Table 7 . . . . Viscosity Effect on Centrifugal Pump Characteristics

Kinematic Viscosity SSU*	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

* SSU = Saybolt Seconds—Universal.

Table 8 . . . . Correction Factors for Pipe Size (For Laminar Flow $N_{Re} < 2000$)

Pipe Size	Inside Diameter		D_i^4 Ft⁴	$K = \frac{5.84 \times 10^{-5}}{D_i^4}$ (See Figure 2)
	Inches	Feet		
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

commercial or private systems (where A_r is 0.5 or 0) it may go to 750 SSU.

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 1-in. IPS pipe circuit is given in Fig. 2.

The required pump capacity, in pounds of fluid per hour is given by the equation:

$$C = \frac{A_p q_t}{c_m \Delta t} \qquad (11)$$

where

C = pump capacity, pounds per hour.
A_p = area of slab, square feet.
q_t = total heat requirement (slab output, q_o, plus back and edge losses) Btu per (hour) (square foot).
c_m = specific heat at temperature t_m, Btu per (pound) (Fahrenheit degree).
Δt = temperature drop through circuit, Fahrenheit degrees.

For a temperature drop of Δt = 20 F, Equation 11 becomes

$$G = \frac{A_p q_t}{160 w_m c_m} \qquad (12)$$

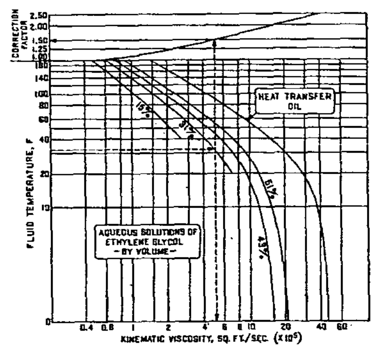
where

G = gallons per minute.
w_m = mean specific weight at temperature t_m, pounds per cubic foot.

An approximate solution for systems using pipe sizes other than 1-in. IPS can be obtained by using Table 8 or Fig. 3. Table 8 is for use when the flow is in the laminar zone. Fig. 3 is for flow in the turbulent zone. For flows where Reynolds number falls between 2000 and 3000, no reliable prediction for pressure loss can be made. It is generally safe to assume the flow to be increased to a Reynolds number of 3000 with the pressure loss estimated at that flow rate.

Figure 2 is based on a pipe size of 1 in. IPS. If another pipe size is used and the flow is *laminar*, the correction factor K from Table 8 can be used. For example, assume a viscosity of 300 SSU, a flow of 5 gpm, and a ¾-in. IPS pipe. Fig. 2 shows that for 1-in. IPS, friction loss would be 15.50 ft/100 ft. Table 8 gives K = 2.62 for ¾-in. pipe; therefore, friction loss would be 15.5 × 2.62 = 40.6 ft/100 ft.

If the flow is in the *transition* zone or is *turbulent*, then Fig. 5 of Chapter 28 can be used in conjunction with Fig. 3. For example, assume a viscosity of 0.0001 sq ft/sec (56.5 SSU), a flow rate of 14 gpm and a 1½-in. IPS pipe size.



(For N_{Re} > 3000)
(Based on data given in Reference 6)

Fig. 3 . . . . Friction Correction Factor for Viscosity

Fig. 5, Chapter 28, shows a head loss for water to be 190 milinches per foot or 1.58 ft/100 ft. Fig. 3 gives a correction factor K of 1.75 for a viscosity of 0.0001 sq ft/sec; hence, the pressure loss is 1.58 × 1.75 = 2.77 ft/100 ft.

INSTALLATION

There are certain precautions that must be taken during installation. They concern internal corrosion, flammability, toxicity, cleaning, joints, and hookup. A comprehensive discussion of these precautions may be found in Reference 5.

Safety

Since ethylene glycol and petroleum distillates are slightly toxic, the system should be installed and maintained independently. There should be no permanent connection between the snow-melting system and the drinking water supply.

Ethylene glycol is not considered flammable. In fact, aqueous solutions of less than 60 percent glycol are used for fire sprinkler systems. These solutions do not freeze, and they are effective fire extinguishing agents.

Petroleum distillates suitable for fluids in snow-melting systems are classified as non-flammable, but have fire points between 300 and 350 F. When using fluids of this type, care should be taken to collect any oil dripping from the seals on the pump. It is good practice also to provide some barrier between the oil lines and the boiler so that in the event of a leak, a flash back from the boiler will not ignite the oil.

There are other non-flammable fluids, such as those used in some transformers, that can be used as the antifreeze. These fluids are three or four times as expensive as the glycols or oils, but combine the fire protection of the glycols with the corrosion protection of the oils.

Internal Corrosion

Ethylene glycol solutions tend to become corrosive in service; therefore, rust inhibitors are generally included. Even with an inhibitor, the solution should be tested annually to determine any change in acidity. If the test indicates that the inhibitor has been exhausted, the entire system should be drained and a fresh solution installed.

To increase the life of the inhibitor, the heat exchanger surfaces should be kept below 285 F which corresponds to about 40 psig steam. Temperatures above 300 F accelerate the deterioration of the inhibitors.

Slab Construction

It has been found satisfactory to use ¾-in pipe or tube on 12-in. centers as a standard coil. If pumping loads require a reduction in friction the pipe size may be increased to 1-in., but the slab depth must be increased accordingly.

The piping should be supported in such a manner that there is a minimum of 2 in. of concrete above and below the pipe. This requires a 5-in. slab for ¾-in. pipe and 5⅜-in. for 1-in. pipe.

If an insulating material is used beneath the structural slab, it is generally good practice to provide a moisture barrier between the insulation and the fill. A roofing material (such as a 55 lb felt) is often used as a moisture barrier. The joints in the barrier should be mopped, and the fill made smooth enough so that there will be no holes or gaps for moisture transfer. Also, the edges of the barrier should be flashed to the surface of the slab so that the ends are sealed.

If the pipe must pass through an expansion joint, a protective coating should be applied to the pipe for a foot or two on both sides of the joint.

If the pipe is kept dry at all times in both summer and winter, no external corrosion problems will occur.

Thermal Stresses

This problem is discussed in Reference 7. In general, there will be no ill effects from the thermal stresses if these rules of installation and operation are followed:

1. Keep the temperature difference between the fluid and the slab surface to a minimum by:
   a. Close pipe spacing (see Fig. 1).
   b. Low temperature drop in fluid, $\Delta t \leq 20$ F deg.
   c. Continuous operation (if economically feasible).
2. Keep pipe near surface to obtain about 2 in. cover.
3. Use reinforcing steel designed for thermal stress if high structural loads are expected (such as on highways).

Control

Normally snow-melting systems are manually controlled. They are started by an operator when snow is anticipated or is falling, and they are shut off when the snow has stopped falling and the area is clear. This is strictly two-position control either 0 or 100 percent operation. One version, with some degree of control, provides a surface-temperature control. The system is started manually, as before, but a thermostat controls the heat input to maintain a surface temperature of approximately 33 F.

There are several fully automatic control systems, however. In general, these systems provide some means of detecting precipitation and simultaneously sensing air temperature. One method is to set a thermostat for a 35 F air temperature and arrange to have the signal from this thermostat activate a heating element on a receptacle. This warm receptacle collects the precipitation, and melts it if it is frozen. The water then runs through a tube and activates another circuit. This second circuit can be used to start the snow-melting system. Another thermostat can be used to control the surface temperature of the snow-melting slab.

For basic information on control equipment, such as thermostats, and for fundamentals of control circuits, see Chapter 43.

Testing

After installation and before pouring concrete, all piping should be tested to about 100 psig. 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