort has been made to present an exhaustive discussion of theory or design because such work is the normal province of the designing engineer.

We have, however, had long experience and intimate contact with the tremendously wide variety of corrosive conditions encountered in piping systems, and this qualifies us, we believe, to discuss authoritatively problems of material selection for radiant heating. Treatment of the technical and mathematical aspects of radiant heating purposely has been segregated as far as possible in the first part of the bulletin. Those whose interest lies primarily in the practical application of radiant heating can turn at once to page 20 for that section of this bulletin treating with present-day methods and procedures of construction and installation.

We gratefully acknowledge the invaluable aid in preparing this bulletin from authorities who have given generously of their time, from editorial comment in technical publications and from articles written by leaders in the heating field. Acknowledgment for use of material from signed articles or publications is given in the text.



The History of Radiant Heating

Two thousand years ago, at Bath, England, radiant heating was used by the Romans. Hot gases from charcoal fires were circulated through ducts to warm walls and floors, just as wrought iron pipe coils are now used to warm room surfaces. Mr. A. H. Barker, an English inventor, rediscovered the principle of radiant heating about 40 years ago when he noticed that at the same air temperature one room in his house was more comfortable than another, due to the warming of one wall of the more comfortable room by furnace flues. By embedding pipe containing hot water in the walls of other rooms he was successful in producing similar effects. Following his discoveries radiant heating developed steadily in England and there have been recorded something over 1000 radiant heating installations in England and France alone.

In the United States there are also some early installations but it is difficult to say whether these early experiments were inspired by European activity or were the independent product of Yankee ingenuity. However, in 1911, wrought iron heating coils were placed behind steel plates in the walls of certain rooms in the Phipps Psychiatric Clinic in Baltimore. This institution is part of Johns Hopkins Hospital.

In 1909 a small school was constructed in the village of Glen Park, Indiana which later became a part of Gary, Indiana. The original building was a 4-room brick building, two stories, with basement. Pipes carrying steam were suspended between the floor joists, over which the conventional wood floor was laid.

A large garage built in Chicago in 1912 was perhaps the first sizable floor-type radiant heating system in America. Because of the large number of doors in this structure, it was not feasible to use the conventional radiators and the designers therefore elected to place wrought iron pipes, carrying hot water, within sheet metal ducts cast into the concrete floor.

About 1915, radiant heating coils were placed under a 4-inch concrete first-floor slab in a residence which is now Riverwood Inn, Amsterdam Road, near Schenectady, New York. Ceiling coils were also used on the second floor.

In 1928, wrought iron pipe coils were embedded in concrete to heat part of the floor of the Sacred Heart Church in Pittsburgh, Pa. This installation is described in detail in another section of this bulletin.

While a certain amount of curious interest in radiant heating was aroused by these buildings, few additional installations were made here until Frank Lloyd Wright built the Johnson Wax Building in Racine, Wisconsin, and placed wrought iron coils in gravel under the concrete floor slab. Following the widespread comment on this building, interest in radiant heating has swept the country and a considerable number of installations have been made.

The Theory of Radiant Heating

The object of any heating system is to maintain healthful and comfortable conditions in enclosed structures, and a great deal of research has been done to determine what constitutes ideal conditions and to outline the permissible variations from this ideal.

The body itself manufactures more than sufficient heat for its needs, and must therefore continuously dissipate this excess. It does this by several means, as outlined in an article on "Radiant Heating" in the January, 1939, ARCHITECTURAL FORUM:

> "Body heat is dissipated into the environment largely by way of the skin, by convection, radiation, conduction, and evaporation. In addition, a small and fixed amount is lost through evaporation in the respiratory tract, by excretion, etc."

The radiation loss is the energy given off from the body by means of thermal radiations to surrounding cooler objects; the convection loss is the heat carried from the body by passage of air over the skin and clothing; the evaporation losses represent the heat necessary to transform surface moisture on the body into vapor; the respiration losses represent the heat that air breathed in and exhaled extracts from the lungs; and the heat losses by excretion are the small amounts of heat carried off by waste products of the body.

According to the American Society of Heating & Ventilating Engineers' "Heating Ventilating Air Conditioning Guide," 22nd Edition, page 785:

> "Healthful comfort requires that heat shall escape from the body at the same rate as it is generated by the oxidation occurring in the body, and in a manner suitable to physiological requirements. Furthermore, the ambient conditions will often cause changes both in the rate of heat generation in the body, and in the operation of the several methods by which the body loses heat. The feeling of heat or cold results not only from the rate at which the body loses heat, but also from the manner in which the heat is abstracted from the body, and the ease with which the body's heat regulating mechanisms can operate."

Thus, it is desirable to regulate the manner in which heat is lost by the body, as well as the total quantity. This can be done by means of radiant heating. On page 786, the "Guide" discusses heat loss in somewhat greater detail as follows:

> "The normal rate of heat production in an average sized sedentary individual is about 400 Btu per hour. When considering radiant heating, one must study separately the evaporation, radiation, and convection losses. The human body is of complicated shape, and radiation takes place freely only from the exposed outer surfaces; there are considerable portions of the body such as the legs, arms, lower part of head, etc., which radiate most of their heat to other portions. It is necessary to determine the equivalent surface of the body from which heat is radiated and a similar value for convection. The total surface may be assumed as approximately 19.5 square feet for convection and 15.5 square feet for radiation, in an average sized individual.
>
> "The loss of evaporation and respiration depends on the temperature and area of the moist surfaces (outside and respiratory) of the body, the air temperature, air movement, and humidity. In air at a temperature of 70°F, this loss for a sedentary individual of average size will be approximately 90 Btu per hour; and at 60°F, about 70 Btu per hour. These values are relative, because the total will vary materially with change of position, bodily activity, age, sex, race, etc.
>
> "The balance of the heat generated in the average human body, approximately 300 to 320 Btu per hour at about 70°F room temperature, is the approximate amount of heat given off by radiation and convection. It is difficult to determine the exact proportions of these two; but it appears that if the body losses are about 190 Btu per hour by radiation, or 12.25 Btu per hour per square foot of radiating body surface, the greatest comfort will result. This leaves about 120 Btu per hour to be lost by convection or 6.01 Btu per hour per square foot of convecting body surface."

While this quotation mentions that greatest comfort will result when the heat lost by radiation is about 190 Btu per hour, and the convection loss is about 120 Btu per hour, other ratios of these two losses may also give acceptable results. The permissible variations from this standard will be discussed in greater detail in the section of this bulletin dealing with Radiation and Comfort. Design problems center about means of regulating the total quantity of heat lost, and the methods by which it is dissipated.

Heat Rays

A wood fire gives off heat rays as well as light. Even though the air may be cool, the radiant heat from the hot coals can be felt at a considerable distance and a sensation of cold immediately follows if the rays are blocked. Similarly, on a cool "snappy" day the sensation of warmth varies widely between sunlight and shade. Both these illustrations show that heat rays can pass through the air without noticeably changing its temperature, but can produce the sensation of heat when they are absorbed by the human body. Scientific investigations have shown that radiant energy may take many forms, such as X-rays, ultra violet rays, light, infra-red rays, and heat rays. All are basically similar, but they differ in wave length. They can all be reflected, absorbed, or focused, and heat rays, like light, can pass practically unchanged through the air.

When heat rays strike a surface, a portion of the radiation is absorbed and the remainder is reflected without any change in wave length. The absorbed rays warm the surface, and it then gives off radiant rays of a longer wave length than the original radiation. This phenomenon is called re-radiation.

The ability of surfaces to absorb, reflect, and reradiate energy explains why, in some sections of the country such as Sun Valley, Idaho, one may ski in a bathing suit and be perfectly comfortable. Radiant heat direct from the sun, reflected rays from the snow, and re-radiated energy from warm objects such as rocks, balance the heat lost by convection to the cold air and the skier is comfortable.

The fact that the heat rays are reflected from the snow, but absorbed by the human body and dark objects, shows that all surfaces are not equally good collectors or receivers of radiant energy.

In general, objects which are rough and dark in color absorb radiant rays most readily, while smooth light colored surfaces reflect them. A dull black surface absorbs radiant rays more readily than any other, and it is also the best radiating surface known. For this reason, the "black body" is spoken of as the perfect radiating surface. When measurements are to be made, the term "emissivity factor" is used to compare any actual surface with the ideal. Thus, a certain material may give off radiant rays 90 per cent as well as a perfect radiator or "black body." Such a surface would have comparative radiating capacity or an "emissivity factor" of 0.90. If a certain surface will absorb radiant heat 90 per cent as well as a black body, it will also radiate heat with 90 per cent of the efficiency of a black body.

In other words, the "emissivity factor" is (a) determined by the character of the surface, (b) is expressed as a number or ratio less than one, and (c) is the same whether the surface is radiating or absorbing energy. In a general discussion of radiation, this "emissivity factor" need be given only passing mention, but when measurements or extremely accurate calculations are made, it must be considered.

It is also a fundamental principle of radiant heat transfer, as it is in other forms of heat exchange, that heat can flow only from a warm body to one at a lower temperature. The lowest temperature that can conceivably be reached is absolute zero, or 460 degrees below zero Fahrenheit. At this temperature, radiation ceases. Therefore, this temperature is a logical reference point, and, if it is known how much heat will be radiated from a surface at a given temperature to a black body at absolute zero, then it is a simple matter to compare the rate of heat transfer between surfaces at different temperatures. It is only necessary to subtract the rate of radiation from a surface at one temperature from that of a similar surface at a higher temperature to find the rate at which heat will be exchanged between them.

It is important at this point in the discussion to note that the body can lose heat by radiation to any surface at a lower temperature and can gain heat from any warmer surface, regardless of the air temperature. Radiation is thus controlled by surface temperatures alone and is independent of the temperature of the surrounding air.

Radiation and Comfort

In the preceding discussion of the theory of radiant heating, mention was made of the fact that comfortable conditions could be maintained under a variety of environments provided the total heat loss from the body by radiation and convection was approximately 300 to 320 Btu per hour. It was stated that ideally, about 190 Btu per hour should be lost by radiation and about 120 Btu per hour by convection. Skiers at Sun Valley, exposed to intense radiant rays and cold air, lose heat primarily by convection and practically none by radiation. A person in a room filled with warm air, but having cold walls, would lose heat primarily by radiation, and very little by convection. It is thus apparent that the sensation of cold can be avoided in either one of two ways:

1. By raising the air temperature to a sufficiently high point (the conventional practice).
2. By raising the temperature of the surfaces surrounding the body (radiant heating system).

It should be emphasized that by either method the total heat emitted from the body is the same, but it is impossible to produce conditions conducive to maximum comfort when an abnormally large radiation loss is permitted.

In illustrating this point, A. H. Barker assumes a normal skin and clothing temperature of 75° F and in an article "Room Warming by Radiation," which appeared in the March, 1932, issue of HEATING, PIPING, & AIR CONDITIONING, page 208, he says:

> " . . . if the walls of a room were uniformly at 75°F, no heat would be lost by radiation. In order to maintain the body comfort the air temperature would have to be about 44° F so that the whole of the heat required to be abstracted from the body at 75°F should be removed by convection currents. Similarly, if the air of the room were at 75°F, no heat would be removed by convection and the surrounding walls would have to be at an average of about 50°F in order that the whole of the surplus body heat might be dissipated by radiation alone. The former condition would produce a feeling of warmth and freshness. The latter would feel equally warm but stuffy. The thermometer reading in the two cases would be widely different though the feeling of warmth would be the same."

It will be noted that, for simplicity, Mr. Barker has assumed that the walls of the room were uniformly heated to certain temperatures, but in actual practice it is impossible to maintain the outside walls at the same temperature as the inside walls, the ceiling, and the floor. These differences of temperature balance each other, however, and somewhere between the temperature of the warmest and coolest surfaces there is one temperature which would be the temperature of all surfaces in a uniformly heated room where the same radiant heat loss from the body would occur. This equivalent temperature is the "Mean Radiant Temperature." In the room Mr. Barker describes as having all walls at 75°F, the same effect could have been achieved had one wall been warmer than 75°F, and another cooler, provided the Mean Radiant Temperature (MRT) were 75°F. This term is widely used in articles on radiant heating.

By properly adjusting air temperature and Mean Radiant Temperature, it is possible to establish conditions of comfort. In an article entitled "Radiant Heating and Cooling" which appeared in the July, 1940, issue of HEATING, PIPING & AIR CONDITIONING, Dr. F. E. Giesecke makes the following statement:

> "During a recent investigation conducted by Dr. Yaglou at Harvard University with 3 male adults clothed in 3 piece suits and at rest during the tests, it was found that comfort conditions were produced with the following three sets of temperatures:
>
> **Air 71°F and MRT 71°F**
> **Air 63°F and MRT 79°F**
> **Air 59°F and MRT 85°F."**

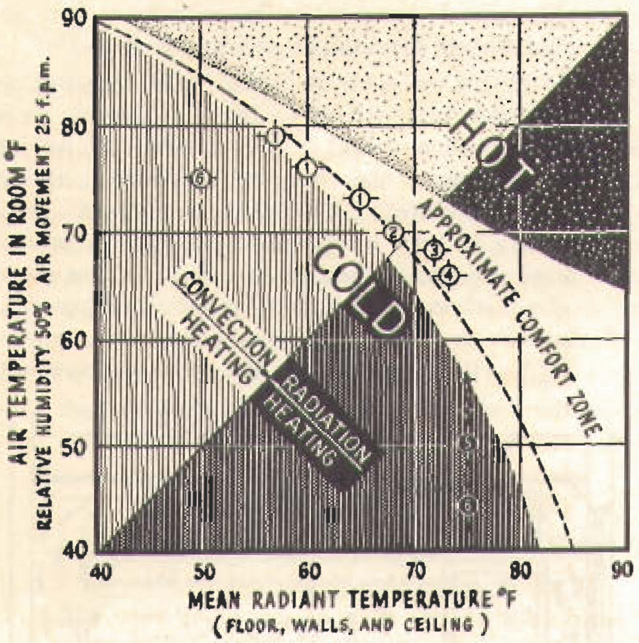


FIG. 1

COMFORT CHART for radiant and convection heating, showing approximate comfortable balance between wall and air temperature for an extremely wide range of conditions. Comfort zone is for winter only, summer values would be somewhat higher. Dash line indicates design-value for mean radiant temperature (average of walls, floor and ceiling) with air temperature given — example: for 65° air, line shows MRT as 72°. Points indicate results of various tests and computations from the following sources: 1, 1, 1. A.S.H.V.E. Laboratory. 2. Comfort Chart, A.S.H.V.E. Guide. 3. Westinghouse Research Laboratory. 4. T. Napier Adlam. 5. and 6, 6. (English practice) L. J. Fowler and Arthur H. Barker.

The January, 1939, ARCHITECTURAL FORUM carried an article entitled "Radiant Heating" and on page 57 a comfort chart is given which is reproduced in this bulletin as Fig. 1. This chart shows that by suitable arrangements to warm certain of the room surfaces, the designer can produce comfortable conditions with a wide range of air temperatures. Examination of the chart will also illustrate differences between English and American standards.

The Advantages of Radiant Heating

A summary of the advantages claimed for radiant heating by its various advocates was published by HEATING, PIPING & AIR CONDITIONING Magazine, June, 1940, in an article on "Radiant Heating & Cooling," by Dr. F. E. Giesecke. The following were listed:

> "1. The radiators are out of sight and do not occupy floor space which can be used for other purposes.
>
> 2. When the structural frame of a building has been completed, the heating system has also been completed and heating can be begun immediately to facilitate completion of interior work.
>
> 3. The heating system does not affect the location of partition walls or later changes of such walls.
>
> 4. When used in prisons or asylums, the system cannot be tampered with by the inmates.
>
> 5. The system can be used for cooling as well as for heating in those localities where the humidity is not too high.
>
> 6. The floors are warmer than in buildings heated by more ordinary systems and cold air currents along the floors are less intense.
>
> 7. Air currents within the room are materially reduced so that dust particles, to which disease producing organisms may be attached, can settle out, thereby producing a purer and more sanitary air within the building.
>
> 8. The first cost of the system depends largely on labor costs and will not vary much from that of the ordinary heating systems.
>
> 9. The cost of operating the system is somewhat lower than that of the ordinary system for the following reasons: (a) for equal comfort, the temperature of the air within the building is slightly lower and hence the cost of heating the air which passes through the building is lower; (b) the heat loss through outside walls is some-

> what lower, especially when the windows have double glazing; (c) when either water or air is used as the heating medium, lower temperatures are used than in ordinary heating systems and therefore an economy in fuel combustion can be effected."

The ARCHITECTURAL FORUM in an article entitled "Radiant Heating" which appeared in the January, 1939, issue sums up the merits of radiant heating from a slightly different viewpoint:

> "Briefly, radiant heating is said to be both better and cheaper than convection heating. More specifically, its advantages are listed under three headings: architectural, physiological, and economic. Its architectural advantages include the fact that it does not mar or interfere with decorations, takes little or no space, may be so arranged as to make alterations an exceedingly simple matter, and easily solves otherwise difficult heating problems arising from frequently used entrances, high rooms, and large glass areas. Its physiological claims embrace both comfort and health: comfort because of more uniform air and radiant temperatures throughout the heated space, a greater comfortable range of bodily activity under a given set of conditions, absence from drafts, and easier ventilation; health because of the reduced contrast between indoor and outdoor air temperatures, higher humidities more easily maintained, and cooler and cleaner air for breathing. Economically, it is said to save up to one-third on fuel, and in some cases to reduce the first cost of the heating plant."

A further advantage which appeals to those charged with the actual construction work is that radiant systems — particularly the floor type — are usually installed and the heating men gone from the job before the building has progressed very far. Work of other types can then go ahead without any conflict of any kind with those installing the heating system. In cold weather, another advantage exists in that carpenters, plasterers, electricians, etc., are able to work in warm, comfortable surroundings. Builders who have had an opportunity to study radiant heating in this light are consistently enthusiastic about this characteristic.

Certain of these advantages, such as the statement that the radiators are out of sight, are so clearly and logically the result of construction methods that no further discussion is necessary. Claims for more uniform temperature distribution, lower cost, and a reduction of the dirt nuisance merit further study, and will be dealt with separately.

Temperature Distribution

Actual temperature measurements made in rooms warmed by various types of radiant heating installations seem to prove that the requirements of good heating practice are met by this system. Cold floors are obviously undesirable, and the Industrial Fatigue Research Board of England has stated that any good heating system should provide an air temperature at the foot level equal to or greater than that at the head level. T. Napier Adlam dealt with this subject of temperature differences in an article "Some Temperature Studies in Radiant Heated Rooms" which appeared in the June, 1931, issue of HEATING & VENTILATING. He says:

> "Fig. 2* illustrates diagrammatically the conditions we generally obtain with a concealed heater or warm-air system. Assume that steam is turned on and a stream of warm air is introduced into the room from the grille or from the top of the concealed heaters. From concealed heaters the temperature of the air may be 130° to 150°, although I have actually measured the air temperature leaving the grilles as high as 190°.
>
> "With a warm-air system the inlet temperature may be as high as 180° to 200°. This warm air is not only detrimental to the system, but, having passed over a high temperature surface, it has become polluted, for when the air passes over a surface at high temperature the dust is broken down chemically and ammoniacal vapors given off. With steam radiators we get similar results, but the air leaving the top of the radiator will be 90° to 110°, depending on the room temperature.

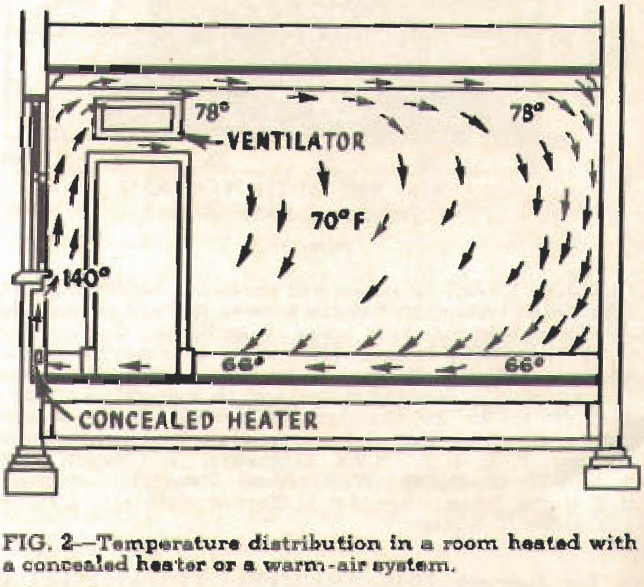


FIG. 2—Temperature distribution in a room heated with a concealed heater or a warm-air system.

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*The original figure number references have been changed to fit the series in this bulletin.

"In either case the warm air naturally rises to the ceiling and will remain there, giving up part of its heat to the cold ceiling, and should there be any outlet at the high level the warmest air will escape before being of further use. As more warm air rises from the source of supply the air at the ceiling, which does not escape, falls gradually. This continues until we get a series of layers at different temperatures. In other words, we have a temperature gradient from ceiling to floor.

"The steepness of this temperature gradient will depend on the temperature of the air rising from the source, the heat loss from the room and the quantity of air which is circulating.

"When using steam pipes and radiators it is usual to get from 6° to 8° difference in temperature between the floor and the ceiling. With warm air or concealed heater I have found a difference of 10° to 14° to be quite common. Fig. 3* illustrates diagrammatically the normal conditions met with in a room heated by steam radiators. These are average observations in rooms from 9 ft. to 10 ft. high. For higher rooms the temperature at the ceiling will be correspondingly higher.

"Fig. 4* shows average recorded temperatures at various heights for heating with radiators and convectors, and it will be clearly seen that the high temperature gradient means greater loss of heat. We find a warm stratum of air for breathing and for the head, with a cooler temperature for the feet, just the opposite to that required.

"I have taken observations in many of the high buildings in this country and find that air is constantly passing through the ventilators over the doors into the corridors or passages at a temperature five or more degrees above the temperature of the air at the breathing line. This chimney effect in tall buildings is a bug-bear to all heating engineers and architects because of the difficulty of being able to overcome its influence. The graduation of heating surfaces is only a partial remedy, for it does not hold good under all weather conditions.

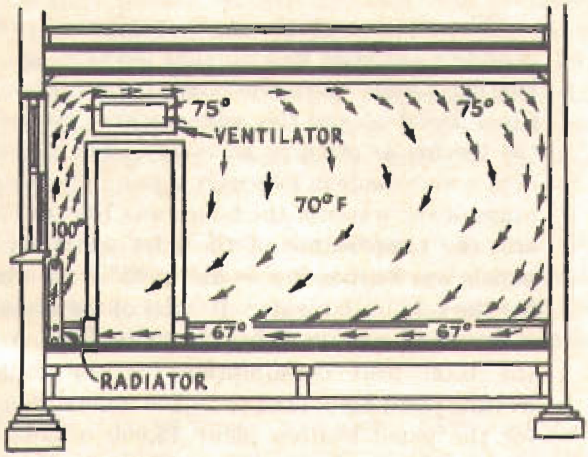

FIG. 3—Normal temperature distribution with a steam radiator. Average observations in rooms of 9 to 10 feet in height.

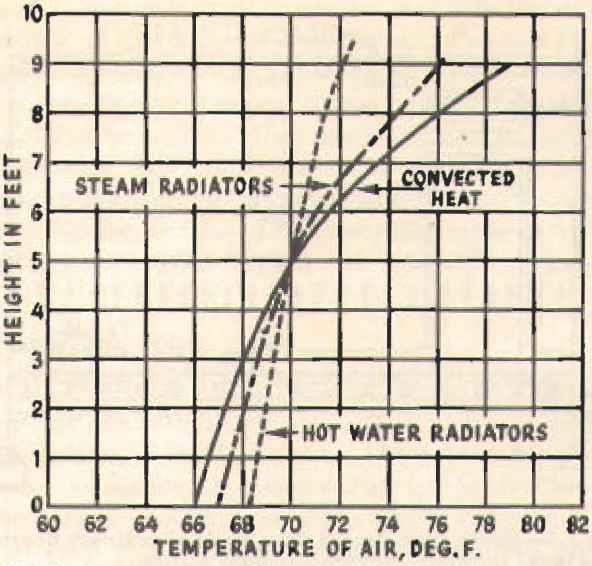

FIG. 4—Average reported temperatures at various heights for heating with radiators and convectors.

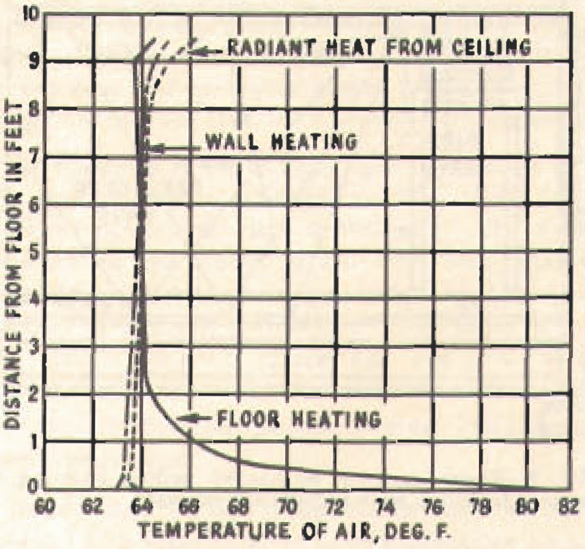

FIG. 5—Comparison of results with radiant heating from ceiling as compared with wall and floor radiant heating.

"Compare this with a building heated with thermal radiations where the air temperature at the ceiling level varies only slightly from that at the breathing line. The result, as can be seen by

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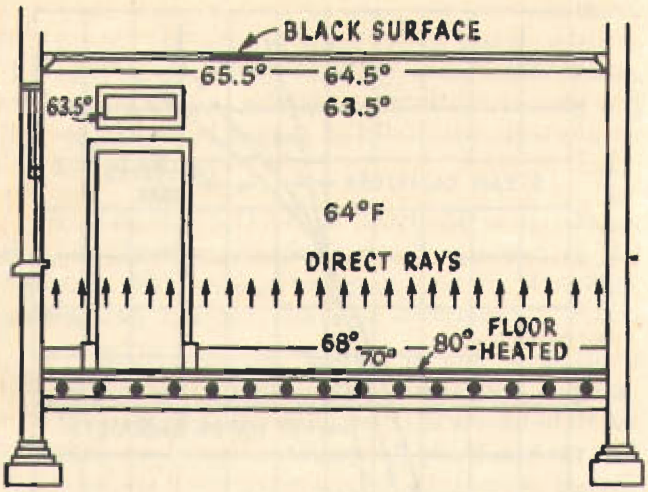

FIG. 6—Room with heated floor made of ordinary flooring material showing temperature distribution.

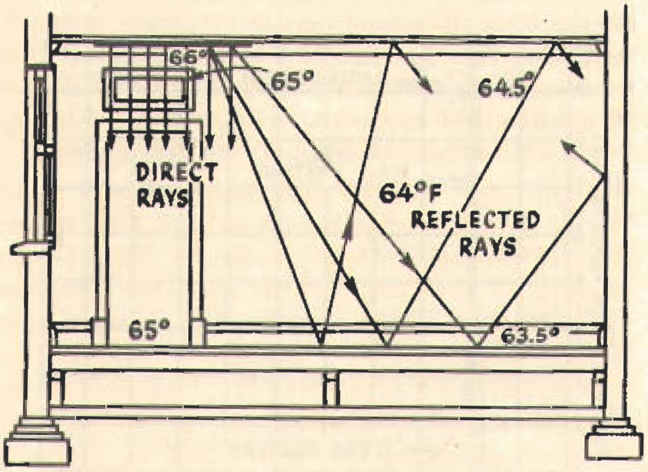

FIG. 7—Room warmed by heated ceiling showing the manner in which radiant rays are reflected.

