Table 22 .... Heat Losses from Horizontal Bare Steel Pipes and Flat Surfaces

In Btu per (Sq Ft of Pipe Surface) (Hour) (F Deg Temperature Difference Between Pipe and Air)

Pipe Size Inches	Linear Foot Factor[a]	Temperature Difference F Deg Between Pipe Surface and Surrounding Air, Air at 80 F.																			
		50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
¼	0.220	2.12	2.48	2.80	3.10	3.42	3.74	4.07	4.47	4.86	5.28	5.72	6.19	6.69	7.22	7.79	8.39	9.03	9.70	10.42	11.18
⅜	0.275	2.08	2.43	2.74	3.04	3.35	3.67	4.00	4.40	4.79	5.21	5.65	6.12	6.61	7.15	7.71	8.31	8.95	9.62	10.34	11.09
1	0.344	2.04	2.38	2.69	2.99	3.30	3.61	3.94	4.33	4.72	5.14	5.58	6.05	6.54	7.07	7.64	8.23	8.87	9.55	10.26	11.02
1¼	0.435	2.00	2.34	2.64	2.93	3.24	3.55	3.88	4.27	4.66	5.07	5.51	5.97	6.47	7.00	7.56	8.16	8.79	9.47	10.18	10.94
1½	0.497	1.98	2.31	2.61	2.90	3.20	3.52	3.84	4.23	4.62	5.03	5.47	5.93	6.43	6.98	7.52	8.12	8.75	9.43	10.14	10.89
2	0.622	1.95	2.27	2.56	2.85	3.15	3.46	3.78	4.17	4.56	4.97	5.41	5.87	6.37	6.89	7.45	8.05	8.68	9.36	10.07	10.82
2½	0.753	1.92	2.23	2.52	2.81	3.11	3.42	3.74	4.12	4.51	4.92	5.36	5.82	6.31	6.84	7.40	7.99	8.63	9.30	10.01	10.77
3	0.916	1.89	2.20	2.49	2.77	3.07	3.37	3.69	4.08	4.46	4.87	5.31	5.77	6.26	6.79	7.35	7.94	8.57	9.25	9.96	10.71
3½	1.047	1.87	2.18	2.46	2.74	3.04	3.34	3.66	4.05	4.43	4.84	5.27	5.73	6.23	6.75	7.31	7.91	8.54	9.21	9.92	10.67
4	1.178	1.85	2.16	2.44	2.72	3.01	3.32	3.64	4.02	4.40	4.81	5.25	5.71	6.20	6.72	7.28	7.87	8.51	9.18	9.89	10.64
4½	1.309	1.84	2.14	2.42	2.70	2.99	3.30	3.61	4.00	4.38	4.79	5.22	5.68	6.17	6.69	7.25	7.85	8.48	9.15	9.86	10.61
5	1.456	1.83	2.13	2.40	2.68	2.97	3.28	3.59	3.97	4.35	4.76	5.20	5.65	6.15	6.68	7.23	7.82	8.45	9.12	9.83	10.58
6	1.734	1.80	2.10	2.37	2.65	2.94	3.24	3.55	3.94	4.32	4.72	5.16	5.61	6.10	6.63	7.19	7.78	8.41	9.08	9.79	10.54
7	1.996	1.79	2.08	2.35	2.63	2.91	3.21	3.53	3.91	4.29	4.69	5.13	5.58	6.07	6.60	7.15	7.75	8.38	9.05	9.76	10.51
8	2.258	1.77	2.06	2.33	2.60	2.89	3.19	3.50	3.88	4.26	4.67	5.10	5.56	6.05	6.57	7.12	7.72	8.35	9.02	9.73	10.48
9	2.520	1.76	2.05	2.31	2.59	2.87	3.17	3.48	3.86	4.24	4.65	5.08	5.53	6.02	6.54	7.10	7.69	8.32	8.99	9.70	10.45
10	2.814	1.75	2.03	2.30	2.57	2.85	3.15	3.46	3.84	4.22	4.62	5.05	5.51	6.00	6.52	7.08	7.67	8.30	8.97	9.68	10.43
12	3.338	1.73	2.01	2.27	2.54	2.83	3.12	3.43	3.81	4.19	4.59	5.02	5.48	5.96	6.48	7.04	7.63	8.26	8.93	9.64	10.39
14	3.665	1.72	2.00	2.26	2.53	2.81	3.11	3.41	3.79	4.17	4.57	5.00	5.46	5.94	6.47	7.02	7.61	8.24	8.91	9.62	10.37
16	4.189	1.70	1.98	2.24	2.51	2.79	3.08	3.39	3.77	4.14	4.55	4.98	5.43	5.92	6.44	6.99	7.59	8.21	8.88	9.59	10.34
18	4.717	1.69	1.96	2.22	2.49	2.77	3.07	3.37	3.75	4.12	4.53	4.96	5.41	5.90	6.42	6.97	7.56	8.19	8.86	9.57	10.32
20	5.236	1.68	1.95	2.21	2.47	2.75	3.05	3.36	3.73	4.11	4.51	4.94	5.39	5.88	6.40	6.95	7.54	8.17	8.84	9.55	10.29
24	6.283	1.66	1.93	2.19	2.45	2.73	3.02	3.33	3.70	4.07	4.48	4.90	5.36	5.84	6.36	6.92	7.51	8.14	8.80	9.51	10.26
Vertical Surface		1.84	2.14	2.42	2.70	3.00	3.30	3.62	4.00	4.38	4.79	5.22	5.68	6.17	6.70	7.26	7.85	8.48	9.15	9.86	10.62
Horizontal Surface Facing Upward		2.03	2.37	2.67	2.97	3.28	3.59	3.92	4.31	4.70	5.12	5.56	6.02	6.52	7.05	7.61	8.21	8.85	9.52	10.24	10.99
Horizontal Surface Facing Downward		1.61	1.86	2.11	2.36	2.64	2.93	3.23	3.60	3.97	4.37	4.80	5.25	5.73	6.25	6.80	7.39	8.02	8.69	9.39	10.14

