Step 9. Design Panel Area

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

Room	Design Panel Area (A_p) Sq ft
A	132 (Unchanged from Step 2)
B	77
C	242

Step 10. Total Panel Output

Add the heat flow upward (q_u) to the design panel output (q_d) and multiply by the design panel area to obtain the total panel output. If the design panel output is different from the panel output (q_d) used in Steps 3 and 4, the heat flow upward (q_u) should be redetermined.

Room	q_u	q_d	$q_u + q_d$	A_p	Total Panel Output $A_p(q_u + q_d)$ Btu/hr
A	12.5	47.7	60.2	132	7946
B	9.5†	32.5	42.0	77	3234
C	5.5†	33.0	38.5	242	9317

† 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 and outlet of the panel (see Chapter 28, Hot Water Heating Systems).

Step 12. Boiler Size

Size the boiler according to method contained in Chapter 35, Heating Boilers, Furnaces, and Space Heaters. 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 Metal Ceiling Panels[12]

Follow the procedure for Hot Water Plaster Ceiling Panels.

Procedure for Concrete Ceiling Panels[13]

Concrete ceiling panels are distinguished from concrete floor panels in intermediate floors by the position of the tubes in the concrete slabs (see Tables 2 and 3). Both types of panels have heat outputs in both directions in amounts determined by the thermal resistances and the temperature differences in the two directions. The effect of both outputs on heating requirements of the spaces and the comfort of the occupants should always be considered. (See section on Procedure for Concrete Floor Panels—Intermediate Slab.)

The procedure for hot water plaster ceiling panels cannot be applied in its entirety to concrete ceiling panels because some of the simplifying assumptions regarding the upward heat flow from plaster panels are not valid for concrete panels. The necessary modification of the plaster ceiling panel procedure is as follows:

Step 1. Heat Loss

Follow the procedure for Plaster Ceiling Panels, Step 1.

Step 2. Required Panel Output

Follow the procedure for Plaster Ceiling Panels, Step 2.

Table 2 .... Thermal Resistance of Concrete Ceiling Panels

Panel Construction	Spacing in.	Thermal Resistance (F deg)(sq ft)(hr) per Btu					
		Heat Flow Ratio q_u/q_d					
		0		0.5[a]		1.0[a]	
		up	down	up	down	up	down
6-in. Concrete Slab—1-in. cover		r_{us}	r_{ds}	r_u	r_d	r_u	r_d
½-in. (nom.) nonferrous tube	9	3.6	0.30	0.9	0.35	0.7	0.45
	12	5.1	0.35	1.1	0.45	0.9	0.55
½-in. (nom.) ferrous pipe or ¾-in. (nom.) nonferrous tube	9	2.6	0.25	0.7	0.30	0.6	0.35
	12	4.0	0.30	0.9	0.40	0.8	0.50
¾-in. (nom.) ferrous pipe or 1-in. (nom.) nonferrous tube	9	2.1	0.20	0.6	0.25	0.6	0.30
	12	3.3	0.30	0.8	0.35	0.7	0.40
	15	4.5	0.35	1.0	0.45	0.8	0.55
1-in. (nom.) ferrous pipe	9	1.6	0.20	0.5	0.25	0.5	0.25
	12	2.6	0.25	0.7	0.30	0.6	0.35
	15	3.6	0.30	0.9	0.40	0.7	0.45
8-in. Concrete Slab—1-in. Cover							
½-in. (nom.) nonferrous tube	9	3.6	0.30	1.0	0.35	0.8	0.40
	12	5.2	0.35	1.2	0.45	1.0	0.55
½-in. (nom.) ferrous pipe or ¾-in. (nom.) nonferrous tube	9	2.9	0.25	0.9	0.30	0.8	0.35
	12	4.0	0.30	1.1	0.40	0.9	0.45
¾-in. (nom.) ferrous pipe or 1-in. (nom.) nonferrous tube	9	2.2	0.20	0.8	0.30	0.7	0.30
	12	3.3	0.30	1.0	0.35	0.8	0.40
	15	4.3	0.35	1.1	0.40	0.9	0.50
1-in. (nom.) ferrous pipe	9	1.7	0.20	0.7	0.25	0.7	0.25
	12	2.7	0.25	0.9	0.30	0.8	0.35
	15	3.7	0.30	1.0	0.40	0.9	0.45

[a] Any ceiling panel also acts as a floor panel to the extent of its upward heat flow. If the upward heat flow is high and the space above is occupied, check floor surface temperature for possible foot discomfort (see Reference 7). Also check effect on heating requirements of the space above. It is not good practice to have the major portion of the upper room's heating requirements supplied by the upward heat flow of a ceiling panel below.

Step 3. Panel Surface Temperature

Follow the procedure for Plaster Ceiling Panels, Step 3.