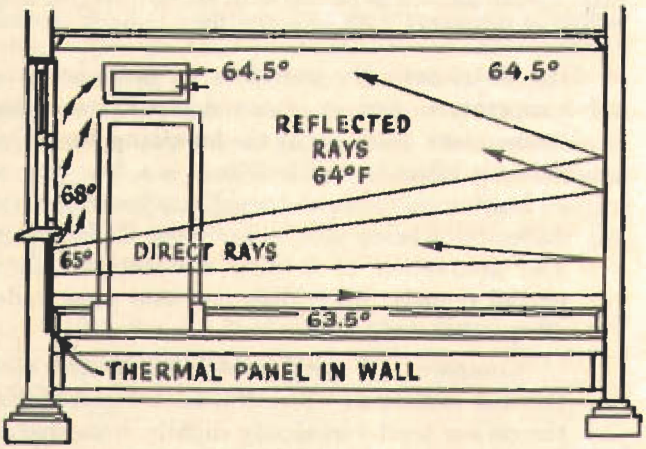

FIG. 8—Room heated with thermal radiations from heated surface on side wall.

Fig. 5*, would be an almost constant temperature throughout the building."

Figs. 6*, 7*, and 8* also from Mr. Adlam's article, show the temperature ranges which may be expected in radiant heating installations with the warmed surfaces located in different portions of the room. In the section of this bulletin which deals with installations, will be found on page 22 a description of the Liverpool Cathedral in Liverpool, England. Measurements were made by Mr. Adlam and were reported as follows in the August, 1931, issue of HEATING & VENTILATING in an article entitled "Applications of Radiant Heating":

> "When the temperature of the air 4 ft. above the floor was 60° it was found that the air temperature at the triforium level was 58½°, just 1½° lower at 97 ft. above the floor than at 4 ft. above the floor. It seems to me that no other method of heating now known could create such conditions in such a high building."

Comparative Cost of Radiant Heating

Operation

In HEATING, PIPING & AIR CONDITIONING magazine, February, 1940, an article entitled "Foreign Experiences with Radiant Heating," by Stephen Zamenhoff appears, and the following statement is made:

> "The author investigated the ceiling panel radiant heating plant in six school rooms in Copenhagen as compared with the radiator heating plant in the six other rooms in the same school. The rooms have dimensions of 25.4 x 30.8 x 11.5 ft.
>
> "The measurements were performed under conditions as close to normal as possible; i.e., the heating plants were operated by an unskilled superintendent and the windows were opened by the teacher as often as necessary. The measurements were made in February-April. The temperature of the water in the boiler was 149° to 176°F and the temperature of the inlet water for the panels was kept as low as 81° to 93° F by admixing the cold outlet water. Results of the measurements were: From February 14 to February 27 the total heat consumption for the radiator heating plant amounted to 20,200 million Btu and for the panel heating plant 14,000 million Btu or 30 per cent less. The radiator heating was

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*The original figure number references have been changed to fit the series in this bulletin.

> much more sensitive to the opening of the windows than the panel plant: opening windows caused practically no increase of heat consumption in the panel plant but caused a very pronounced increase of heat consumption in the other. It should be pointed out that the lower heat consumption of the panel plant was ascertained on week days only; on Sundays and holidays when the boiler temperature sank to 122°F and the temperature of inlet water for the panel heating plant was not lowered correspondingly, the heat consumption of the panel heating plant was higher than for the radiator heating plant.'"

The high heat consumption over the weekends could be expected because at such times the panels were actually continuing to do their normal heating job while the radiators were maintaining considerably less than normal conditions.

In a bulletin entitled "Heating by Radiant Means" published by Sarco Company of New York City, Mr. T. Napier Adlam, Chief Engineer, makes the following comment:

> "I would like to mention the question of economy. After many years of experience it is well established that the saving in fuel consumption is between 30 and 40% while if electric heating is installed with good electric controls the saving is even greater. Recently, while in England, I called on one of the largest manufacturers of metal radiant heat panels in the country and during my conversation I was informed that the annual output of these heaters has increased every year from the time of their inception over 20 years ago. I was also informed by the same firm that in all cases where they supply radiant heaters instead of ordinary cast iron radiators, they reduce the size of the boiler by 40% below that which they would supply for similar jobs where cast iron radiators or convectors are used. Seeing that hundreds of these systems are sold every year this seems to be sufficient proof of the saving effected."

This reduction of boiler size, although not yet considered standard practice in this country, is apparently possible because of the lower air temperatures and better operating efficiency of the radiant heating system.

Results such as those cited above have been consistently reported in every investigation so far conducted. Under the war-time fuel oil rationing program owners of radiant systems were able to go through the heating season in perfect comfort, yet with the use of so little oil that a sizable quantity would remain at the end of the season. At the same time, neighbors under the same regulations were unable to keep their houses comfortable with full fuel quotas burned in conventional systems. Similar results have also been found in both gas and coal-burning installations. Thus far, investigation has failed to reveal any cases in which operating costs were higher with radiant heating.

Installation

The matter of installation costs for radiant heating systems has been rather interesting to watch during the growth of the technique. There have been two factors in particular — engineering and fabrication — which have undergone slow but steady changes, with the result that the systems have become less costly as time went on. To be sure, some of the earlier installations were quite expensive but there have always been instances where owners were willing to pay more for the considerable benefits of radiant heating. This continued demand, small as it was, served as a trial-and-error period during which time much was learned that later proved very valuable.

As engineers came to know more and more about the performance of radiant heating, their designs reflected consistently less uncertainty. The various elements in the design, which were once unknown quantities and had to be guessed at, became more familiar in terms of performance until today there is little excuse for over-engineering. The effect of this circumstance on installation costs is obvious — today's radiant heating systems are much less expensive than earlier ones.

In addition, the men doing fabrication work had to contend with somewhat the same uncertainty because the system was new to them and, in many cases, involved the comparatively new techniques of pipe welding and bending. However, it has been the universal experience that, after the first few installations were made by any given fabricator, his costs also declined steadily.

Taking these factors together, it can now be said that for most communities radiant heating need not cost any more than any other good heating system. For example, radiant systems in the northeast section of the United States are now found to vary somewhere in between 6 and 10 per cent of the total cost of the structure in residential work, depending on the building itself and the refinements to the heating system which individual owners may care to add.

There is evidence also that installation costs have not yet reached the minimum. Largely as a result of improved pipe fabricating techniques brought about by the war, it can reasonably be expected that costs for welding, bending, etc., will be still further reduced. For example, manufacturers are at work developing various pipe welding machines which, it is expected, will reduce the time consumed in making each weld to a matter of seconds as against several minutes (for smaller sizes) required by the present manual techniques.

Ceiling coils are generally considered to be more expensive than the floor-type elements by about 10 to 15 per cent. Floor coils have been found in many cases to be quite inexpensive and in residences have particularly aided in making available the economies and functional advantages of basementless houses which frequently allow more house "above the ground" to be built for the same, or lower, cost. In passing, it is well to note that the trend toward basementless construction, though small, is strong and is now much more practical since the cold floors in earlier designs no longer exist because heat can be placed where it is needed.

As typical examples of installation economy, a house in Connecticut was recently completed in which both floor and ceiling coils were used and the owner has stated that this heating system was less costly than any of the others he had considered. The Greenville Steel & Foundry Company's heating system, described on page 30, was fabricated in their own shops but a company official recently commented that even when allowance was made for shop overhead, they were able to realize a saving over a conventional system.

The Reduction of Dirt Deposits

The seventh advantage of radiant heating listed by Dr. Giesecke and quoted in the first part of this section of the bulletin mentions that dust and dirt problems are reduced with radiant heating.

A recent study by R. A. Nielsen of Westinghouse Research Laboratories in East Pittsburgh, Pa., contains information which indicates that cleaning problems may be greatly reduced as a result of maintaining wall and ceiling surfaces at higher temperatures. The results of this investigation were summarized in an article "Dirt Patterns on Walls" which appeared in the June, 1940, issue of HEATING, PIPING & AIR CONDITIONING. A photograph is included in this article showing 5 parallel pipes, all painted yellow, and carrying gas, vacuum, compressed air, hot and cold water.

The first four were clean, while the cold water line was very dirty, showing that dirt tends to precipitate on cold surfaces. The following statement is also made:

> "Another example of thermal precipitation is the familiar patterned walls near radiators and warm air registers. Above the radiator the wall is generally dark; especially, is it noticeable just at the top of the radiator where light and dark vertical patterns show the paths taken by air currents. The section of wall actually behind the radiator (excepting the top couple of inches) is really clean, since it is heated by radiant energy to a temperature above that of the passing air. Convective and diffusive forces tend to deposit dirt on the wall but there the temperature gradients are large enough to *repel* all dirt and the wall remains clean. Above the radiator the wall temperature becomes lower than the warm air temperature; convection and thermal gradients then act together with the result that the wall soon becomes coated with precipitated dirt. The warm air rising to the ceiling establishes a high temperature gradient there and the result is that the ceiling becomes dark. Above a supply register the case is similar to that of the radiator. The heated air is carried close to the wall and the temperature gradient is sufficient to cause precipitation of some of the dirt. If a hood or baffle is placed over the top of the radiator, it is found that the wall above the radiator is cleaner because the warm air had been deflected away from the wall and cooler air has replaced it. The old saying that 'hot air is dirty' is true in that hot air certainly has the ability to establish temperature gradients which indicate on the walls that the air was dirty."

Further observations in many radiant heated structures indicate that warming of the room surfaces can be expected to materially reduce the tendency for dirt to deposit.

In the April, 1940, issue of DOMESTIC ENGINEERING an article entitled "O. K. to Slab Heating" appears. Actual experience with a radiant heated house in Lebanon, Ohio, designed by A. H. Harmon, Architect, is described, and the following statement is made:

> ". . . with the even distribution of heat, there are no excessively dirty spots in the rooms."

Calculation and Design of Radiant Heating Installations

In the foreword to this bulletin, it was stated that no attempt would be made to deal exhaustively with the question of design. The only purpose of this section is to lead the reader to authoritative source material which can be used for design purposes and to add a few pertinent suggestions which have occurred to us after long study of many installations.

The "Heating Ventilating Air Conditioning Guide," 22nd Edition, Chapter 45, covers the subject of calculation in rather complete detail. This treatise describes a method by which the temperature and area of a warm surface necessary to establish a given Mean Radiant Temperature may be calculated. As subsequent editions of this work are published, there is no question but that it will continue to reflect the best thinking in the industry on the subject of radiant heating.

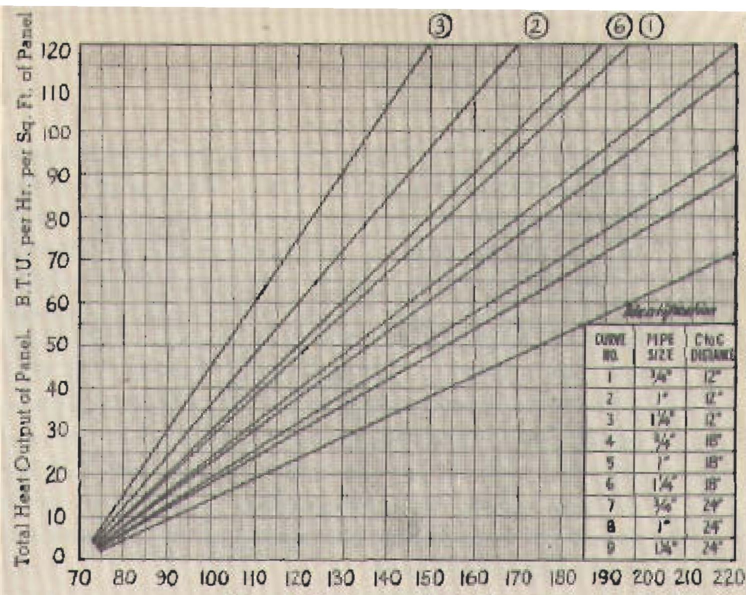
TABLE 1

Surface	Factor of Emissivity, %
Absolute black surface	100
Rough concrete	94
Wrought iron, oxidized	94
Smooth lamp black	93
Rough lime mortar	90
Planed wood (not polished)	88
Steel, oxidized	79
Copper, black oxidized	78
Copper (polished)	4

The perfect radiator, or "black body," was mentioned previously under the topic "Heat Rays," and it was stated that the relative ease with which various surfaces dissipate radiant energy is measured by an "emissivity factor." Typical values for per cent emissivity are given by Mr. T. Napier Adlam in an article "Calculations for Radiant Heating," page 65 of the October, 1931 issue of HEATING AND VENTILATING. Table I (above) is based on Mr. Adlam's data and on similar published experimental information.

In a series of articles which appeared in the June, July, August, and September, 1940 issues of HEATING, PIPING & AIR CONDITIONING, Dr. F. E. Giesecke develops a slightly different method. It is based on a calculation of the panel area and temperature needed to maintain a predetermined air temperature, and the MRT is figured as a final check.

In this last-mentioned series of articles by Dr. Giesecke, certain experimental results were given which served as the inspiration for further study, later appearing in an article published in the September, 1941, issue of PLUMBING AND HEATING BUSINESS entitled "A Working Method for Calculating a Floor Type Radiant Heating System." The method described is exceedingly simple and lends itself very well to the requirements of practical heating work and includes, for example, a composite curve showing the relationship between pipe size and spacing, water temperature, and total heat output per square foot of panel (Fig. 9). Copies of this article may be obtained from A. M. Byers Company.



Curves Showing Relation Between: (A) Heat dissipated per sq. ft. of panel surface, (B) Mean water temperature, (C) Ferrous pipe size and spacing. Based on 3.5 B.T.U. per hr. transfer per sq. ft. of pipe surface per °F temperature difference water to air.

FIG. 9

Calculation of Pipe Required

The rate of heat loss from a room or structure to be heated by radiant means is calculated in much the same manner that is employed when conventional systems are involved. Room air temperatures are generally assumed to be 70°F although actual operation will normally require a few degrees less. The differential between the suitable minimum design temperature and 70°F can then be used to calculate conductance and infiltration losses. Chapter 4 of the 22nd Edition of the A.S.H.V.E. "Guide" lists the heat transmission coefficients which can be used for this work.

For example, if it were desired to work out a floor type radiant system for a one-room basementless structure, heat losses through the walls and ceilings would be calculated in accordance with "Guide" principles. Then, an additional quantity—usually 25 to 30 per cent of all other losses—would be included for loss into the ground. This is, of course, only an approximation but it has proved sufficiently accurate to be suitable for practical work. If the plan were to place the heating coils in the ceiling, just the reverse of the above-outlined procedure would be followed —that is, losses through the floor would be calculated in the regular way but an additional percentage would be included to cover ceiling losses. The reason for this variation in calculating technique is that a different temperature gradient exists from the plane of the pipe coils to the cold air (or ground, as the case may be) than is the case with conventional heating systems where the transmission is assumed to be consistent from indoor air at a uniform temperature in all parts of the room.

Once the total of all heat losses is determined, the next step is to break the heating requirement down to a value expressed in Btu per hour per square foot of panel surface. The curve in Fig. 9 can then be consulted to determine pipe size, approximate spacing, and mean operating temperature. Obviously, a wide choice exists but as a general thing pipe size and spacing are chosen to provide a mean operating temperature level between 120°F and 140°F. Good practice would seem to indicate that the closer the design basis is to, say, 140°F, the more efficient the system in overall size. One-inch pipe is most generally used because it represents probably the best compromise between "dollar efficiency" (the smaller pipe sizes provide more heating surface per linear foot per dollar cost) and fabricating ease (the larger pipe sizes simplify the manual welding job). However, if the heating requirement (considering heat travel in both directions from the pipe) is above approximately 85 Btu per hour per square foot of panel, 1¼-inch pipe is indicated while loads less than about 30 Btu per hour per square foot call for ¾-inch.

Curves in Fig. 9 are based on work done by Dr. F. E. Giesecke and reported in the August, 1940, issue of HEATING, PIPING AND AIR CONDITIONING as follows:

> "It has been found by experience that it is safe, under usual conditions, to base a heating panel design on a heat transmission value of about 3.5 Btu per hour per square foot of external pipe surface and per °F temperature difference water to air. This is roughly equivalent to 1.2 Btu per lineal foot of 1 inch standard weight pipe, 1 Btu per foot of ¾-inch pipe and 0.80 Btu per foot of ½-inch pipe.
>
> "It is evident that the unit rate of heat delivery by a pipe coil to its concrete or plaster jacket must vary with the distance between pipe coils and with the difference between the temperature of the pipe coil and that of the air. The unit rate of heat delivery increases as the distance between pipe coils increases and also as the temperature difference (water in pipe and air in room) increases. The unit rate of 3.5 suggested above is an average value.
>
> "In constructing pipe coils, it is customary to space 1-inch pipe from 12 to 16 inches on centers; ¾-inch pipe from 9 to 12 inches on centers; and ½-inch pipe from 6 to 8 inches on centers.
>
> "To design a pipe coil for a ceiling panel having an area of 74 square feet and delivering 4000 Btu per hour to the room, assume the pipe size and spacing — say ¾-inch pipe spaced 9 inches on centers.
>
> "Assume that the insulation of the panel is such that 15 per cent of the heat flows upward and 85 per cent downward; the pipe coil must then deliver 4000/0.85 or about 4700 Btu per hour to the panel. If, say, 90 lineal feet of pipe are used, the heat delivery must be 4700/90 or about 52 Btu per foot. Since 1 foot of ¾-inch pipe delivers about 1 Btu per °F temperature difference, water to air, this temperature difference must be 52 degrees. Hence, if the air temperature is assumed to be 65°F, the mean water temperature must be 117°F.
>
> "If the water flows through the coil at a low velocity so that its temperature drop through the coil is 20 degrees, the temperature of the water in the flow riser must be 127°F and in the return riser 107°F. If the velocity is higher, so that the water will cool only 10 degrees in flowing through the coil, the temperatures in the flow and return risers must be 122°F and 112°F."

To facilitate practical work, the calculation of the quantity of pipe required for any given room can be reduced to a simple formula based on the above-given unit rate of heat transfer:

$$P = \frac{HL}{3.5 \times A \times dT}$$

Where: P = linear feet of pipe
HL = total heating load (in all directions from panel)
A = external pipe surface area per linear foot (see page 17)
dT = temperature difference, water to room air

To make use of this formula, choice of pipe size and mean operating water temperature must first be made from Fig. 9.

Design of Supply and Return Mains

Design work is usually simplified if a tentative system of supply and return mains for a multi-room structure is worked out before any time is spent designing the elements for the individual rooms. As a general thing, the best results will be obtained by placing the supply main around the periphery of a structure in order to take advantage of the warmest water in the coldest areas and thus create a more uniform heating effect.

In a system where long main runs are involved or where many individual elements are fed from one set of mains, it is considered good practice to reverse either the supply or return and thus tend to equalize the total pressure drop due to frictional resistance in the mains serving each element. The system thus becomes largely self-balancing and danger of "short-circuiting" is avoided.

Proper pipe size in mains can be quickly and easily chosen from the tables given in Chapter 16, 22nd Edition, of the A.S.H.V.E. "Guide." It is obviously important that this design detail be carefully considered. Otherwise, the system may be unduly restricted with resultant poor performance.

After a tentative layout of the mains has been accomplished, it is possible to reduce accordingly the calculated amount of pipe needed in the individual element for any particular room through which a main passes. This is due to the fact that the pipe in the mains performs a heating function, the same as any other length of pipe. Actually, this is an additional economy in a well-designed radiant system. Since the mains are usually larger in pipe size than the anticipated room elements, a proportionate increase in heat emission results. Main length can thus be rationalized into equivalent lengths of "room-piping" by multiplying the actual main length by the ratio of main area per linear foot to room piping area per linear foot.

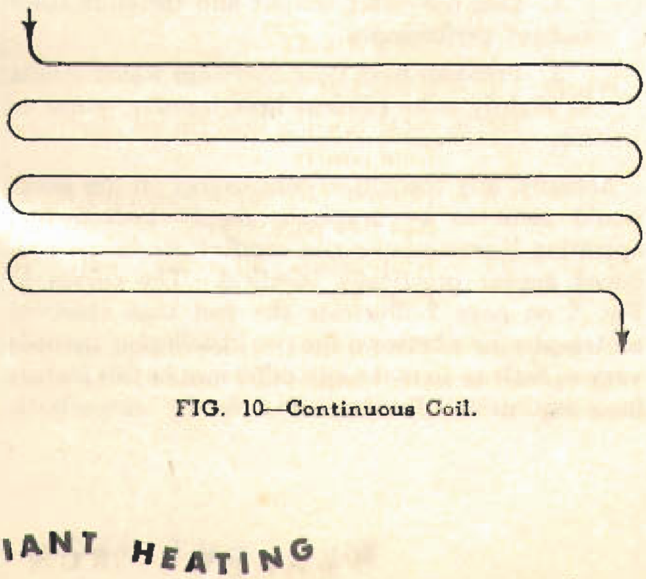


FIG. 10—Continuous Coil.

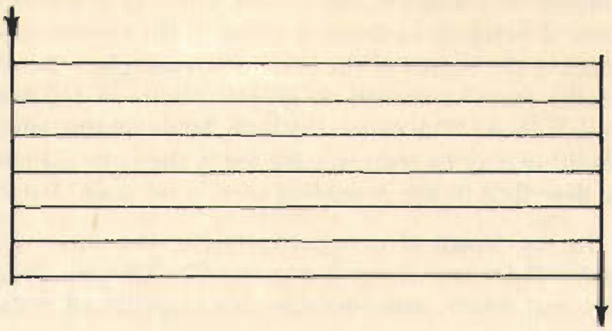


FIG. 11—Grid

As an example, if a 2-inch main, 20 feet long, runs through a room in which it is planned to use 1-inch coils, the equivalent length of main would be (0.622 ÷ 0.344) x 20, or 36 feet. This quantity can then be directly subtracted from the calculated quantity of 1-inch pipe required.

Coil Design

Pipe elements for radiant systems, have in the past taken several different forms but present practice has rather definitely crystallized around two basic patterns: the continuous coil (Fig. 10) and the grid (Fig. 11) or combination of them. The characteristics of each type are different and the choice between the two merits some study.

As a general thing, the continuous coil is a little less expensive to fabricate and a little easier to design particularly where an irregular plan is involved. Such a unit makes use of full random pipe lengths and pipe waste is therefore kept to a minimum, as is the welding necessary to salvage short lengths. The over-all welding required is also usually less than with the grid. However, the technique of bending is introduced — at least to a greater degree — and this tends to counter-act the welding economy to a certain extent.

The limiting factor in the otherwise desirable use of the continuous coil is due to rapid rise in total frictional resistance with increases in the total length of the coil. Pump sizes, and therefore initial cost, as well as current costs during operation, place a rather definite economic limit to the head against which the circulator must work. For this reason, then, the use of the continuous coil is restricted to small areas.

The grid, on the other hand, can be made to serve even very large areas and still provide excellent thermal distribution with light hydraulic load. Grid headers, or manifolds, are usually made of larger pipe sizes in order to facilitate welding in the smaller pipe running the length of the grid. For example, a 2-inch header may be chosen to supply 1-inch or 1¼-inch "run" pipes. The proportionately large heating effect resulting may be compensated for in the same manner as described in the preceding section on main design.

In the design of a radiant system, the choice between these two forms is not usually difficult. Since the heat losses, and therefore the quantity of water required, have already been calculated for each area, a rough index to circulator size is immediately available.. Main lengths and sizes have also been determined and this information further narrows down the field of possible, practical, circulator sizes. The difference between the maximum frictional resistance against which these one or two sizes will pump the required quantity of water and the friction head already accounted for in mains, boiler, and fittings gives a specific answer as to whether an element for a given area should be a grid or a coil. Figure 13 shows a typical radiant heating coil arrangement which makes use of both forms.

For large areas, a number of ingenious compromises between these two basic forms may be worked out in order to retain the virtues of both. One such modified form is shown in Fig. 12. Coil lengths have been run up to the maximum; common supply and return headers then connect to the main just as in an elementary grid system. Fabricating costs are thus kept to a minimum yet good hydraulic characteristics are developed.

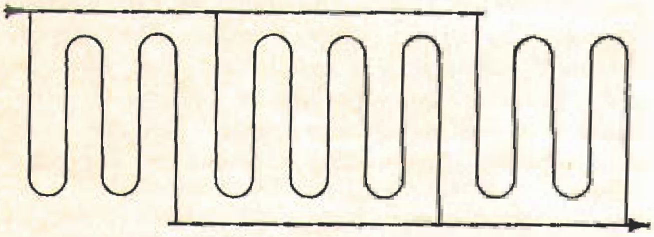


FIG. 12—Combination Grid and Continuous Coil

As a matter of design, it should be noted that it is occasionally found desirable to effect a slight concentration of piping within a single element, to meet unusually high heating requirements. For example, if a given room contains a huge glass area along one side, a slight concentration of pipe at that side may be in order. This should not be excessive — 2 or 3 adjacent pipe runs set on closer-than-usual centers — because unduly warm spots in the panel surface tend to work against the evenness of radiant heating which is one of its principle virtues.

Location of Coils

The designer's question as to where to locate radiant heating coils — that is, floor, wall, or ceiling — is not so intricate as might be imagined. The choice rests on a few simple, practical considerations and heavily favors the floor elements. Installations in this country during the past few years have been in the floor about 95 per cent of the time. The balance have been in the ceiling, with only a very occasional wall coil being used to supplement either floor or ceiling units.

The reason for the predominating choice of the floor coil is largely economic. As a rule, ceiling installations cost 10 to 20 per cent more than the corresponding floor element and this factor is usually decisive. As further theoretical merit, the floor coil offers these advantages:

1. More constant relationship to occupant as he moves about.
2. Closer to occupant and therefore more efficient due to diminishing heating effect as he moves away from source of heat.
3. More efficient transfer of convected heat.
4. Greater effect at lower temperature due to sensitivity of feet and legs to heat and cold.

The single most important practical factor favoring ceiling installations is that ceiling surfaces can be operated at a higher temperature than the floor without producing discomfort. Occasionally, this point becomes sufficiently important as to void the economic advantage of the floor coils. Other theoretical points favoring ceiling location are:

1. Less convected output and therefore truer radiant performance.
2. Freedom from floor coverings which results in slightly more efficient heat transfer, water to air.

