put from that panel. The required panel output is given in the following table.

Available Panel Area Sq Ft	Required Panel Output, q_d Btu/(hr) (sq ft)
Room A 132 sq ft	$\frac{6300}{132} = 47.7$
Room B 127 sq ft	$\frac{2500}{127} = 19.7$
Room C 306 sq ft	$\frac{8000}{306} = 26.1$

Step 3. Panel Surface Temperature

From Fig. 15 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. This use of Fig. 15 for Room A is illustrated in Fig. 15A.

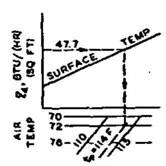


Fig. 15A . . . . Determination of Panel Surface Temperature for Room A from Fig. 15

The values of t_p determined for Rooms A, B, and C are as follows:

Room A t_p = 114 F
Room B t_p = 92 F
Room C t_p = 97 F

Step 4. Upward Heat Flow

Determine the upward heat flow from each panel using Fig. 18. The upward heat flow must be determined in order to obtain the downward panel resistance and to select the proper size of boiler. The use of Fig. 18 is illustrated for Room A in Fig. 18A. Note that the U values shown on Fig. 18 are those

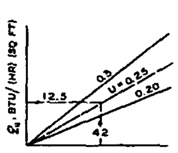


Fig. 18A . . . . Determination of Upward Heat Flow for Room A from Fig. 18

for the entire structure of which the panel is a part and are taken from room air (temperature, t_a) to air above the panel (temperature, t_b) and for that reason $q_u \neq U(t_p - t_b)$. U values may be obtained from Chapter 9, Heat Transmission Coefficients of Building Materials.

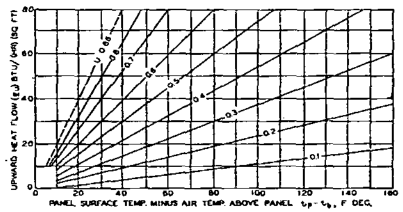


Fig. 18 . . . . Upward Heat Flow from Plaster Ceiling Panel

The values of q_u for Rooms A, B, and C as determined from Fig. 18 are as follows:

Room	U	$t_p - t_b$ F Deg	q_u Btu/(hr)(sq ft)
A	0.25	42	12.5
B	0.25	20	6.0
C	0.05	97	5.0

Step 5. Downward Panel Resistance

Assume tentative pipe or tube spacings for the panel construction to be used from those listed in Table 1, choosing the closer spacings when higher outputs are required. Also in Table 1 find the resistance of each panel (r_d), using heat flow ratios calculated from the flow rates determined in Steps 2 and 4, interpolating as required.

Room	Spacing (Inches)	Heat Flow Ratio	Resistance (r_d)
A	4½	$\frac{12.5}{47.7} = 0.26$	0.35
B	9	$\frac{6}{19.7} = 0.30$	0.90
C	9	$\frac{5}{26.1} = 0.19$	0.85

Step 6. Mean Water Temperature

For the required panel output (q_d) found in Step 2, the panel resistance (r_d) found in Step 5, and the room air temperature (t_a), find the mean water temperature (t_{mw}) from Fig. 15. This use of Fig. 15 is illustrated in Fig. 15B.

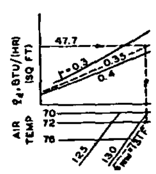
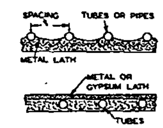
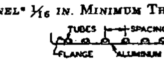


Fig. 15B . . . . Determination of Mean Water Temperature for Room A from Fig. 15

Table 1 . . . . Thermal Resistance of Plaster and Metal Ceiling Panels

	Spacing in.	Thermal Resistance to Downward Heat Flow (r_d) (F deg) (hr) (sq ft) per Btu					
		Heat Flow Ratio, q_u/q_d					
		0	0.2	0.4	0.6	0.8	1.0[a]
Plaster Panels[b] Standard Gypsum Plaster, Three Coats	4½	0.30	0.34	0.38	0.42	0.46	0.50
							
⅜ in. (nom.) non-ferrous tube or ½ in. (nom.) ferrous pipe *above* metal lath tied at 8-inch intervals with good tube embedment, or ⅜ in. (nom.) nonferrous tube *below* metal or gypsum lath.	6 9 12	0.45 0.75 1.15	0.51 0.85 1.29	0.57 0.95 1.43	0.63 1.05 1.57	0.69 1.15 1.71	0.75 1.25 1.85
Aluminum Panel[c] $\frac{1}{16}$ in. Minimum Thickness							
							
pipe or tube installed so that excellent heat conduction to ceiling surface is obtained.	3	0.07	0.07	0.07	0.07	0.07	0.07

[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.
[b] Recommended maximum inlet water temperature (t_{max}) 140 F.
[c] Recommended maximum inlet water temperature (t_{max}) 220 F.

Values of t_{mw} for Rooms A, B, and C as determined from Fig. 15 are as follows.

Room A t_{mw} = 131 F, Room B t_{mw} = 110.5 F, Room C t_{mw} = 119 F

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 subject to the following:

a. If $t_{mw} + \frac{(t_i - t_o)}{2}$ is equal to or less than t_{max} (see Nomenclature and Table 1, this mean water temperature (t_{mw}) is an acceptable design mean water temperature (t_{dmw}). Proceed to Step 8.

b. If $t_{mw} + \frac{(t_i - t_o)}{2}$ is greater than t_{max}, go back to Step 5 and select a panel construction which has a lower panel resistance (r_d). This can be accomplished by either or both of the following:

1. Reducing the tube spacing,

2. Decreasing the upward heat flow (q_u) by providing additional insulation above the panel.

If the required mean water temperature is still too high apply either or both of the following:

1. Reduce the heat loss of the room,

2. Provide supplementary heating.

In Example 1, assume $t_i - t_o$ = 15 F deg and t_{max} = 140 F. Then since t_{mw} = 131 F, $t_{mw} + \frac{1}{2}(t_i - t_o)$ = 138.5 F and is less than t_{max}. Thus 131 F can be used as the design mean water temperature t_{dmw}.

Step 8. Design Panel Output

From Fig. 15, find the panel output (q_d) for design mean water temperature (t_{dmw}), room air temperature (t_a), and panel resistance (r_d). Fig. 15C shows how Fig. 15 is used to find q_d for Room B in this step.

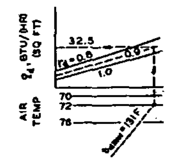


Fig. 15C . . . . Determination of Design Panel Output for Room B from Fig. 15

The mean water temperature (t_{mw}) found for Room A in Step 6 was used as the design mean water temperature (t_{dmw}). The panel output for Room A which was determined in Step 2 is therefore the design panel output for this room. Design panel outputs for Rooms B and C can be found from Fig. 15 using the design mean water temperature (t_{dmw}).

Room	Design Panel Output (q_d) Btu per (hr) (sq ft)
A	47.7
B	32.5
C	33.0