the floor above, and down the outside walls. In this way the walls and ceiling become heating panels.

If water is used as the medium, the pipes through which the water circulates—almost always under forced circulation—are placed in the floor, walls, or ceiling in such a manner that as much as possible of the heat emitted by the pipes will be delivered to the space to be heated.

Table 2. Total Heat Emission by Radiation[a]

Body or Mean Radiant Temperature Deg F	Radiation in Btu per square foot per hour emitted to surroundings with a temperature of absolute zero by bodies at various temperatures and with emissivity factor e				Body or Mean Radiant Temperature Deg F	Radiation in Btu per square foot per hour emitted to surroundings with a temperature of absolute zero by bodies at various temperatures and with emissivity factor e			
	e 1.00	e 0.95	e 0.90	e 0.80		e 1.00	e 0.95	e 0.90	e 0.80
30	99.7	94.7	89.8	79.7	71	137.0	130.1	123.3	109.7
35	103.9	98.7	93.6	83.1	72	137.9	131.0	124.0	110.3
40	108.0	102.8	97.2	86.4	73	138.9	132.0	124.9	111.0
45	112.5	106.9	101.3	89.0	74	140.2	133.1	126.1	112.1
46	113.3	107.7	102.0	90.8	75	141.6	134.4	127.4	113.2
47	114.3	108.6	102.9	91.5	80	147.2	140.0	132.5	117.9
48	115.2	109.5	103.8	92.3	85	152.9	145.2	137.6	122.4
49	116.0	110.3	104.5	92.8	90	158.5	150.5	142.7	126.9
50	116.9	111.0	105.3	93.6	100	170.3	161.7	153.2	136.2
51	117.9	112.0	106.4	94.4	110	182.3	173.2	164.2	146.0
52	118.8	112.9	106.9	95.1	120	195.6	185.7	176.1	156.5
53	119.8	113.8	107.8	95.9	130	210.9	200.4	189.8	168.8
54	120.6	114.6	108.6	96.6	140	224.1	212.9	201.8	179.2
55	121.7	115.5	109.4	97.3	150	238.0	226.1	214.4	190.5
56	122.6	116.4	110.3	98.1	160	252.1	239.8	226.9	201.8
57	123.5	117.4	111.3	98.9	170	271.6	258.0	244.5	217.2
58	124.4	118.2	112.0	99.6	180	289.1	274.9	260.1	231.3
59	125.3	119.0	112.8	100.3	190	307.7	292.1	276.9	246.1
60	126.3	119.9	113.8	101.1	200	326.5	310.2	293.9	261.3
61	127.1	120.7	114.4	101.8	210	349.3	331.9	314.3	279.5
62	128.2	121.8	115.3	102.6	220	373.0	354.4	335.7	298.2
63	129.1	122.6	116.2	103.3	250	439.5	417.6	395.6	351.6
64	130.1	123.5	117.1	104.1	300	577.3	548.2	519.6	461.8
65	131.0	124.4	117.9	104.8	350	743.0	705.8	668.6	594.3
66	132.1	125.5	118.8	105.8	400	945.8	898.5	850.8	756.5
67	133.0	126.4	119.7	106.4	450	1181.0	1121.0	1063.0	944.0
68	134.0	127.3	120.5	107.2	500	1470.0	1396.0	1323.0	1176.0
69	135.0	128.3	121.5	108.0	550	1798.0	1708.0	1619.0	1439.0
70	136.0	129.3	122.3	108.8	600	2181.0	2072.0	1962.0	1745.0

[a]These factors are calculated from the formula

$$q_r = e\left(\frac{0.173 \times T^4}{100,000,000}\right)$$

where

q_r = total radiation, Btu per (sq ft) (hr)
e = emissivity.
T = absolute temperature, degrees Fahrenheit.

Practical limits for surface temperature of heating panels are given in Table 3.

In this example water will be selected as the medium.

8. *Determine the size, length, and location of the pipe coils in the panels.*

When hot-water pipes are imbedded in concrete slabs or attached to plastered surfaces, their rate of heat emission varies with many factors. If the pipes are imbedded in dense concrete slabs, it may be assumed that the rate of heat emission of ½-in. pipe, spaced 6 in. on centers; ¾-in. pipe, spaced 9 in. on centers; and 1-in. pipe spaced 12 in. on centers; per foot of length of pipe and per degree difference between the temperature of the water in the pipe and that of the air in the space to be heated, is

0.8, 1.0, and 1.2 Btuh, respectively. If the distance between the pipes is increased, the rate of heat emission, per foot of pipe, is also increased; if the distance is doubled, the rate of heat emission is increased about 15 per cent. If the pipes are attached to plastered ceilings, the rate of heat emission is slightly less, probably about 10 per cent less, than when the pipes are imbedded in concrete slabs. The data given regarding heat emission of panels are intended as general guides for the designer. Additional experience and research are needed to develop definite and complete data. However, after a heating panel has been designed and installed, any small error can easily be corrected by modifying the temperature of the water circulating through the coils.

When the heating pipes are attached to a plastered ceiling, a portion of the heat emitted by the pipes is delivered to the space below the ceiling and a portion to the space above the ceiling. The relative quantities depend on the degree of insulation applied above the heating coils.

When the heating pipes are imbedded in a concrete floor slab a portion

Table 3. Highest Safe Surface Temperatures for Heating Panel

Type of Panel	Surface Temperature Deg F
Plastered Ceiling (Pipes Imbedded)	115
Plastered Walls (Pipes Imbedded)	120
Floor, Any Method	90
Floor, Border and Aisles	120
Iron, Hot Water Medium[a]	160
Iron, Steam Vapor[a]	180
Electrically Heated Panels[a]	200

[a]Low surface temperature radiation is recommended regardless of the heating medium employed.

of the heat emitted by the pipes will flow upward into the space to be heated, and the remainder will flow downward into the ground.

When the heating pipes are placed below the concrete floor slab instead of being imbedded in the slab, a larger portion of the heat will flow into the ground, and a smaller portion into the space to be heated.

In the following example *it is assumed that the insulation above the pipe coils is such that 90 per cent of the heat emitted by the pipe coils will flow into the room and 10 per cent into the space above.*

Since the room is to receive 35,117 Btuh, and since the room is assumed to receive only 90 per cent of the heat emitted by the coils attached to the plastered ceiling, the coils must emit 35,117/0.9 or 39,000 Btuh. If ¾-in. pipe and a mean water temperature of 140 F are selected, the heat emitted, per foot of pipe, will be 0.9 (140 − 68) or 65 Btuh. The quantity of pipe required will therefore be 39,000/65 = 600 lineal feet.

The pipe coils can be arranged in any convenient manner, but should be arranged so that the temperature of the water in the pipe will vary only slightly; otherwise, the temperature distribution over the ceiling will not be uniform. Generally, it is best to arrange the pipes so as to form two-pipe reversed-return systems, as suggested by the two sketches in Fig. 10. By using 33 runs of ¾-in. pipe, welded to two 1¼ in. mains, sufficient pipe surface is secured; the ¾-in. pipes will then be spaced about 8½ in. on centers, which is satisfactory.

The friction heads of water flowing in pipes and fittings are so well known that the pipe coils can be designed so that each will receive its