Actually, any theoretical controversy on this point would seem to be academic simply because the operating characteristics and comfort conditions produced appear practically identical. The curves in Fig. 5 on page 7 illustrate the fact that observed air temperatures between the two installation methods vary so little as to make any difference in this feature inconsequential. Furthermore, equally enthusiastic

TYPICAL RADIANT HEATING PIPING
(ALL COILS 1"; GRID, 1¼")

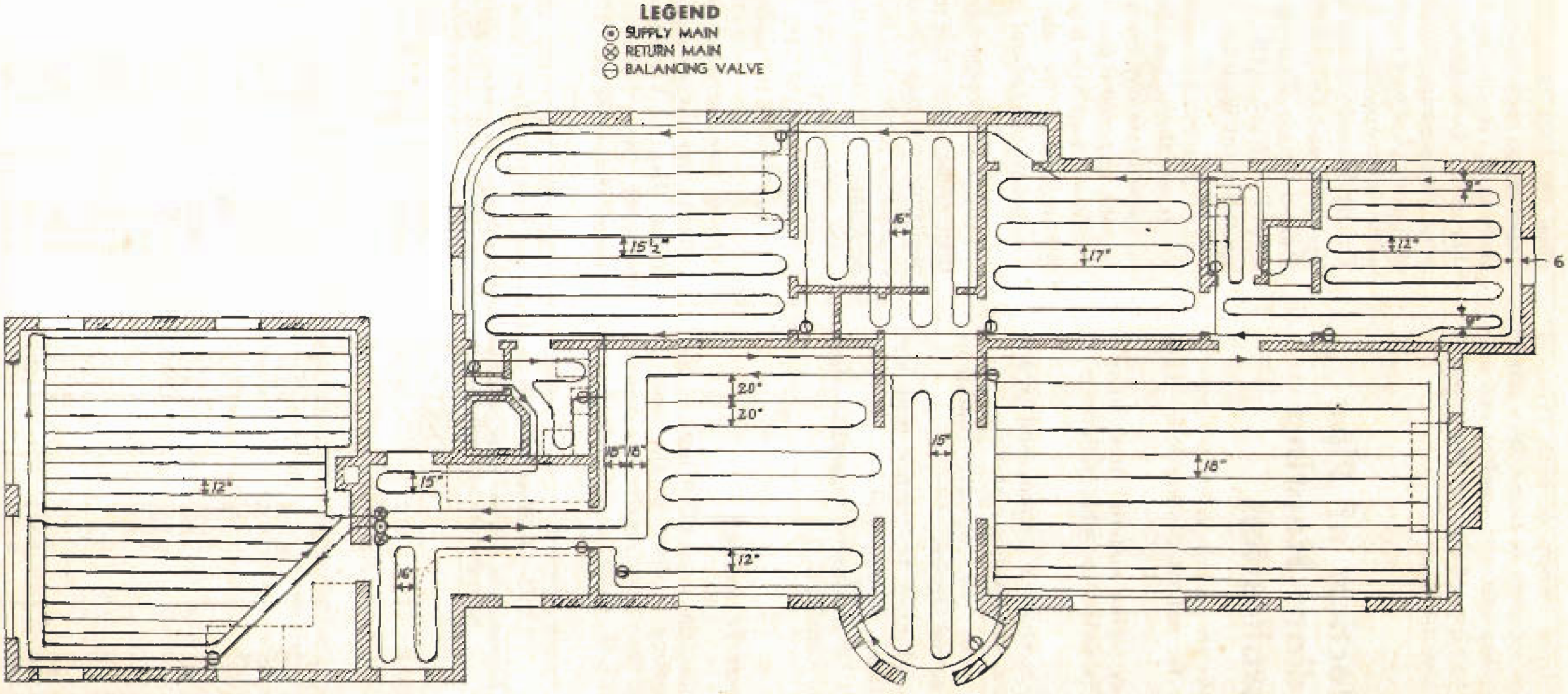


FIG. 13

reports have come from owners of both types of systems so there does not seem to be much to choose from as far as operating cost and comfort are concerned. Thus it can be expected that the floor element will remain as first choice.

The Selection of Pipe for Radiant Heating Installations

Four considerations are of primary importance in the selection of pipe for radiant heating coils. They are:

1. Satisfactory piping material must transfer heat with the smallest possible difference in temperature.
2. It must be mechanically strong, and expand at the same rate as surrounding materials.
3. It must resist the corrosive conditions encountered in actual service.
4. The material must be readily bent and welded into a strong, durable unit.

These factors will be considered separately since each warrants careful examination.

Heat Transfer

The ideal piping material must allow heat to pass readily from the heating medium to the material surrounding the pipe. The heat transfer rate depends on the ease with which the metal conducts heat, and upon the heat dissipating qualities of the surface. Experiments were made at the American Society of Heating & Ventilating Engineers' Research Laboratory at the U. S. Bureau of Mines Building in Pittsburgh to determine the relative heat transfer capacities of ferrous pipe and copper tubing. These tests were made in cooperation with the Associated Copper Tubing Manufacturers and in an article by F. C. Houghten and Carl Gutberlet which appeared in the Journal section of the January, 1932, issue of HEATING, PIPING & AIR CONDITIONING, the following statement is made:

> "The small temperature difference existing between the steam and the outside surface of the pipe bears out the generally accepted fact that the important factor in resistance to heat flow from a bare pipe is in the transfer from the metal surface to the air, rather than the thermal resistance of metal itself."

Thus, while copper has a higher heat conductivity than wrought iron, this property of the material is of negligible importance in radiant heating work. In the conclusion to the article mentioned in the preceding paragraph, it is stated that:

> "The heat loss from bare copper pipe is approximately 54% of the loss from bare black iron pipe of the same nominal size . . ."

Even more striking differences in heat transfer capacity have been observed with copper tubing, and in the "Heating Ventilating Air Conditioning Guide" for 1944, pages 345 and 347, are tables which are reproduced in Figs. 14 to 17, inclusive. These

FIG. 14—Heat Losses from Horizontal Bare Black Iron Pipes.

Expressed in Btu per hour per linear foot per degree Fahrenheit difference in temperature between the pipe and surrounding still air at 70° F.

Nominal Pipe Size (Inches)	Hot Water				Steam		
	120 F	150 F	180 F	210 F	227.1 F (5 Lb.)	297.7 F (50 Lb.)	337.9 F (100 Lb.)
	Temperature Difference						
	50 F	80 F	110 F	140 F	157.1 F	227.7 F	267.9 F
½	0.455	0.495	0.546	0.584	0.612	0.706	0.760
¾	0.555	0.605	0.666	0.715	0.748	0.866	0.933
1	0.684	0.743	0.819	0.877	0.919	1.065	1.147
1¼	0.847	0.919	1.014	1.086	1.138	1.324	1.425
1½	0.958	1.041	1.148	1.230	1.288	1.492	1.633
2	1.180	1.281	1.412	1.512	1.578	1.840	1.987
2½	1.400	1.532	1.683	1.796	1.883	2.190	2.363
3	1.680	1.825	2.010	2.153	2.260	2.630	2.840
3½	1.900	2.064	2.221	2.433	2.552	2.974	3.215
4	2.118	2.302	2.534	2.717	2.850	3.320	3.590
5	2.580	2.804	3.084	3.303	3.470	4.080	4.385
6	3.036	3.294	3.626	3.886	4.074	4.765	5.160
8	3.880	4.215	4.638	4.960	5.210	6.100	6.610
10	4.760	5.180	5.680	6.090	6.410	7.490	8.115
12	5.590	6.070	6.670	7.145	7.500	8.800	9.530

FIG. 15—Heat Losses from Horizontal Bare Bright Copper Pipe.
Expressed in Btu per hour per linear foot per degree Fahrenheit difference between the pipe and surrounding still air at 70° F.

Nominal Pipe Size (Inches)	Hot Water (Type K Copper Tube)				Steam (Standard Pipe Size Pipe)		
	120 F	150 F	180 F	210 F	227.1 F (5 Lb.)	297.7 F (50 Lb.)	337.9 F (100 Lb.)
	Temperature Difference						
	50 F	80 F	110 F	140 F	157.1 F	227.7 F	267.9 F
½	0.180	0.210	0.218	0.229	0.299	0.338	0.355
¾	0.236	0.275	0.291	0.307	0.357	0.408	0.418
1	0.290	0.338	0.354	0.373	0.440	0.492	0.523
1¼	0.340	0.400	0.418	0.443	0.510	0.571	0.598
1½	0.390	0.463	0.473	0.507	0.598	0.671	0.710
2	0.490	0.525	0.600	0.628	0.719	0.813	0.851
2½	0.580	0.675	0.709	0.750	0.840	0.953	1.008
3	0.680	0.788	0.848	0.871	0.987	1.107	1.165
3½	0.760	0.888	0.946	1.000	1.114	1.235	1.307
4	0.940	1.000	1.045	1.107	1.210	1.361	1.456
4½	.....	.....	.....	.....	1.335	1.495	1.488
5	1.020	1.200	1.255	1.320	1.465	1.670	1.755
6	1.160	1.375	1.410	1.500	1.685	1.890	1.942
8	1.460	1.725	1.820	1.890	2.100	2.373	2.510

FIG. 16—Radiating Surface per Linear Foot of Wrought Iron Pipe.

Nominal Pipe Size (Inches)	Surface Area (Sq. Ft.)	Nominal Pipe Size (Inches)	Surface Area (Sq. Ft.)	Nominal Pipe Size (Inches)	Surface Area (Sq. Ft.)
½	0.22	2	0.622	5	1.456
¾	0.275	2½	0.753	6	1.734
1	0.344	3	0.917	8	2.257
1¼	0.435	3½	1.047	10	2.817
1½	0.498	4	1.178	12	3.338

FIG. 17—Radiating Surface per Linear Foot of Copper Tubing.

Tube Size (Inches)	Surface Area (Sq. Ft.)	Tube Size (Inches)	Surface Area (Sq. Ft.)	Tube Size (Inches)	Surface Area (Sq. Ft.)
½	0.164	2	0.556	5	1.342
¾	0.229	2½	0.687	6	1.604
1	0.295	3	0.818	8	2.128
1¼	0.360	3½	0.949	..	.....
1½	0.426	4	1.080	..	.....

tables show that 2″ copper tubing carrying 120° water loses only 41.5% as much heat as the same nominal size of wrought iron pipe.

The foregoing discussion of heat loss applies, of course, in the strict sense only to coils suspended freely in air.

For maximum heat loss, large surface area is desirable. Figures 16 and 17 show 2″ wrought iron pipe has 12% more surface per foot than 2″ copper tubing.

Pipe surrounded by loose fill loses heat by conduction as well as by radiation and convection. When this third factor is introduced, wrought iron's greater surface area facilitates heat transfer because more particles can bear against each foot of pipe.

If pipe is buried in solid concrete, radiation and convection exchange are eliminated, and heat is transferred only by conduction. In this case large surface area per foot of coil is desirable and intimate contact between pipe and concrete is essential. This raises the question of physical properties and particularly expansion problems.

Physical Properties

Wrought iron and concrete or plaster expand at practically identical rates. It is thus possible to bury wrought iron coils in solid concrete and maintain a solid bond between the two materials without cracking the masonry or setting up high stresses in the pipe. On the other hand, non-ferrous piping materials expand about 30% faster. This means that it is practically impossible to maintain the intimate contact necessary for maximum heat transfer and greatly increases the danger of cracking. Stresses at the joints of copper or brass conductors may also be raised to the breaking point if fittings or couplings are locked in masonry. These considerations have led to the widespread use of wrought iron for radiant heating coils.

The Question of Corrosion

Corrosion resistance is another extremely important requirement which must be considered when piping materials are being selected. The proved resistance of wrought iron to many different types of corrosion has led to its selection for most radiant heating installations both in England and this country. Even at first glance, the necessity for use of an unusually corrosion resistant piping material is evident because of the impracticability of tearing out wall, floor, or ceiling sections to repair or replace faulty pipe. Since the use of wrought iron will add only about ten per cent to the cost of a radiant heating system, compared with the use of the least expensive materials, no better insurance can be purchased.

Internal Corrosion

Corrosion on the interior surface of piping materials in a closed hot water heating system is not generally a matter of great concern. The reason for this is that, once filled, only relatively small quantities of fresh water are added as time goes on and thus the available amounts of corrosive elements are strictly limited. Also, radiant heating systems are usually operated at temperatures sufficiently low to prevent the release of semi-bound gases which would prove actively corrosive.

However, the study of corrosion should be approached as an individual problem rather than to accept without question any broad, general rules. Thus, in a new locality or in an area serviced by a new water supply where a long-time history of the effect of that water on piping materials is not available, it may be felt advisable to study the water carefully in advance of the actual construction.

To facilitate such studies, A. M. Byers Company has, for many years, conducted an organized program of water analysis and building surveys in the principal cities of the country. This mass of data provides a background for comparing waters on the sound basis of chemical analysis. Thus, having determined which municipal supplies most closely resemble a new one, materials or treatment can be selected on the basis of their actual performance under similar or even identical conditions.

Survey information of this type is available without charge from the Engineering Service Department of the company.

While the chemical composition of the water is of fundamental importance, air infiltration is also an active promoter of corrosion, and there is a possibility of air entering the system at the pump, or at fittings, valves, or expansion tank.

Even though these various corrosive factors may not result in perforation of the pipe wall, the use of a corrosion resistant material such as wrought iron is desirable, since it is important to avoid reduction of flow by tuberculation. Naturally, if the coils become seriously plugged with corrosion products formed by action of the water on the pipe material, flow is reduced to a marked degree and heat transfer is retarded, lowering the capacity of the system. The hundreds of reported cases where hot water lines of corrosion resistant wrought iron pipe have been in service for decades without a serious reduction in flow capacity amply illustrate the uniformly satisfactory service which can be expected from wrought iron radiant heating installations.

When steam instead of hot water is used as the heating medium, it becomes much more necessary to guard against failures resulting from interior corrosion of the heating coils. Condensate will form in any low pressure system and severe corrosive conditions are set up at once when this occurs because of the extremely active nature of most condensates.

The proven superior durability of wrought iron over other commonly used piping materials when handling steam condensate is a safeguard against failures from this source.

External Corrosion

Past experience has conclusively proved that it is most unwise to assume that radiant heating coils are beyond the reach of corrosive attack on the exterior pipe surface simply because they are located in the normally-dry portions of the structure. As a matter of fact, a corroding effect may easily result from (a) the presence of moisture which is condensed from the atmosphere on the relatively cold metal surface when the system is not in use, (b) the presence of active chemicals and moisture from the air or from plaster or concrete in contact with the pipe, (c) ground water seepage in installations laid in gravel fill on the ground, or (d) water entering the structure proper through leaks or as a result of vapor-born moisture.

Moisture which condenses on the cold exterior surface of radiant heating coils when the system is not in use dissolves carbon dioxide from the air and thus gradually becomes acidic. If piping materials of inferior durability are used, failure may ensue through penetration of the pipe wall from the outside surface. The desirability of using wrought iron is recognized by leading authorities in the radiant heating field since it has been used for many years for very similar services such as brine coils in ice skating rinks which are usually cast into concrete slabs. Its durability is a matter of record.

Fabrication

In most modern installations, coils have been bent from wrought iron pipe, and the joints welded. Wrought iron pipe can be readily bent, and the following minimum diameters of bends are recommended for cold bending standard weight wrought iron pipe if some degree of flattening is permitted.

Size	Minimum Diameter of Bend, Center to Center
½"	2.8"
¾"	3.5"
1"	4.3"
1¼"	5.5"
1½"	7.0"
2"	11.0"

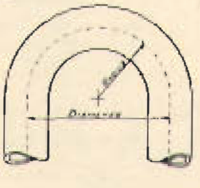


FIG. 18

In passing, it should be mentioned that the bending work involved in radiant heating is an exceedingly simple technique and can be rapidly and smoothly handled by craftsmen familiar with it. As long as a few basic principles are followed, no concern over distortion or restriction need be felt. The work may be done either by hand or machine, depending on the facilities available. A. M. Byers Company has made a considerable study of pipe bending over a period of years and has available a technical bulletin on the subject. Copies may be secured from the Engineering Service Department.

In all branches of industry, welded piping installations have been made with wrought iron and the excellent inherent weldability of wrought iron pipe is a matter of record. Tests conducted by internationally recognized standards societies, such as Lloyd's Register of Shipping, American Bureau of Shipping, and the Bureau of Marine Inspection and Navigation, U. S. Department of Commerce, have demonstrated not only the ease of welding the metal, but also the sound durable welds that can be obtained. The weldability of wrought iron also makes it possible to eliminate the pinhole leaks often encountered in the seams of pipe made from less readily welded materials. Photographs of a number of welded wrought iron radiant heating installations will be found in this bulletin. Of course, if a threaded and coupled installation is preferred, the use of wrought iron is again desirable because it also has superior threading properties which produce an extremely tight joint.

After a system has been fabricated and installed, common practice is to subject it to a severe test so as to be sure there are no leaks before concrete, plaster, or flooring is applied. There are several methods of testing but the basic system most generally used involves placing the entire piping arrangement under a hydraulic pressure of 125 to 200 psi for several hours.

Such procedure will normally disclose any poor welds or pipe which might have been damaged or over-stressed during fabrication. The expense involved is small — certainly much less than would be the case if repairs were necessary after the installation was completed and the rest of the structure finished.

There is another extremely important but intangible question to be answered in selecting material for any piping system which is expected to last over a period of years with complete freedom from repairs or replacements. This question is whether to use a new, untried material or a quality material, the durability of which has been proven beyond the shadow of a doubt by many years of actual service under an exceedingly wide variety of corrosive conditions. Wrought iron is the oldest ferrous metal known, its recorded history going back many centuries. Thus, the engineer specifying wrought iron does not need to rely on manufacturers' claims or accelerated or laboratory corrosion tests, but can base his selection on records of actual service under almost any conceivable conditions. This is becoming increasingly important because of the welter of claims and conflicting testimony concerning the many different metals which have been developed in recent years in attempts to duplicate the durability of wrought iron.

FIG. 19

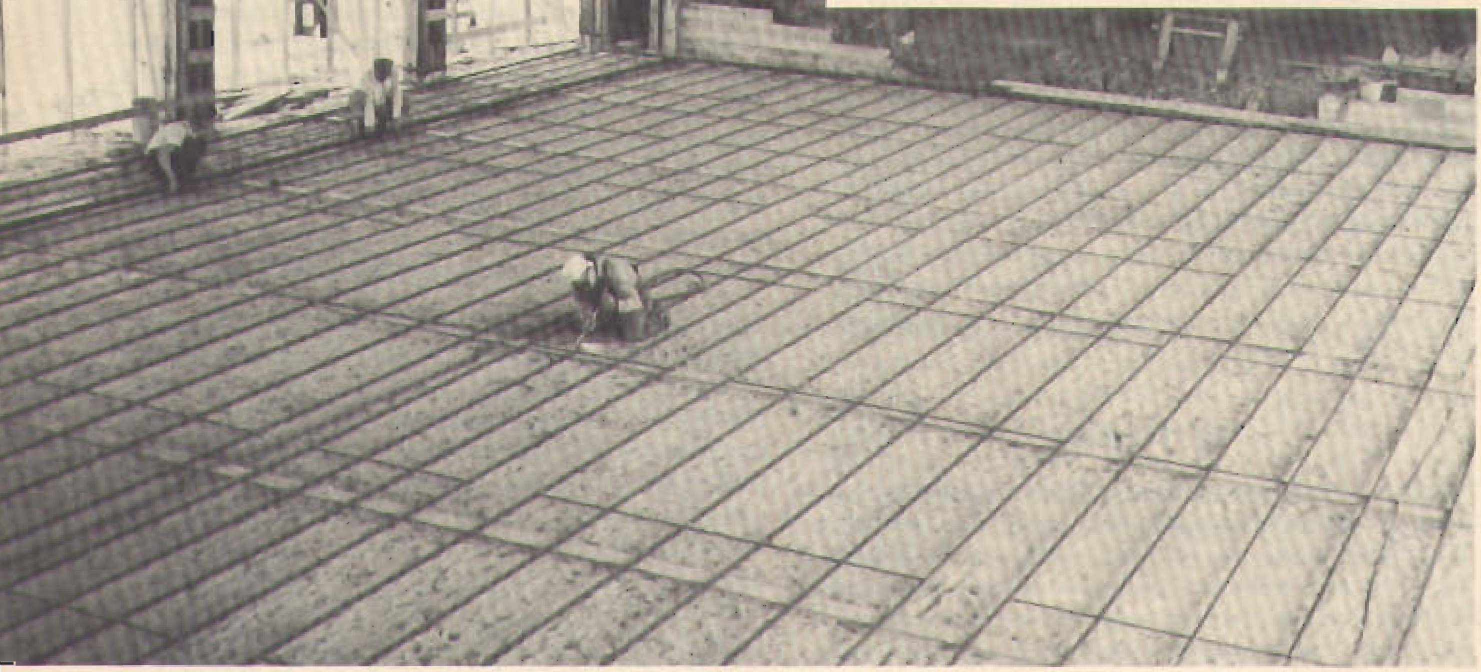


FIG. 20

Chapels, Jacksonville, Florida Naval Air Station

These structures were designed by Robert and Company of Atlanta, Georgia in collaboration with Naval authorities. Heating work was done under the direction of Mr. F. E. Markel, Manager of the Mechanical Department of Robert and Company at the Station. Preliminary architectural plans called for sliding doors along almost the entire length of the sides of both auditoriums. Since space was not available for conventional heating equipment, a floor type radiant heating system was chosen for both of these buildings.

Central station steam is used with a heat exchanger to supply hot water for the heating coils. Each of the chapels is supplied with hot water pumped by a circulator with a rated capacity of 65 gpm against an 18-foot head.

The heating elements are of the grid type and are located in the concrete slab forming the floor. Marble tile and quarry tile is the floor finishing material.

An outdoor compensating bulb modulates the flow of hot water according to outside conditions. A 3-way valve of the modulating type located on the pump header governs the flow of water. This valve is also controlled by a modulating thermostat with its remote bulb buried in the chapel floor 1 inch beneath the surface of the concrete. Control is so arranged that, when the water flow becomes 100 per cent recirculating, the pumps are cut off.

In both structures, the balconies at the rear of the auditoriums include a small grid beneath each row of seats. A riser is used to connect the various levels. Additional steps to the various levels in the chancel are handled in the same way.

When the wall sections of these chapels are closed during occupancy periods, air is exhausted by means of conventional exhaust fans. (Figs. 19-23).

FIG. 21

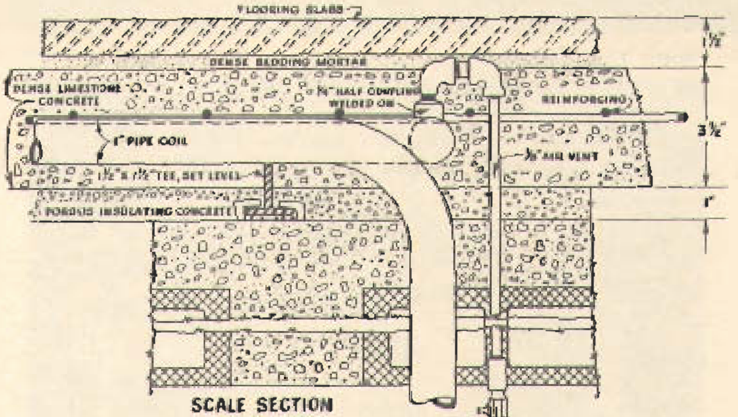
FIG. 22

FIG. 23

FIG. 24

THE SACRED HEART CHURCH
Pittsburgh, Pennsylvania

One of the pioneer radiant heating systems in this country was installed in 1928 in part of the floor of the Sacred Heart Church in Pittsburgh, Pennsylvania. Carlton Strong was the architect, and Kaiser, Neal & Reid were associated with him in this project which is shown in Fig. 24. The details of the wrought iron coils are given in Figs. 25 and 26 and the system has worked very well during the past 16 years. Incidentally, this method of construction is very similar to that used in many large skating rinks where wrought iron pipe is commonly used for cooling coils carrying refrigerated brine.



SCALE SECTION
FIG. 25

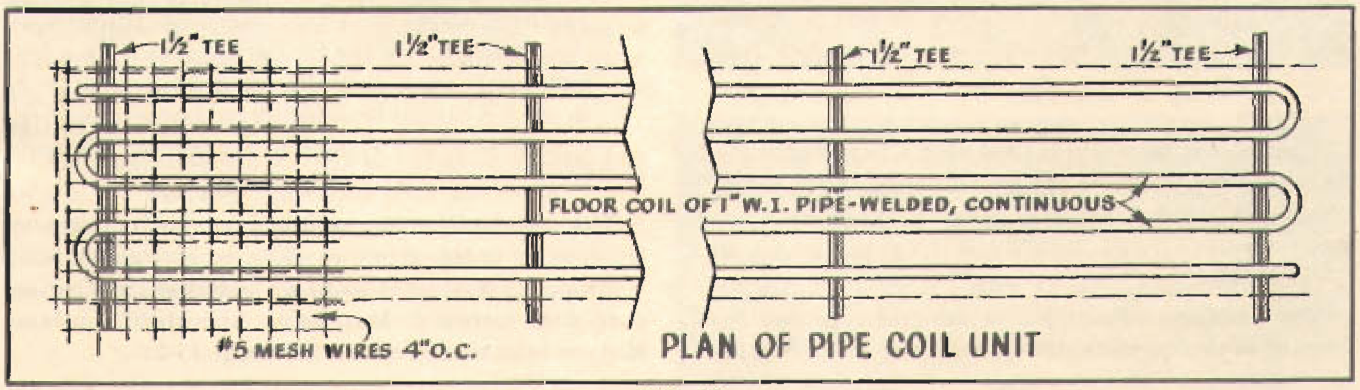


FIG. 26

FIG. 27

ST. MARY'S CHURCH
Wytheville, Virginia

Fig. 27 shows a church in Wytheville, Virginia, which is heated by radiant means.

Father Michiel McInerney, of Belmont, North Carolina, designed the system and Mr. E. Y. Spraker, Contractor of Wytheville, Virginia, made the installation. During the seasons the system has been in operation, very severe weather has been experienced, with temperatures as low as 2 degrees below 0. Despite this, the system has worked to the satisfaction of all concerned.

Fifteen pound steam was selected for the heating medium, and eight supply lines, each regulated by a valve, were run from a central control point in the sachristy to supply headers along one side of the building under the floor. Return headers ran very close to the supply headers, and five hairpin coils of 1¼ inch pipe ran from each supply header across the church between the open-work floor joists, and back to the return headers. The supply side of each loop was just above the return side; that is, the hairpins were set on edge. Over the floor joists, wire lath was laid and ⅜ inch reinforcing bars were placed over the lath on 4 inch centers. Cellotex strips ½ inch thick were laid along the side walls to provide for expansion, and flattened brass tubing expansion joints were laid across the church to divide the floor into 8 foot sections. A 2 inch concrete slab was then poured over the lath, and trowelled down to form the finished floor. Wire lath was also secured to the lower surfaces of the joists and covered with 1½ inch of asbestos cement plaster. Thus, the steam coils warmed the air between the joists and this air warmed the concrete floor. It, in turn, radiated heat to the room. The joists, being open-work, also permit air to circulate from grilles in the sanctuary steps at one end of the building, under the floor and between wall studs, to similar openings 8 foot above the floor in the vestibule walls at the far end of the church.

LIVERPOOL CATHEDRAL
Liverpool, England

The Liverpool Cathedral, Liverpool, England, is heated by radiant means and, speaking of this building, Mr. T. Napier Adlam says in the July, 1938, issue of HEATING, PIPING & AIR CONDITIONING:

> "The height of the cathedral inside is about 113 feet and the triforium walking way which is carried along both sides at a height of 97 feet above the floor makes it possible to make very accurate observations of air conditions at high level. When the temperature of the air taken at 4 feet above the floor was 60°F, it was found that the air temperature at the triforium level, more than 90 feet above, was 58½°F—just 1½°F lower than at 4 feet above the floor. It seems to me that no other known method of heating could create these ideal conditions in such a high building, because I have conducted tests in similar cathedrals where warm air systems have been installed and the temperature at high level is much too hot to be comfortable. It has been found after several years experience that the inside temperature of 58° to 60°F gives perfect comfort under all outside conditions, and is an ideal temperature for the organ—which is one of the largest (if not the largest) in England.
>
> "Another remarkable feature is the thermal storage of the structure, for it is found that if the oil furnaces are turned off, it takes 36 hours for the temperature in the cathedral to fall 1°F. It has been found in actual operation throughout the winter, that if the fires are operated for a few hours only each day, the temperature change is so small it cannot be detected on the thermometer, regardless of any change in the outside temperature."

