## 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

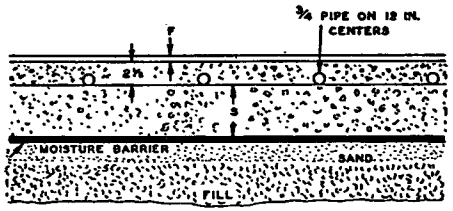


FIG. 16. DETAIL OF SNOW MELTING PANEL

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.

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*, $\phi$. 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 $\phi$ for various uses of snow melting systems. As a result, $\phi$ is usually taken as unity or as zero. Since a very thin layer of snow will reduce $\phi$, but will not be objectionable, the selection of $\phi = 1$ provides a safety factor in the design. Until such time as $\phi$ 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 $\phi$ of less than unity. For a more complete discussion of free area ratio, see Reference 6. The equations for the design of a snow melting system have been derived and explained in detail in Reference 7. The inclusion of $\phi$ 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

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



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)

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

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

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

*where*

$p_{av}$ = vapor pressure of moist air, inches of mercury.
$q_e$ = heat of vaporization, Btu per (hour) (square foot).
$q_h$ = heat transfer by convection and radiation, Btu per (hour) (square foot).
$q_m$ = heat of fusion, Btu per (hour) (square foot).
$q_o$ = heat output off surface of slab $q_s + q_m + q_e + q_h$, Btu per (hour) (square foot).
$q_s$ = sensible heat transferred to snow, Btu per (hour) (square foot).
$s$ = rate of snow fall, inches of water equivalent per hour.
$t_a$ = air temperature, Fahrenheit.
$t_t$ = water film temperature, Fahrenheit.
$t_m$ = fluid (water and anti-freeze solution), temperature, Fahrenheit.
$v$ = wind velocity, miles per hour.
$\phi$ = free area ratio.

Values for $s$ for certain cities are given in Table 3. Using the values for $s$ given in Table 3, the appropriate values for $t_a$ and $v$, the values for $q_o$ may be found in Table 4. In preparing Table 4, only values of $p_{av}$ for relative humidities of 80 percent were used. The variation in $q_o$ and $t_m$ for humidities of 75, 80, 85 and 90 percent are given in Reference 6, and may be calculated by solving Equations 12 and 13.

$$\frac{dt_m}{dp_{av}} = -537\,(0.0201v + 0.055)\,\phi \tag{12}$$

$$\frac{dq_o}{dp_{av}} = -1074\,(0.0201v + 0.055)\,\phi \tag{13}$$

After determining the total heating requirements (the slab output) it is necessary to make allowance for back and edge losses. These losses vary from 30 to 50 percent, depending upon the amount of insulation that is used.

When determining the size of heat exchanger required, the actual film coefficient of an anti-freeze solution must be used. The manufacturer must therefore be given data on the type of anti-freeze solution, its concentration, and the temperature range to be expected during operation.

### Pumping Head

The pumping head for a snow melting system may be computed by means of hydraulic tables or formulas (see chapter on Fluid Flow) except