

Table 6 Heat Equivalent of Electric Motors

Motor hp	Btu per (hp) (hr)		
	Connected load in ref. space ¹	Motor losses outside ref. space ²	Connected load outside ref. space ³
1/4 to 1/2	4,250	2,545	1,700
1/2 to 3	3,700	2,545	1,150
3 to 20	2,950	2,545	400

¹ For use when both useful output and motor losses are dissipated within refrigerated space; motors driving fans for forced circulation unit coolers.
² For use when motor losses are dissipated outside refrigerated space and useful work of motor is expended within refrigerated space; pump on a circulating brine or chilled water system, fan motor outside refrigerated space driving fan circulating air within refrigerated space.
³ For use when motor heat losses are dissipated within refrigerated space and useful work expended outside of refrigerated space; motor in refrigerated space driving pump or fan located outside of space.

varying rates depending upon the temperature, type of work, clothing, size, etc. The average hourly load due to occupancy is shown in Table 7. When people go into the refrigerated space for short durations, they will carry with them a considerable amount of heat over and above that listed in Table 7. Therefore, some allowance must be made if the traffic load of this type is heavy.

SHORT METHOD

There are many short or rule-of-thumb methods of estimating load. Some, based on external surface only. These are basically incorrect since the usage load will depend upon the volume, and the volume of a refrigerator is not proportional to the external surface. To illustrate, assume two refrigerators both with external areas equal to 1600 sq ft. If they are both 10 ft high, one may have floor dimensions of 35 x 10 ft, another 20 x 20 ft. Calculation will show a 12.5 percent variation in volume.

A short method based on volume as well as surface will give more dependable results than a method based on surface only. Of the four general sources of heat in the refrigerator (wall losses, air change, product, and miscellaneous), the external surface will always be proportional to the wall losses. The problem of simplification is with the remaining three sources in terms of volume. Table 8 gives the probable values for the gains due to air changes, product, and miscellaneous. The values are based on experience, and judgment must be used in its application.

To find the hourly load, the total 24 hr load is divided by the desired compressor operating time.

Refrigeration equipment is designed to operate continuously without ill effect, and it is the defrost problem that determines the compressor operating time.

When the refrigerant temperature is 30 F or higher, there is no frost and the general practice has been to select equipment based on 20 or 22 hr operation.

Table 7 Heat Equivalent of Occupancy

Cooler temperature F	Heat equivalent/person Btu/hr
50	720
40	840
30	950
20	1,050
10	1,200
0	1,300
-10	1,400

For refrigerant temperatures below 30 F and storage temperatures of 35 F and higher, off-cycle defrosting has been generally used; defrosting by stopping compressor and allowing the relatively warm box air to pass through the coil until the frost melts. Off-cycle defrosting for a 35 F storage temperature requires the compressor to be off one hour for every two hours of compressor operation, and the load calculations are based on 16 hr operation. Where a positive defrost method is used and the defrosting time is reduced, the compressor operating time can be increased; this averages about 20 hr. However, it is suggested that the equipment manufacturer's recommendations on operating time be followed.

For refrigerators maintaining temperatures below 34 F, off-cycle defrosting cannot be used and some positive method of defrosting must be provided.

All of these methods add some heat to the refrigerator. The amounts of heat vary considerably with different methods. It is suggested that the recommendations of the manufacturer be followed, both in the heat added due to defrosting and the suggested operating time.

The calculated hourly load is used as a guide in selecting equipment. Since the compressor sizes are limited to comparatively large increments, the compressor selection must be guided by the calculated load; and the actual selection of compressor may change the calculated time up or down. The evaporator should be selected to balance the selected compressor capacity, and not the original calculated load.

Examples 2, 3, and 4 illustrate typical load calculations and compressor capacity selection.

Example 2: Calculate the total load for a 20 ft x 10 ft x 10 ft (outside dimensions) refrigerated room, having 4 in. of cork insulation. The room is to be maintained at 30 F, while the outside air is at 90 F dry-bulb temperature and 60 percent relative humidity. The product is 2000 lb of beef at 40 F to be cooled to 30 F in 24 hr. The electrical load in the room is 200 watts.

Solution A: The outside surface area of the room is 1000 sq ft (20 x 10 x 4 + 10 x 10 x 2). From Table 1, for a temperature difference of 60 F deg, the heat gain factor for 4 in. cork insulation is found to be 108 Btu per (sq ft) (24 hr). The wall heat gain is 1000 x 108 = 108,000 Btu per 24 hr.

Assuming that the walls are 1 ft thick, the internal volume of the room is 19 x 9 x 9 = 1540 cu ft. From Table 4, the number of air changes per 24 hr is found to be 14. From Table 5, the heat required to cool the outside air is found to be 2.53 Btu per cu ft. The air change load is 1540 x 14 x 2.53 = 54,600 Btu per 24 hr. From Table 4, Chapter 69, the specific heat of beef is 0.77 Btu per (lb) (F deg). The product load is 2000 x 0.77 x (40 - 30) = 15,400 Btu per 24 hr.

The load due to electrical equipment in the room is 200 x 3.41 x 24 = 16,400 Btu per 24 hr.