The low temperature gradient thus attained and the low air temperature at which comfortable conditions were maintained suggests that radiant heating may find increased favor with architects for such hard-to-heat structures as churches.

FIG. 28

COMMUNITY CHURCH
Kansas City, Missouri

This unusual church building was designed by Frank Lloyd Wright and the heating contractors were Westerlin & Campbell Company of Chicago. A floor type radiant heating system was installed at the time the building was built in the winter of 1941. Approximately 4500 feet of 2 inch and 2½ inch genuine wrought iron pipe spaced on about 16-inch centers constituted the heating coils.

Hot water is used as the heating medium. Pipes are pitched in order to provide for complete drainage and vents were installed at high points in the system.

The smaller rooms in this structure are heated by a forced warm air system which is convertible for summer cooling and humidity control. Under carefully controlled conditions during the summer, chilled water is circulated through the floor piping at about 53°F. This circulation of chilled water is used for precooling only.

FIG. 29

FIG. 30

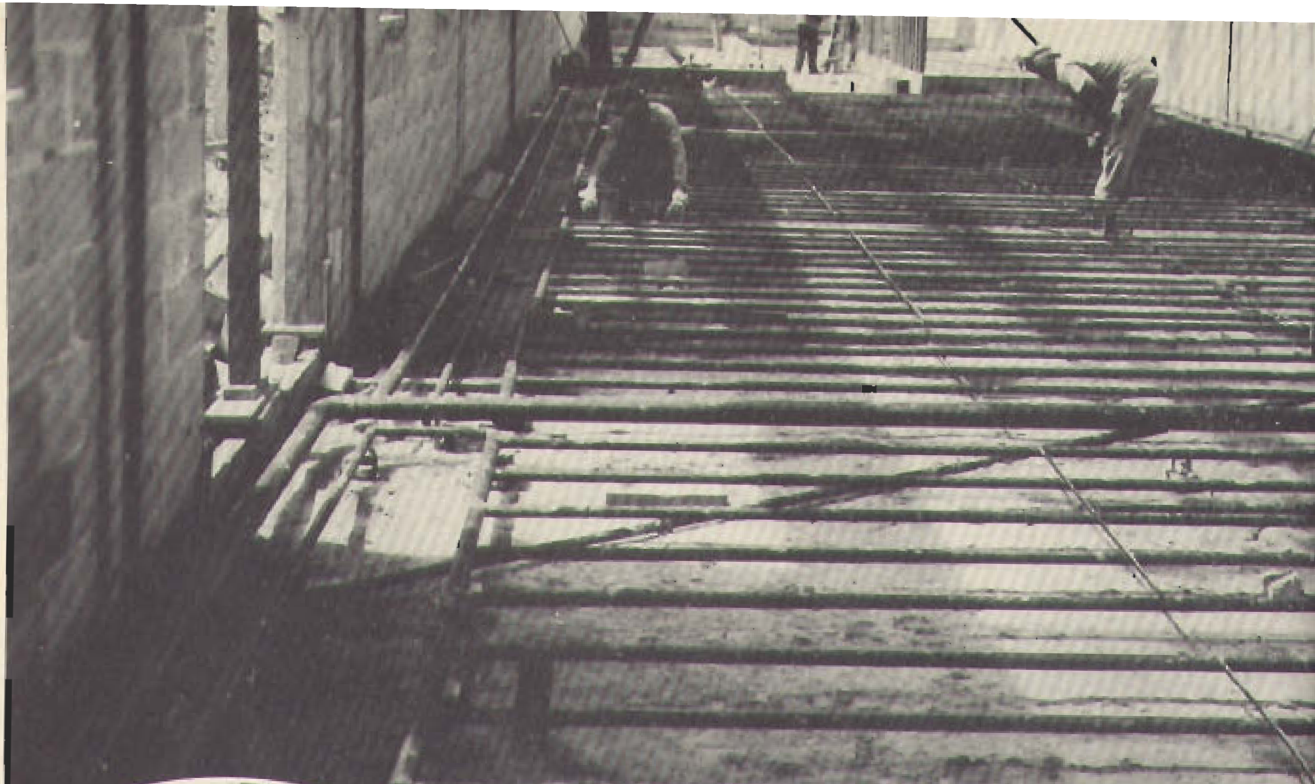


FIG. 31

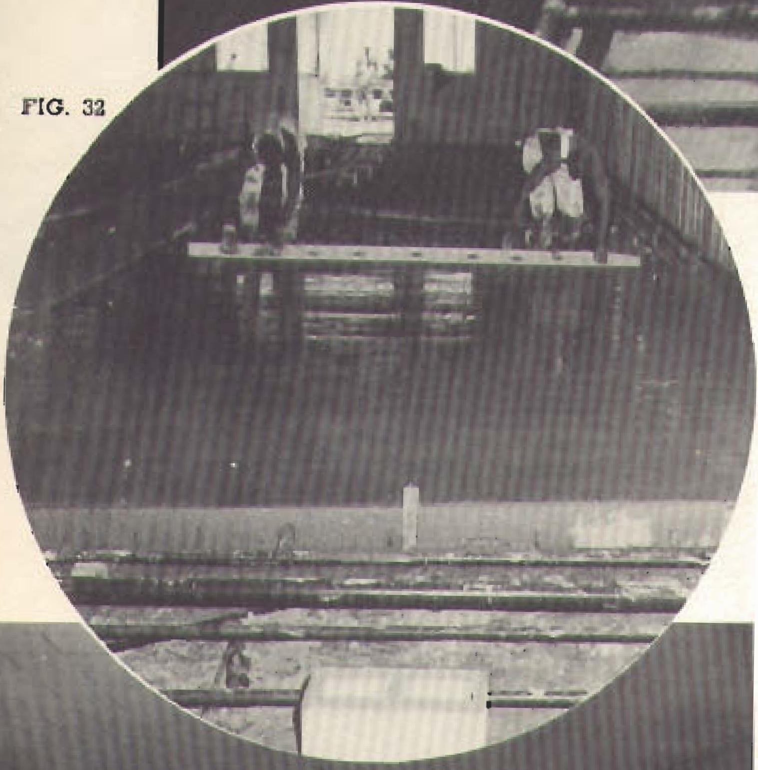


FIG. 32

DISPENSARY WARDS
Jacksonville Naval Air Station

Two large hospital wards connected with the dispensary at this station were recently completed and made use of floor type radiant heating systems. An interior view of one of the single story ward sections is shown in Fig. 33. These structures were designed by Robert and Company of Atlanta, Georgia, as were the chapels in Figs. 19 to 23.

Approximately 15,000 feet of 1-inch, 2-inch and 3-inch wrought iron pipe were used to fabricate the floor coils shown at the roughing-in stage in Fig. 31. All joints were welded. The heating grids carry hot water from a converter supplied with steam from a central station.

Pipes were pitched slightly to provide drainage and were cast directly in the concrete floor as shown in Fig. 32.

One of the principle reasons for the choice of radiant heating in hospital construction is the cleanliness which results. In this particular installation, though, the space economy made possible by the elimination of heating devices resulted in a saving of about 2 feet in width for the entire length of the structure.

FIG. 33

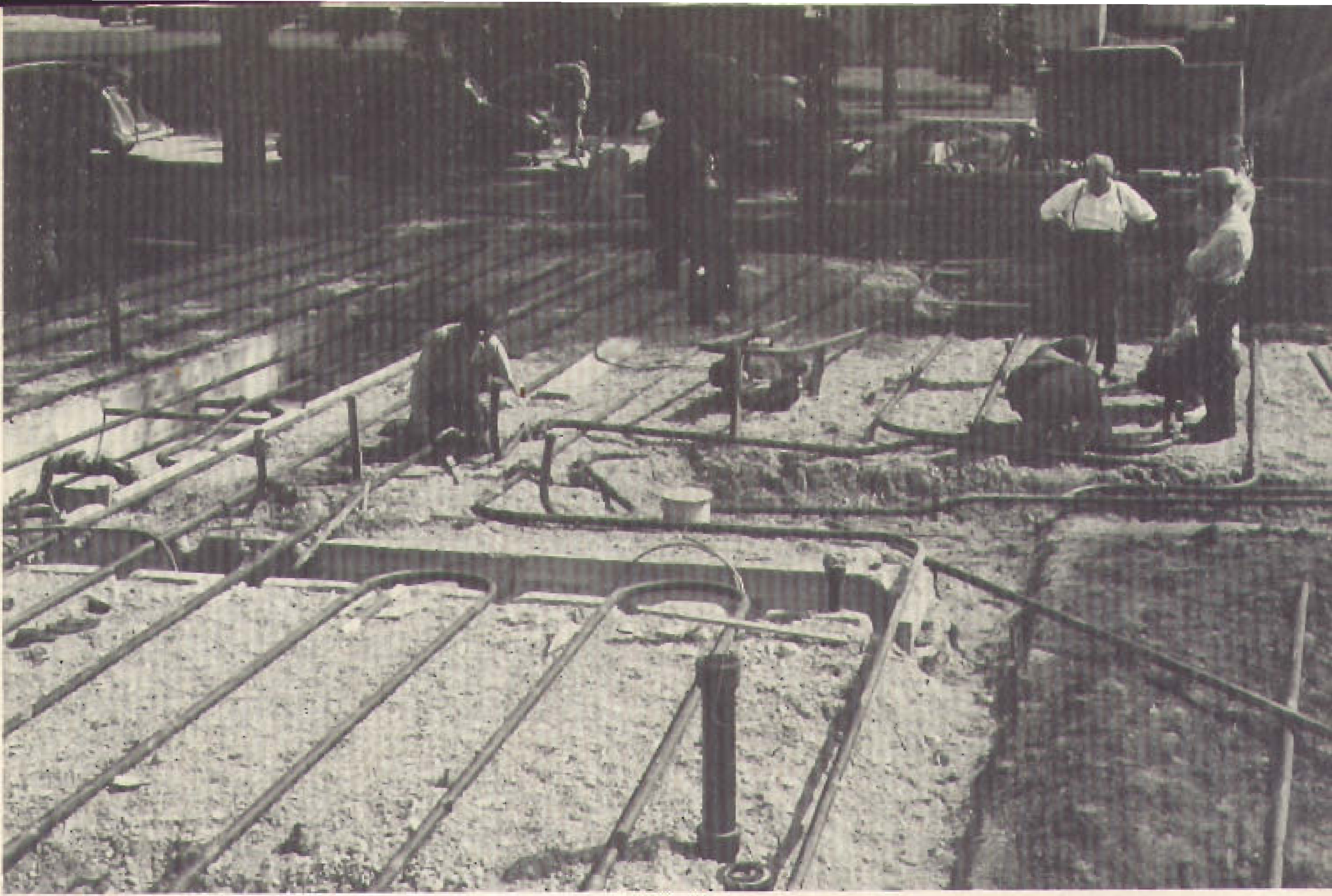


FIG. 34

FIG. 35

EIEL CLINIC, Osage, Iowa

The 12-room, 1-story structure comprising the Eiel Clinic at Osage, Iowa, was completed in February, 1941. Robert Blandin of Osage was the architect and O. D. Kingsbury the heating contractor. Globe Machinery & Supply Company of Des Moines fabricated the radiant heating coils.

Fig. 34 shows the coils, on a bed of rip-rap, during fabrication. They were then covered with gravel as shown in Fig. 35 and finally a finish slab of concrete was poured.

An oil-fired boiler supplies hot water to the heating coils. Over the finished floor a covering of rubber tile was used. According to the owner's reports, the radiant heating system is very efficient and economical.

FIG. 36

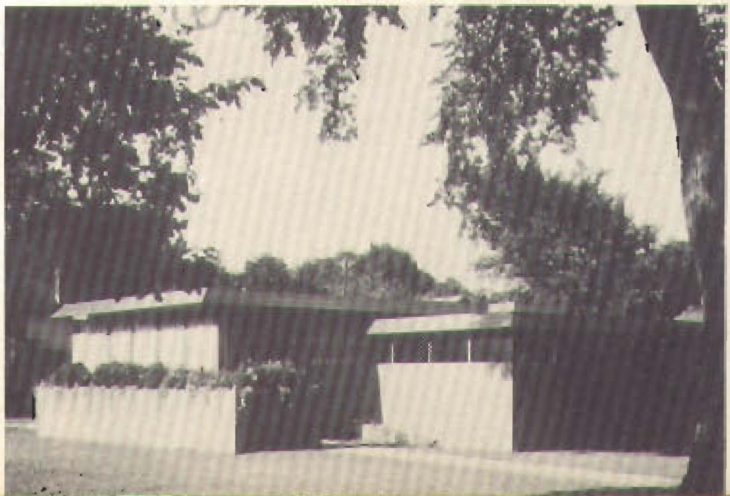


FIG. 37

FIG. 38

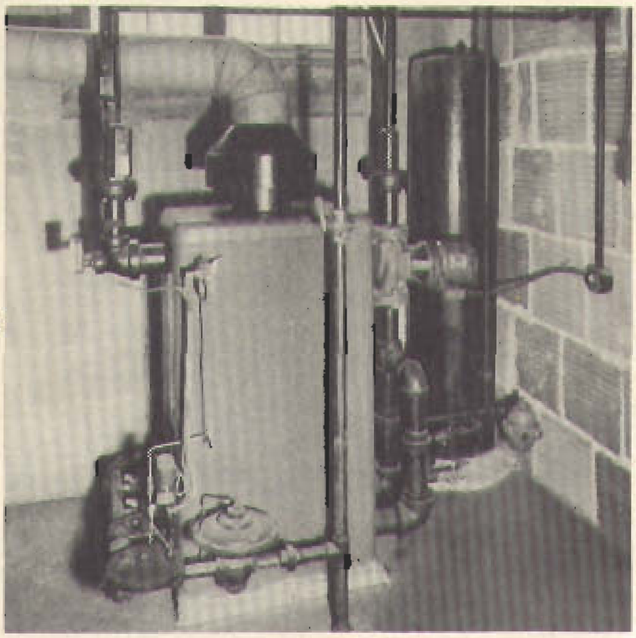
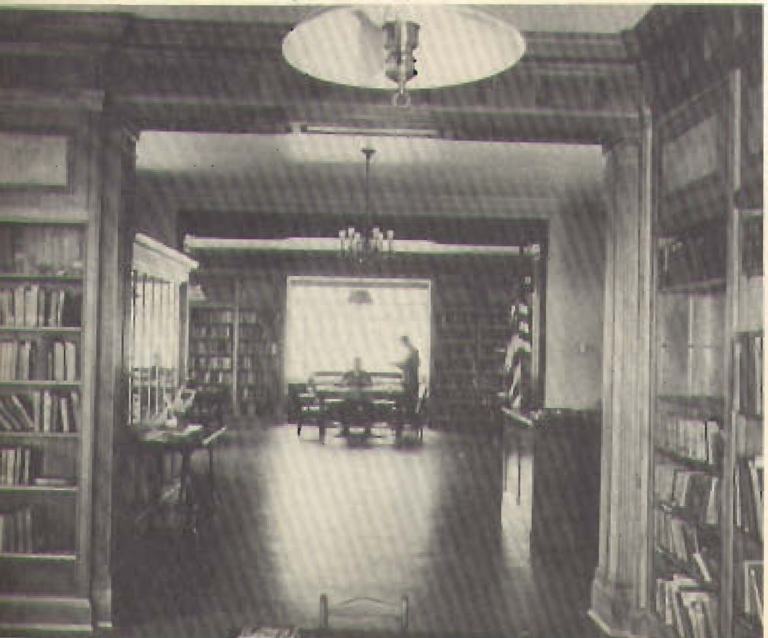


FIG. 39



NORTH HILLS LIBRARY
Pittsburgh, Pennsylvania

Fig. 40 shows an unusually attractive small library which was designed by Franklin & Brown, architects of Pittsburgh, and completed in the spring of 1942. A floor type radiant heating system was used except in some small rooms in a partial basement which were heated by conventional radiators supplied with the same hot water as used in the radiant system.

Approximately 1400 feet of 1-inch, 1¼-inch, and 1½-inch wrought iron pipe was used to fabricate the continuous coils which were cast into the concrete slab comprising the first floor as shown in Fig. 37. Pipes were laid level but since the boiler is located in the basement it was felt that sufficiently good drainage could be naturally accomplished. Manually operated vents are located beneath the slab in the basement or crawl space and are connected to the pipe runs by small diameter pipes tapped into the top of the heating coils and turned downward through 180°. A gas-fired boiler as shown in Fig. 38 maintains water temperatures in a given range as determined by the high and low limit aquastats (which appear on the supply main as it emerges from the top of the boiler) and the thermostat-controlled burner.

Automatic control is accomplished by means of a conventional room-air thermostat which actuates the burner regulator. A cutout is operated by the low limit aquastat so that when boiler water temperature falls below a given level, circulation is stopped. Extremely even performance of the heating system is accomplished by means of this arrangement.

Battleship linoleum is used as a floor covering over the concrete. Fig. 39 illustrates the accessibility of the entire floor surface which permits easy and rapid cleaning, unhampered by any of the conventional heating devices.

FIG. 40

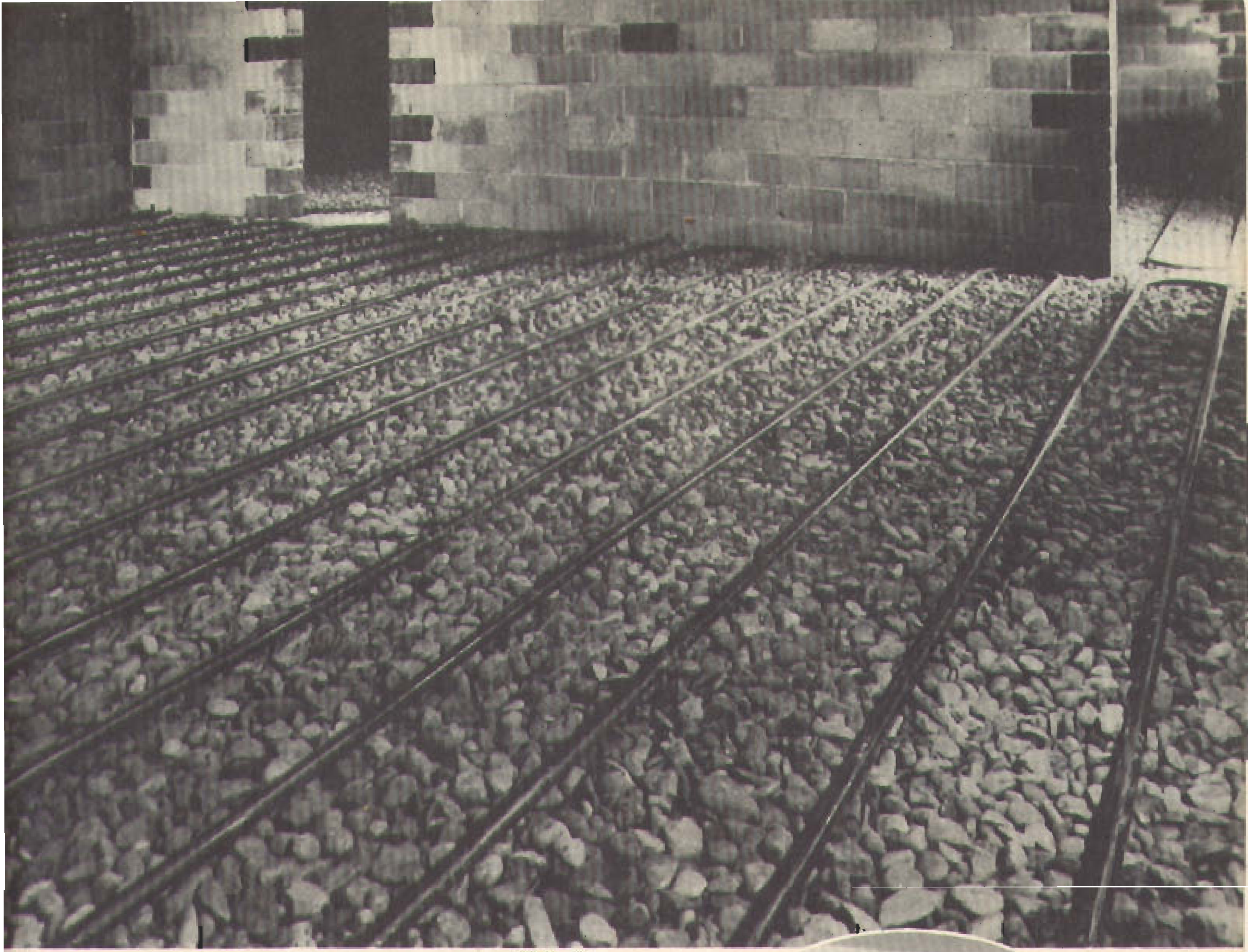


FIG. 41

TAVERN, Pittsburgh, Pennsylvania

A small tavern, shown in Fig. 42, located near Pittsburgh, demonstrates the adaptability of floor type radiant heating systems to commercial structures. The comfort conditions produced in this building are excellent, yet no space is lost to heating devices and cleaning operations are greatly facilitated.

Radiant heating coils were laid on a gravel base as shown in Fig. 41 and covered with a 4-inch concrete slab. Linoleum was used as a floor covering.

Automatic control is accomplished by means of a room-air type thermostat. Performance has been consistently excellent.

The heating contractor who made this installation compared his costs against suitable estimates for other good conventional heating system and stated that he felt certain that the radiant heating system was less costly than the others.

FIG. 42

FIG. 43

FIG. 44

FIG. 45

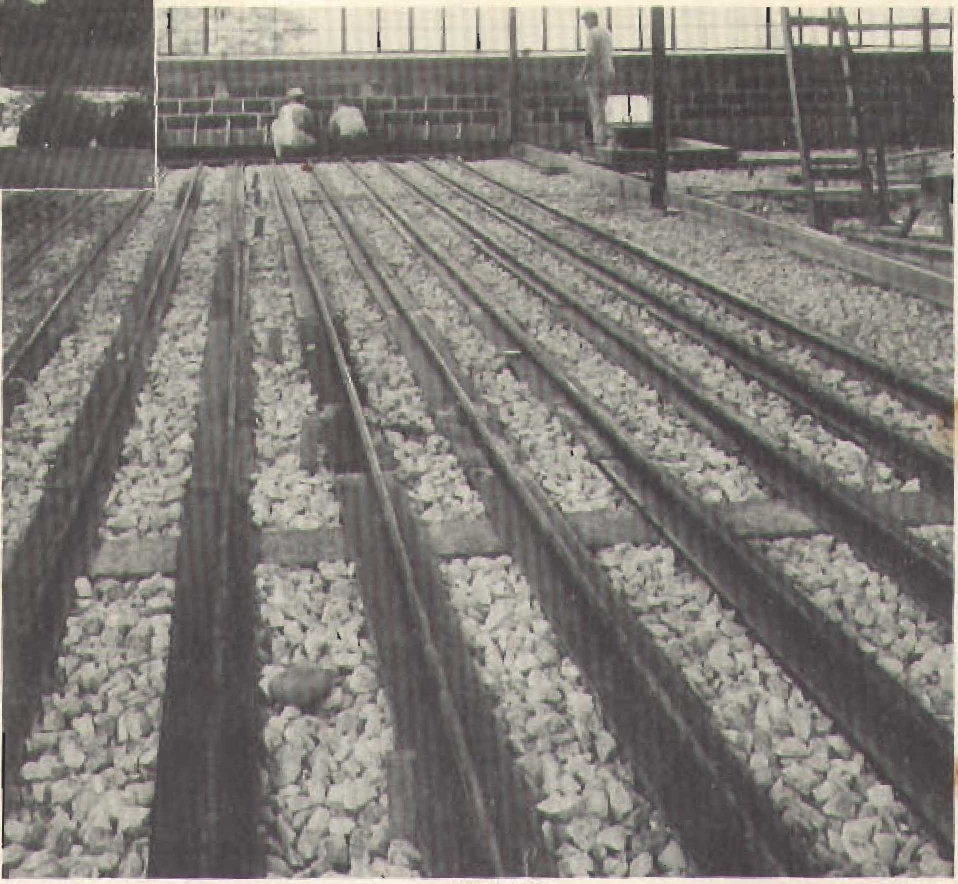


FIG. 46

FACTORY BUILDING, Towson, Maryland

The Murray Corporation at Towson, Maryland recently completed an addition to their manufacturing buildings which is shown in Fig. 43. The architect was Lawrence A. Menefee of Baltimore and Stockett M. Whiteley was the consulting engineer. The floor type radiant heating coils were fabricated by the Heat and Power Corporation of Baltimore, who were the heating contractors working with L. R. and G. Clyde Andrews of Towson, the general contractors.

The structure is a 1-story, basementless building used for light manufacturing purposes as shown in Fig. 44.

The radiant heating grids, 3 of which were used to cover the entire floor area, were partially shop-fabricated as shown in Fig. 45. Eight foot lengths of 1¼-inch wrought iron pipe were welded into 2-inch headers of the same material. These 6 units were then moved to the job site and welded into long grids as shown in Fig. 46. Beneath each pipe a 1-inch thick strip of semi-rigid insulating material was used to restrict downward heat flow to the ground. A 6-inch concrete slab was then poured over the pipes and crushed rock fill as Fig. 47 illustrates. Before pouring of the concrete, the system was tested for 2 hours at a hydraulic pressure of over 200 psi.

The radiant heating grids are pitched slightly toward the boiler room to facilitate drainage and each grid is vented at the high point. A 1/6-horsepower pump located on the return main in the boiler room provides circulation. The 3 grids are balanced manually by means of suitable valves in the boiler room.

War-time material shortages have made it impossible for these owners to procure suitable automatic controls. The system has been very satisfactorily operated, however, by the boiler plant engineer who manually operates the 3-way mixing valve to suit conditions indicated by thermometers in the supply and return lines.

