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_f = water film temperature, Fahrenheit.
t_m = fluid (water and anti-freeze solution), temperature, Fahrenheit.
v = wind velocity, miles per hour.
ϕ = 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.

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

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

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.

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 4 on Fluid Flow) except that allowances must be made for the physical properties of the circulating fluid. This fluid may be an aqueous solution of ethylene glycol, or it may be a petroleum distillate. In either case, the manufacturer should be contacted for the physical properties. Ethylene glycol solutions should contain a rust inhibitor (probably triethanolamine phosphate), and this will affect the properties slightly.

For large installations, the friction losses should be calculated by the Fanning equation

$$h_f = \frac{flV^2}{2gd} \qquad (14)$$

where

h_f = the loss in head of the fluid under conditions of flow, in feet.
l = the length of the pipe, in feet.
V = the velocity, in feet per second.
g = the acceleration due to gravity = 32.174 ft per (second) (second).
d = the internal diameter of the pipe, in feet.
f = a dimensionless friction coefficient.

TABLE 3. SNOWFALL DATA FOR VARIOUS CITIES[a]

City	Number of Readings with Maximum Temperature in 6-Hour Period below Freezing at Various Snowfall Rates				Total Readings Taken	Assumed Design Rate of Snowfall[b]
	Snowfall Rate in Equivalent Inches of Water per Six Hours.					
	0.00 to 0.24	0.25 to 0.49	0.50 to 0.74	0.75 to 0.99		s
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Albany, N. Y.	2052	29	5	1	3720	0.16
Asheville, N. C.	463	5	1	0	3536	0.08
Billings, Mont.	1640	4	0	0	3532	0.08
Bismarck, N. D.	2838	0	0	0	3720	0.08
Boise, Idaho	1300	3	0	0	3720	0.08
Boston, Mass.	1323	11	4	2	3720	0.16
Buffalo, N. Y.	1871	23	3	1	3720	0.16
Burlington, Vt.	2390	9	0	0	3720	0.08
Caribou, Maine	1353	19	1	0	1672	0.16
Chicago, Ill.	1498	3	0	1	2976	0.08
Cincinnati, Ohio	1045	3	0	0	3720	0.08
Cleveland, Ohio	1569	2	0	0	3720	0.08
Columbus, Ohio	1351	4	1	0	3720	0.08
Denver, Col.	1207	4	0	0	3720	0.08
Detroit, Mich.	1830	5	2	0	3720	0.08
Evansville, Ind.	916	5	1	1	3720	0.08
Hartford, Conn.	1514	44	9	3	3720	0.25
Kansas City, Mo.	1189	12	2	1	3720	0.16
Madison, Wisc.	2370	5	2	0	3720	0.08
Minneapolis, Minn.	2703	7	0	0	3720	0.08
Oklahoma City, Okla.	613	8	4	0	3720	0.16
Omaha, Neb.	1795	8	1	0	3720	0.16
Philadelphia, Pa.	891	10	2	1	3720	0.16
Pittsburgh, Pa.	1365	6	2	0	3720	0.08
Portland, Maine	2054	33	4	1	3720	0.16
St. Louis, Mo.	1088	5	0	1	3720	0.08
Salt Lake City, Utah	1482	5	0	0	3720	0.08
Spokane, Wash.	1545	11	1	0	3720	0.16
Washington, D. C.	533	7	2	1	3348	0.16
New York, N. Y.[c]						0.16

[a] Data from *U. S. Weather Bureau*. Based on readings taken 1:30 a.m., 7:30 a.m., 1:30 p.m., and 7:30 p.m. daily from November 15 to February 15 from 1940 to 1949. (Where the total readings are less than 3720 the period of record is less than 10 years). The difference between Col. 6 and the sum of readings in Cols. 2, 3, 4, and 5 is the number of readings with a maximum temperature (in the 6-hr period) above freezing.

[b] The design rate is found as follows: Proceed to left (on line from any city) from Column 5 until the column containing the tenth reading is found. Assume that the larger value in the heading of the selected column is an *average maximum* value, and should be multiplied by 2 to obtain the maximum rate for a 6-hour period. This maximum rate divided by 6 is the design rate per hour. This is equivalent to dividing the larger value in the heading of the selected column by 3.

For example: For Albany, N. Y. Columns 5 and 4 total six readings, and consequently the tenth reading is in Column 3, which has the larger value of 0.49 in the column heading. Dividing 0.49 by 3, the design water equivalent of 0.16 inches per hour is found, as listed in Column 7.

[c] New York City record was not used in this tabulation since the records for that station were not comparable with those of the other stations.

The factor f can be determined from the Moody chart which is Fig. 4 of Chapter 4, Fluid Flow. In determination of the Reynolds number, the effect of the inhibitor should be taken into account. The manufacturer of the anti-freeze solution must therefore be consulted. For