found to be 0.622 sq ft. The total annual loss through the insulation = 89.04 × 0.622 × 165 (linear feet) × 4000 (hours) = 36,550,000 Btu. The annual bare pipe loss as determined in the solution of Question 2 was found to be 188,000,000 Btu. The saving due to insulation is then 188,000,000 − 36,550,000 = 151,350,000 Btu per year.

From the solution of Question 3 it was found that the heat supplied to the system cost $0.804 per million Btu; therefore, the monetary value of the saving = 0.804 (dollars) × 151.35 (million Btu) = $121.69, or 81.2 per cent of the cost when using uninsulated pipe.

5 ● The manufacturer's list price for 85 per cent magnesia insulation is $0.36 per linear foot for 1-in. (standard thick) material to cover a 2-in. pipe. Determine the period of time required for the saving found in Question 4 to pay for the cost of the insulation if it can be purchased and applied at 80 per cent of list price (20 per cent discount).

The applied cost of insulation = 165 (linear feet) × 0.36 (dollars) × 0.80 (net) = 47.52. Since the annual saving as found in Question 4 amounts to $121.69, the insulation will pay for its cost in 47.52 ÷ 121.69 = 0.3905 years; in other words, the cost will be repaid 2.56 times by the saving obtained in one heating season.

6 ● The conductivity of magnesia insulation is 0.455 at the mean temperature which will result under the conditions of Question 4. Estimate the most economical thickness of magnesia for application on the pipe when operating under the conditions which are given in the foregoing problems and when a 20 per cent return is required on the investment for insulation.

Use chart given in Fig. 3. Begin at the left bottom margin and proceed successively as shown by the dotted line example to the following essential data which are collected from the problems previously given:

4000 hours operation per year.
$0.804 value of heat, dollars per million Btu.
169.4 deg temperature difference.
0.455 conductivity of insulation.
20 per cent discount from list, cost of insulation.
20 per cent fixed charges, return on investment.
2-in. pipe size.

Solution of the problem by use of Fig. 3 results in a required thickness of approximately 1.05 in. The nearest commercial thickness procurable is standard thick (1⅓₂ 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 18).

7 ● 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.

Chapter 40

ELECTRICAL HEATING

Resistors, Heating Elements, Electric Heaters, Unit Heaters, Central Fan Heating, Electric Steam Heating, Electric Hot Water Heating, Heating Domestic Water Supply, Industrial Heating, Reversed Cycle Refrigeration, Auxiliary Electric Heating, Control, Calculating Capacities, Power Problems, Insulation

ELECTRIC heating is steadily assuming a more important place in heating, ventilating and air conditioning installations, accelerated in many territories by the load building efforts of the utilities which usually include reduced rates to encourage such installations. Electrical heating has a logical place in the heating industry because of its features of flexibility, cleanliness, safety, convenience and ease of control. Electrical heating practice has many basic principles in common with fuel heating, but there are also important differences. When heat units are delivered to each room by wire, no combustion process is necessary, either at a central plant or at the individual room units. The maximum output of an electric heater is a fixed constant, unaffected by the temperature of the surrounding air and it follows that the maximum total load on an electrical heating system is the total wattage of connected electric heaters, regardless of weather conditions. The real obstacle to the more general adoption of electric heating for buildings is the cost of the electricity itself. Because the heat units produced electrically are more costly, their conservation is of more relative economic importance than with fuel heating, so that sponsors of electric heating give greater attention to temperature-insulated building construction, and to economy by accurate controls.

All heat is a form of energy. Fuels hold stored chemical energy which is released into heat by combustion. Electrical power is a form of energy which can be released into heat by passing it through a resisting material. Both fuel and electric heating have two divisions: *first*, the conversion of energy into heat; *second*, the distribution and practical use of the heat after it is produced.

In converting the chemical energy of fuels into heat by combustion, there is necessarily a considerable variation in thermal efficiency. This is not true, however, when converting electric power into heat, because 100 per cent of the energy applied in the resistor is always transformed into heat. In electric heating practice the engineer need not be concerned about efficiencies of heat production, but rather about efficiencies of heat utilization. It is the engineer's problem to distribute the electrically