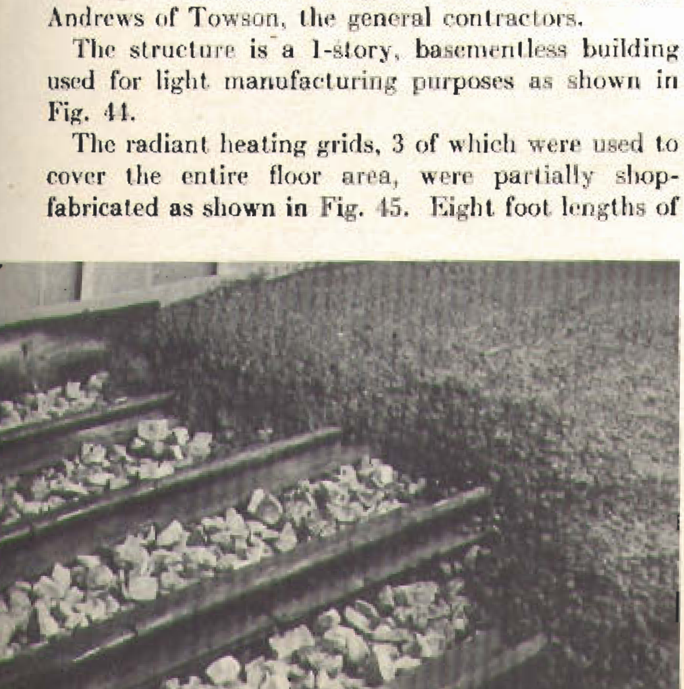


FIG. 47

FIG. 48

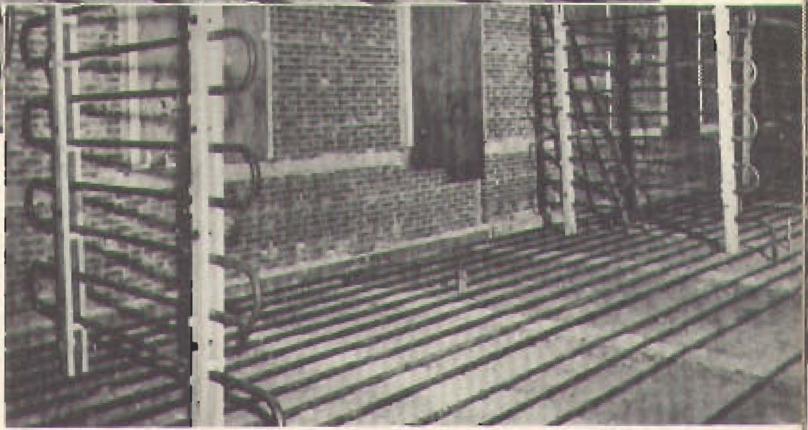
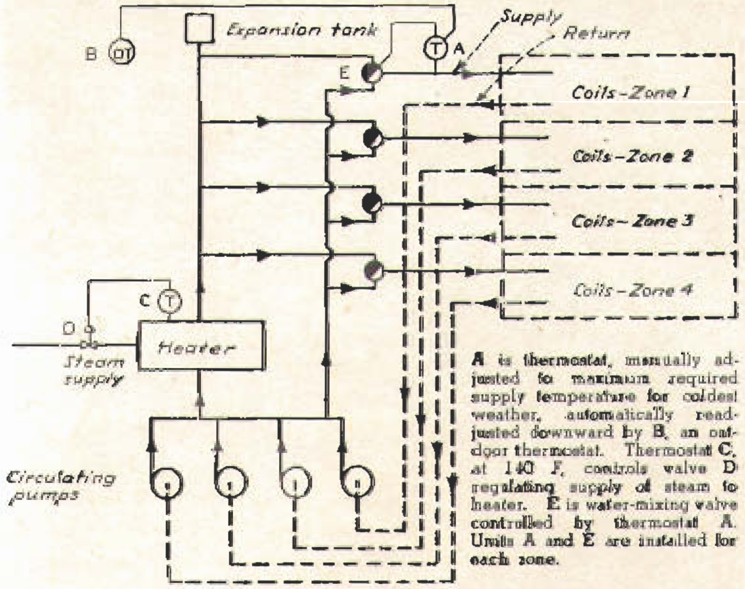


FIG. 49



A is thermostat, manually adjusted to maximum required supply temperature for coldest weather, automatically readjusted downward by B, an outdoor thermostat. Thermostat C, at 140 F, controls valve D regulating supply of steam to heater. E is water-mixing valve controlled by thermostat A. Units A and E are installed for each zone.

FIG. 50—Four-zone radiant-heating hookup with forced circulation of hot water.

INDUSTRIAL PERSONNEL BUILDING
Long Island, New York

A recently completed 1-story, basementless building at an eastern war plant provides an interesting example of the adaptation of radiant heating to industrial buildings. This structure is 80 feet by 280 feet long and was designed and built by Stone & Webster Engineering Corporation. One portion of this building houses the Personnel Department of this company and is divided into office spaces, interviewing, and medical examination rooms. The remainder of the building includes 2 cafeterias, which can accommodate 450 people each and a centrally located kitchen.

Floor type radiant heating coils were used throughout as shown in Fig. 48. In a few small areas where heating demands appeared to be higher than floor coils alone could satisfy, some supplementary wall coils were installed in interior partitions as in Fig. 49.

A concrete floor was poured over the wrought iron heating coils. A severe hydrostatic test was applied to each circuit for a period of 12 to 24 hours before concrete was poured. Approximately 20,000 feet of wrought iron pipe was used to make up these panels and all bending and welding operations were performed at the job site. Portable manual bending equipment as shown in Fig. 51 was used.

The building is divided into four heating zones each of which is controlled by a 3-way mixing valve. As shown in the schematic diagram, Fig. 50, manual adjustment is possible to meet variable demands in the different zones.

Floors are covered with asphalt tile in the office area, while the balance of the structure has a monolithic floor.

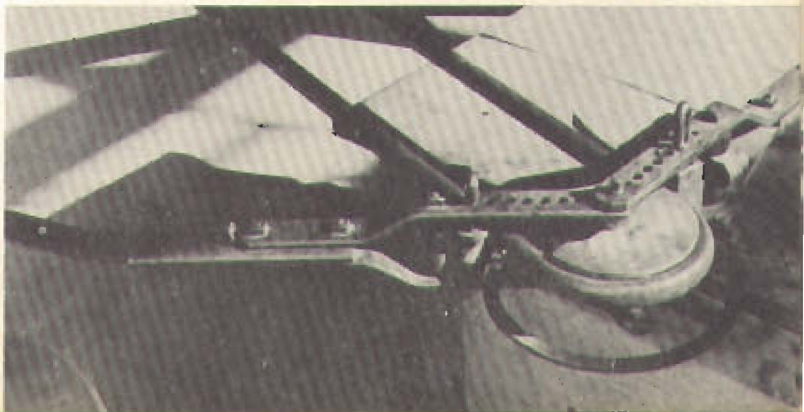


FIG. 51

FIG. 52

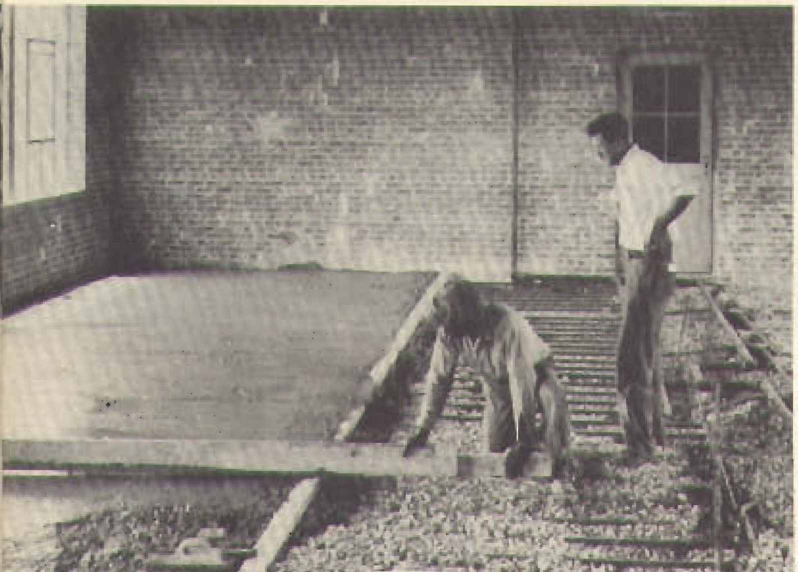


FIG. 53

OFFICE BUILDING
Greenville, South Carolina

The radiant heating system in the new office building at the Greenville Steel and Foundry Company's plant in Greenville, South Carolina, is of the floor panel type. This building is a 2-story structure about 40 feet by 50 feet. Figs. 52 and 53, show construction of the first floor. Wrought iron pipe was welded into grids in the Greenville Steel & Foundry Company's own shops, and ½-inch and ¾-inch pipe was used. As will be readily seen from the photographs, a broken stone fill was first laid on the ground and the pipes carefully laid on this foundation. Additional stone was then placed around the pipe and a concrete slab about 2 inches thick was poured to form the finished floor. The pipe was slightly pitched and provisions were made for draining the coils.

The construction used on the second floor is shown by Fig. 54 and it will be noted that the pipe grids were laid over a cork insulation. Structural members supporting this floor were steel beams. Hot water circulated by a pump driven by a ¼-horsepower motor circulates the water and, according to an official of this company, they are very much pleased with the performance of the heating system. It is said to have been less expensive than any of the other methods considered even when shop overhead was included in the cost of the coils.

The design was worked out by the plant engineers who collaborated with Mr. T. Napier Adlam of Sarco Company and Mr. H. G. Faust of Crane Company, Greenville. An indoor-outdoor thermostat controlling the water temperature was selected.

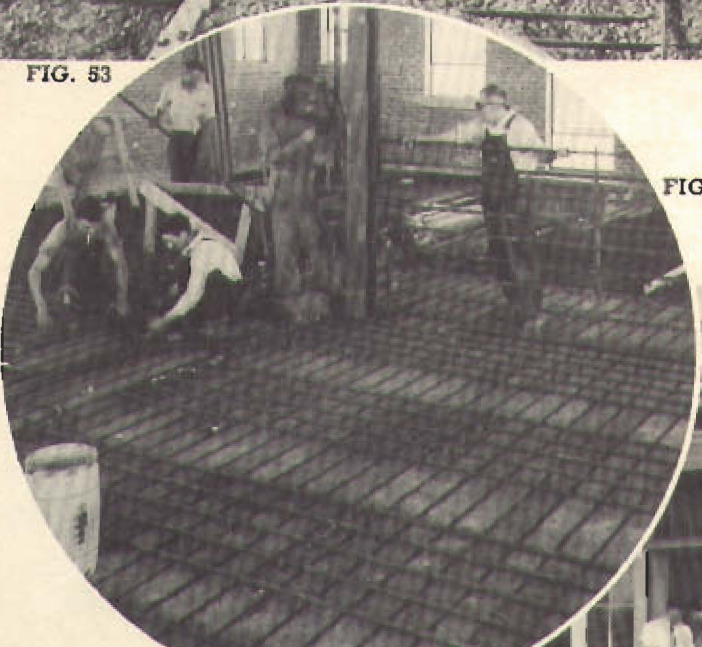


FIG. 54

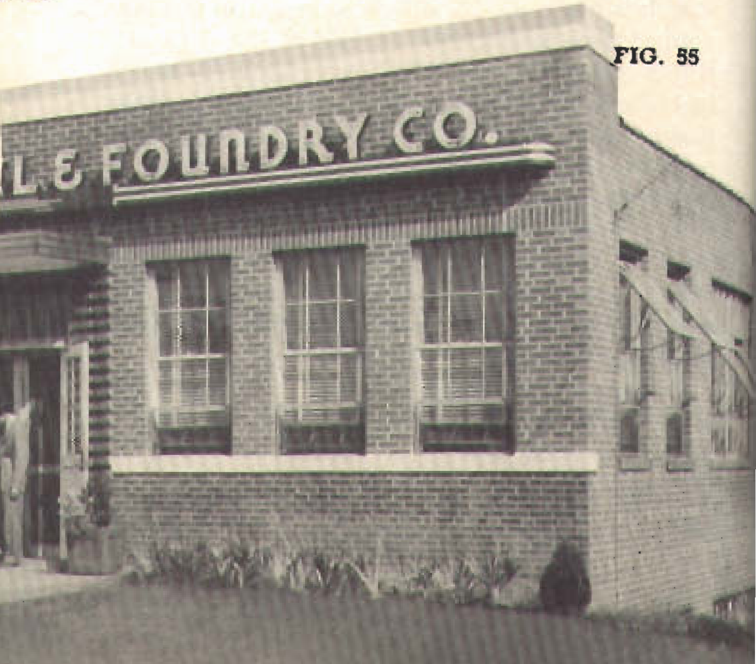


FIG. 55

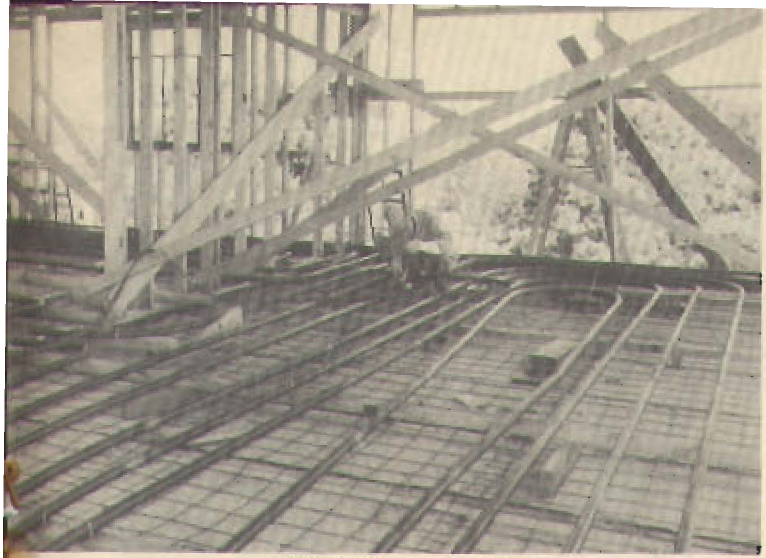


FIG. 56

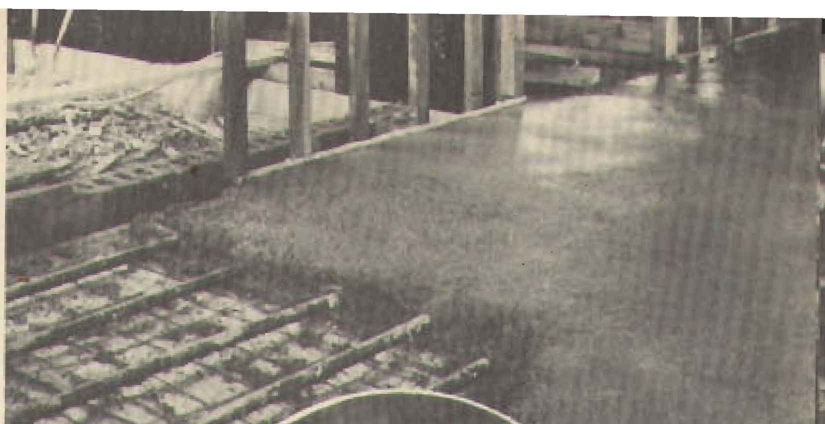


FIG. 57

PETERSON RESIDENCE
Falmouth, Massachusetts

Ernest Gunnar Peterson, architect of Falmouth, Massachusetts, recently designed and built for his own use the "combination" house overlooking Vineyard Sound illustrated in Fig. 59. The ground floor houses his office and drafting room (Fig. 60) while the family living quarters occupy the upper floor (Fig. 61). Floor type radiant heating is used throughout and has provided exceptionally comfortable conditions even in the face of severe exposure and huge glass areas.

The radiant heating coils are embedded in the concrete slab which comprises the ground floor. Pipes were partially covered with the fill under the concrete (Fig. 58).

The second floor is also made up of a concrete slab which is supported by precast concrete joists (Figs. 56 and 57). The heating pipes are here completely surrounded by concrete.

Asphalt tile was used as the primary floor surfacing material throughout the house, with random carpeting in the living quarters.

Hot water is supplied from an oil-fired boiler located on the ground floor. Proof of the economy of this type of heating system is provided by the fact that, under severe fuel oil rationing perfect comfort was maintained even though considerably less than the authorized fuel quota was used. Installation costs also appeared very reasonable as the total cost of the radiant heating system amounted to only about 8 per cent of the total cost of the structure.

Observed air temperatures in this residence are typical of radiant heating performance and are worthy of note. A thermostat setting of 68°F is used in the living room zone while a setting of 60 to 62° F is quite satisfactory in the bedroom zone. These settings have been found to provide exceptional comfort even in very severe weather.

FIG. 58

FIG. 59

FIG. 60

FIG. 61

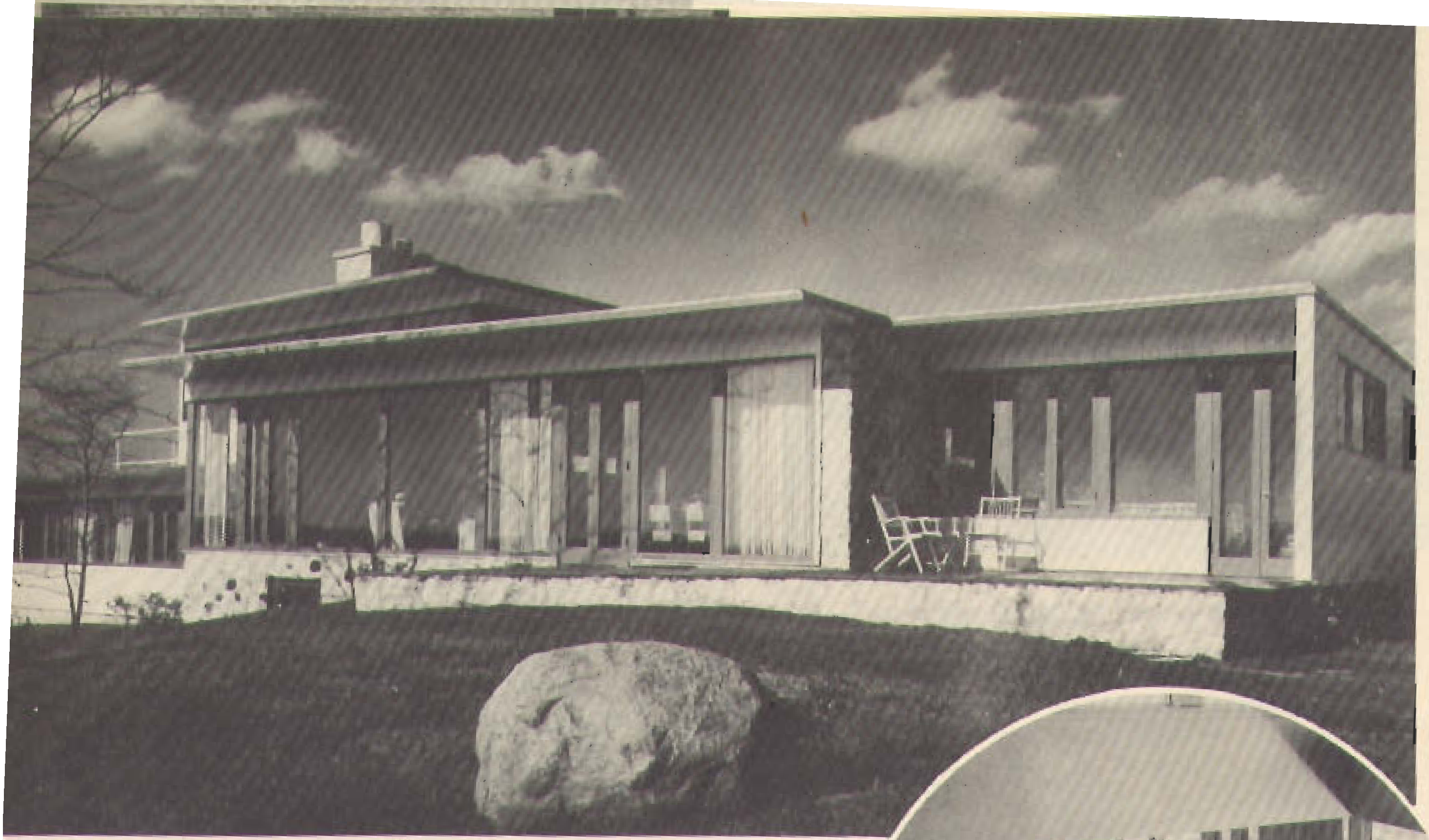


FIG. 62

RESIDENCE
Barrington, Illinois

FIG. 63

Late in 1941 an exceedingly interesting residence was completed at Barrington, Illinois. George Fred Keck of Chicago was the architect and the Illini Heating Company of Chicago were the heating contractors.

The house as shown in Fig. 62 is located on a small rise and the large glass panels command an excellent view. The finished cost of the structure was approximately $25,000.

The radiant heating system in this house is supplemented during the day by solar heating. The low angle of the winter sun allows the rays to come directly into the rooms during a large part of the day. The interior view shown in Fig. 63 illustrates the pleasing manner in which the outdoor scenery blends in and becomes a part of the rooms. Because of these huge glass areas, the heating problem is necessarily somewhat more severe than is normally the case. However, the radiant heating system has performed excellently without creating any of the drafts or making use of the unsightly heating appliances which are common with conventional heating systems.

The first floor coils were laid on a sand fill and topped with concrete. The second floor coils were also embedded in a concrete slab. In the bathroom a supplementary wall coil was used to increase the radiant effect over and above the amount which could be secured from the floor coil alone. The pipe coils are ¾-inch wrought iron and all joints are welded.

An oil-fired boiler supplies hot water for the system. An outdoor control is used, which varies the temperature of the water in accordance with changes out of doors. A square-head balancing cock is provided for each room in order to control the quantity of water supplying the heating elements in the individual rooms.

The system cost approximately $1900, which is a little less than 8% of the total cost of the structure.

ARMSTRONG RESIDENCE
Gary, Indiana

Mr. Andrew Armstrong's new home is built on the sand dunes near Lake Michigan. As shown in Fig. 64, 2-inch wrought iron pipe was laid in the sandy soil to form the heating element of the radiant heating system. About 4 inches of sand was packed over the coils and a 2-inch concrete mat was then poured. The finished floor was supported by this mat and consisted of 4-inch thick concrete slabs laid in sections 4 feet square. Hot water at between 180 and 200° F is circulated through the pipe coils and warms the slab.

Frank Lloyd Wright was the architect and Edward J. Munkhoff of Gary, Indiana, was the heating contractor. Fig. 65 shows the completed residence.

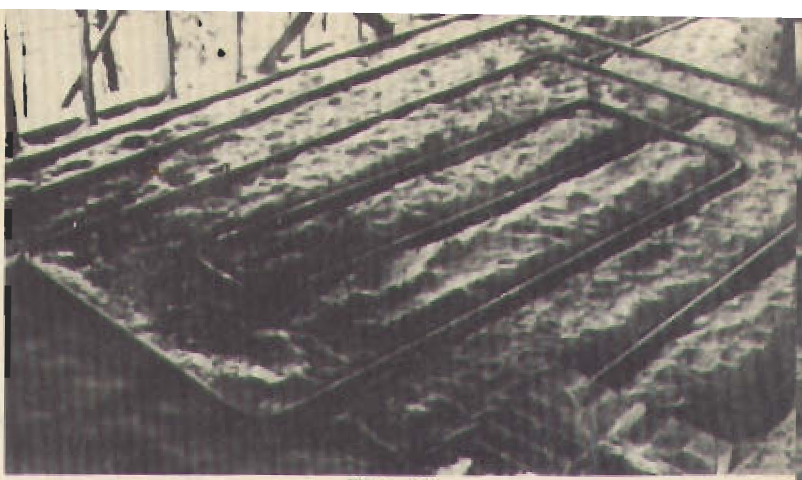


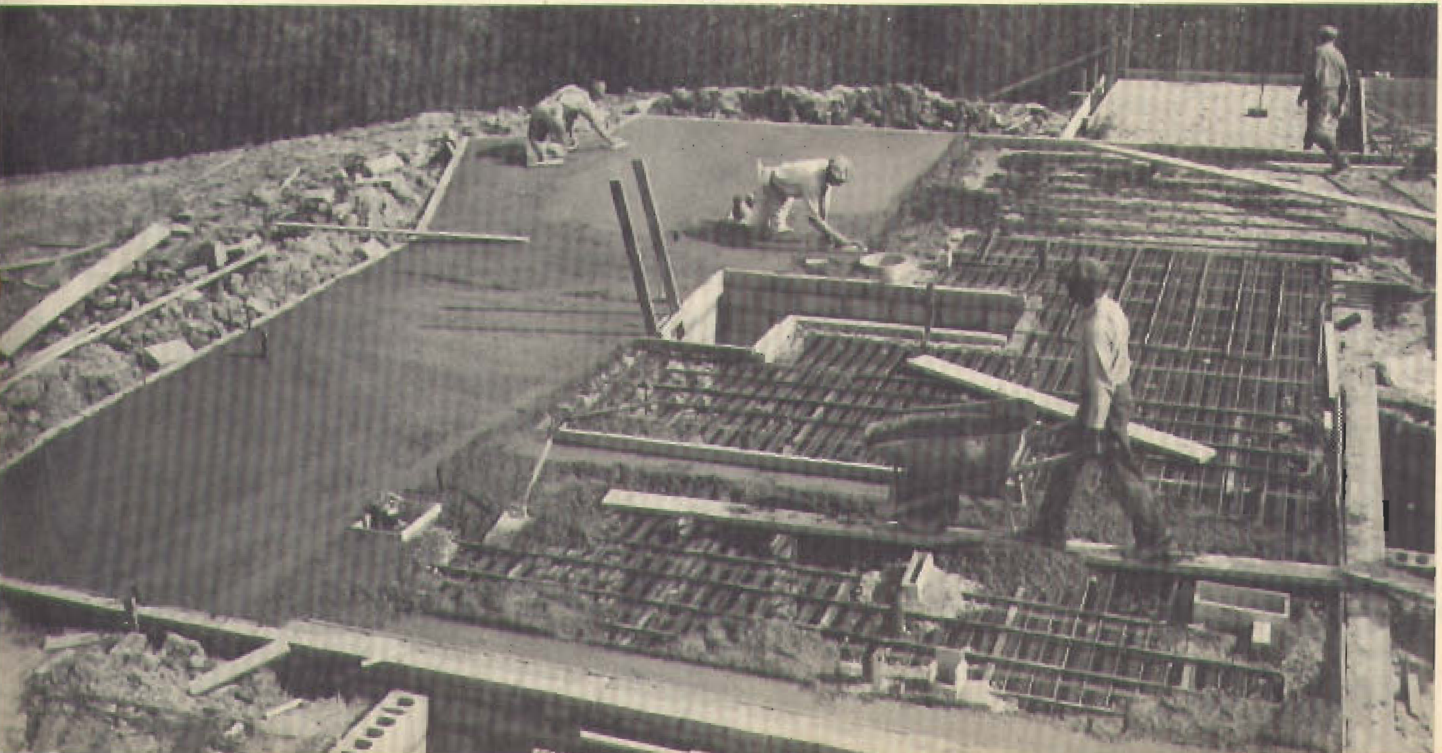
FIG. 64

FIG. 65

RIDEOUT RESIDENCE
Cleveland, Ohio

A new residence for Mr. and Mrs. J. G. Rideout was built in the fall of 1941, at Sunset Springs, Moreland Hills, Cuyahoga County, Ohio, a few miles from Cleveland. A partial basement was dug and concrete block walls were built up to ground level. Steel bar joists were placed about 2 feet apart to support the first floor. Metal lath was laid over the joists and the pipes over the lath. Fig. 66 shows concrete being placed around the coils. The lath served as a form and the concrete was mixed fairly dry so that it would not flow through the lath. The unexcavated portion of the house is heated by floor coils laid on Haydite "popcorn" and covered with concrete. The rooms on the second floor are heated by wrought iron coils in the ceiling. Mr. Rideout, an industrial designer by profession, acted as his own architect and heating engineer.

