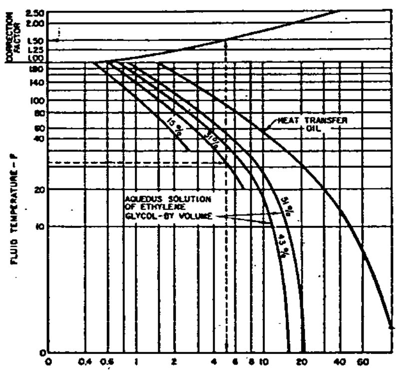
between the snow-melting system and the drinking water supply.

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



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

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

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 oil. 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. As stated previously, a low-limit thermostat should be set to prevent the antifreeze solution from cooling to a temperature where the kinematic viscosity would be excessive.

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 13, Automatic Control, of the 1961 GUIDE AND DATA BOOK.

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 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 2: Assume that there are three independent hydraulic systems to be used in the snow-melting application described in *Example 1*. One system will be for the Class I area, another for the Class II, and the third for the emergency area, or Class III area.

Determine the hydraulic requirement for the Class II system, assuming an area of 100,000 sq ft.

Solution: The heating requirement has been determined as 160 Btuh per sq ft. Since an area of this type has a large perimeter, assume the edge and back losses add about 40 percent or 64 Btu per sq ft. The total heat requirement, then, will be taken as 224 Btuh per sq ft or 22.4×10^6 Btuh for the 100,000 sq ft area.

The fluid temperature is determined by using Equation 7:

$$t_m = 0.5\, q_o + t_f$$

Since

$$q_o = 160 \text{ Btuh per sq ft, and } t_f = 33 \text{ F}$$
$$t_m = 0.5 \times 160 + 33 = 113 \text{ F.}$$

If an oil antifreeze is used, the specific heat, c_m, the kinematic viscosity ν_m, and the specific weight w_m, at 113 F can be found by interpolation in Table 6 as

$$c_m = 0.440 \text{ Btu per (lb)(F deg)}$$
$$\nu_m = 4.30 \times 10^{-5} \text{ sq ft per sec.}$$

An approximate determination of viscosity can be made by interpolation in Table 6, but an accurate value requires the use of *ASTM Standard Viscosity Chart B*.

$$w_m = 59.4 \text{ lb per cu ft}$$

Then from Equation 12

$$G = \frac{A_p q_t}{160 w_m c_m} = \frac{10^5 \times 224}{160 \times 59.4 \times 0.440} = 5380 \text{ gpm}$$

Equation 12 is based on a temperature drop of 20 F deg, therefore, the fluid must enter the slab at 123 F and leave at 103 F in order to have the desired mean temperature of 113 F.

Assume that the coil with the longest *equivalent* length is 300 ft and has a flow of 12 gpm. Such an arrangement would suggest the use of a coil of 1 in. IPS. From Table 1, Chapter 50, of the 1961 GUIDE AND DATA BOOK, the ID = 1.049 in. = 0.0875 ft, which gives an internal cross-sectional area of 0.00600 sq ft.

For 12 gpm the flow is 0.0268 cu ft per sec and the velocity is

$$V = \frac{0.0268}{0.00600} = 4.47 \text{ fps}$$

and Reynolds number, N_{Re}, is

$$N_{Re} = \frac{VD}{\nu_m} = \frac{4.47 \times 0.0875}{4.30 \times 10^{-5}} = 9100$$

From Fig. 19, Chapter 7 of the 1961 GUIDE AND DATA BOOK, using a roughness factor $e = 0.00015$, whence $e/D = 0.00172$, the friction factor f is found to be 0.034. Substituting in Equation 10 yields

$$h_f = f\frac{LV^2}{D2g} = 0.034 \times \frac{300}{0.0875} \times \frac{4.47^2}{2 \times 32.16}$$
$$= 36.6 \text{ ft of fluid} = 15.1 \text{ psia}$$

The friction loss could have been approximated two ways: (1) by using Fig. 2, and (2) by using Fig. 3 of this chapter in conjunction with Fig. 5 of Chapter 8.

In order to use Fig. 2, the viscosity of the oil must be known in SSU. As given above the kinematic viscosity of the oil at 113 F is 4.30×10^{-5} sq ft per sec. From Table 8, 4.30×10^{-5} sq ft per sec is equal to 39.1 SSU. Entering Fig. 2 at 39.1 SSU and reading friction loss for 12 gpm gives 12.8 ft per 100 ft. For a 300-ft coil this is 38.4 of fluid. This compares fairly well with the more exact figure of 36.6 ft as found by using the Fanning equation.

If the friction loss were approximated by Fig. 3 and Fig. 5 of Chapter 8, the result would have been 40.5 ft which is determined as follows: From Fig. 5 of Chapter 8, the loss for *water* flowing at 12 gpm in a one-inch pipe is 1200 milinches per foot or 10 ft per 100 ft. In this case, then, the loss for *water* would be 30 ft.

The correction factor for oil as compared to water is given in Fig. 3 as 1.35. The friction loss then would be 1.35×30 or 40.5 ft. Both of the approximation methods are conservative, but for large systems, this conservative approach may be costly.

The pump must deliver 5380 gpm against a 14.8 psia head. The heat exchanger must deliver 22.5 million Btuh with an inlet temperature of 103 F and an outlet temperature of 123 F. Actually some allowance should be made for the temperature drop in the piping between the slab and the heat exchanger.

Both the pump and heat exchanger manufacturers should be advised that the fluid is an oil and will operate over a wide temperature and viscosity range. If a low-limit thermostat is placed in the fluid line so that the minimum fluid temperature is 5 F, it can be seen from Tables 6 and 7 that the viscosity can reach about 300 SSU. From Table 8, it can be found that such a viscosity can reduce the pump head 5 percent and the capacity 3 percent. This means that the pump should be rated

$$\text{at } \frac{14.8}{0.95} = 15.6 \text{ psia and } \frac{5380}{0.97} = 5550 \text{ gpm.}$$

The expansion tank should be designed in accordance with the procedure outlined in Chapter 8, Hot Water Heating Systems. The amount of expansion should be based on the change in volume from the low temperature limit to the high temperature limit. Assuming the temperature range to be

$$5 \text{ to } +123 \text{ F, the expansion would be } \frac{62.4 - 59.1}{59.1} = 5.6$$

percent of the total volume in the system.

REFERENCES

[1] W. P. Chapman and S. Katunich: Heat requirements of snow melting systems (ASHAE TRANSACTIONS, Vol. 62, 1956, p. 359).