Step 4. Upward Heat Flow Estimate

a. If the upper surface of the slab is exposed to form a floor, find the heat flow upward from Fig. 16, using the panel surface temperature (t_p) found in Step 3, and the air temperature of the space above.

b. If the upper surface of the slab is not exposed, use the equation:

$$q_u = C_1(t_b - t_p) \qquad (10)$$

Table 3 .... Thermal Resistance of Bare Concrete Floor Panels

Panel Construction	Spacing in.	Thermal Resistance (F deg)(sq ft)(hr)/Btu							
		Heat Flow Ratio q_u/q_d or q_u/q_{ds}							
		1		3		5		10	
		up	down	up	down	up	down	up	down
4-in. Concrete Slab—2-in. Cover		r_{us}	r_{ds}	r_{us}	r_{ds}	r_{us}	r_{ds}	r_{us}	r_{ds}
½-in. (nom.) nonferrous tube	9	0.57	0.52	0.46	0.84	0.43	1.17	0.42	1.97
	12	0.73	0.68	0.58	1.16	0.54	1.65	0.51	2.86
½-in. (nom.) ferrous pipe or ¾-in. (nom.) nonferrous tube	9	0.49	0.42	0.41	0.66	0.39	0.90	0.38	1.80
	12	0.63	0.55	0.50	0.93	0.48	1.30	0.46	2.35
6-in. Concrete Slab—2-in. Cover									
½-in. (nom.) nonferrous tube	9	0.59	0.70	0.47	1.05	0.45	1.39	0.43	2.25
	12	0.78	0.90	0.60	1.40	0.56	1.97	0.54	3.21
¾-in. (nom.) nonferrous tube	9	0.51	0.61	0.43	0.87	0.41	1.13	0.40	1.78
	12	0.68	0.78	0.54	1.23	0.51	1.63	0.49	2.61
¾-in. (nom.) ferrous pipe	9	0.47	0.55	0.40	0.77	0.39	0.98	0.38	1.50
	12	0.63	0.71	0.50	1.07	0.48	1.44	0.46	2.36
1-in. (nom.) nonferrous tube or 1-in. (nom.) ferrous pipe	12	0.59	0.66	0.48	0.98	0.46	1.30	0.45	2.11
	15	0.73	0.83	0.57	1.21	0.54	1.73	0.51	2.74

Step 5. Upward and Downward Panel Resistance

Follow the procedure for Plaster Panels, Step 5, using Table 2 to find both resistances (r_{us} and r_{ds}).

Step 6. Mean Water Temperature and Upward Heat Flow

a. Follow the procedure for Plaster Panels, Step 6.

b. Find the heat flow upward from the panel (q_u) from Fig. 16. Add to the thermal resistance of the slab to upward heat flow (r_{us}), the resistance to heat flow (r_{ms}) of any material between the upper surface of the slab and the space above to obtain the resistance (r_u) to be used in Fig. 16. The mean water temperature (t_{mw}) found and the air temperature of the space above the panel are the other two factors to be used.

Step 7. Design Mean Water Temperature

Select the highest mean water temperature (t_{mw}) as the design mean water temperature (t_{dmw}).

Step 8. Design Panel Output

Follow the procedure for Plaster Panels, Step 8.

Step 9. Design Panel Area

Follow the procedure for Plaster Panels, Step 9.

Step 10. Total Panel Output

Follow the procedure for Plaster Panels, Step 10.

Step 11. Fluid Circuit

Follow the procedure for Plaster Panels, Step 11.

Step 12. Boiler Size

Follow the procedure for Plaster Panels, Step 12.

Procedure for Plaster Wall Panels

A design graph has not been prepared for wall panels but a design can be approximated using the equations of heat transfer from walls together with the thermal resistance properties of plaster ceilings from Table 2. The procedure for Plaster Ceiling Panels is used as a guide.

Step 1. Heat Loss

Follow the procedure for Plaster Ceiling Panels, Step 1.

Step 2. Required Panel Output

Follow the procedure for Plaster Ceiling Panels, Step 2.

Step 3. Panel Surface Temperature

Assume a trial panel surface temperature and determine the resulting heat output from Figs. 9 and 10 as explained in the accompanying section of the test. (Additional heat flow due to the infiltration can be estimated from Fig. 12, if desired.) Assume successive trial panel surface temperatures until the temperature is found at which the combined heat transfer from the panel equals the output determined in Step 2.

Step 4. Reverse-Side Heat Flow

Follow the procedure for Plaster Ceiling Panels, Step 4.

Step 5. Panel Resistance

Follow the procedure for Plaster Ceiling Panels, Step 5.

Step 6. Mean Water Temperature

For the required panel output found in Step 2, the panel resistance found in Step 5, and the room air temperature, calculate the required mean water temperature as follows:

$$t_{mw} = t_p + r_d(q_d) \qquad (11)$$

Step 7. Design Mean Water Temperature

Follow the procedure for Plaster Ceiling Panels, Step 7.

Step 8. Design Panel Output

From equations, Step 6, and Figs. 9 and 10 find the panel output for design mean water temperature t_{dmw} by successive trials.

Step 9. Design Panel Area

Follow the procedure for Plaster Ceiling Panels, Step 9.

Step 10. Total Panel Output

Follow the procedure for Plaster Ceiling Panels, Step 10.

Step 11. Fluid Circuit

Follow the procedure for Plaster Ceiling Panels, Step 11.

Step 12. Boiler Size

Follow the procedure for Plaster Ceiling Panels, Step 12.

Procedure for Hot Water Concrete Floor Panels (Slab-On-Grade)[12]

The procedure for designing a concrete floor panel (slab-on-grade) will be illustrated by *Example 2*.

Example 2: Three rooms, A, B, and C, are to have a common water supply temperature; that is, they represent a single zone. They are to be maintained at 72 F air temperature