FIG. 66



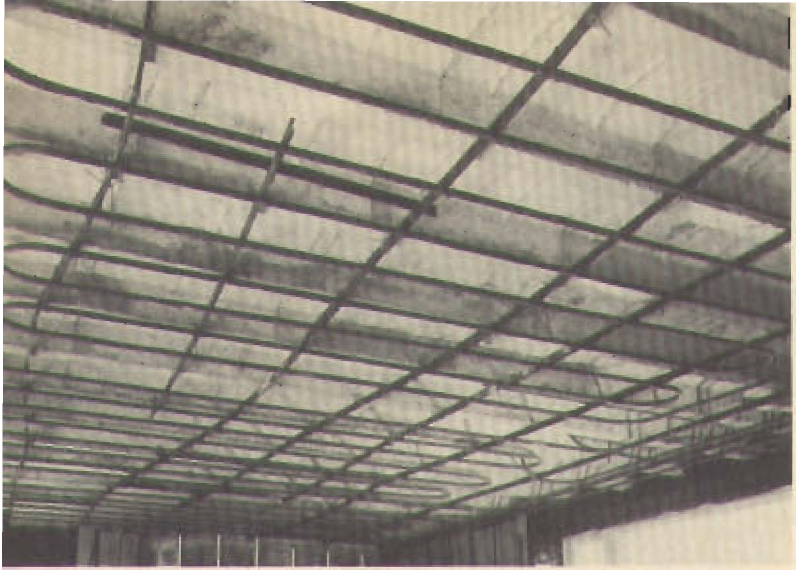


FIG. 67

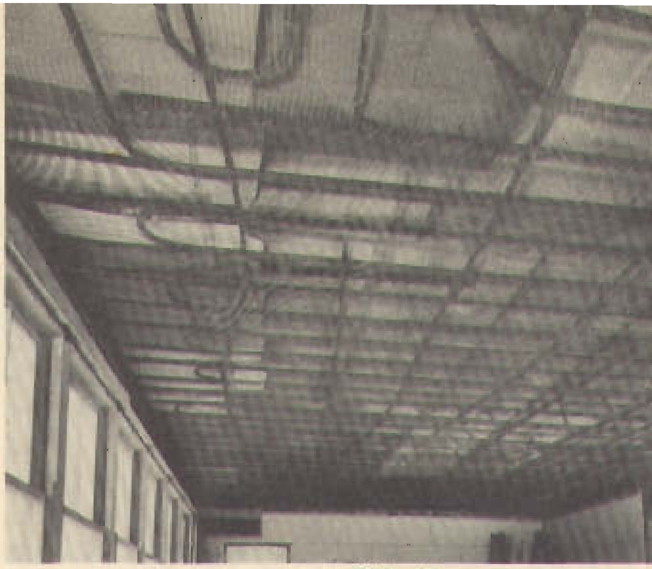


FIG. 68

STIMM RESIDENCE, Williamsville, New York

Fig. 71 shows a modern residence recently built by H. F. Stimm, Inc., at Williamsville, New York. Sebastian J. Tauriello of Buffalo was the architect and Raymond Viner Hall, architect of Port Allegany, Pennsylvania, collaborated in the design of the radiant heating system.

Pan-type concrete construction was used through most of the first floor with the radiant heating coils resting on top of the concrete as shown in Fig. 69. Solid concrete construction was used in a few locations and in those instances the heating coils were fully enclosed in the slab. Ceiling coils were used on the second floor, also as indicated in Fig. 70.

Figs. 67 and 68 show the ceiling coils at 2 stages of construction. In the former the pipes are shown tied to the 1½-inch channels which in turn were anchored to the ceiling beams. Metal lath was then fastened to the pipes and the finished plaster ceiling applied.

Hot water is the heating medium and is supplied from a stoker-fired boiler. Control is accomplished by means of a 3-way valve which is positioned by a liquid expansion thermostat mounted outdoors. An indoor thermostat is also integrated in the system to prevent over-heating.

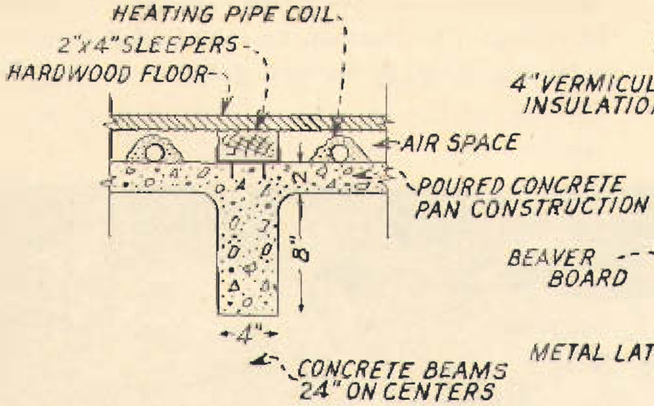


FIG. 69—Diagram of first floor construction showing location of heating coils.

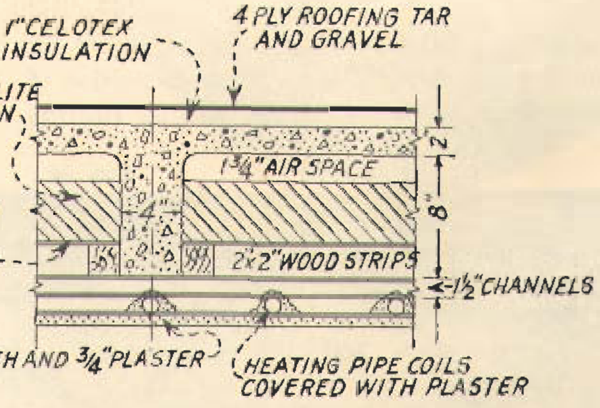
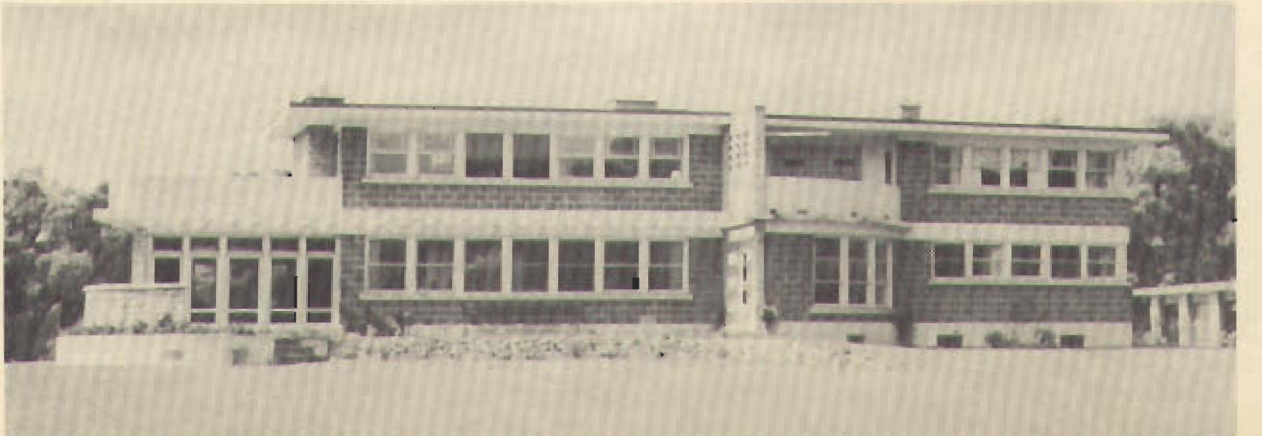


FIG. 70—Sketch of roof section with radiant heating coils installed below concrete beams.

FIG. 71



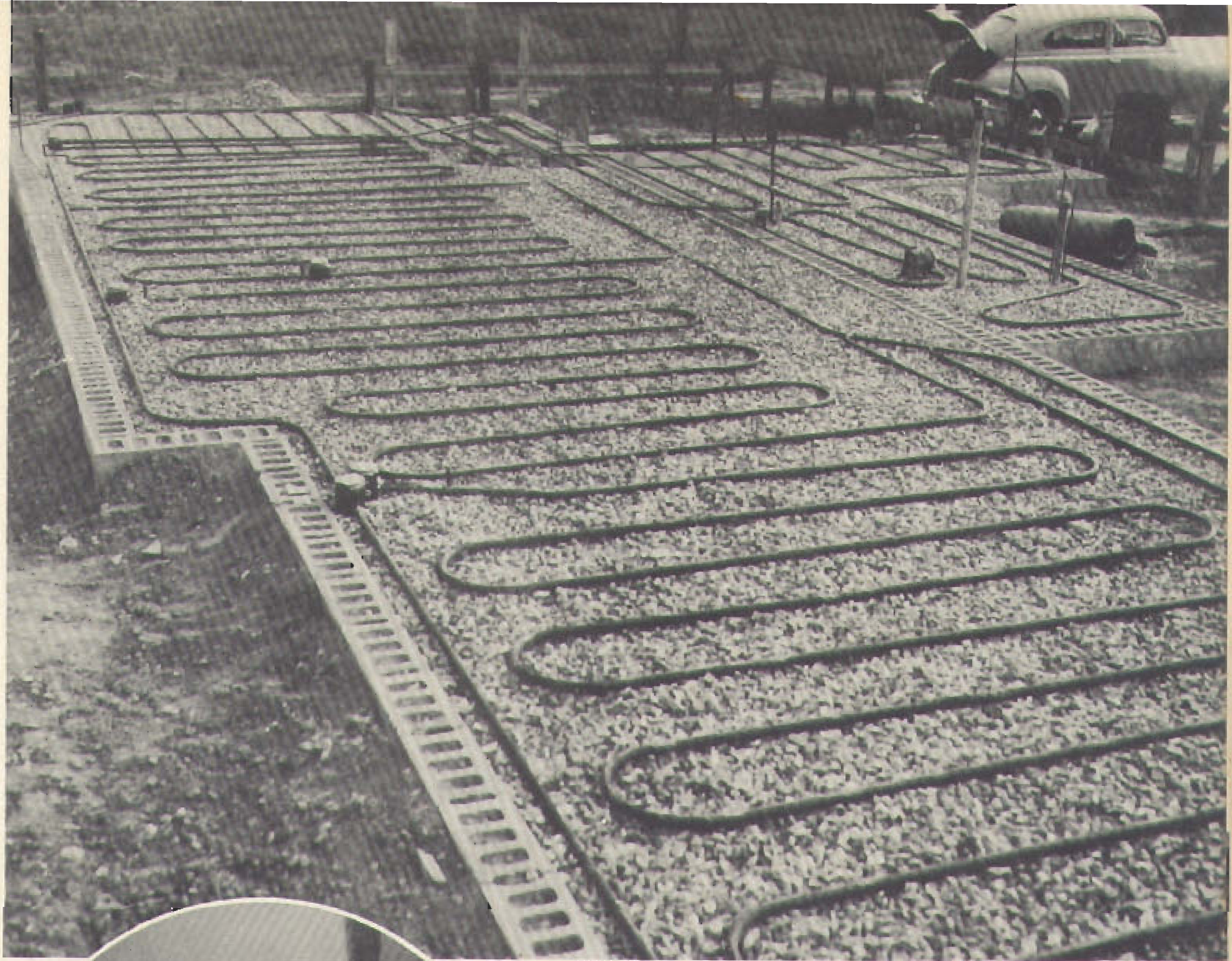


FIG. 72

MOORHOUSE RESIDENCE
Lancaster, Pennsylvania

A very interesting modern house was recently built near Lancaster, Pennsylvania by Mr. William Moorhouse. The architect was Philip F. Hallock and Raymond Viner Hall, architect, was associated with him. The heating problems in this house were increased to a certain degree by the use of extraordinarily large glass areas as shown in Fig. 73. This photograph also illustrates the extreme suitability of radiant heating which leaves areas beneath the windows free for attractive decoration.

The house is heated by a floor type radiant system using ¾-inch, 1-inch, and 1½-inch wrought iron pipe which was fabricated at the job site and cast directly into the concrete floor. After the system had been in operation for a short period of time, pre-finished wood block flooring was applied with mastic. Fig. 72 shows the heating pipes in place on the crushed stone fill before the concrete was poured.

FIG. 73

FIG. 74

FIG. 75

STANLEY RESIDENCE

Muscatine, Iowa

Mr. C. M. Stanley of the Stanley Engineering Company in Muscatine recently built a new home in that city. Acting as his own designer, Mr. Stanley specified that genuine wrought iron pipe coils carrying hot water should be used to warm the floors. The first floor coils, fabricated from 1200 feet of 2-inch wrought iron pipe, were laid on gravel under the concrete first floor slab. All joints were welded. Coils for the second floor were fabricated from 1200 feet of 1¼-inch wrought iron pipe. Figs. 75 and 76 show these coils installed.

Westerlin & Campbell, engineers and contractors of Chicago, fabricated the coils and Sanitary Plumbing & Heating Company of Muscatine did the installation work.

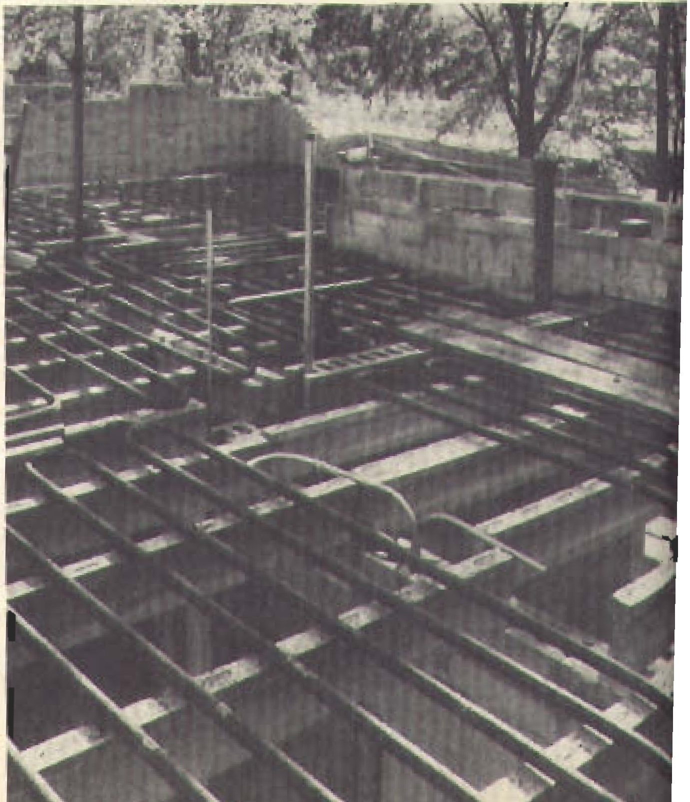


FIG. 76

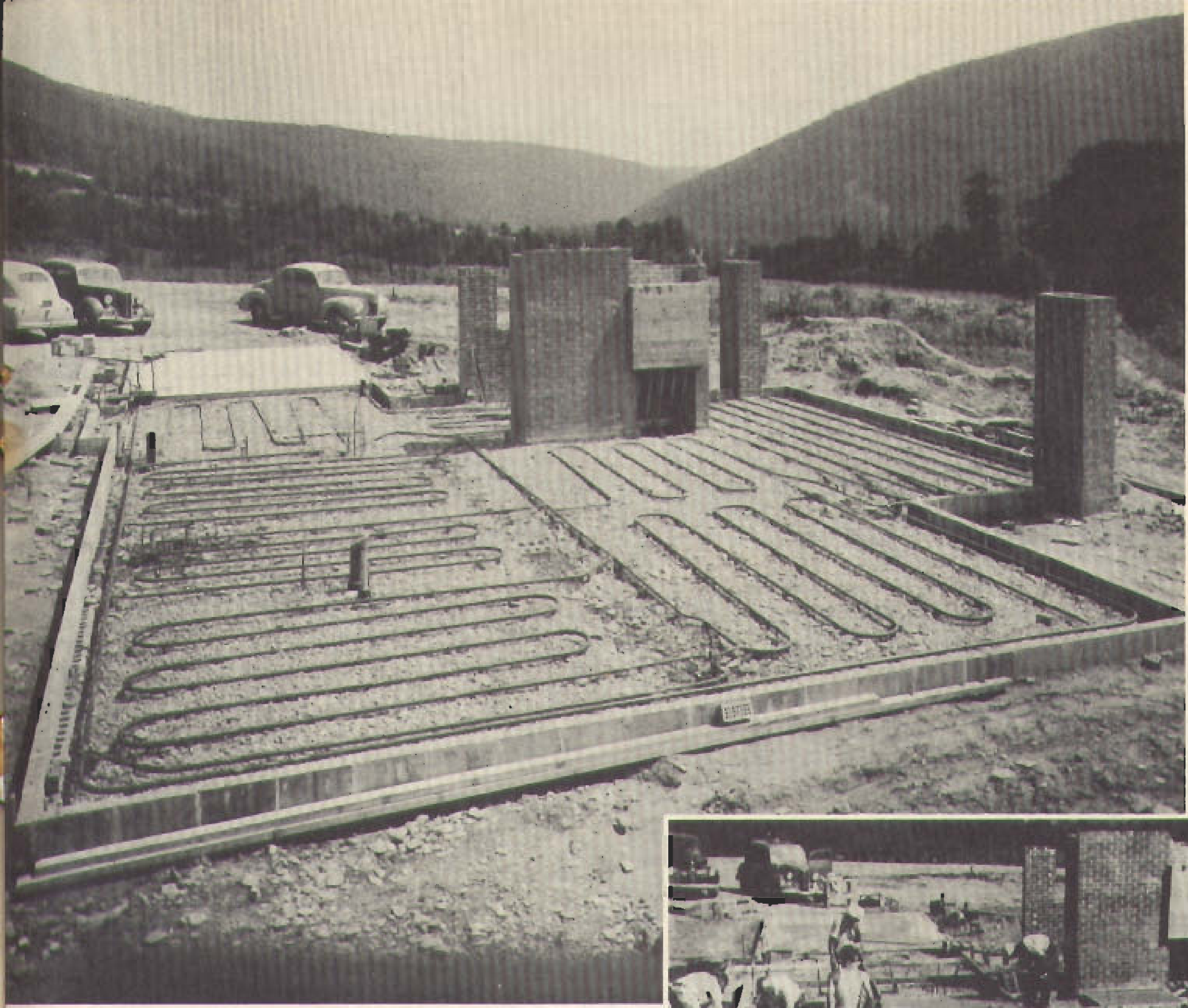


FIG. 77

FIG. 78

OVERMIER RESIDENCE

Emporium, Pennsylvania

This residence, designed by Raymond Viner Hall of Port Allegany, Pennsylvania, was the first of five radiant heated residences designed by Mr. Hall, on a knoll overlooking Emporium. The others, namely, residences for J. R. Steen, R. A. Palmateer, P. H. Sassaman, and P. Haas, were all F.H.A. financed and all five have 1-inch wrought iron pipe heating coils. Building costs were in the \$6000–\$8000 bracket and the heating systems ran from \$500–\$550 complete. The installation method typical of that in all five homes is shown by the photographs labeled Figs. 77, 78, and 79, which were taken while the Overmier house was under construction.

FIG. 79

FIG. 80

COFFEY RESIDENCE

Concord, Massachusetts

In this traditional residence (Fig. 80) two of the rooms are heated by the floor type radiant heating system. The installation is worthy of note because of the use of conventional wood flooring in a manner typical to this type of construction.

The heating coils are placed on top of the concrete floor slab (Fig. 82) and operate in an air space bounded by the conventional wood flooring which was fastened directly to the sleepers shown in this illustration. Care was taken to make certain that properly seasoned flooring was used and the owners have reported performance of an excellent character.

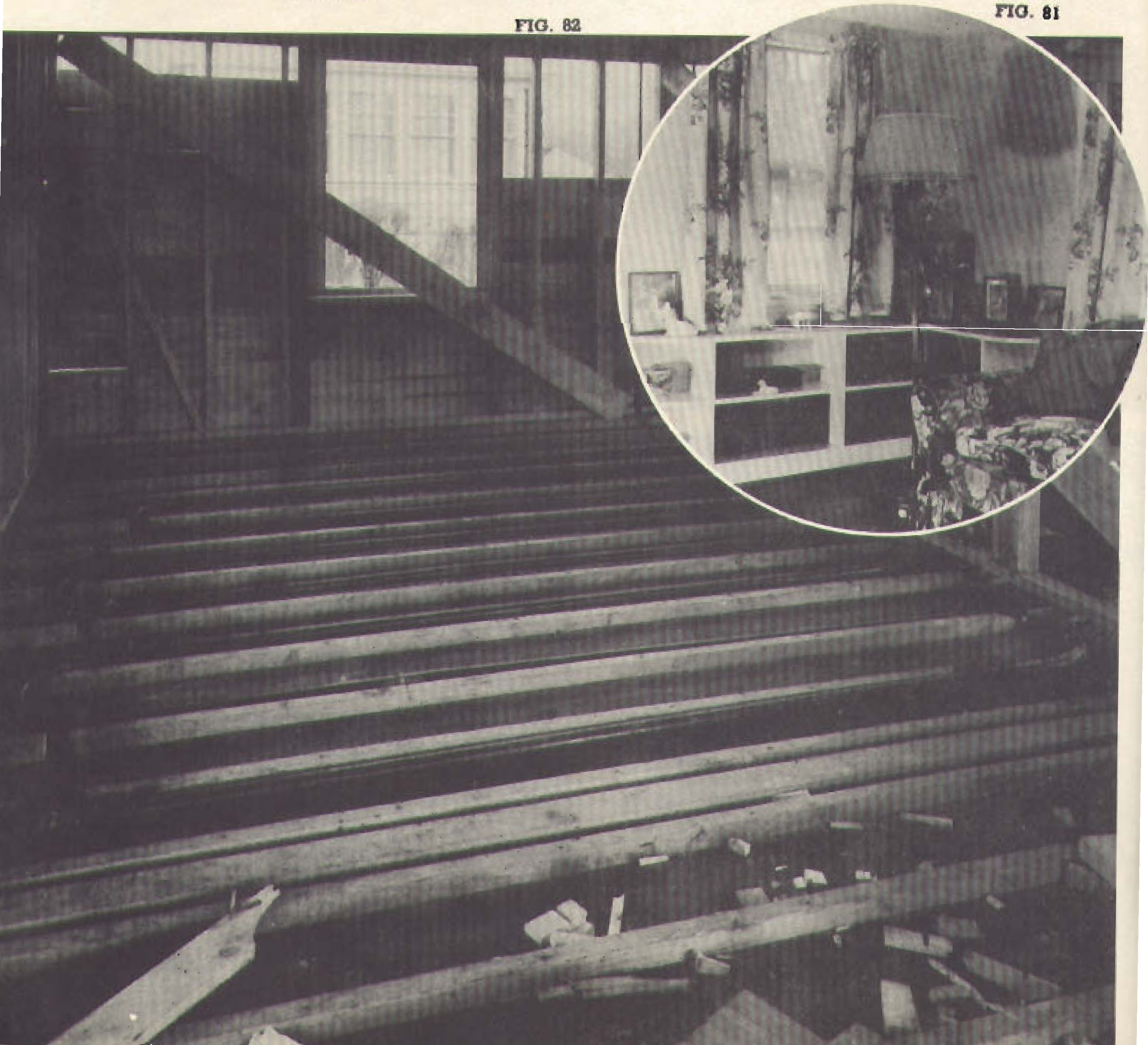


FIG. 81

FIG. 82

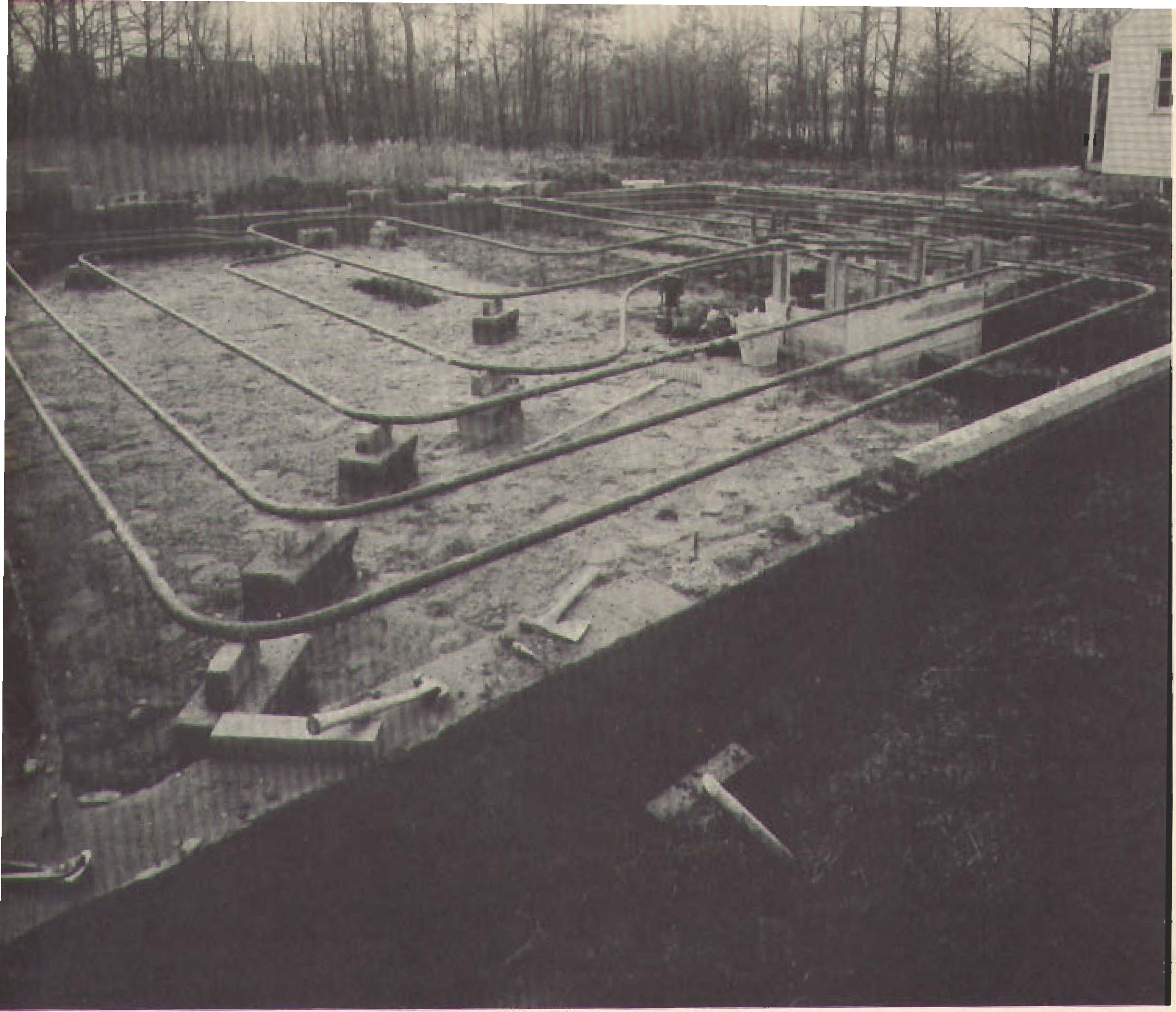


FIG. 83

SCHEERS RESIDENCE

Oaklyn, New Jersey

The George J. Scheers residence at Oaklyn, New Jersey is an excellent example of the adaptation of radiant heating to even small residences. This house is of the utility type and all available space is put to good use as is demonstrated by Fig. 84 which shows the ground floor utility space off the kitchen. This space houses the automatic washer, the water heater, the small gas-fired boiler and circulator for the floor type radiant heating system.