Values are for Flat Surfaces four square feet or more in area.

[a] To secure losses per linear foot, multiply sq ft losses in table by this factor. The losses per sq ft of pipe surface for pipes larger than 24 in. can be considered the same as the losses for the 24-in. pipe.

Solution:

$$R_1 = \frac{1}{f_c} + \frac{1}{C} = \frac{1}{1.63} + \frac{1}{0.84} = 1.80$$

$$R_2 = \frac{1}{U} = \frac{1}{0.14} = 7.14.$$

Then, by Equation 9:

$$\frac{1.80}{7.14} = \frac{70 - t_s}{70 - (-20)}$$

$$t_s = 47.3 \text{ F}.$$

The concrete surface temperature is of interest since reference to a psychrometric chart or table will show that moisture condensation could occur on this surface under the above conditions (47.3 F) if the relative humidity in the room exceeds 44 percent. Additional roof insulation should be considered above the slab to avoid condensation at this point if higher relative humidities in the room are anticipated.

The same procedure can be used for determining the temperature at any point within the structure.

A chart for determining inside wall surface temperature is given in Fig. 13 of Chapter 14 of the 1964 Guide And Data Book.

CONDUCTIVITY OF INDUSTRIAL INSULATIONS

The conductivities of various materials used for insulating steam and hot water systems are given in Table 21. They are given as functions of the mean temperatures or the arithmetic mean of the inner and outer surface temperatures of the insulations.

BARE SURFACE HEAT LOSSES—FLAT SURFACES AND PIPE

Heat losses from horizontal bare steel pipes, based on tests at Mellon Institute and calculated from the fundamental radiation and convection equations (Chapter 4), are given in Table 22. This table also gives the heat losses or surface conductances for flat, vertical, and horizontal surfaces for surface temperatures up to 1080 F with the surrounding air at 80 F. The surface per linear foot of pipe is given in the second column of Table 22.

Table 23 .... Heat Losses from Bare Tarnished Copper Tube[a]

Nominal Diameter of Tube (Inches)	Temperature of Tube, F							
	120	150	180	210	240	270	300	330
	Temperature Difference, Tube to Air, F Deg							
	50	80	110	140	170	200	230	260
	Heat Loss per Linear Foot of Tube, Btu per Hr.							
¼	8	14	21	29	37	46	56	66
⅜	10	18	28	37	48	60	72	85
½	13	22	33	45	59	72	88	104
¾	15	26	39	53	68	85	102	121
⅞	17	30	45	61	79	97	117	139
1	21	37	55	75	97	120	146	173
1¼	25	45	66	90	117	145	175	207
1½	29	52	77	105	135	167	203	241
2	37	66	97	132	171	212	257	305
2½	44	78	117	160	206	255	310	367
3	51	92	136	186	240	297	360	428
3½	59	104	156	212	274	340	412	490
4	66	118	174	238	307	381	462	550
5	80	142	212	288	373	464	561	669
6	93	166	246	336	432	541	656	776
8	120	215	317	435	562	699	848	1010
10	146	260	387	527	681	848	1031	1227
12	172	304	447	621	802	999	1214	1446

[a] Extracted from Reference 9, Used by permission.

