tion is not always used. The amount of induced air varies with unit design.

A fourth less common arrangement is similar, but makes use of hot water in the induction unit in winter and cold water in the induction unit in summer. Control of the valve on the unit is obtained by use of a summer-winter type thermostat. The unit is provided with drip pan and drain piping to remove condensation. No recirculation is used.

On cargo ships, tankers and vessels not carrying passengers or not having air conditioning, heating of crews' spaces and officers' staterooms is usually obtained through a central system having filters, preheaters and reheaters. A minimum temperature of air leaving the preheater is controlled by a duct thermostat. The reheater is controlled by a sub-master discharge-duct thermostat, reset by outside master control. Relationship between sub-master and master control (wherein discharge temperature is raised as outdoor temperature drops), is set according to a schedule based on the ship's itinerary.

Ductwork for all systems described is designed for conventional velocity. However, if power is available, and suitable duct construction and adequate sound absorbing facilities are provided, high velocity systems may be used.

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CHAPTER 49

SNOW MELTING

***Design:** Heating Requirement, Hydraulic Requirement, **Installation:** Safety, Internal Corrosion, Slab Construction, Thermal Stresses, Control, Testing, Draining, Drifting Snow, Design Example*

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 must determine and satisfy two primary requirements: (1) the heating requirement, and (2) the hydraulic requirement. Each of these is treated in this chapter. Several points regarding installation practices are also discussed.

DESIGN

Heating Requirement

The heating requirement for snow melting is 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.

Mass transfer due to evaporation. The rate of evaporation of the melted snow from the snow-melting slab is affected by the wind speed and the vapor-pressure difference between the air and the melted snow. The vapor pressure of air, however, is fixed by the relative humidity and the temperature of the air. If the slab surface temperature is fixed, then the evaporation loss varies with changes in air temperature, relative humidity, and wind speed.

Heat transfer by convection and radiation from the melted snow to the ambient air and surfaces. A combined film coefficient has been used with sufficient accuracy to determine the combined convection and radiation loss. This coefficient is based on a heat transfer from a *wetted* surface, such as the film of melted snow, to air. The coefficient is a function of wind speed alone. The heat transfer, of course, is dependent upon the film coefficient and the temperature difference between the surface and the air. Since the surface temperature is fixed, the convection and radiation losses vary with changes in air temperature and wind speed.

To determine evaporation and heat transfer from the melted snow to the air it is necessary to know three of the four climatic factors: (1) wind speed, (2) air temperature, and (3) relative humidity, and (4) rate of snowfall. The fourth factor, rate of snowfall, is necessary to determine the heat required to warm the snow to 32 F, and to melt it.

Before deriving equations to give quantitative values for the effects of these four factors, it is necessary to consider the insulating effect of the snow before it is melted. As stated previously, the first flakes fall on a dry, warm surface, and are then warmed to 32 F and melted. During the time that the flakes are being warmed, and before they are completely melted, they can be considered as tiny blankets or insulators. The effect of this insulation has been measured[1] and can be of considerable magnitude. Since the snowflakes cover a fraction of the surface area, it has been convenient to think of the insulating effect as an area ratio. The area covered by the snowflakes is the insulated area, and the uncovered area is the uninsulated area. The term free area ratio A_r has been adopted to represent the ratio of the uncovered, or free, area to the total area or,

$$A_r = \frac{A_f}{A_t} \qquad (1)$$

where

A_r = Free area ratio.
A_f = Free area, sq ft.
A_t = Total area, sq ft.

hence

$$0 \leq A_r \leq 1$$

For $A_r = 1$, the system would have to melt the snow so rapidly that the snow accumulation would be absolutely zero. This is impossible from a theoretical standpoint, but for all practical purposes it is permissible to have $A_r = 1$ as a maximum. For $A_r = 0$, the surface would be completely covered with snow to a depth sufficient to completely prevent evaporation and heat transfer losses. Research on the insulating effects of snow indicate that there are just three practical values for the free area ratio, 0, 0.5, and 1. This will be covered in greater detail in a later section.

The equations for the heating requirements of a snow-melting system have been derived and thoroughly explained in Reference 2. The general equation for slab output, q_o, as derived and discussed thoroughly in Reference 1, is

$$q_o = q_s + q_m + A_r(q_e + q_h) \qquad (2)$$

where

q_s = sensible heat transferred to snow, Btu per (hour) (square foot).
q_m = heat of fusion, Btu per (hour) (square foot).
A_r = ratio of snow-free area to total area, dimensionless.
q_e = heat of evaporation, Btu per (hour) (square foot).
q_h = heat transfer by convection and radiation, Btu per (hour) (square foot).