Fig. 83 shows the radiant heating coils when fabrication was nearing completion and just before the concrete floor slab was poured.

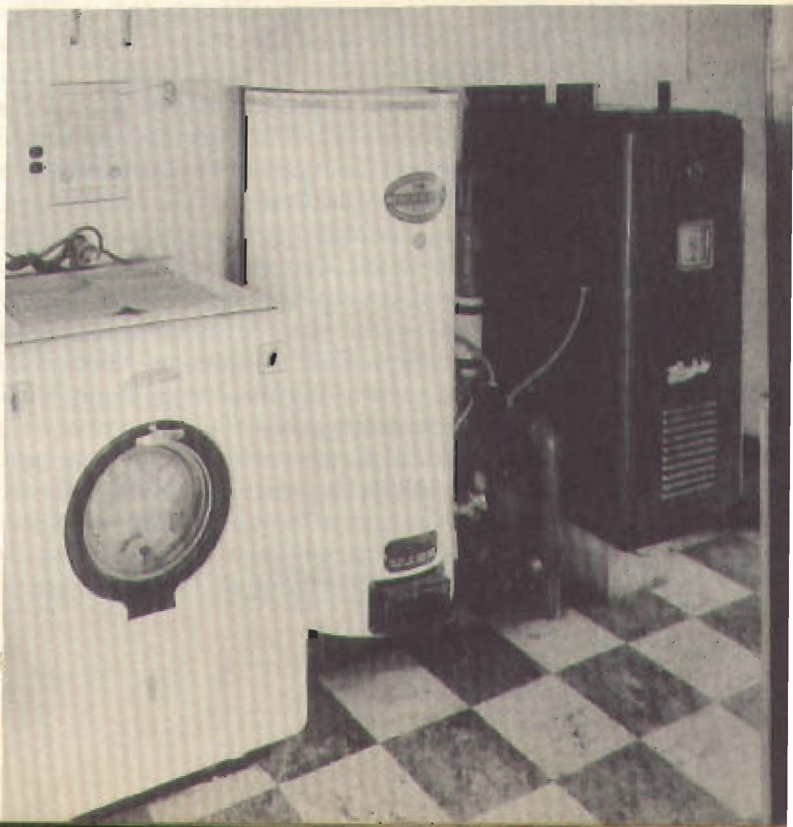


FIG. 84

Notes on Modern Installation Methods

The construction photographs on the preceding pages illustrate the fact that floor type radiant heating systems have been most widely used although quite an appreciable number of ceiling installations have been and are being made. The use of wall coils as supplementary elements to floor coils is shown in Fig. 49 on page 29. Although such construction is relatively rare, occasions sometimes arise in which the practice is advisable.

Most of the illustrations embody concrete slabs but it should be noted that this is not at all necessary. The reason for this predominance is that concrete slabs, particularly those on the ground, have long been known to be very hard to heat and designers have been among the first to recognize the ability of radiant heating to solve this specific problem. Questions concerning the preferable slab thickness are frequently raised and it is well to point out that, as the photographs show, installations have been successfully made with concrete ranging from 1½ to 6 or 7 inches over the pipes. Obviously the thickness of the concrete section over the pipes will have a bearing on the water temperatures required but experience has demonstrated that, as long as the pipes are in intimate contact with the concrete, these variations are slight.

The transmission of heat will also vary slightly for different types .of ceiling construction, depending primarily on the degree of contact between the pipe and the plaster. As a general rule the more completely the plaster is worked through the metal lath and up around the pipes the better the heat transmission will be. Another factor affecting the performance of ceiling installations is the treatment afforded the air space on the back side of the pipes, provided that these have not been completely covered with plaster. Where possible, most designers have preferred to place a fill-type insulation in the rafter space directly behind the pipe and plaster. That practice restricts heat flow away from the heating surface.

For wood floor construction (as outlined on pages 43 and 44) considerable variation is also permissible in the thickness of wood over the pipes. Installations have been successfully made with single thickness wood floors, wood sub-floors covered with linoleum or asphalt tile, and double thickness wood floors. The heat transmission constants in these instances vary more widely than is the case with concrete construction due to the relatively greater insulating effect of the wood. For this reason the transmission coefficient described on page 12 is not suitable in all cases. It would be impractical to attempt a general rule applying to all wood floors, consequently it is recommended that such questions be taken up with the Engineering Service Department.

A typical layout for floor type elements in residential construction is shown in Fig. 13. The location of balancing cocks for each element is clearly marked and is worthy of note. These are usually small tee-handle or square-head plug type valves set down in apertures in the floor. In concrete work the aperture is cast around the valve at the time the floor is poured and is covered upon completion with a removable traffic plate. Where wood floors are involved, the valves can be made accessible through a hinged access panel either in the floor or in the rigid element below the pipes (false floor, ceiling, or insulating material, whichever the case may be).

The valves may be placed anywhere in the circuit for any particular room since their restricting action will be effective at any point. To simplify residential work designers occasionally have chosen to use either individual supplies or returns for each room element, locating all the balancing valves in the heater room. Such practice can be made just as efficient as any other since the individual supplies or returns can be considered as contributing to the heating effect in any other room through which they pass. If this practice is not followed the valves may be placed in closets or out-of-the-way corners.

The function of these valves is to control the flow of water and therefore the heat input into each area and thus balance the system. Allowance for differences in floor coverings, exposure, etc., can best be made in this way. Normally, the valves are positioned when the system is first put into operation and are not again used until the heating requirements in any of the rooms vary in relation to other rooms.

The hot water systems shown on the preceding pages are all of the closed type making use of an expansion, or compression, tank, to allow for the expansion of water in the system as it is heated. Boiler piping details are the same as for conventional forced hot water systems and consequently no effort has been made to go into this feature in any detail.

No attempt has been made to select photographs of "perfect" installations. The illustrations have been taken at random from a collection of hundreds showing practical work in actual progress. Considerable variations in structural methods is apparent and in this connection it might be pointed out that installation generally does not require a high degree of precision. The work progresses rapidly and smoothly with average craftsmen, once careful engineering and sound planning have been applied. The latter are essential to any good heating system.

Questions Concerning Radiant Heating

In literally thousands of contacts with architects, engineers, contractors, and prospective builders, certain questions have been asked regarding radiant heating and its application. The answers to many of these questions have been given in the various sections of this bulletin and answers to others can be tentatively given on the basis of studied opinion. It is the purpose of this section of the bulletin to anticipate some of the questions which may logically be asked and summarize the information available in answer to them.

What is Radiant Heating?

Radiant heating is a method of maintaining comfort conditions in enclosed spaces by limiting the heat loss from the human body by radiation and convection. This is accomplished by warming relatively large areas of the floor, ceiling, or walls of rooms to low temperatures, as contrasted with the common practice of heating small surfaces to high temperatures. The fundamental principles of radiant heating are discussed in the section on "Theory" which begins on page 2.

What are the Advantages of Radiant Heating?

The outstanding advantages of radiant heating have been discussed in detail in the section on "The Advantages of Radiant Heating," which begins on page 5.

How Does Radiant Heating Differ from Conventional Systems?

In conventional heating systems the heat loss from the body is regulated by maintaining an air temperature high enough to provide comfort conditions. Heat loss from the body to the air is the primary concern of the engineer designing a conventional system. As explained on page 2 heat loss to the air is just one of several ways in which the body dissipates its excess heat, and a considerable quantity is lost by radiation of heat rays from the body which are absorbed by cold walls or other surfaces in the room. By reducing the heat lost by means of these rays, it is possible to maintain comfort conditions at lower air temperatures.

How Does the Cost of Radiant Heating Compare with Conventional Systems?

In the section beginning on page 8 of this bulletin, the question of cost is dealt with in some detail. In general, however, the statement may be made that radiant heating installations will cost just about the same as other good conventional systems. Comments on operating costs have generally indicated that savings up to about 30 per cent may be anticipated.

What Air Temperature Should be Maintained in a Radiant Heated Room?

In the section of this bulletin on "Radiation and Comfort," the results of scientific study of this question are presented. (See page 4).

What is Meant by Mean Radiant Temperatures?

This term is used in detailed studies as a measure of the equivalent surface temperature of the floor, walls, and ceiling of a room. It is discussed in some detail on pages 4 and 5.

How May a Radiant Heating System be Controlled?

Automatic controls are considered almost essential with radiant heating systems. Unless a boiler room attendant is on duty at all times or unless the installation is of a very inexpensive nature, manual control does not seem particularly desirable. There have been a few such installations made — with excellent success, according to the owners — but the steady development of good, low-cost controls has made their use a sensible investment.

One of the conditions prevailing in radiant heated space which was not anticipated in early installations is the close relationship existing between air temperatures and the mean radiant temperature (MRT). Actual experiment has shown that it is practically impossible to depress air temperatures below the MRT without extensive refrigeration or its equivalent, large quantities of cold outdoor air. Since infiltration is always present in most structures to a sizable extent, it is likewise most unlikely that air temperatures would ever remain appreciably above the MRT for any length of time.

The importance of this fact in studying the control problem is that the designer is left free to choose from any of the conventional control schemes. For example, there have been hundreds of radiant systems installed in this country which embodied the common room-air type of thermostat. Such a device can be counted on to do an acceptable job in the average structure. However, the heating industry as a whole is in agreement on the point that modulated constant circulation will produce a more uniform effect than can be accomplished with conventional room-air thermostats.

In larger structures, it is usually considered advisable to anticipate comfort demands to some extent by making use of control devices actuated by changes in outdoor temperatures instead of room-air temperatures. Variations outdoors usually precede changes in indoor temperatures, with the result that, if the earlier demand is used to actuate the controls, the heating system can start its compensatory effect in advance of actual demand. Most devices of this nature do not make use of the "rate of flow" variable in establishing control but instead rely entirely on temperature changes in the heating medium which is constantly circulated. It is felt that the absence of the "on-off" characteristic of such control systems produces a more uniform heating effect, particularly in the larger structures. A great many radiant installations have been made using this type of control and reported results indicate an excellent performance.

Can a Room be Kept at a Comfortable Temperature with Floor Coils Alone?

This is entirely a question of design and depends on the rate at which heat is lost from the room. If the heat load can be balanced by the heat given off by a floor at 85°F or less, then the floor heating system should be entirely satisfactory. As a general rule, floor surface temperatures can be expected to remain under this figure if the required output into the room is not in excess of 75 to 80 Btu per hour per square foot of floor. This should not, however, be considered an inflexible rule since outputs as high as 150 Btu per hour have been observed with floor temperatures at 70°F. Hundreds of floor systems have been in operation for a considerable period of time and the complaint of over-warm floors in properly controlled installations has never been made.

If the design of the building is such that more heat must be supplied to the room than can be given off by a floor warmed to 85 degrees, then it is necessary to use ceiling coils or wall coils which can be run at a higher temperature. Coils in these locations may either carry the load alone or may be supplementary to the floor elements.

In describing schools and churches in England, heated by warm floor slabs, A. H. Barker makes the following comments in an article "Room Warming by Radiation" which appeared in the March, 1932, issue of HEATING, PIPING & AIR CONDITIONING:

> "These are raised to about 70°F and the effect is very pleasing; a feeling of warmth and comfort is produced, even though the surrounding air is quite cold."

American observations have disclosed floor surface temperatures between 68° and 85°F, with varying air temperatures, which have proved consistently comfortable. Consequently, it can safely be said that for almost all structures, floor coils alone will perform excellently.

In a Wall Heating System, Should the Coils be in the Outside or Inside Walls?

From the standpoint of heat economy, panels in interior walls should conserve heat best, since the heat which flows from the back of the panel will be dissipated in an adjoining room rather than lost to the outside air. To prevent a feeling of chilliness near windows, however, coils have occasionally been placed around or immediately under wall openings.

What Piping Material Should be Used for Radiant Heating Work?

A detailed discussion of this question has been included in the section of this bulletin which begins on page 16.

Is Steam or Hot Water the Preferable Medium?

Both steam and hot water have been satisfactorily used and installations of both types are described in this bulletin. Hot water has, however, been more widely used and it will be noted that in the majority of installations described in this bulletin, hot water was selected. Steam will, in some cases, give a faster acting installation due to the higher temperatures used. However, the disadvantages accruing to steam generally make hot water the first choice. Among these disadvantages are: (a) greater danger from corrosion; (b) more delicate installation technique required since all pipes must be carefully pitched; (c) ease and accuracy of control of hot water; (d) poor efficiency since steam pipes must be placed farther from heating surface to prevent local over-heating and uneven expansion.

What Effect will Heat Have on Wood Floors?

Based on information developed from an appreciable number of radiant heating installations beneath wood floors, no out-of-the-ordinary results need be expected. Such systems seem to perform in a manner identical with concrete construction both as to operating characteristics and comfort conditions. The low temperatures and relatively slight air movement encountered apparently do not set up a drying action any more severe than is normally the case with conventional heating systems. It should be remembered that the temperatures encountered in radiant systems are not much above those of a mid-summer day and that floor surface temperatures are usually less than the temperature of the skin.

Perhaps the major underlying reason for this consistent success has been that in all cases the owners insisted on either well-dried or mill-finished wood. Thus, excessive drying action after installation would not have been the case in any event. Such precautions are undoubtedly well-founded since "green" wood could certainly be expected to be just as troublesome when used with a radiant heating system as it would with any other system.

There are a number of ways in which the heating pipes can be worked into wooden construction and a few are illustrated on this page. Fig. 85 shows perhaps the most common technique — the wood flooring is fastened directly to a concrete slab by means of the conventional mastic which most flooring manufacturers have available for use with their product. Care should be taken in this type of construction to see that the amount of mastic used is kept at a minimum.

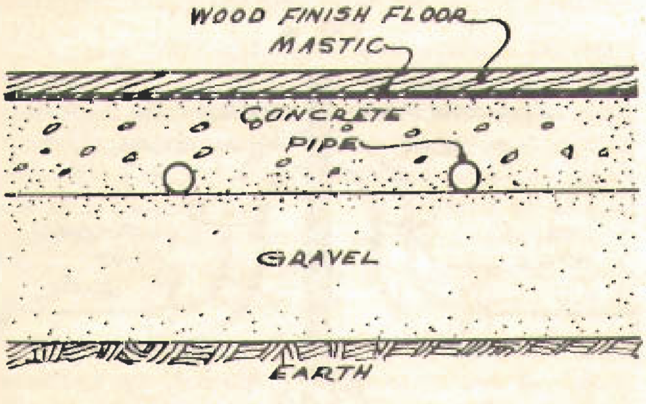


FIG. 85—Wood Floor on Concrete.

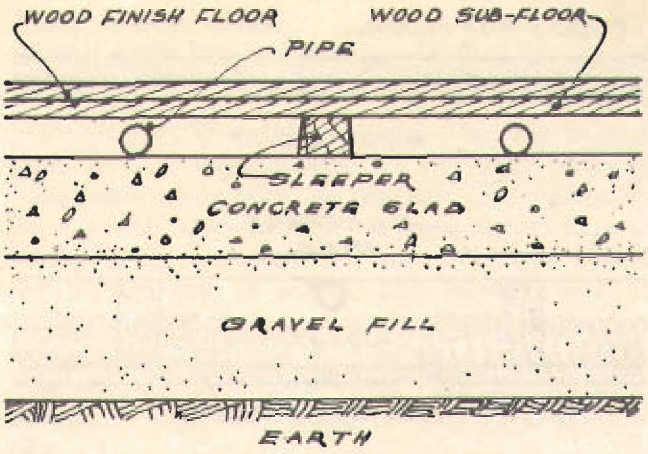


FIG. 86—Furred Wood Floor on Concrete.

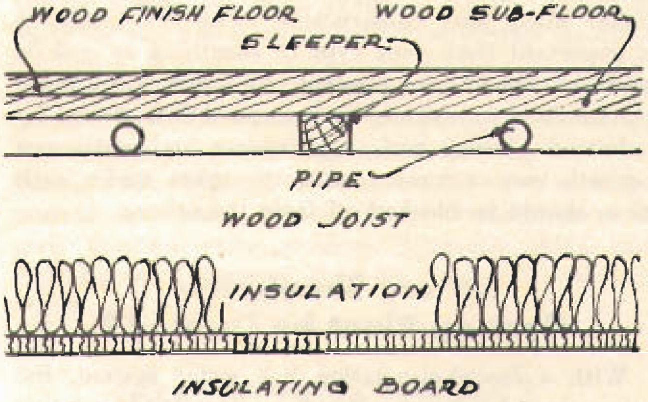


FIG. 87—Furred Wood Floor—Pipes Resting on Joists.

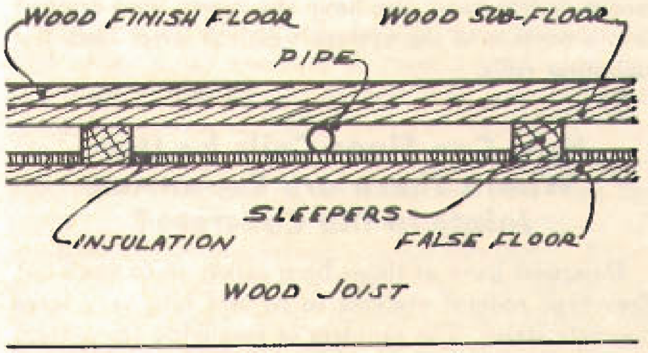


FIG. 88—Furred Wood Floor—Pipes Resting on False Floor.

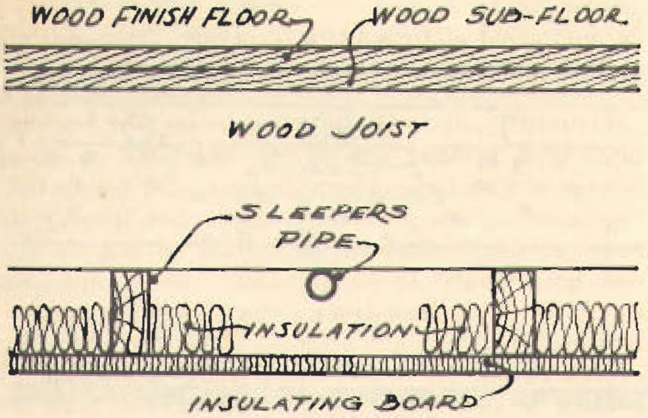


FIG. 89—Conventional Wood Floor—Pipes Fastened to Bottom of Joists.

In Fig. 86, another method is shown which has also been used where concrete sub-floors are involved, while Figs. 87, 88 and 89 illustrate three of the several combinations which can be worked out for conventional wood joist construction. For the latter, it is important that some type of sheathing or seal be used as shown to prevent excessive convection currents and to restrict the downward flow of heat by radiation. Where such open spaces are continuous beneath two or more rooms, the space under each room should be blocked off from the others.

Where Should the Heating Plant be Located?

With a forced-circulation hot water system, the movement of the water is independent of the relative elevations of the boiler and the radiating surfaces. At times, the boiler has been placed in a utility room at ground level, while on other projects, a small basement has been excavated. With a gravity circulation system, it is, of course, necessary to have a difference in elevation between the boiler and the coils, and in order to allow condensate to drain from the coils, a steam system must also have the return lines drained into a portion of the system which is lower than the radiating coils.

How Can Floor Coils be Used Where There are Expansion Joints in the Concrete?

Designers have at times been called on to work out floor-type radiant systems to be cast into very large concrete slabs. The problem of arranging the system so as not to interfere with expansion joints in the slab requires a little planning and some interesting solutions have been developed.

The most direct way to handle the problem, of course, is to place the pipes below the slab, leaving all sections perfectly free to move in any direction with changes in temperature. Pipes may be totally surrounded with the crushed stone or gravel fill or they may be placed at the top surface of the fill so that they are in contact only with the bottom edge of the slab. Of the two, the latter is obviously preferred because of the more efficient heat transfer characteristic but the former method has been used with satisfactory results. However, where the slab must be very thick — say, in excess of 6 inches — in order to carry heavy loads, such practice does not seem particularly desirable from a heating standpoint.

An ingenious compromise with the above plan is to design the heating elements so that they are completely contained within the concrete sections formed by the expansion joints. These elements can be cast directly into the slab and fed from mains placed down in the fill or in trenches. In designs of this nature, it is well to allow enough length in the connecting link between element and main for free movement of the slab without excessive stress on the link or its joints.

A third solution to the problem was recently worked out by consulting engineers collaborating with the engineers of one of the armed services in designing a system for aircraft hangars. Their plan also involved designing the heating elements to be contained within

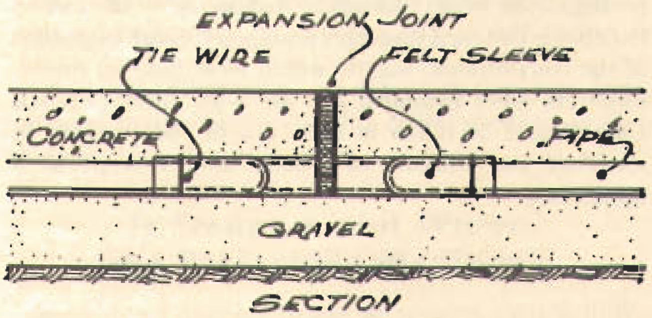


FIG. 90

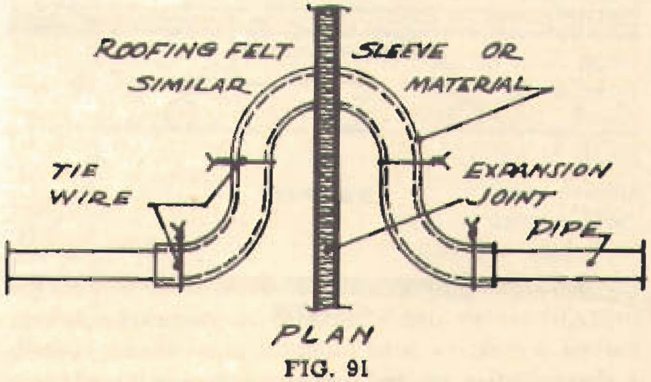


FIG. 91

Loop in Pipe Crossing Concrete Expansion Joint.

the slab sections but in this case the mains too were cast in the concrete. At about six points in the hangar plan it was necessary that supply and return mains cross expansion joints and at these places an interesting "loop" arrangement was worked out which permitted the slab sections to move freely and yet allowed the mains to move sufficiently to accommodate the stress. Figs. 90 and 91 show this construction plan. Although the idea has not yet been put to the test, it does seem to merit attention. As an alternate to the padded loop principle, the use of pipe expansion joints placed within apertures cast in the adjoining slabs has also been suggested.

How Can Radiant Heating Systems be Drained?

The problem of drainage is one which requires a little study in advance of construction. The question to be determined immediately is whether it is very likely that complete drainage of the system will ever be required. Normally, the only predictable reason for complete draining is to prevent freezing and damage due to a shut-down in cold weather. However, the practice of leaving some heat on in buildings during periods of non-use in winter is becoming more and more common, particularly in residences. The development of dependable, low-cost automatic controls has made it quite practical to reduce room temperatures to 50-55°F and allow the heating system to run at this level. Apparently the reason for this change in practice is that the average owner would prefer to stand the relatively small fuel costs rather than go to the trouble of "closing" the structure, with all the attendant fuss over draining the water pipes and plumbing fixtures, removing or using up perishable food, medicine, etc. Based on such reasoning, about 50% of the radiant heating systems on which it has been possible to secure much information have been installed without any particular concern for drainage.

The possibility of freezing as a result of failure of electric power or fuel supply also deserves some consideration. Generally, such shut-downs are of short duration and the relatively large thermal storage capacity of the structure — especially where the pipes are in a concrete slab — can be counted on to hold temperatures above freezing until service is restored. However, where "storage" is light, such as in typical wood joist construction, some concern seems logical.

When preliminary studies show that means for drainage are desirable, several steps can be taken. The most positive is to pitch all pipes about ¼-inch in every 10 feet toward a common low point where a tap or drain line can be installed. Such construction permits rapid and complete emptying of the system and definitely eliminates any danger from freezing.

Frequently, it is the practice to lay the heating pipes level, or approximately so, and count on using compressed air to blow out the lines. For residential construction, this obviously requires the services of some outside craftsman. A suitable fitting should also be provided to accommodate the air line. It should be noted that drainage by this means cannot be considered complete since all water would not be evacuated and this residue would collect at low points, perhaps in sufficient volume to fill short sections of pipe.

Partial drainage in some systems can be accomplished by starting up the circulator and allowing it to operate until all water is moving freely through the piping. If the draining device is then opened, while the circulator continues to run, quite a bit of water can be evacuated. Such practice, though, could not be expected to give much protection against freezing.

Various permanent-type anti-freeze liquids can be injected into the water with good results. Although this method of protection against freezing has been followed on only a few occasions, it does seem to present a solution where extreme consideration is given to the freezing problem. Normally, this is not the case and it seems unlikely that such practice merits general adoption.

Are Air Vents Needed?

Since most radiant systems are operated at relatively low temperatures and velocities, the use of air vents does not seem so specifically necessary as is the case with ordinary systems. However, most designers have seemed to feel in the past that "an ounce of prevention is worth a pound of cure" and have chosen to use a few vents to prevent any possibility of air lock.

It has rather consistently been the practice to vent high spots in the mains or to place a vent wherever the plane of the system changes. At such elevated points, air tends to collect and can become a very serious matter, particularly if the piping is inaccessible. Either manual or automatic air vents can be tapped into the piping system through lengths of small-diameter pipe and run to a suitable outlet. They are often placed in the corners of cupboards, in interior partitions with hinged access panels, in apertures in the floor covered with removable traffic plates or turned through 180° and dropped below the coils such as in the Sacred Heart Church of Pittsburgh shown on page 21.

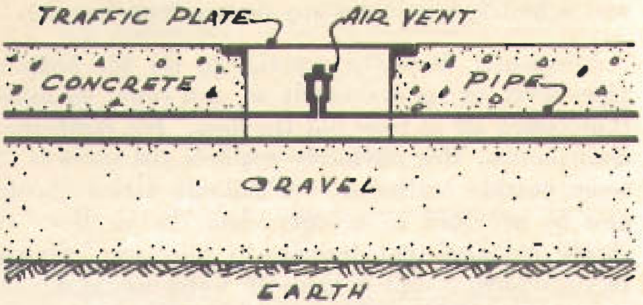


FIG. 92—Enclosed Air Vent.

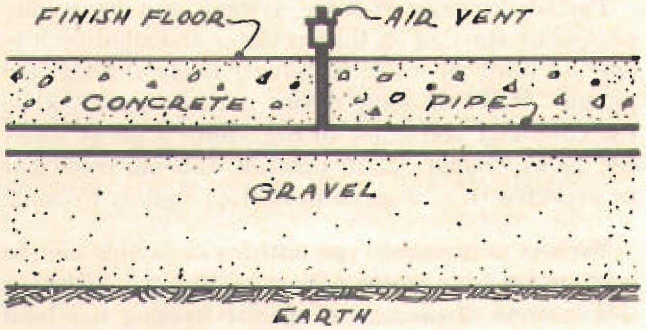


FIG. 93—Exposed Air Vent.

In any case, the time and expense involved in placing a few vents is small compared to the total cost of the system and would seem to represent sound engineering. Recent but as yet unmarketed product developments are aimed at doing away with vents entirely in all hot water systems but until such time as these are announced and made available to the industry, the air vent will probably continue to be used on radiant systems.

What is the Effect on Relative Humidity?