Heat losses from tarnished copper pipe and tube[9] are given in Table 23. The surface per linear foot of tube is given in Table 24. Table 2, Section A, also gives the surface conductances for flat surfaces of different emissivities and orientations in contact with still air. Table 25 gives the area, in square feet, of flanges and fittings for various standard pipe sizes. These tables can be used to advantage in estimating the amount of insulation required.

Example 12 shows how the annual heat loss from uncovered pipe may be computed from the data in Table 22.

Example 12: Compute the total annual heat loss from 165 ft of 2 in. bare pipe in service 4000 hr per year. The pipe is carrying steam at 10 psi pressure and is exposed to an average air temperature of 80 F.

Solution: The pipe temperature is taken as the steam temperature, which is 239.4 F, obtained by interpolation from Steam Tables. The temperature difference between the pipe and air = 239.4 − 80 = 159.4 F. By interpolation in Table 22 between temperature differences of 150 and 200 F, the heat loss from a 2-in. pipe at a temperature difference of 159.4 F is found to be 2.615 Btu per (hr) (sq ft) (F deg). The total annual heat loss from the entire line = 2.615 × 159.4 × 0.622 (linear ft factor) × 165 (linear ft) × 4000 (hr) = 171,100 (MB = 1000 Btu).

Table 24 .... External Surface per Linear Foot of Copper Tubing

Outside diameter ⅛ in. greater than nominal size

Tube Size (Inches)	Surface Area (Sq Ft)	Tube Size (Inches)	Surface Area (Sq Ft)	Tube Size (Inches)	Surface Area (Sq Ft)
⅛	0.164	2	0.556	5	1.342
¼	0.229	2½	0.687	6	1.604
1	0.295	3	0.818	8	2.128
1¼	0.360	3½	0.949	...	.....
1½	0.426	4	1.080	...	.....

HEAT FLOW CALCULATIONS

In calculating heat flow, Equations 10 and 11 are generally used. Equation 10 is used for flat surfaces (Fig. 5), and Equation 11 is used for cylindrical surfaces (Fig. 6).

$$q_s = \frac{t_s - t_a}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + R_s} \tag{10}$$

$$q_s = \frac{t_s - t_a}{\frac{r_s \log \frac{r_1}{r_s}}{k_1} + \frac{r_s \log \frac{r_1}{r_s}}{k_2} + R_s} \tag{11}$$

where

q_s = rate of heat transfer per square foot of outer surface of insulation, Btu per (hour) (square foot).

Table 25 .... Area of Flanged Fittings, Square Feet[a]

Nominal Pipe Size (Inches)	Flanged Coupling		90 Deg Ell		Long Radius Ell		Tee		Cross	
	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy
1	0.320	0.438	0.795	1.015	0.892	1.083	1.235	1.575	1.622	2.07
1¼	0.383	0.510	0.957	1.098	1.084	1.340	1.481	1.925	1.943	2.53
1½	0.477	0.727	1.174	1.332	1.337	1.874	1.815	2.68	2.38	3.54
2	0.672	0.848	1.65	2.01	1.84	2.16	2.54	3.09	3.32	4.06
2½	0.841	1.107	2.09	2.57	2.32	2.76	3.21	4.05	4.19	5.17
3	0.945	1.484	2.38	3.49	2.68	3.74	3.66	5.33	4.77	6.95
3½	1.122	1.644	2.98	3.96	3.28	4.28	4.48	6.04	5.83	7.89
4	1.344	1.914	3.53	4.64	3.96	4.99	5.41	7.07	7.03	9.24
4½	1.474	2.04	3.95	5.02	4.43	5.46	6.07	7.72	7.87	10.07
5	1.622	2.18	4.44	5.47	5.00	6.02	6.81	8.52	8.82	10.97
6	1.82	2.78	5.13	6.99	5.99	7.76	7.84	10.64	10.08	13.75
8	2.41	3.77	6.98	9.76	8.56	11.09	10.55	14.74	13.44	18.97
10	3.43	5.20	10.18	13.58	12.35	15.60	15.41	20.41	19.68	26.26
12	4.41	6.71	13.08	17.73	16.35	18.76	19.67	26.65	24.87	34.11

[a] Including areas of accompanying flanges bolted to the fitting.