

the footnotes to Table 3. Briefly, snow-melting systems are classified as to the urgency for melting as follows:

Class I (minimum): Residential walks or driveways and interplant areaways.

Class II (moderate): Commercial (stores and offices) side-walks and driveways, and steps of hospitals.

Class III (maximum): Toll plazas of highways and bridges, and aprons and loading areas of airports.

These classifications depend upon the allowable rate of snow melting. For example, a residential system does not have to melt snow as rapidly as a commercial system. In fact, a depth of snow of an inch for an hour or so during a heavy storm might not be objectionable with a residential system. On the other hand, a store manager would consider the system inadequate if half an inch of snow accumulated on the sidewalk in front of the store. The difference, then, between a Class I system and a Class II system is in the required ability of each system to melt snow. The one feature that is common to all classes is that the systems must be adequate for some combination of weather factors. The designer may select equipment having capacity to melt snow whenever conditions are milder than some critical values, but be willing to have an inadequate system for a given fraction of the time. In other words, the designer will take a calculated risk providing he knows the odds of that risk. For a residential system, where initial cost must be at a minimum, the designer must accept more frequent snow accumulations.

Table 3 contains the design heat requirements for the 3 classes of snow-melting systems. Under Class I systems, the values in parentheses are *riding rates* and, since they exceed the Class I design rates, should be taken as design output for

this classification. Design rates may be altered by the designer if he feels that a particular job should have different design criteria from those given in the footnotes of Table 3. Any change in design conditions used should be based on the frequency distribution given in Table 1.

Use of Tables 1, 3, and 4 is illustrated by *Example 1*.

Example 1: An engineer has been retained to design snow-melting systems for the service areas of a turnpike running from the eastern edge of the Wisconsin-Illinois border north-west to the Wisconsin-Minnesota border just east of St. Paul. He decides that Chicago data will be adequate for the southern terminus and that Minneapolis-St. Paul data will be adequate for the northern terminus. His problem is to determine the heat and hydraulic requirements of the systems for service areas between Chicago and St. Paul.

Solution: Assume, for this example, that the city in question is Madison, Wis. Weather bureau records indicate that the annual average number of days with snow cover of an inch or more would be 100, and that the engineer can assume an average snowfall of 40 inches. In addition, he can estimate about 11 days per year with a snowfall of an inch or more (see Reference 3).

For the walkways to the restaurant from the parking area a Class I design rate could be used. This rate could be taken as 90 Btuh per sq ft. This is in good agreement with data in Tables 3 and 4 which give the rate at 89 (design rate) for Chicago and 95 (riding rate) for Minneapolis.

The lanes leading from the turnpike to the gasoline pumps and parking areas should be rated as Class II areas. A check of Tables 1 and 3 would indicate that 160 Btuh per sq ft would be adequate.

If an emergency area were included, for a wrecking truck, ambulance, or police garage, it would be wise to consider a Class III rate for such areas. An inspection of Table 1 for Chicago shows that a rate of 275 Btuh per sq ft would be ade-

Table 5 . . . Physical Properties of Antifreeze Solutions*

Fluid	Freezing Protection Temp. F	Item	Fluid Temperature—Fahrenheit							
			-20	0	20	40	120	140	160	200
Ethylene Glycol 15.3% by vol.	+20	$\rho \times 10^3$	—	—	—	2.64	0.840	0.687	0.577	0.458
		c	—	—	—	0.935	0.956	0.960	0.962	0.969
		w	—	—	—	64.0	62.8	62.5	62.1	58.8
Ethylene Glycol 31.4% by vol.	0	$\rho \times 10^3$	—	—	6.86	4.18	1.19	0.955	0.784	0.609
		c	—	—	0.833	0.850	0.895	0.905	0.910	0.923
		w	—	—	65.7	65.4	64.1	63.7	63.3	60.0
Ethylene Glycol 42.7% by vol.	-20	$\rho \times 10^3$	—	16.1	9.47	5.75	1.46	1.20	0.950	0.748
		c	—	0.764	0.775	0.788	0.832	0.845	0.856	0.884
		w	—	66.8	66.7	66.3	65.3	64.9	64.4	60.6
Ethylene Glycol 51.2% by vol.	-40	$\rho \times 10^3$	46.3	21.3	12.13	7.54	1.77	1.46	1.14	0.870
		c	0.682	0.717	0.726	0.745	0.809	0.823	0.835	0.854
		w	68.2	67.6	67.4	67.2	65.9	65.4	65.0	61.1
Heat Transfer Oil	-40	$\rho \times 10^3$	105	43.1	29.7	14.0	3.13	2.51	2.06	1.48
		c	0.382	0.390	0.400	0.408	0.444	0.452	0.462	0.480
		w	62.9	62.5	62.0	61.6	59.1	58.6	57.6	55.3
Water	+32	$\rho \times 10^3$	—	—	—	1.71	0.603	0.494	0.413	0.328
		c	—	—	—	1.005	0.999	0.999	1.001	1.005
		w	—	—	—	62.4	61.7	61.4	61.0	60.1

* Based on data given in Reference 8.

