TABLE 9. VISCOSITY EFFECT ON CENTRIFUGAL PUMP CHARACTERISTICS

KINEMATIC VISCOSITY SSU[a]	CORRECTION FACTORS		
	Pump Head	Pump Capacity	Pump Efficiency
0 to 30	1.00	1.00	1.00
50	1.00	1.00	0.94
100	0.98	1.00	0.88
200	0.96	0.98	0.79
300	0.95	0.97	0.73
400	0.93	0.96	0.68
500	0.92	0.96	0.65
600	0.91	0.95	0.62
700	0.90	0.94	0.59
800	0.89	0.94	0.57
900	0.88	0.93	0.55
1000	0.87	0.92	0.53

[a] SSU = Saybolt Seconds— Universal.

2. Keep pipe near surface—about 2 in. cover.
3. Use reinforcing steel designed for thermal stress if high structural loads are expected (such as on highways).

Testing

After installation and before pouring concrete, all piping should be tested to about 100 psi. This pressure should be maintained until all welds and connections have been checked for leaks. If an oil is used as an antifreeze, the test should be performed with air or some gas (only 50 psi required with an air test) but *not with water*. The danger of using water is that the pipe may not be thoroughly dried when the oil is introduced. The water will tend to collect, and when the temperature falls below 32 F the collected water may freeze and cause damage.

Draining

Proper drainage is necessary for both the slab surface and the coil.

The slab must be sloped so that the water from the melted snow can run off. Puddles are objectionable on sidewalks or drives. They cause splashing, and they retard heat flow from the embedded pipes.

The pipes must be placed so that they may be drained. If the antifreeze becomes corrosive it must be drained. It is not good practice to rely entirely on blowing of air through the system.

Drifting Snow

It is quite likely that some drifting will occur on every system that is adjacent to a wall or vertical surface. The designer should try to anticipate this condition and add extra piping in these areas. If possible, coils should be added in the vertical surface. Another expedient is to carry the drainage to the area expected to be drifted. The drainage will tend to wash away some of the snow.

Design Example

Example 4: Design a snow-melting system for an area of 10,000 sq ft in Pittsburgh, Pa. using a *free area ratio* of 0.5. Assume an air temperature of 10 F and a wind velocity of 10 mph. Use an oil antifreeze solution.

TABLE 10. CORRECTION FACTORS FOR PIPE SIZE (For Laminar Flow, $N_{Re} < 2000$)

PIPE SIZE	INSIDE DIAMETER		D_i^4	$K = \frac{5.84 \times 10^{-5}}{D_i^4}$
	Inches	Feet	Ft[4]	(See Figure 20)
½	0.622	0.0518	7.18×10^{-6}	8.13
¾	0.824	0.0687	2.23×10^{-5}	2.62
1	1.049	0.0874	5.84×10^{-5}	1.00
1¼	1.380	0.115	1.75×10^{-4}	0.334
1½	1.610	0.134	3.26×10^{-4}	0.179
2	2.067	0.172	8.75×10^{-4}	0.0667
2½	2.469	0.206	1.81×10^{-3}	0.0322
3	3.068	0.256	4.30×10^{-3}	0.0136
3½	3.548	0.296	7.68×10^{-3}	0.00760
4	4.026	0.335	1.26×10^{-2}	0.00462
5	5.047	0.421	3.14×10^{-2}	0.00186
6	6.065	0.505	6.50×10^{-2}	0.000898

Solution : From Table 5 select a snowfall rate of 0.08. From Table 6 find the required heat output of top of slab as $q_o = 168$ for $R_A = 1$, and $q_o = 64$ for $R_A = 0$. Then for $R_A = 0.5$ use $q_o = 116$ because $0.5(168-64) + 64 = 116$. From Equation 12 $t_m = 0.5q_o + t_f = (0.5 \times 116) + 33 = 91$ F.

Assume that back and edge losses are 40 percent. Then the total heat requirement on heat exchanger is

$$A_p q_t = 10{,}000 \times 1.40 \times 116 = 1{,}624{,}000 \text{ Btuh.}$$

From Equation 25

$$G = \frac{A_p q_t}{160 w_m c_m} = \frac{1{,}624{,}000}{160 \times 60.5 \times 0.431} = 390 \text{ gpm}$$

(Interpolating from Table 7, $w_m = 60.5$ and $c_m = 0.431$ for $t_m = 91$ F.)

Since a temperature drop of 20 deg was used, the fluid must enter the slab at 101 F and leave at 81 F.

Assume that the coil circuit of longest *equivalent* length is 300 ft and has a flow of 12 gpm and the pipe is 1-in. *IPS*. From Table 1, Chapter 26, the I.D. = 1.049 in. = 0.0875 ft and the I. D. section area = 0.864 sq in. = 0.00600 sq ft, hence for 12 gpm, the flow is 0.0268 cu ft per sec and the velocity = $\frac{0.0268}{0.00600} = 4.47$ fps.

Interpolating from Table 7, the kinematic viscosity is 4.92×10^{-5} ft² per sec. (An accurate interpolation requires the use of *ASTM* Standard Viscosity chart B.)

$$\text{Hence the Reynolds number} = \frac{VD}{\nu} = \frac{4.47 \times 0.0875}{4.92 \times 10^{-5}} = 7950$$

From Fig. 4 of Chapter 4, using a roughness factor of $e = 0.00015$, whence $e/D = 0.00172$, the friction factor f is found to be 0.0355. Substituting in Equation 23

$$h_f = f \times \frac{L}{D} \times \frac{V^2}{2g} = 0.0355 \times \frac{300}{0.0875} \times \frac{4.47^2}{64.3}$$

$$= 37.9 \text{ ft of fluid} = 15.9 \text{ psia.}$$

The pump must deliver 390 gpm against a 15.9 psia head. The heat exchanger must deliver 1,624,000 Btuh with an inlet temperature of 81 F and an outlet temperature of 101 F. (Actually an allowance should be made for temperature drop in the piping between the slab and the heat exchanger.)

The expansion tank should be designed in accordance with the procedure outlined in Chapter 21, Hot Water Heating Systems. The amount of expansion should be