ranged as header coils with the pipes spaced from 6 to 18 in. on centers. The coils are generally installed with $1\frac{1}{2}$ to 4 in. of cover above the coils. It is recommended that insulation be used to reduce the perimeter and reverse losses. Fig. 4 shows the application of pipe coils in slabs resting on grade. Coils should be embedded completely and should not rest on an interface. Any supports used for positioning the heating coils should be non-absorbent and inorganic. It is suggested that reinforcing steel, angle iron, pieces of pipe, or stone concrete mounds be used. No wood, brick, concrete block or similar materials should be used for support of coils. Generally, a waterproofing layer is desirable to protect insulation and piping.

b. Where the coils are embedded in structural load supporting slabs above grade, construction codes may affect their position. Otherwise, the coil piping is installed in the same manner as described for slabs resting on grade.

c. A warm-up and start-up period for concrete panels should be similar to that outlined for plaster panels.

Air Heated Ceilings, Walls, and Floors

Several methods have been devised to warm the interior room surfaces by circulating heated air through passages behind these surfaces. In some cases, the heated air is recirculated in a closed system. In others, all or

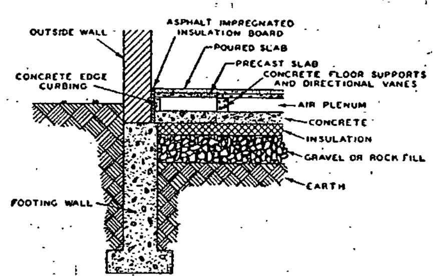

FIG. 6. WARM AIR FLOOR PANEL CONSTRUCTION

a part of the air is passed through the room on its way back to the furnace to provide supplementary heating and ventilation.[2] Figs. 5 and 6 indicate two common types of construction. Care must be exercised to assure compliance with any building codes that might apply. (See also section on Warm Air Ceiling Panel Systems in Chapter 19.)

Electrically Heated Ceilings, Walls, or Floors

Several different forms of electric resistance units are available for heating the interior room surfaces. These include: (1) resistance cables that may be embedded in a manner similar to hot water piping in concrete or plaster; (2) prefabricated electric heating panels to be attached to room surfaces; and (3) electrically heated fabrics or other materials for application to, or incorporation into, finished room surfaces. Figs. 7 and 8 indicate two methods of installation. The constructions of electric panels for ceilings, walls, and floors are described in greater detail in Chapter 41, Electric Heating.

HEAT OUTPUT FROM PANEL SURFACES

A heated panel transfers heat to a room by convection and radiation. In the following paragraphs, the two transfer mechanisms are first considered separately and then combined to facilitate design calculations.

Radiation Transfer

The radiation transfer can be evaluated by means of the Stefan and Boltzmann equation:

$$q_r = 0.173\,F_a F_e \left[\left(\frac{T_p}{100}\right)^4 - \left(\frac{T_r}{100}\right)^4\right] \quad (1)$$

where

q_r = heat transfer by radiation, Btu per (hour) (square foot).
T_p = temperature of panel heated surface, Fahrenheit, absolute.
T_r = mean radiant temperature of all unheated surfaces, Fahrenheit, absolute.
F_a = the configuration factor (dimensionless).
F_e = the emissivity factor (dimensionless).

A combined configuration and emissivity factor for a simple, box-like room in which there is a uniformly heated ceiling, floor, or wall, all

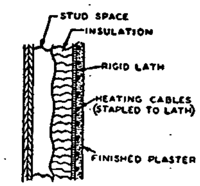

FIG. 7. ELECTRIC HEATING CABLES IN PLASTER

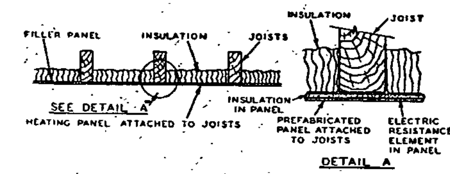

FIG. 8. PREFABRICATED ELECTRIC PANEL

other surfaces are at another temperature, and all surfaces are perfectly diffusing is given by Hottel[3] as:

$$F_c = F_a F_e = \frac{1}{\dfrac{1}{F_{1-2}} + \left(\dfrac{1}{e_1} - 1\right) + \dfrac{A_1}{A_2}\left(\dfrac{1}{e_2} - 1\right)} \quad (2)$$

where

F_c = combined configuration and emissivity factor.
F_{1-2} = view factor = 1.0.
e_1 and e_2 = emissivities of the surfaces.
A_1 and A_2 = areas of the surfaces.

In practice the emissivity of conventional, non-metallic, non-reflecting surfaces will be found to be about 0.9. When this emissivity is used in Equation 2, the combined factor will be found to be about 0.87 for most rooms. Substituting this value in Equation 1, the constant becomes about 0.15 and the equation can be rewritten:

$$q_r = 0.15\left[\left(\frac{t_p + 460}{100}\right)^4 - \left(\frac{\text{AUST} + 460}{100}\right)^4\right] \quad (3)$$

where

t_p = temperature of panel surface, Fahrenheit.
AUST = area-weighted average temperature of unheated surfaces in room, Fahrenheit.