ρ = Kinematic viscosity, (feet squared per second) (e.g. for oil at 60 F, $\rho = 0.000140$ ft² per sec.).

c = specific heat, Btu per (pound) (Fahrenheit degree).

w = specific weight, pounds per cubic foot.

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quate for $A_r = 1$ for 99.4 percent of the time. Similarly, 275 would be adequate 99.4 percent of the time in St. Paul. Therefore, 275 Btuh per sq ft seems sufficient for the emergency areas. Table 3 in Class III column lists 350 Btuh per sq ft for Chicago and 254 for St. Paul but for uses similar to the areas in this example, 275 should be adequate.

Hydraulic Requirement

After determining the heating requirements, it is necessary to determine the hydraulic requirements of the system. This can be done by means of the procedures explained in Chapter 4, Fluid Flow, but it is necessary to use the proper physical properties of the antifreeze solution. A complete discussion of the hydraulic problem is given in Reference 4.

The main consideration is the proper allowance for viscosity. Table 5 gives viscosities for typical fluids used as

Table 6 . . . Conversion of Kinematic Viscosity Units*

Centistokes	(FF/Sec) $\times 10^6$	SSU ^b	Centistokes	(FF/Sec) $\times 10^6$	SSU ^b
2	2.15	32.6	31	33.4	145.7
2.5	2.69	36.0	32	34.4	150.2
3	3.23	36.0	33	35.5	154.7
3.5	3.77	37.6	34	36.6	159.2
4	4.30	39.1	35	37.7	163.7
4.5	4.84	40.8			
5	5.38	42.4			
6	6.46	45.6	36	38.7	168.2
7	7.53	48.8	37	39.8	172.7
8	8.61	52.1	38	40.9	177.3
9	9.68	55.5	39	42.0	181.8
10	10.8	58.9	40	43.0	186.3
11	11.8	62.4	41	44.1	190.8
12	12.9	66.0	42	45.2	195.3
13	14.0	69.8	43	46.3	199.8
14	15.1	73.6	44	47.3	204.4
15	16.1	77.4	45	48.4	209.1
16	17.2	81.3	46	49.5	213.7
17	18.3	85.3	47	50.6	218.3
18	19.4	89.4	48	51.6	222.9
19	20.4	93.6	49	52.7	227.5
20	21.5	97.8	50	53.8	232.1
21	22.6	102.0	55	59.2	255.2
22	23.7	106.4	60	64.6	278.3
23	24.7	110.7	65	69.9	301.4
24	25.8	115.0	70	75.3	324.4
25	26.9	119.3			
26	28.0	123.7			
27	29.1	128.1			
28	30.1	132.5			
29	31.2	136.9			
30	32.3	141.3			

Over 70.0 centistokes, SSU = 4.635 X centistokes.

* Kinematic viscosity in (ft²/sec) = 1.076 X 10⁻⁴ X centistokes.

^b Values listed for SSU (Saybolt Seconds—Universal) are for fluid temperatures of 100 F. To obtain the Saybolt Universal viscosity equivalent to a kinematic viscosity determined at a Fahrenheit temperature t , multiply the equivalent Saybolt Universal viscosity at 100 F by $1 + (t - 100) 0.000064$; for example, 10 centistokes at 210 F are equivalent to 83.9 X 1.0070 or 84.3 sec Saybolt Universal at 210 F. (Taken from ASTM D 445 - 53.)

antifreezes for snow-melting systems. Viscosities are given in feet squared per second. Table 6 can be used in conversion of viscosity units. A large increase in viscosity will be noted for glycols and oils—about 20 times—as the fluid temperature changes from 160 F to 0 F. This viscosity change has two effects. First, an increase in viscosity will increase the fluid friction in the piping circuit. Second, an increase in viscosity will decrease the pump capacity—in both volume and head. The effect of viscosity on fluid friction in the piping circuit is illustrated in Fig. 2.

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

$$h_f = \frac{fV^2}{2gD} \quad (10)$$

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 which can be determined from Fig. 4, Chapter 4. The Reynolds number can be computed from data in Table 5 of this chapter.

Solutions for the pipe friction should be plotted for temperatures at the starting condition (probably 0 F) and at the operating condition (use either 120 or 160 F). Then on the same graph, the operating curve of the pump should be plotted (see Reference 4 for such a graph). The intersection of the fluid friction curve and pump operating curve will give the operating point for the system. Table 7 can be used to allow for the viscosity effect on the pump.

The designer must decide on the tolerable viscosity limit. Generally it is between 300 and 500 SSU, although for

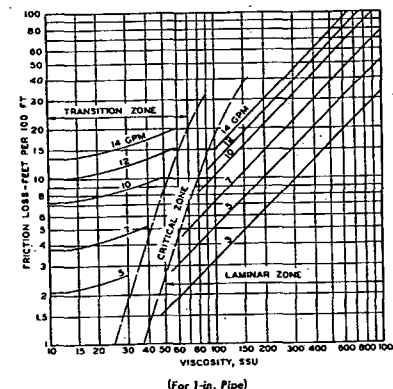


Fig. 2 . . . Effect of Viscosity on Friction Loss