when the outdoor air temperature is zero F. The floors in the three rooms are covered with heavy wall-to-wall carpeting, without a pad. Insulation which has a conductance of 0.4 Btu per (hr) (sq ft) (F deg) is placed along the edge of the slab and extends downward 2 ft below it.

Step 1. Heat Loss

Calculate the heat loss of each room, following the recommendations contained in Chapter 25 of the 1961 Guide And Data Book, but do not include any heat loss through the area covered by the panel.

If very large rooms are involved, the rooms should be subdivided into areas having somewhat similar heat requirements, *i.e.*, separate the interior areas requiring little or no heat input, from the exterior areas directly influenced by outdoor weather conditions. Each such area should then be treated as a separate room for the purpose of design.

Room dimensions, exposure, and calculated heat losses are as follows:

Room	Dimensions Feet	Exposed Wall Feet	Heat Loss Btu per hr
A*	11 x 12 x 8	23	3300
B	11 x 12 x 8	12	2500
C	15 x 21 x 8	21	8000

* Compare with Room A of *Example 1*. The rooms are the same except that in this example a lower heat loss is assumed to permit the room to be heated by a floor panel alone without developing an inadmissibly high panel surface temperature (Step 3). The lower heat loss is presumably the result of adding insulation to Room A.

Step 2. Required Panel Output

Divide the heat loss of each room by the maximum floor area in the room which can be used as a heating panel. The result is the minimum heat output per square foot of panel that will satisfy the requirements of the room. The panel that requires the highest output per square foot will generally control the design, because the temperature of the water in the system must be high enough to produce the required output from that panel.

Room	Available Panel Area Sq ft	Required Panel Output (q_u) Btu/(hr) (sq ft)
A	132	25.0
B	127	19.7
C	306	26.1

Step 3. Panel Surface Temperature

From Fig. 16 find the panel surface temperature needed to yield the required heat output to each room, using the output determined in Step 2 and the design room air temperature.

Floor panel surface temperatures in excess of about 85 F are not recommended because of the probability of discomfort to the feet. If the required heat output cannot be obtained from an 85 F floor panel, heat losses should be reduced or supplementary heating should be provided.

Room	Panel Surface Temperature (t_p)
A	85.0 F
B	82.5 F
C	85.3 F

Table 4 .... Thermal Resistance of Floor Coverings

Description	Resistance, r_{ue} (F deg)/hr)/(sq ft)/Btu
Bare concrete, no covering	0.00
Asphalt tile	0.05
Rubber tile	0.05
Light carpet	0.6
Light carpet with rubber pad	1.0
Light carpet with light pad	1.4
Light carpet with heavy pad	1.7
Heavy carpet	0.8
Heavy carpet with rubber pad	1.2
Heavy carpet with light pad	1.6
Heavy carpet with heavy pad	1.9

Step 4. Downward and Edgewise Heat Flow

a. Determine the temperature of the surface of the concrete slab (t_s) by adding to the panel surface temperature, the temperature difference caused by the thermal resistance of the floor covering, if any:

$$t_s = t_p + (q_u \times r_{ue}) \qquad (12)$$

The value of (r_{ue}) for various floor coverings is given in Table 4.

Room	t_p	q_u	r_{ue}	t_s
A	85.0 F	25.0	0.8	105.0 F
B	82.5 F	19.7	0.8	98.3 F
C	85.3 F	26.1	0.8	106.2 F

b. Determine the downward and edgewise heat loss coefficient C_s from Fig. 17 for the insulation to be used. Insulation with a conductance of 0.4 Btu per (hr) (sq ft) (F deg) extending two feet below the slab results in a slab downward and edgewise heat loss coefficient of 0.97 Btu per (hr)(ft) (F deg).

c. Apportion the downward and edgewise heat loss uniformly across the panel as follows:

$$q_{ue} = \frac{P \times C_s(t_s - t_{ue})}{A_p} \qquad (13)$$

Room	P	$t_s - t_{ue}$	A_p	q_{ue}
A	23	105.0 F	132	17.7
B	12	98.3 F	127	9.0
C	21	106.2 F	306	7.1

Step 5. Upward Panel Resistance

Assume a tentative pipe or tube size and a spacing for each panel, choosing closer spacings and larger pipe or tube when higher heat outputs are required. From Table 3, find the thermal resistance (r_{ue}) of the slab of each panel, using heat flow ratios (q_u/q_{ue}) calculated from the flow rates determined in Steps 2 and 4, interpolating as required. To the slab resistance (r_{ue}), add the resistance of the floor covering (r_{ue}, Step 4) to obtain the panel resistance to upward heat flow (r_u).

