

service interruptions which may result from frozen water in pipes, it is essential that an efficient insulation be utilized. This table is based on the use of a material having a conductivity of 0.30. The initial water temperature is assumed to be 10 deg above, and the surrounding air temperature 50 deg below, the freezing point of water (temperature difference, 60 F).

The last column of Table 9 gives the minimum quantity of water at initial temperature of 42 F which should be supplied every hour for each linear foot of pipe, in order to prevent the temperature of the water from being lowered to the freezing point. The weights given in this column should be multiplied by the total length of the exposed pipe line expressed in feet. As an additional factor of safety, and in order to provide against temporary reductions in flow occasioned by reduced pressure, it is ad-

TABLE 8. HEAT GAINS FOR INSULATED COLD PIPES

Rates of heat transmission given in Btu per (hour) (Fahrenheit degree temperature difference between fluid in pipe and surrounding still air)

Based on materials having conductivity, $k = 0.30$

NOMINAL PIPE SIZE (INCHES)	ICE WATER THICKNESS			BRINE THICKNESS			HEAVY BRINE THICKNESS		
	Thickness of Insulation (Inches)	Btu Per Linear Foot	Btu Per Sq Ft Pipe Surface	Thickness of Insulation (Inches)	Btu Per Linear Foot	Btu Per Sq Ft Pipe Surface	Thickness of Insulation (Inches)	Btu Per Linear Foot	Btu Per Sq Ft Pipe Surface
1/4	1.5	0.110	0.502	2.0	0.098	0.446	2.8	0.087	0.394
1/2	1.6	0.119	0.431	2.0	0.111	0.405	2.9	0.094	0.340
1	1.6	0.139	0.403	2.0	0.124	0.352	3.0	0.104	0.294
1 1/4	1.6	0.155	0.357	2.4	0.131	0.300	3.1	0.113	0.260
1 1/2	1.5	0.174	0.351	2.5	0.134	0.270	3.2	0.118	0.238
2	1.5	0.200	0.322	2.5	0.151	0.244	3.3	0.147	0.197
2 1/4	1.5	0.228	0.303	2.6	0.170	0.226	3.4	0.162	0.176
3	1.5	0.269	0.293	2.7	0.186	0.202	3.5	0.176	0.167
3 1/4	1.5	0.295	0.282	2.9	0.191	0.183	3.7	0.182	0.154
4	1.7	0.294	0.248	3.0	0.241	0.165	3.9	0.202	0.138
5	1.7	0.349	0.239	3.0	0.259	0.150	4.0	0.228	0.130
6	1.7	0.404	0.233	3.0	0.318	0.140	4.0	0.263	0.116
8	1.9	0.455	0.201	3.0	0.383	0.135	4.0	0.309	0.110
10	1.9	0.559	0.198	3.0	0.438	0.131	4.0	0.364	0.108
12	1.9	0.648	0.194	3.0					

visable to double the rates of flow listed in the table. It must be emphasized that the flow rates and periods of time designated apply only for the conditions stated. To estimate for other service conditions, the following method of procedure may be used.

If water enters the pipe at 52 F instead of 42 F, the time required to cool it to the freezing point will be prolonged to twice that given in the table, or the rate of flow of water may be reduced so that the quantity required will be one-half that shown in the last column of Table 9. However, if the water enters the pipe at 34 F, it will be cooled to 32 F in one-fifth of the time given in the table. It will then be necessary to increase the rate of flow so that five times the specified quantity of water will have to be supplied in order to prevent freezing.

If the minimum air temperature is -38 F (temperature difference 80 F) instead of -18 F, the time required to cool the water to the freezing point will be 60/80 of the time given in the table, or the necessary quantity of water to be supplied will be 80/60 of that given.

In making calculations to arrive at the values given in Table 9, the loss of heat stored in the insulation, the effect of a varying temperature difference due to the cooling of pipe and water, and the resistance of

TABLE 9. DATA FOR ESTIMATING REQUIREMENTS TO PREVENT FREEZING OF WATER IN PIPES WITH SURROUNDING AIR AT -18 F

NOMINAL PIPE SIZE (INCHES)	NUMBER OF HOURS TO COOL 42 F WATER TO FREEZING POINT	WATER FLOW REQUIRED AT 42 F TO PREVENT FREEZING, POUNDS PER LINEAR FOOT OF PIPE PER HOUR					
		Thickness of Insulation in Inches (Conductivity, $k = 0.30$)					
		2	3	4	2	3	4
1/4	0.42	0.50	0.57	0.54	0.45	0.40	
1/2	0.83	1.02	1.16	0.68	0.55	0.48	
1	1.40	1.74	2.02	0.84	0.68	0.58	
1 1/4	1.94	2.48	2.90	0.95	0.75	0.64	
1 1/2	2.25	4.27	5.08	1.24	0.94	0.79	
2	4.55	6.02	7.20	1.47	1.11	0.93	
2 1/4	5.92	7.96	9.69	1.73	1.29	1.06	
3	7.35	9.88	12.20	1.98	1.46	1.19	
3 1/4	10.05	13.90	17.25	2.46	1.78	1.43	
4	13.00	18.10	22.70	2.96	2.12	1.70	
5	15.80	22.20	28.10	3.43	2.45	1.93	

the outer surface of the insulation to the transfer of heat to the air, have all been neglected. When these factors enter into the computations it is necessary to enlarge the factor of safety. Also as stated, the time shown in the table is that required to lower the water to the freezing point. A longer period would be required to freeze the water, but the danger point is reached when freezing starts. The flow of water will stop and the entire line will be in danger as soon as the water freezes across the section of the pipe at any point.

When water must remain stationary longer than the times designated in Table 9, the only safe way to insure against freezing is to install a steam or hot water line, or to place an electric resistance heater along the side of the exposed water line. The heating system and the water line are then insulated so that the heat losses from the heating system are not excessive, and the heating effect is concentrated against the water pipe where it is needed. For this form of protection 2 in. of an efficient insulation may be applied.

ECONOMICAL THICKNESS OF PIPE INSULATION

The thicknesses of insulation which ordinarily are used for various temperature conditions are given in Table 10. Where a thorough analysis of economic thickness is desired, this may be accomplished through the use of the chart, Fig. 6.

The dotted line on the chart illustrates its use in solving a typical

TABLE 10. THICKNESS OF PIPE INSULATION ORDINARILY USED INDOORS*

STEAM PRESSURE PSIG OR CONDITION	STEAM TEMPERATURE FAHRENHEIT DEGREES	THICKNESS OF INSULATION		
		Pipes Larger Than 4 in.	Pipes 2 in. to 4 in.	Pipes 1/2 in. to 1 1/4 in.
0 to 25	212 to 267	1 in.	1 in.	1 in.
25 to 100	267 to 338	1 1/2 in.	1 in.	1 in.
100 to 200	338 to 388	2 in.	1 1/2 in.	1 in.
Low Superheat	388 to 500	2 1/2 in.	2 in.	1 1/2 in.
Medium Superheat	500 to 600	3 in.	2 1/2 in.	2 in.
High Superheat	600 to 700	3 1/2 in.	3 in.	2 in.

* All piping located outdoors or exposed to water is ordinarily insulated to a thickness 1 in. greater than shown in this table, and covered with a waterproof jacket.