Studies of relative humidity in radiant heated spaces are not yet complete but there is sufficient evidence at hand to form some tentative opinions.

There is, of course, no reason to believe that the absolute moisture content of air within a given space would be in greater quantity with a radiant system than with a conventional system. However, measurements taken at the breathing line by recording instruments have consistently shown over long periods of time that air down in this zone will register a much higher relative humidity than is normally expected during the heating season. Values of 25 to 30 per cent are not unusual in most cases.

There appears to be one basic reason for this showing and that is the uniformity of air temperatures throughout the room from floor to ceiling. Since there is no blanket of excessively warm air collected at the ceiling in a radiant heated room, it is reasonable to expect that the absence of the "blotter" action set up by warm strata permits air-born moisture to be evenly distributed. Discussion of this point with authorities such as Paul R. Jordan, author of "Ventilation Manual for Sheet Metal Contractors," seems to disclose such reasoning as the most logical.

From a comfort standpoint, this feature is exceedingly important. Whether lower air-temperatures permit higher relative humidity at the breathing line, or vice-versa, the fact remains that the benefits obtained through higher relative humidity during the heating season are available with radiant heating. Only in highly special cases, then, would it seem to be necessary to augment a radiant system with mechanical apparatus to add moisture to the air for treatment of disease or preventing the drying-out of furnishings.

What Provisions for Ventilation Must be Made?

Unless conditions of use or occupancy are severe, it will be found that radiant heating will provide a sensation of freshness to room air that is little short of amazing. The reason for this is that the "stuffiness" and "cooked-air" common to conventional systems are absent, since room air never comes in contact with any high-temperature surfaces. The fresh air entering any building from outdoors through the cracks around windows and doors and their frames actually is in very sizable quantity and thus no fear need be felt for any "staleness" developing. As previously stated, the exact opposite is true. Thus, for the great majority of structures no additional ventilation is required.

In buildings such as schools, churches, and theaters where there are a great many occupants for long periods of time, it is frequently considered advisable to increase the quantity of incoming fresh air. There are a number of ways of accomplishing this, depending on the structural characteristics of the building and the magnitude of the heating job caused by the fresh, cold air. Needless to say the subject of ventilation and related equipment is lengthy and no attempt will be made to deal exhaustively with it here. A few methods which have already been successfully used will be briefly described but it is recommended that such special problems be taken up with the Engineering Service Department.

The February, 1944, issue of HEATING AND VENTILATING contained an article by Mr. F. E. Markel describing the use of radiant heating in two large chapels at a southern military station. Since mechanical ventilation was considered advisable due to heavy occupancy load, exhaust fans of a suitable capacity were installed to draw fresh air through the normal building openings and empty "stale" air from the auditorium. Such an installation appears quite efficient from an engineering point of view and, in this instance, provided a high degree of comfort.

Obviously, if the exhaust requirements are inordinately high, the foregoing ventilation scheme could conceivably require greater quantities of cold air than floor systems could reasonably meet. In such cases, it would be necessary to bring fresh air in through ducts so as to be heated before passing into occupied areas. However, the limit of the heating job which floors can handle under these conditions is not yet a definitely known factor. In England, extensive use has been made of "fresh air" schools in which one wall is left open almost all year. A folding wall section is provided which can be closed during periods of severely inclement weather. Under these conditions, the load on the heating system caused by cold air is obviously tremendous, yet the floor-type radiant system provides an excellent degree of comfort.

In passing, it might be well to mention that air entering radiant heated space is warmed very quickly. Recent tests in an aircraft hangar demonstrated that a drop of 22° F in air temperature caused by opening the large doors, was picked up completely in 6½ minutes after the doors were closed. It should also be remembered that the air itself is not the primary comfort-producing medium and the entry of cold air from whatever source will not produce the same discomfort as in conventional systems, provided that the floor can be kept warm.

Special cases frequently impose unusual ventilating conditions. A separate hospital building housing patients with contagious diseases recently built in a mid-western city posed a rather difficult problem which was solved in an interesting manner. Fresh, bacteria-free air is admitted to the patient's rooms through outlets in the center of the ceiling while radiant heating coils are located in the ceiling around the air outlet. No air is recirculated, but instead a fresh supply is warmed to about room temperature and treated before entering the duct system.

"Split" systems such as the last-described are actually much improved when incorporated with radiant systems. Once the heating load is removed from the air stream and taken over by the radiant system, the problem of providing ventilation without drafts is greatly simplified. In many cases, the ventilating load will require only a relatively small air flow which can be nicely handled without any possibility of discomfort. Since air is introduced at about room temperature, no extreme convection currents are set up. Unless summer cooling is also involved (which is usually the largest load), duct sizes can often be greatly reduced with a corresponding saving in air-moving and treating equipment.

What Effect Will Floor Coils Have on Floor Coverings?

So far as is now known, none of the commonly used floor covering materials will suffer from the use of floor coils. Hundreds of installations involving rugs, linoleum, asphalt tile, hard wood, rubber tile, and various monolithic surfaces, have been closely observed for several years and no deleterious effects have yet been discovered. The reason for this condition is that the floor surface temperatures in a properly-controlled installation will not go above 85°F, which seems to be within the temperature ranges that all of these substances can be expected to withstand.

Where mastics are used, such as in fastening asphalt tile or wood to concrete, it does seem reasonable to inject a note of caution to the effect that only the minimum amounts of mastic be used. If too much is applied, it would be more than likely that some would work out of the joints and conceivably cause some annoyance.

Well-dried lumber should be used for any wood floor installation. Obviously, if the lumber is "green" there will be undue shrinking or buckling, regardless of the type of heating system. To make certain of getting seasoned wood, many designers have chosen to use mill-prefinished flooring.

Linoleum, asphalt tile, and kindred products, have also proved quite practical even though earlier opinion was that the temperatures involved would harm them. Actually, the absence of any severe drying action seems to permit the materials to give normal service life.

Floor coverings, although not affected themselves, do affect the operation of the system to some extent. Since they introduce a barrier to the flow of heat from the water to the room, the temperature of the water must be somewhat higher to start with. If, for example, a water temperature of 120°F was used in designing a particular system on the basis of a bare floor, the use of a rug and pad would probably require a temperature of about 140° to 150°F, depending on the nature of the coverings. Linoleum and asphalt tile have a less severe effect and, if they were employed in the example above, the resulting water temperature would be closer to 130° to 140°F.

The increase in operating temperature due to floor coverings does not seem to alter the efficiency of the system to any great extent. To be sure, losses at the boiler and in any exposed piping are slightly increased. Where coils are located on the ground, downward losses are probably also increased a little but, taken altogether, there never has been any practical evidence that these relatively small inefficiencies affect fuel costs to a noticeable degree.

How Can a Ceiling Coil Installation Prevent Cold Floors?

The familiar saying that heat rises is based on the fact that hot air rises. Thus, if the air is heated in a room it will tend to be warmer at the ceiling than at the floor. This characteristic is mentioned in the section on temperature distribution which will be found on page 7 of this bulletin. On the other hand, radiant rays pass through the air without noticeably affecting its temperature, but when they strike an absorbing surface, such as that of a wood floor, carpet, or piece of furniture, the surface is warmed. This explains why a room having a warmed ceiling will have a warm floor as well. The rays from the ceiling are absorbed by the floor and it in turn warms a layer of air immediately above the floor. As shown in Fig. 7, there is practically no difference between the temperature of the air at the floor and other points in the room when ceiling coils are used.

What will be the Effect of Radiant Heating on Paint?

Engineers of one of the large paint manufacturers in Pittsburgh have commented on the possible effect on paint of warming wood, plaster or metal surfaces, and in their opinion, no difficulty need be anticipated due to deterioration of the paint or change in the composition of the pigments if the operating temperature remains below 230°F. The warmed surfaces in radiant heating installations are usually maintained at temperatures far below this limit.

What Effect will Radiant Heating Have on Household Furnishings?

Floor coils, as mentioned elsewhere in this bulletin, are rarely used if the temperature of the warmed surface must exceed 85°F. To attain this surface temperature, hot water in the coils is usually maintained at between 95° and 140°F. Thus, if air is free to circulate over the floor, furnishings will not be heated to above 85°, but if furnishings are built in such a way that they prevent heat from escaping, the highest temperature to which they might be heated would be something less than the temperature of the circulating water. However, intense investigation indicates that there has been no trouble due to drying out of furnishings in the floor heating installations which have been made.

Ceiling coils, being somewhat removed from furnishings, would have relatively little tendency to heat them to an undesirable degree, and here again no unfavorable experience has been recorded.

When wall panels are used, it may be necessary to keep furnishings a sufficient distance away from the panels to allow for air circulation. In an office near New York City heated by warm panels placed around the room between the baseboard and the chair-rail, it was found that filing cabinets and similar heavy furnishings masked the heating effect and it was necessary to keep them a short distance from the wall. This same effect would be noted in even greater degree with conventional heating systems and, in general, it is safe to assume that less drying of furnishings will result with radiant heating than with other commonly used methods.

What will be the Effect of Heat on Plaster and Concrete?

The question of the effect of heat on concrete seems to have been fairly satisfactorily answered at this time, since a number of buildings with wrought iron heating coils embedded in or under concrete floors are proving eminently satisfactory. For example, the Sacred Heart Church in Pittsburgh has the coils completely surrounded by concrete, and after sixteen seasons, there has been no cracking of the concrete or trouble of any kind.

The Portland Cement Association has investigated the effect of high temperatures on concrete, and some reduction of the strength of small samples seems to occur at 200°F or over, but in their technical data sheet, ST32, published in April, 1937, the following statement is made:

> "While the tests cited above show that small concrete specimens lose considerable of their strength upon exposure to heat, many reinforced concrete structures have successfully withstood relatively high temperatures for many years and appear to be in such condition that they will continue to serve their purpose indefinitely. Reinforced concrete chimneys are an outstanding example of such performance, many of which have been in service for more than 20 years. Concrete chimneys exposed to 600 deg. F. are not uncommon and they have been used for even higher temperatures."

At this point, it may be well to consider briefly the question of applying heat to structures during the pouring of concrete or its curing period. This matter frequently arises in connection with construction work planned for cold weather and has been discussed at some length with engineers of the Portland Cement Association. The following statements from this authority are worthy of note:

> "Without going too deeply into the hydration of cement in concrete, it can safely be said that the less water used in an ordinary plastic concrete, the stronger the resulting concrete will be. On the other hand, after the concrete has set, it is necessary that it be in a more or less saturated condition for at least seven days so that the hydration can be complete. Within limits, the longer it is cured in a moist condition, the stronger it will become.
>
> "It is apparent that if concrete is cast over a network of pipes carrying water at a temperature of from 100°F to 150°F, the danger of getting an improperly cured concrete is great unless provisions are made to keep the water from escaping. This can be readily done by covering the surface with an impervious paper or by painting the surface with one of the colorless wax-like curing compounds which seal the surface. The relatively low heat from the pipes will actually hasten a high early strength of the concrete if proper curing is provided."

Even in a building with a conventional heating system, cracking of plaster is a common problem and when the plaster is heated, particular care should be taken to assure satisfaction. Designers usually prefer metal lath for radiant heating work and European practice has often included the use of a reinforcing scrim of jute bagging cloth. This mesh, about 8 threads to the inch, is worked into the finish coat of a 3-coat plaster job. In the United States, although some similar installations have been made, the practice is generally disregarded and no adverse effects have ever been noted.

Selection of a good grade of plaster, uniform heating, curing in accordance with the manufacturers' recommendations, and adequate mechanical support for the lath all seem to be steps in the right direction.

Will Dirt Streak on Walls be Troublesome when Radiant Heating is Used?

This question has been dealt with at some length in the section entitled "The Reduction of Dirt Deposits" which begins on page 10. Considerable data so far accumulated indicates that radiant heating promises to reduce dirt problems very greatly.

If Radiant Heat Behaves in Much the Same Manner as Light, Will it be Possible to Heat a Room with a Great Many Windows?

Perhaps the best answer to this may be given by reference to an article in the March, 1932, issue of HEATING, PIPING & AIR CONDITIONING entitled "Room Warming by Radiation" by Arthur H. Barker of London, England. He states that:

> "In England there is a greatly increased use of this method in what are called open air schools which are schools with wide opening windows on each side and in all ordinary weather these are kept open so that there is a free passage of air through the classrooms. In these conditions the heat can only be delivered by radiation as all convected heat would at once be blown away."

An open air school in Amsterdam, heated by radiant means, was illustrated in the article on "Radiant Heating & Cooling" written by Dr. F. E. Giesecke for the June, 1940 issue of HEATING, PIPING & AIR CONDITIONING. The exterior walls of this building were practically all glass.

Research has indicated that clean glass surfaces reflect radiant rays from a low-intensity source, and thus prevent them from passing through the glass. It is true, however, that if the glass is allowed to become dirty, the thin layer of dirt will absorb radiant energy which will then be transferred to the outside air by conduction through the glass.

A word of warning should be inserted, however, to say that heat loss through windows is very high. If in a radiant heating installation sufficient panel surface is not introduced to balance this heat loss, it will be impossible to maintain sufficiently high temperatures for comfort. This difficulty would be encountered regardless of the heating system used and, while radiant heating has many advantages for use in rooms where glass losses are high, panels must be properly designed if satisfaction is to be complete. From the standpoint of sound engineering, though, the best practice would seem to be to use double glazing or storm sash, weatherstripping, etc., in order to accomplish the most economical operating conditions.

Will the Time Lag in Starting and Stopping be Excessively Long?

This question must be broken down into two parts: lag as it applies to warm-up from a "dead-cold" start and lag encountered during normal operation.

When a radiant heating system is started up in a completely unheated building — such as a building completed during cold weather — a considerable period of time will elapse before comfort conditions are produced. This is due to the fact that structures heated by radiant means store large quantities of heat in structural members during normal operation and some time must elapse before, in a manner of speaking, these "reservoirs" are "filled." Actually, this lag is little, if any, less than is encountered under similar conditions where conventional systems are employed even though, with the latter, the sensation that the heating system is operating can be felt very quickly. Even though the radiators are warm or the registers are delivering hot air, the room surfaces are still abnormally cold for a long period of time before air-born heat can warm them to the place where the high radiant loss from the body is reduced to a point of comfort. This explains the cold, clammy feeling which will exist in a house, perhaps for two or three days, after it has been unoccupied during the winter.

Some earlier experiences with radiant systems had led to the tentative opinion that lag during normal operation was unusually long but later investigation has tended to show that such conditions were probably due to a poor control hook-up. As a matter of fact, there is increasing evidence today that a properly controlled radiant system is perhaps the most responsive of all. Observations in one poorly insulated building (and therefore most likely to show lag and over-ride) in Pittsburgh demonstrated that temperatures were easily held within 1.5°F, plus or minus, from the thermostat setting even in the face of outdoor temperature variations of as much as 42°F in 6 hours. The control devices used on this system were of the simplest and least expensive type and it is likely that even this excellent performance could be improved with the more accurate controls normally used in the better structures.

Where Can Coils for Radiant Heating be Obtained?

Any piping contractor who is equipped to bend pipe should have no difficulty in producing coils for radiant heating work. Fabrication is discussed on page 19 of this bulletin.

Will Heat Loss to the Soil be Excessive with Floor Coils in Basement-less Houses?

Heat loss into the ground with any type of heating system is not an easily-determined quantity. Study of this factor has been going on for a number of years but so far only some rather general constants have been developed. Various research bodies have the problem under study at the present time but to date no broad or conclusive results have been published. The unofficial consensus of this work seems to indicate that loss to the ground is even less than the most recent estimates, although these have been revised to reduce formerly-used coefficients. Chapters 4 and 6 of the 22nd Edition of "Heating Ventilating Air Conditioning Guide" contain a good discussion of the point.

For radiant heating work, it is generally assumed that heat will flow into the ground from pipes in concrete at a rate approximately equal to 25 to 30 per cent of the upward flow. If good insulating material is used beneath the pipes, this figure is assumed to be reduced to 10 to 20 per cent. A great many installations have been made on this basis and, since actual operating results closely bear out the calculated performance, it can safely be assumed that these values are sufficiently accurate for practical purposes. There are at least two apparently sound theoretical approaches to such a calculation and both agree, under normal conditions, very closely with the above estimates.

Since these approximate figures for heat flow into the ground for radiant systems do not represent a loss much greater than would be encountered from the same space using a conventional system, it cannot be said that the radiant system is any more inefficient than another system due to ground losses. Certainly, operating cost figures from a great many installations tend to indicate that sizable economies rather than increased costs can be expected (see pages 8 and 9).

Dr. F. E. Giesecke has considered this question in some detail in an article "Radiant Heating & Cooling" which appeared in the September, 1940, issue of HEATING, PIPING & AIR CONDITIONING. For a coil carrying water at slightly over 97°F, laid in 6″ of sand with the centers of the pipes 1″ beneath the sand surface, and covered with a 4″ concrete slab, Dr. Giesecke's calculations indicate that the heat dissipated to the room should be about 20.5 Btu per square foot per hour, and the loss to the soil should be about 5.7 Btu per square foot per hour. The coil would, therefore, have to be designed to supply heat at the rate of 20.5 + 5.7 or 26.2 Btu per hour per square foot of floor slab. This example, of course, was given merely as a means of illustrating the method of calculation and designers will doubtless want to check the constants assumed against the corresponding values for materials they plan to use before accepting this percentage of loss as a basis for design.

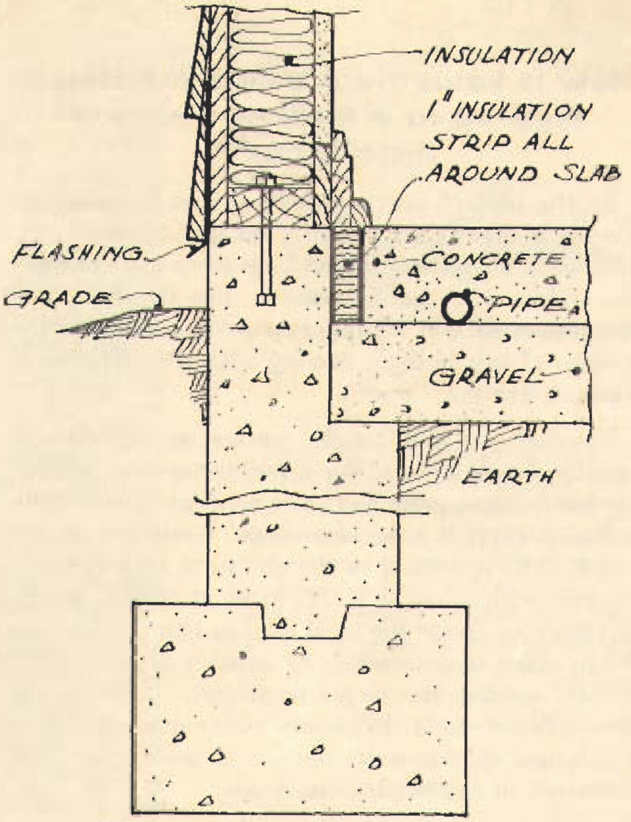


FIG. 94—Floor Slab Insulated at Edge.

In passing, it is interesting to note that recent studies demonstrate that losses from concrete slabs on grade are greatest at the edge and through footers. The magnitude of these "edge-wise" losses is so great that it is felt highly advisable to break the continuity of the concrete section with an insulating strip rather than allow it to connect directly with any masonry sidewall or footer and thus present a high-conductance path to the ground through the large surfaces presented by the wall or footer. Fig. 94 shows structural details as recommended by the Portland Cement Association to accomplish this insulating effect.

What are Some of the Hazards which Must be Avoided?

In an article "Room Warming by Radiation," by Arthur H. Barker which appeared in the March, 1932, issue of HEATING, PIPING & AIR CONDITIONING, the following dangers are listed as possible causes of expensive repairs:

"1. Fracture from unequal expansion.

2. Corrosion, either internal or external

3. Stoppage of the pipes.

4. Settlement of the structure to which most buildings are liable which might cause airlock.

5. The heat from the embedded pipes might cause extensive cracking of the plaster."

Experience has shown that the first of these dangers is of negligible importance if genuine wrought iron pipe is used since it expands at almost identically the same rate as concrete, plaster or other similar materials which might be placed around it. This question is discussed in greater detail on page 18.

Wrought iron's excellent resistance to corrosion also eliminates the need for concern over the second danger. On page 18 will be found additional comments on corrosion.

Stoppage of the pipes is a remote possibility if genuine wrought iron is used, since it has definitely proved its ability to give good service over a long period of years in similar installations. A word should be inserted at this point, however, in regard to welding operations. Poor or careless welders can create conditions within the fluid channel which can be seriously detrimental to the performance of the system. For this reason, only skilled craftsmen should be employed and their work carefully checked.

The avoidance of airlock requires some consideration and proper provision for venting should be made. Venting arrangements are illustrated in Figs. 92 and 93.

Precautions for avoiding cracking of the plaster are outlined on page 48. It has also been suggested that in new buildings the heat should be turned on slowly so that the plaster may be thoroughly cured before it is exposed to operating temperatures.

Can Piping Failures be Replaced?

Piping failures in a radiant heating system can be repaired just as plumbing or heating system failures are handled at the present time. In this connection, it is interesting to note that owners think nothing of placing inaccessible piping behind probably the most costly structural surfaces in a house — the bathroom walls and floors. Furthermore, such services are usually much more severe than the conditions encountered in a radiant heating system. However, while it is possible to cut away concrete or plaster and repair piping failures, an ounce of prevention is worth many pounds of cure and it is highly desirable to use a durable piping material. As explained in the section of this bulletin on "The Selection of Pipe for Radiant Heating Coils," the use of genuine wrought iron has proved a satisfactory means of preventing trouble of this type.

How is Radiant Heating Measured?

Of necessity, special instruments have been devised to measure the combined air temperature and mean radiant temperature. In the section on "Radiation and Comfort," page 4, mean radiant temperature is discussed and its relation to air temperature is considered. In the "Heating Ventilating Air Conditioning Guide" 22nd Edition, page 797, the following comments on measurement are made:

> "Radiant heating is intended to control the rate of radiant heat loss from the human body and should be measured by calorimetric methods.
>
> "The apparatus for this purpose consists essentially of a cylinder, maintained at the accepted surface temperature of the human body, together with an accurate (usually electrical) measuring of the varying rate of heat supply required to maintain this exact temperature. This instrument, the eupatheoscope, is readily adapted to function like a thermostat so as to turn heat on or off, when the desired temperature of 80° F, or any other predetermined surface temperature of the cylinder, decreases or increases as a result of changes in the equivalent temperature.
>
> "For testing work, the globe thermometer is a useful instrument. It consists of an ordinary mercury thermometer, with its bulb placed in the center of a sphere from 6 to 9 inches in diameter, usually made of thin copper and painted black and sometimes covered with cloth. The temperature recorded by the thermometer with its bulb in the center of the sphere is termed the radiation-convection temperature."

Can Heating Coils be Laid in Cinder Fill?

The use of cinders in contact with or near radiant heating coils is very hazardous, regardless of the piping material used. Cinders invariably contain sulphur compounds and neither ferrous nor non-ferrous materials will give anything like normal service under such conditions. Coils should always be buried in such a way that they are surrounded by non-sulphur-bearing materials such as broken limestone, gravel, sand, or concrete. If connecting lines must be laid through cinder fill, the trench should always be filled for a few inches under the pipe with broken limestone and a slush coat of lime mortar should be placed over the pipe. These precautions will neutralize the acid from the cinders, and should greatly prolong the life of the installation.

How is Equivalent Direct Radiation Figured in a Radiant Heating Installation?

To the best of our knowledge, there is no simple relation between the number of square feet of Equivalent Direct Radiation needed for a given room and the size and area of heating panels. The significance of this statement will be apparent from a study of the sections of this bulletin dealing with the "Theory of Radiant Heating," page 2.

However, it is a simple matter to convert the calculated heating load for a radiant system (in Btu per hour) into square feet of equivalent direct steam radiation (E.D.R.), or vice-versa. Since one square foot E.D.R. is defined as the ability to emit 240 Btu per hour with steam at 215°F, in air at 70°F, it is only necessary to divide the total load in Btu per hour by 240 in order to determine the number of square feet E.D.R. needed for a given project. Since sizing nomenclature used by some boiler manufacturers makes use of this unit, its use is occasionally encountered in radiant heating work.

How May Surface Temperatures be Calculated?

The inside surface temperature of a wall exposed to the outdoor air is primarily determined by its over-all heat conductivity, the temperature difference between the indoor and outdoor air, and by the "film coefficient" of the inside surface. Authorities with whom this question has been discussed agree that calculation of approximate interior surface temperatures may be made by means of the following formula:

$$T_s = T_a - \frac{C \text{ x } (T_a - T_o)}{f_i}$$

T_s = Inside surface temperature, °F.

T_a = Temperature of air in room.

T_o = Temperature of outside air.

C = Over-all heat transfer coefficient, Btu per square feet per hour per degree of temperature difference between inside and outside air. Values for "C" are listed for all the commonly-used types of walls in the A.S.H.V.E. "Guide".

f_i = Film coefficient for inside wall surface, expressed in Btu per square foot per hour per degree F difference in temperature between inside air and inside wall temperature. A value of 1.65 is commonly used for this coefficient.

Looking Ahead

The thousand or more radiant heating installations now operating cover a wide variety of applications. There are homes, ranging in price from $3,000 up to 25 or more times that sum. There are industrial office buildings, churches, and chapels, aircraft hangars, factories, garages. There are plants where only radiant heating, with its complete concealment of all metal parts and minimum convection currents, could meet safety requirements. There is the roof of a cathedral where radiant heating eliminates hazards from avalanches of snow, and the Reptile House of a Zoo. There is the "Monkey House" in the biological laboratory of a world-famous hospital, and the laboratory of an ordnance plant. There is the tap-room of a tavern, a public library, a prison. These by no means exhaust radiant heating possibilities; rather, the diversity indicates that the possibilities have barely been tapped.

In contacts with many owners, A. M. Byers Company has collected a large and important reservoir of information on radiant heating from what might be termed the "human" angle; the simple homely things that do more to explain its popularity than all the engineering data in the world. Among the users whose reactions are on file there are, for example:

. . . The man who reported that radiant heating saved his furniture; his dogs found the radiant-heated floor more comfortable to sleep on.

. . . The man who "never tired" of searching for the cold-spots present in all other houses . . . but absent in his.

. . . The young couple who luxuriated in the opportunity, provided by radiant heating, of doffing shoes as well as wraps at their front door.

. . . The gloating householder whose friends had fuel bills of $20 and $22, while his (in a comparable house, radiant heated) was only $13.13.

. . . The man whose wife "found to her amazement she had to turn the thermostat down day after day . . . we now find a 60 degree setting most favorable."

. . . The employer who reported (1) fewer creaking joints among old employees, and (2) lowered clothes-pressing bills, as two of many dividends from radiant heating.

These are not cited as typical, but merely to indicate range and variety. Whether from a college professor who translates the comfort of radiant heating into thermometer readings and heat unit measurements, or from some user overjoyed to find that the bathroom floor is really warm, all these reflect an enthusiasm and satisfaction that is highly significant and promising.

No one knows what forms the homes, the schools, the hospitals, churches, offices, and plants of tomorrow will take — but one thing is sure. There will still be winter, and where people live there must be warmth. And there is every indication that in these buildings of tomorrow, as in so many today, radiant heating is going to play an all-important part.

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