temperature drop is used in determining water flow rates, and a total pump head of more than 30 ft is undesirable due to noise caused by high water velocity.

Panel systems involving several rooms and panels comprising a single zone, require that all coils be selected for the same inlet water temperatures. Panel areas and pipe spacing must be selected to make this possible.

INSTALLATION DETAILS, ACCESSORIES, AND CONTROLS

Installation details, as given in Chapter 22, Hot Water Systems, also apply to piping systems for panel heating. Control problems of panel heating systems are discussed in Chapter 39, Automatic Control.

Efficient venting of air from the coils may be obtained by arranging the circulation so that the air moves in the direction of water flow to a high point in the system where an automatic float-type vent or connection to expansion tank should be provided for its release. Coils should be installed as nearly level as possible or, if they are on sloping surfaces due to structural conditions, they should be arranged to vent air at their high points. Arrangements of pumps, expansion tanks, drainage, and flow and return mains may be generally the same as for conventional hot water heating systems.

SNOW MELTING

The practicability of melting snow by means of heated coils has been demonstrated in a large number of installations in sidewalks, roadways, ramps, and runways. In addition to eliminating the need for snow removal, other advantages gained are greater safety to pedestrians and vehicles, and reduction of labor in removal of slush from floors.

The design of a snow-melting system involves primarily (1) a determination of the heat requirement which depends on snow fall and atmospheric conditions, (2) the coil and piping design which depends on heat transfer from a panel and on friction loss in piping due to the circulating medium used, and (3) the selection or design of a heat exchanger for heating the circulating medium.

DESIGN

Heating Requirements

The heating requirements for snow melting are affected by four atmospheric factors: (1) rate of snowfall, (2) air temperature, (3) wind velocity, and (4) humidity. The effects of these factors can be evaluated by consideration of the action of snow falling on a warmed surface.

The first flakes fall on a dry, warm surface, and are then warmed to 32 F and melted. The water from the melted snow soon forms a film over the entire area and starts to evaporate. The evaporation of the film is a *mass* transfer from the surface to the atmosphere. In addition, there is a *heat* transfer from the film to the ambient air and surfaces.

Both the mass and heat transfers attain a maximum only when the film is entirely free of snow. Theoretically this is impossible because some time will elapse while the snow is warmed to 32 F. For all practical purposes, however, it is permissible to assume the snow to be melted as fast as it falls. The surface is therefore considered entirely free of snow. The ratio of free area to total area is known as the *free area ratio*, ϕ. When

$\phi = 1$, there is no snow on the surface and the mass and heat transfer is at a maximum. When $\phi = 0$, the snow covers the entire area and there is no mass or heat transfer.

At this time there are no data on the permissible values of ϕ for various uses of snow melting systems. As a result, ϕ is usually taken as unity or as zero. Since a very thin layer of snow will reduce ϕ, but will not be objectionable, the selection of $\phi = 1$ provides a safety factor in the design. Until such time as ϕ can be evaluated by tests, it is good practice to use $\phi = 1$ for bridge ramps, public walks, emergency exits, etc. For private drives and walks where low installation costs are imperative, it may be permissible to use values of ϕ of less than unity. For a more complete discussion of free area ratio, see Reference 6. The equations for

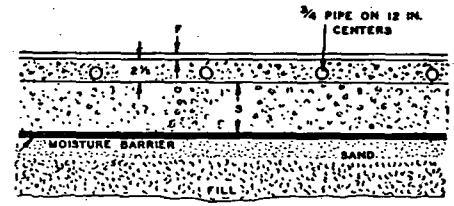


FIG. 16. DETAIL OF SNOW MELTING PANEL

F = Depth of Finish Coat—Assumed as ½ in. of concrete. Finish Coat may be asphalt but then cover slab should be reduced from 3 in. Depth of slab should always keep thermal resistance equal to 3 in. of concrete.

S = Depth required by structural design.

the design of a snow melting system have been derived and explained in detail in Reference 7. The inclusion of ϕ in the equations is explained in Reference 6.

The four equations for the heating requirement are:

1. Sensible heat q_s to raise the temperature of the snow to 32 F

$$q_s = 2.6s\,(t_f - t_a) \tag{7}$$

2. Heat of fusion q_m to melt the snow

$$q_m = 746s \tag{8}$$

3. Heat of vaporization q_e (mass transfer)

$$q_e = 1074\,(0.0201v + 0.055)\,(0.185 - p_{av})\,\phi \tag{9}$$

4. Heat transfer q_h (convection and radition)

$$q_h = 11.4\,(0.0201v + 0.055)\,(t_f - t_a)\,\phi \tag{10}$$

The equation for the required fluid temperature to provide an output of $q_o = q_s + q_m + q_e + q_h$ has been derived in Reference 7 and for construction similar to Fig. 16, is

$$t_m = 0.5\,q_o + t_f \tag{11}$$

where

p_{av} = vapor pressure of moist air, inches of mercury.
q_e = heat of vaporization, Btu per (hour) (square foot).