

TABLE 13. THICKNESSES OF INSULATION ORDINARILY USED INDOORS^a

STEAM PRESSURES (LB GAGE) OR CONDITIONS	STEAM TEMPERATURES DEGREES FAHRENHEIT	THICKNESS OF INSULATION		
		Pipes Larger Than 4 in.	Pipes 2 in. to 4 in.	Pipes 1½ in. to 1¼ in.
0 to 25	212 to 267	1 in.	1 in.	1 in.
25 to 100	267 to 338	1½ in.	1 in.	1 in.
100 to 200	338 to 388	2 in.	1½ in.	1 in.
Low Superheat	388 to 500	2½ in.	2 in.	1½ in.
Medium Superheat	500 to 600	3 in.	2½ in.	2 in.
High Superheat	600 to 700	3½ in.	3 in.	2 in.

^aAll piping located outdoors or exposed to weather is ordinarily insulated to a thickness ½ in. greater than shown in this table, and covered with a waterproof jacket.

TABLE 14. THICKNESS OF LOOSE INSULATION FOR USE AS FILL IN UNDERGROUND CONDUIT SYSTEMS

STEAM PRESSURES (LB GAGE) OR CONDITIONS	STEAM TEMPERATURES DEGREES FAHRENHEIT	MINIMUM THICKNESS OF INSULATION IN INCHES					MINIMUM DISTANCE BETWEEN STEAM AND RETURN
		STEAM LINES			RETURN LINES		
		Pipes Less than 4 in.	Pipes 4 in. to 10 in.	Pipes Larger than 12 in.	Pipes Less than 4 in.	Pipes 4 in. and Larger	
Hot Water, or 0 to 25	212 to 267	1½	2	2½	1¼	1½	1
25 to 125	267 to 352	2	2½	3	1¼	1½	1¼
Above 125, or superheat	352 to 500	2½	3	3½	1¼	1½	1½

data on commonly used forms of tunnels and conduit systems have been published by the *National District Heating Association*².

Pipes in tunnels are covered with sectional insulation to provide maximum thermal efficiency and are also finished with good mechanical protection in the form of metal or waterproofing membrane outer jackets. Conduit systems are in more general use than tunnels. Pipes carried in conduits may be insulated with sectional insulation; however, the more usual practice is to fill the entire section of the conduit around the pipes with high quality, loose insulating material. The insulation must be kept dry at all times, and for this purpose effective waterproofing membranes enclose the insulation. A drainage system is also provided to divert water which may tend to enter the conduit.

The economical thickness of insulation for underground work is difficult of accurate determination due to the many variables which have to be considered. As a result of theories developed by J. R. Allen³, together with experimental data presented by others, the usual endeavor is to secure not less than 90 per cent efficiency for underground piping. Table

14 can be used as a guide in arriving at the minimum thickness of loose insulation fills to use for laying out conduit systems. Other factors such as the number of pipes and their combination of sizes, as well as the standard conduit sizes, are primary controlling factors in the amount and thickness of insulation for use.

When sectional insulation is applied to lines in tunnels or conduits, usual practice is to apply the most efficient materials ½ in. less in thickness than that determined by the use of Fig. 3. Fig. 3 is based on conditions of insulation exposed to the air, whereas normal ground temperature is substituted for air temperature in determining the temperature difference for use with the chart when applying it for underground pipe line estimates.

PROBLEMS IN PRACTICE

1 • What precautions must be taken in selecting insulation used for covering pipe lines carrying materials at temperatures lower than the dew point?

Materials intended for this service should be as moisture proof as possible and in addition an outer covering should be applied which is proof against diffusion of air and water vapor. If the material permits the diffusion of air, the air will reach a point in the covering where the temperature is below the dew point. The condensed water will gradually accumulate until the covering becomes saturated, which will increase the conductivity and perhaps lower the mechanical strength of the covering until it becomes worthless.

2 • Compute the total annual heat loss from 165 ft of 2-in. bare pipe in service 4000 hours per year. The pipe is carrying steam at 10 lb pressure and is exposed to an average air temperature of 70 F.

The pipe temperature is taken as the steam temperature, which is 239.4 F, obtained from Table 6, Chapter 1. The temperature difference between the pipe and air = $239.4 - 70 = 169.4$ deg. By interpolation of Table 1 between temperature differences of 157.1 F and 227.7 F, the heat loss from a 2-in. pipe at a temperature difference of 169.4 deg is found to be 1.677 Btu per hour per linear foot per degree temperature difference. The total annual heat loss from the entire = $1.677 \times 169.4 \times 165$ (linear feet) $\times 4000$ (hours) = 188,000,000 Btu.

3 • Coal costing \$11.50 per ton and having a calorific value of 13,000 Btu per pound is being burned in the furnace supplying steam to the pipe line given in Question 1. If the system is operating at an over-all efficiency of 55 per cent determine the monetary value of the annual heat loss from the line.

The cost of heat per 1 million Btu supplied to the system = $1,000,000 \times 11.5$ (dollars) $\div 13,000$ (Btu) $\times 2000$ (lb) $\times 0.55$ (efficiency) = \$0.804. The total cost of heat lost per year = 0.804×188 (million Btu) = \$151.15.⁴

4 • If the steam line given in Question 1 is covered with 1-in. thick 85 per cent magnesia, determine the resulting total annual heat 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.

By interpolation of Table 6 between temperature differences of 157.1 F and 227.7 F, the coefficient of transmission for 1-in. magnesia on a 2-in. pipe is found to be 0.525 Btu per hour per square foot of pipe surface per degree temperature difference at a temperature difference of 169.4 deg. The total hourly loss per square foot of insulated pipe will then be $0.525 \times 169.4 = 89.04$ Btu. From Table 3 the area per linear foot of 2-in. pipe is

⁴A closely approximate solution of this problem may be quickly made by use of the estimating chart given in Fig. 1.

¹Handbook of the National District Heating Association, Second Edition, 1932.

²Theory of Heat Losses from Pipes Buried in the Ground, by J. R. Allen (A.S.H.V.E. TRANSACTIONS, Vol. 26, 1920).