Table 1 .... Heat Gain Factors (Walls, Floor and Ceiling)

Btu per (sq ft) (24 hr)

Insulation	Temp difference (ambient temp minus storage temp), F deg																	
Cork or equivalent in.	1	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
3	2.4	96	108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288
4	1.8	72	81	90	99	108	117	126	135	144	153	162	171	180	189	198	207	216
5	1.44	58	65	72	79	87	94	101	108	115	122	130	137	144	151	159	166	173
6	1.2	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144
7	1.03	41	46	52	57	62	67	72	77	82	88	93	98	103	108	113	118	124
8	0.90	36	41	45	50	54	59	63	68	72	77	81	86	90	95	99	104	108
9	0.80	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96
10	0.72	29	32	36	40	43	47	50	54	58	61	65	68	72	76	79	83	86
11	0.66	26	30	33	36	40	43	46	50	53	56	60	63	66	69	73	76	79
12	0.60	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72
13	0.55	22	25	28	30	33	36	39	41	44	47	50	52	55	58	61	63	66
14	0.51	20	23	26	28	31	33	36	38	41	43	46	49	51	54	56	59	61
Single glass	27.0	1080	1220	1350	1490	1620	1760	1890	2030	2160	2290	2440	2560	2700	2840	2970	3100	3240
Double glass	11.0	440	500	550	610	660	715	770	825	880	936	990	1050	1100	1160	1210	1270	1320
Triple glass	7.0	280	320	350	390	420	454	490	525	560	595	630	665	700	740	770	810	840

Note: Where wood studs are used multiply the above values by 1.1

weight, specific heat above and below freezing, its freezing temperature, and latent heat. When a definite weight of product is cooled from one state and temperature to another state and temperature, some or all of the following calculations must be made:

Heat removal from initial temperature to some lower temperature above freezing:

$$Q = W \times c \times (t_i - t_s) \quad (4)$$

Heat removal from initial temperature to freezing point of product:

$$Q = W \times c \times (t_i - t_f) \quad (5)$$

Heat removal to freeze product:

$$Q = W \times h_{if} \quad (6)$$

Heat removal from freezing point to final temperature below freezing:

$$Q = W \times c_f \times (t_f - t_f) \quad (7)$$

where

Q = heat removed, Btu.
W = weight of product, pounds.
c = specific heat of product above freezing, Btu per (pound) (Fahrenheit degree).
t_i = initial temperature above freezing, Fahrenheit.
t_s = lower temperature above freezing, Fahrenheit.
t_f = freezing temperature of product, Fahrenheit.
h_{if} = latent heat of fusion, Btu per pound.

Table 2 ... Minimum Insulation Thicknesses

Storage temperature F	Cork or equivalent thickness (inches)	
	Northern U. S.	Southern U. S.
50 to 60	2	3
40 to 50	3	4
25 to 40	4	5
15 to 25	5	6
0 to 15	6	7
0 to −15	7	8
−15 to −40	9	10

Table 3 ..... Allowance for Sun Effect

(Fahrenheit degrees to be added to the normal temperature difference for heat leakage calculations to compensate for sun effect—not to be used for air conditioning design)

Type of surface	East wall	South wall	West wall	Flat roof
Dark colored surfaces such as Slate roofing, Tar roofing, Black paints	8	5	8	20
Medium colored surfaces, such as Unpainted wood, Brick, Red tile, Dark cement, Red, gray or green paint	6	4	6	15
Light colored surfaces, such as White stone, Light colored cement, White paint	4	2	4	9

Table 4 .... Average Air Changes per 24 hr. for Storage Rooms due to Door Openings and Infiltration (above 32 F)

Volume cu ft	Air changes per 24 hr	Volume cu ft	Air changes per 24 hr
200	44.0	6,000	6.5
300	34.5	8,000	5.5
400	29.5	10,000	4.9
500	26.0	15,000	3.9
600	23.0	20,000	3.5
800	20.0	25,000	3.0
1,000	17.5	30,000	2.7
1,500	14.0	40,000	2.3
2,000	12.0	50,000	2.0
3,000	9.5	75,000	1.6
4,000	8.2	100,000	1.4
5,000	7.2		

Note: For heavy usage multiply the above values by 2.
For long storage multiply the above values by 0.6.

