assumed, it is obvious that a temperature closer to 583, or for instance 582 F may be selected. The mean temperatures of the two insulations corresponding to the new assumptions are (1200 + 582) ÷ 2 = 891 and (582 + 136) ÷ 2 = 359, and the interpolated conductivities corresponding to the new mean temperatures are 0.798 and 0.468 for the diatomaceous silica and 85 percent magnesia, respectively. By substituting in Equation 2

$$q_o = \frac{1200 - 136}{\frac{5.36}{0.798} + \frac{2.29}{0.468}} = \frac{1064}{6.72 + 4.90} = 91.5 \text{ Btu.}$$

Again referring to Fig. 4, it is seen that the temperature drop from the outer surface of the insulation to the surrounding air for a heat loss of 91.5 Btu = 58 deg, which

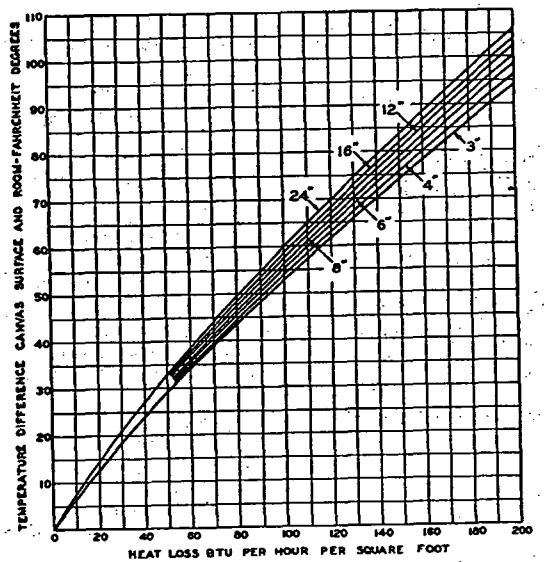

FIG. 4. HEAT LOSS FROM CANVAS-COVERED CYLINDRICAL SURFACES OF VARIOUS DIAMETERS

corresponds to the surface temperature of 136 F last assumed. The temperature drop through the diatomaceous silica is 91.5 × 6.72 = 615 F, corresponding to a temperature of 585 F between the two materials, which checks very closely with the temperature of 582 F last assumed. The heat loss is therefore 91.5 × 8.312 ÷ 3.312 or 230 Btu per sq ft of pipe surface. Since the surface area per linear foot of 6-in. pipe is 1.734 sq ft (Table 3), the heat loss per linear foot of pipe will be 230 × 1.734 = 399 Btu per hr.

The rate of heat loss from a surface maintained at constant temperature is greatly increased by air circulation over the surface. In the case of well-insulated surfaces, the increases in losses due to air velocity are very small as compared with increases from bare surfaces, because of the fact that air flowing over the surface of the insulation can increase only the conductance of heat from surface to air, and cannot change the internal conductance of the insulation itself. The maximum increase in heat loss

due to air velocity ranges from about 15 percent in the case of 1-in. thick insulation, to about 5 percent in the case of 3-in. thick insulation, provided that the insulation is thoroughly sealed so that air can flow only over the surface. If the conditions are such that the air may circulate through cracks and crevices in the insulation, the increases may be far greater than those given. Therefore, it is essential that insulation be applied in such a manner that air circulation within it, or between it and the pipe, is avoided.

Piping which is covered with a water-mixed product or insulation which will absorb moisture, particularly in damp locations, should be coated with a corrosion resisting paint, such as black asphaltum. This precaution may prevent early failure due to external pipe corrosion.

The frequent practice of omitting insulation on that portion of a pipe which passes through a masonry wall, or which may be in contact with other metals, should be avoided. Physical contact between the pipe surface and other structural materials of high thermal conductivity will result in heat transfer much greater than that shown in Tables 1 and 2 for transfer from bare pipe to air.

The saving due to use of insulation on piping is illustrated in *Example 4*.

Example 4: If the steam pipe given in *Examples 1* and *2* is covered with 1 in. thick 85 percent magnesia, determine the resulting total annual loss through the insulation. Also compute the monetary value of the annual saving and the percentage of saving over the heat loss from the bare pipe.

Solution: By referring to Fig. 1, the coefficient for 1 in. magnesia covering on a 2-in. pipe is found to be 0.300 Btu per (hr) (linear ft of pipe) (deg temperature difference) at a temperature difference of 169.4 F. Referring to Table 7 the correction factor to be applied is 1.05 × 0.300 = 0.315.

The total hourly loss per linear foot of pipe will then be 0.315 × 169.4 = 53.3 Btu. The total annual loss through the insulation = 53.3 × 165 (linear ft) × 4000 (hr) = 34,600 Mb. The annual bare pipe loss as determined in the solution of *Example 1* was found to be 181,600 Mb. The saving due to insulation is then 181,600 − 34,600 = 147,000 Mb per year.

From the solution of *Example 2*, it was found that the heat supplied to the system cost $0.804 per thousand Mb. Therefore, the monetary value of the saving = 0.804 (dollars) × 147 (thousand Mb) = $118.00, or 81.0 percent of the cost when using uninsulated pipe.

LOW TEMPERATURE PIPE INSULATION

Surfaces maintained at temperatures lower than the surrounding air are insulated to reduce the flow of heat and to prevent condensation. The insulating material should absorb a minimum amount of moisture, because the absorption of moisture substantially increases the conductivity of the material. This property is particularly important in the insulation of surfaces that are below the dew-point of the surrounding air. In such cases, due to vapor pressure difference, it is necessary to seal the surface of the insulating material against the penetration of water vapor which would condense within the material, causing a serious increase in heat flow, possible breakdown of the material, and corrosion of metal surfaces. An insulating material with a high degree of moisture absorption might pick up moisture before application and then, when the seal is in place and the temperature of the insulated surface reduced, release that moisture to the cold surface. There are a number of methods of producing vapor seals, some of which have been worked out by insulation