1.05 in. The nearest commercial thickness procurable is standard thick (1 1/32 in.) magnesia.

(It is of interest to note that the use of Fig. 3 will generally result in solutions which, for all practical purposes, agree closely with the specifications for thicknesses given in Table 12.)

6 ● Determine the minimum thickness of wool felt insulation having a conductivity of 0.30 necessary to prevent condensation of moisture on a 4-in. pipe carrying cold water at a temperature of 40 F when the surrounding air reaches *maximum conditions of 90 F with a relative humidity of 90 per cent.*

The difference between the temperature of the pipe and the surrounding air is 90 − 40 = 50 deg. For quick estimating purposes use the chart given in Fig. 2. Enter this chart at the lower left margin on the 90 per cent relative humidity line and proceed horizontally to the right to intersect the 90 deg air temperature line. Project a line up to the 50 deg temperature difference line, and then horizontally to the right to the intersection with the 4-in. pipe size line. From this point proceed down to intersect the 0.30 line which denotes the conductivity of the insulation. Directly opposite this point of intersection the correct thickness of insulation is read from the scale on the lower right margin. This chart solution denotes that wool felt 2.4-in. thick is sufficient to prevent condensation. The nearest commercial thickness procurable is 2½ in.

For prevention of condensation as well as for protection against freezing, if the thickness determined theoretically cannot be had, it is better to apply the next greater thickness procurable rather than to use any lesser thickness because an additional factor of safety is thus obtained.

7 ● A 3-in. pipe covered with 2 in. of hair felt insulation carries water out-of-doors. Weather Bureau records for the locality denote that a minimum outdoor temperature of zero F may be expected to prevail for a period not to exceed 10 hours. By use of Table 11 determine what degree of protection is provided against freezing if the water is stationary in the line for the 10 hour period.

Table 11 denotes that 4.27 hours are required to lower water temperature from 42 F to the freezing point (a 10 F drop) when the initial temperature difference between the water and air is 60 F. The temperature drop in the example is 45 − 32 = 13 F and the temperature difference is 45 − 0 = 45 F. The time required to lower the water from 45 F to the freezing point will therefore be $4.27 \times {}^{13}\!/_{10} \times {}^{6}\!/_{45} = 7.4$ hours.

It is evident that insufficient protection is provided to prevent freezing if a temperature of zero F prevails outside for any period longer than 7 hours 24 min.

8 ● With data given in Question 7 and its solution, determine the minimum flow of water which must be maintained to prevent freezing if the length of the water line is 85 ft.

From Table 11 it is seen that a flow of 0.94 lb of water per linear foot per hour is sufficient to prevent a drop in the water temperature from 42 F to the freezing point when the temperature difference between air and water is 60 F. With the conditions stated, a flow of $0.94 \times {}^{19}\!/_{13} \times {}^{45}\!/_{60} = 0.542$ lb of water per linear foot of pipe line per hour, or $85 \times 0.542 = 46.07$ lb of water per hour must flow through the line in order to prevent freezing.

Chapter 37

DISTRICT HEATING

Underground Steam Piping, Selection of Pipe Sizes, Provision for Expansion, Capacity of Returns with Various Grades, Pipe Conduits, Pipe Tunnels, Service Connections, Steam per Square Foot of Heating Surface, Fluid Meters and Metering, Rates

THOSE phases of district heating which frequently fall within the province of the heating engineer are outlined here with data and information for solving incidental problems in connection with institutions and factories and for the design of heating systems for buildings which are to be supplied with purchased steam. A complete district heating installation should not be attempted without a thorough study of the entire problem by men competent and experienced in that industry.

UNDERGROUND STEAM PIPING

The methods used in district heating work for the distribution of steam are applicable to any problem involving the supply of steam to a group of buildings. The first step is to establish the route of the pipes, and in this matter the local conditions so fully control the layout that little can be said regarding it.

Having established the route of the pipes, the next step is to calculate the pipe sizes. In district heating work it is common practice to design the piping system on the basis of pressure drop. The initial pressure and the minimum permissible terminal pressure are specified and the pipe sizes are so chosen that the required amount of steam, with suitable allowances for future increases, will be transmitted without exceeding this pressure drop. The steam velocity is therefore almost disregarded and may reach a very high figure. Velocities of 35,000 fpm are not considered high. By the use of this method the pipe sizes are kept to a minimum with consequent savings in investment.

The steam flowing through any section of the piping can be computed from a study of the requirements of the several buildings served. In general a condensation rate of 0.25 lb per hour per square foot of equivalent heating surface is a safe figure. This allows for line condensation which, however, is a small part of the total at times of maximum load. Any unusual requirements such as those for process steam should be individually calculated.

The steam requirements for water heating should be taken into account, but in most types of buildings this load will be relatively small compared with the heating load and will seldom occur at the time of the heating