Table 5 ... Heat Removed in Cooling Air to Storage Room Conditions

(Btu per cu ft)

Storage room temp F	Temperature of outside air, F: 85		90		95		100	
	Relative humidity, Percent: 50	60	50	60	50	60	50	60
65	0.65	0.85	0.93	1.17	1.24	1.54	1.58	1.95
60	0.85	1.03	1.13	1.37	1.44	1.74	1.78	2.15
55	1.12	1.34	1.41	1.66	1.72	2.01	2.06	2.44
50	1.32	1.54	1.62	1.87	1.93	2.22	2.28	2.65
45	1.50	1.73	1.80	2.06	2.12	2.42	2.47	2.85
40	1.69	1.92	2.00	2.26	2.31	2.62	2.67	3.06
35	1.86	2.09	2.17	2.43	2.49	2.79	2.85	3.24
30	2.00	2.24	2.26	2.53	2.64	2.94	2.95	3.35

Storage room temp F	Temperature of outside air, F: 40		50		90		100	
	Relative humidity, Percent: 70	80	70	80	50	60	50	60
30	0.24	0.29	0.58	0.66	2.26	2.53	2.95	3.35
25	0.41	0.45	0.75	0.83	2.44	2.71	3.14	3.54
20	0.56	0.61	0.91	0.99	2.62	2.90	3.33	3.73
15	0.71	0.75	1.06	1.14	2.80	3.07	3.51	3.92
10	0.85	0.89	1.19	1.27	2.93	3.20	3.64	4.04
5	0.98	1.03	1.34	1.42	3.12	3.40	3.84	4.27
0	1.12	1.17	1.48	1.56	3.28	3.56	4.01	4.43
−5	1.23	1.28	1.59	1.67	3.41	3.69	4.15	4.57
−10	1.35	1.41	1.73	1.81	3.56	3.85	4.31	4.74
−15	1.50	1.53	1.85	1.92	3.67	3.96	4.42	4.86
−20	1.63	1.68	2.01	2.09	3.88	4.18	4.66	5.10
−25	1.77	1.80	2.12	2.21	4.00	4.30	4.78	5.21
−30	1.90	1.95	2.29	2.38	4.21	4.51	4.90	5.44

c_f = specific heat of product below freezing, Btu per (pound) (Fahrenheit degree).
t_f = final temperature below freezing, Fahrenheit.

The product load is represented by the sum of the several loads given above. If it is necessary to remove the heat from the product in a given number of hours, the equivalent load, based on 24 hour calculations, is found as follows:

$$\text{Btu per 24 hr} = \frac{\text{Product load} \times 24}{\text{Hr reqd for product load}}$$

Specific heats above and below freezing and *latent heats of fusion* for many products are given in Table 4, Chapter 69. It should be noted that the latent heat of fusion has a definite relationship to the water content of the product; in the absence of data on the latent heat of a product and with a knowledge of its moisture content, the latent heat may be estimated by multiplying the percentage of water expressed as a decimal by 144, the latent heat of fusion of water. Most food products have a freezing temperature in the range of 26 to 31 F, with an average freezing temperature of about 28 F. If the exact freezing temperature is unknown, it may be assumed to be 28 F.

For a discussion of food freezing, refer to Section V of the 1964 Guide And Data Book.

Example 1: 100 lb of lean beef are to be cooled from 65 to 40 F, after which it is to be frozen and cooled to 0 F.

Solution: From Table 4, Chap. 69, the specific heat of lean beef before freezing is 0.77 Btu per (lb)(F deg) and after freezing is 0.40 Btu per (lb)(F deg). The latent heat of fusion is 100 Btu/lb.

To cool from 65 F to 40 F in chill room:

$$100 \times 0.77 \times (65 - 40) = 1925 \text{ Btu}$$

To cool from 40 F to freezing point in freezer:

$$100 \times 0.77 \times (40 - 28) = 924 \text{ Btu}$$

To freeze:

$$100 \times 100 = 10{,}000 \text{ Btu}$$

To cool from freezing point to storage temperature:

$$100 \times 0.40 \times (28 - 0) = 1120 \text{ Btu}$$

Total = 1925 + 924 + 10,000 + 1120 = 13,969 Btu

Fresh fruits and vegetables give up heat during storage. It must be remembered that they are alive and continue to undergo changes during storage. The most important of these changes is produced by respiration, a process in which the oxygen of the air is combined with the carbon of the plant tissue. During this process, energy is released in the form of heat. The amount of heat liberated varies with the type and temperature of the product. The colder the product, the less the heat of respiration. The rate of evolution of heat of various products is listed in Table 4, Chapter 69.

HEAT GAIN FROM PEOPLE, LIGHTS AND OTHER SOURCES

All electrical energy dissipated in the refrigerated space (lights, motors, heaters, etc.) must be included in the heat load. Each watt is equal to 3.42 Btu per hr. Heat equivalents of electric motors are shown in Table 6. People give up heat at