Room	Pipe or Tube Spacing	q_u/q_{ue}	r_{ue}	r_{ue}	r_u
A	9 in.	$\frac{25}{17.7} = 1.41$	0.47	0.8	1.27
B	12 in.	$\frac{19.7}{9.0} = 2.19$	0.55	0.8	1.35
C	9 in.	$\frac{26.1}{7.1} = 3.68$	0.40	0.8	1.20

All rooms: ½-in. pipe or ⅝-in. tube; 4-in. concrete slab.

Step 6. Mean Water Temperature

For the required panel output (q_u) found in Step 2, the panel resistance (r_u) found in Step 5, and the room air temperature (t_a), find the mean water temperature (t_{mw}) from Fig. 16.

Room	t_{mw}
A	116.5
B	109.0
C	116.5

Step 7. Design Mean Water Temperature

Select a single design mean water temperature (t_{dmw}) for each group of rooms which is to comprise a zone, choosing the highest mean water temperature (t_{mw}) of the group. In the example, 116.5 F is chosen.

Step 8. Design Panel Output

From Fig. 16 find the panel output (q_u) for design mean water temperature (t_{dmw}), room air temperature (t_a), and panel resistance (r_u). Also from Fig. 16 find the design panel surface temperature. If it exceeds 85 F (see Step 3) in a room, go back to Step 5 and choose a wider spacing or smaller pipe or tube for that room.

Room	(q_u)	t_p
A	25.0	85.0 (unchanged)
B	24.0	84.5
C	26.1	85.3 (unchanged)

Step 9. Design Panel Area

Divide the room heat loss found in Step 1 by the design panel output found in Step 8.

Room	A_p
A	132 (unchanged)
B	104
C	306 (unchanged)

Step 10. Total Panel Output

Add the apportioned downward and edgewise heat flow (q_{ue}) to the design panel output (q_u) and multiply by the design panel area to obtain the total panel output. If the design panel output is appreciably different from the panel output (q_u) used in Steps 3 and 4, the apportioned downward and edgewise heat flow (q_{ue}) should be redetermined.

Room	q_u	q_{ue}	$q_u + q_{ue}$	A_p	$A_p(q_u + q_{ue})$
A	25.0*	17.7*	42.7	132	5636
B	24.0	11.6**	35.6	104	3702
C	26.1*	7.1*	33.2	306	10159

* Unchanged. ** Redetermined.

Step 11. Fluid Circuit

Design the fluid circuit (panel piping and mains) for a temperature drop of 10 to 20 F deg between the water inlet (t_i) and outlet (t^o) of the panel (see Chapter 8, Hot Water Heating Systems).

Step 12. Boiler Size

Select the size of the boiler according to method contained in Chapter 43 of the 1961 Guide And Data Book. The net Btu rating of the boiler should equal or exceed the total output of all panels plus any other loads on the boiler.

Procedure for Hot Water Concrete Floor Panels (Intermediate Slab)[12]

The procedure for designing a hot water concrete floor panel of intermediate slab type is given in the following 12 steps.

Step 1. Heat Loss

Follow the procedure for slab-on-grade construction, Step 1.

Step 2. Required Panel Output

Follow the procedure for slab-on-grade construction, Step 2.

Step 3. Panel Surface Temperature

Follow the procedure for slab-on-grade construction, Step 3.

Step 4. Downward Heat Flow Estimate

A. Follow the procedure for slab-on-grade construction, Step 4, part 1.

B. Estimate the heat flow downward as follows:

1. If the underside of the concrete slab is exposed to form a ceiling, find the heat output downward (q_d) from Fig. 15, using the slab surface temperature (t_s) found in Step 3 as the panel surface temperature (t_p), and the air temperature of the space below.

2. If the underside of the concrete slab is not exposed, use the equation:

$$q_d = C_s(t_s - r_s) \qquad (14)$$

Step 5. Upward and Downward Panel Resistance

Follow the procedure for slab-on-grade construction, Step 5, using Table 3 to find both resistances (r_{ue} and r_{de}).

Step 6. Mean Water Temperature and Downward Heat Flow

a. Follow the procedure for slab-on-grade construction, Step 6.

b. Use Fig. 15 to find the downward heat flow (q_d). Add to the slab resistance to downward heat flow, (r_{de}), the resistance to heat flow, (r_{de}), of any material between the underside of the slab and the ceiling surface, to find the total resistance to downward heat flow (r_d) to be used in Fig. 15. The water temperature (t_{mw}) found above and the air temperature (t_i) of the space below the ceiling are the other two factors to be used.

If the heat flow downward (q_d) differs appreciably from the estimate made in Step 4, repeat Steps 5 and 6 using the calculated value.

Step 7. Design Mean Water Temperature

Follow the procedure for slab-on-grade construction, Step 7.

Step 8. Design Panel Output

Follow the procedure for slab-on-grade construction, Step 8.