ture range of operation, the source of heat (steam, hot water, etc.), and the flow rate through the exchanger.

Hydraulic Requirements

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 8.

The main consideration is the proper allowance for viscosity. Table 5 gives viscosities for two typical fluids used as antifreezes for snow melting systems. Notice the large increase in viscosity for both fluids—about 20 times—as the fluid temperature changes from an operating temperature

Table 5. Physical Properties of Antifreeze Solutions

Solution	Freezing Protection Temp., F.	% By Volume	Item	Fluid Temperature, F			
				0	80	120	160
Ethylene Glycol[a]	0	31.4	$\nu \times 10^5$	—	1.92	1.14	0.77
			c	—	0.839	0.854	0.874
			w	—	65.1	64.4	63.6
	−20	42.7	$\nu \times 10^5$	16.1	2.55	1.46	0.95
			c	0.764	0.813	0.832	0.856
			w	66.8	66.0	65.3	64.4
	−40	51.2	$\nu \times 10^5$	21.3	3.16	1.77	1.14
				0.717	0.788	0.809	0.835
			w	67.6	66.8	65.9	65.0
Light Oil[b]	−40	100	$\nu \times 10^5$	43.1	5.60	3.13	2.06
			c	0.390	0.426	0.444	0.462
			w	62.5	60.7	59.8	59.0

[a] Interpolated from Reference [10]. [b] From Socony-Vacuum Oil Co.
ν = kinematic viscosity, (feet squared per second) (*e.g.* for oil at 80 F, ν = 0.000056 ft² per sec.)
c = specific heat, Btu per (pound) (Fahrenheit degree).
w = specific weight, pounds per cubic foot.

of 160 F to the starting temperature of 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. 17.

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

$$h_f = \frac{flV^2}{2gD}$$

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.

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 plot the operating curve of the pump (see Reference 8 for such a graph). The intersection of the fluid friction curve and pump operating curve will give the operating point for the system. Use the data in Table 6 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 commercial or private systems (where A_r is 0.5 or 0) it may go to 750 SSU.

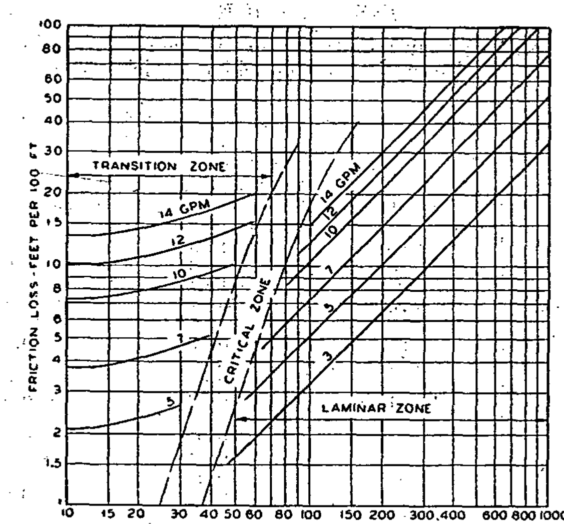

Fig. 17. Effect of Viscosity on Friction Loss
(For 1-in. Pipe)

Efficiency loss is not important, but head and capacity losses are. Reduced flow means a longer period of time for the system to become operative from a cold start.

The viscosity limit is controlled by means of a low-limit thermostat. For example, if it is desired to hold the viscosity of the solution to less than 200 SSU (43.1 ft sq per sec), then for the oil shown in Table 5, the low limit control would be set at 0 F.

For small installations, a quick method of determining the fluid friction for a one-inch IPS pipe circuit is given in Fig. 17.

The pump capacity, in pounds of fluid per hour is given by

$$C = \frac{A_p q_t}{c_m \Delta t} \tag{15}$$

where

C = pump capacity, pounds per hour.
A_p = area of slab, square feet.