Item	Btu/24 Hr
Wall gain	108,000
Air change	54,600
Product	15,400
Electrical	16,400
Calculated Load	194,400
Add 10 percent safety factor	19,440
Total load	213,840

For 16 hr compressor operation, the load becomes 213,840/16 = 13,360 Btu per hr.

For 20 hr compressor operation, the load is 213,840/20 = 10,690 Btu per hr.

Solution B: (Short method using Table 8). The wall heat gain is the same as in **Solution A** = 108,000 Btu per 24 hr. The usage, heat gain (Table 8) is 55.2 Btu per (24 hr) (cu ft) or 1540 x 55.2

Refrigeration Load

Table 8 Usage Heat Gain, Btu per 24 hr for One Cu Ft Interior Capacity

Volume cu ft	Service*	Temperature difference (ambient temp minus storage room temp), F deg										
		1	40	50	55	60	65	70	75	80	90	100
20	Average	4.68	187	234	258	281	305	328	351	374	421	468
	Heavy	5.51	220	276	303	331	358	386	413	441	496	551
30	Average	3.30	132	165	182	198	215	231	248	264	297	330
	Heavy	4.56	182	228	251	274	297	319	342	365	410	456
50	Average	2.28	91	114	126	137	148	160	171	182	205	228
	Heavy	3.55	142	177	196	213	231	249	267	284	320	355
75	Average	1.85	74	93	102	111	120	130	139	148	167	185
	Heavy	2.88	115	144	158	173	188	202	216	230	259	288
100	Average	1.61	64	81	89	97	105	113	121	129	145	161
	Heavy	2.52	101	126	139	151	164	176	189	202	227	252
200	Average	1.38	55	69	76	83	90	97	103	110	124	138
	Heavy	2.22	90	111	122	133	144	155	166	178	200	222
300	Average	1.30	52.0	65	71.5	78	84.5	91	97.5	104	117	130
	Heavy	2.08	83.2	104	114	125	136	146	156	166	187	208
400	Average	1.24	49.6	62	68.2	74.4	80.6	86.8	93	99.2	112	124
	Heavy	1.96	78.4	98	108	118	128	137	147	157	176	196
500	Average	1.21	48.4	60.5	66.6	72.6	78.7	84.7	90.7	96.8	109	121
	Heavy	1.87	74.8	93.5	103	112	122	131	140	150	168	187
600	Average	1.17	46.8	58.5	64	70	76	82	88	94	105	117
	Heavy	1.85	74.0	92.5	102	111	120	130	139	148	167	185
800	Average	1.11	44.4	55	61.1	66.6	72.2	77.7	83.3	88.8	100	111
	Heavy	1.76	70.4	88.0	96.8	106	115	123	132	141	158	176
1,000	Average	1.10	44.0	55.0	60.5	66	71.5	77	82.5	88	99	110
	Heavy	1.67	66.8	83.5	91.9	100	108	117	125	134	150	167
1,200	Average	.995	39.8	49.8	54.7	59.7	64.7	69.7	74.7	79.6	89.6	99.5
	Heavy	1.53	63.2	79.0	86.9	94.8	103	111	119	128	142	158
1,500	Average	.920	36.8	46.0	50.6	55.2	59.8	64.4	69	73.6	82.8	92
	Heavy	1.50	60.0	75.0	82.5	90.0	97.5	105	113	120	135	150
2,000	Average	.825	33.4	41.8	45.9	50.1	54.3	58.5	62.7	66.8	75.2	83.5
	Long storage	.775	31.0	38.8	42.6	46.5	50.4	54.3	58.1	62	69.8	77.5
3,000	Average	.750	30.0	37.5	41.3	45.0	48.8	52.5	56.2	60.0	67.5	75.0
	Long storage	.576	23.0	28.8	31.7	34.6	37.3	40.3	43.2	46.1	51.8	57.6
5,000	Long storage	.403	16.1	20.2	22.2	24.2	26.2	28.2	30.2	32.2	36.3	40.3
7,500	Long storage	.305	12.2	15.3	16.8	18.3	19.8	21.4	22.9	24.4	27.5	30.5
10,000	Long storage	.240	9.6	12.0	13.2	14.4	15.6	16.8	18.0	19.2	21.6	24.0
20,000	Long storage	.187	7.48	9.35	10.3	11.2	12.2	13.1	14.0	15.0	16.8	18.7
50,000	Long storage	.178	7.12	8.90	9.79	10.7	11.6	12.5	13.4	14.2	16.0	17.8
75,000	Long storage	.176	7.04	8.80	9.68	10.6	11.5	12.3	13.2	14.1	15.8	17.6
100,000	Long storage	.173	6.92	8.65	9.52	10.4	11.2	12.1	13.0	13.8	15.6	17.3

* For average and heavy service, product load is based on product entering at 10 deg above the refrigerator temperature; for long storage, the entering temperature is approximately equal to the refrigerator temperature. Where the product load is unusual, do not use this table.

= 85,200 Btu per 24 hr. The total load is 108,000 + 85,200 = 193,200 Btu per 24 hr.

Example 3: Find the total load for a refrigerated storage room; 15 ft x 11 ft x 9 ft (outside dimensions) with 4 in. cork insulation, two triple-glass windows, each 6 ft x 5 ft. The ambient air temperature is 90 F and the room temperature is to be 40 F. Two men work in the room from 8 A.M. to 4 P.M., and 800 watts of lighting and motors are in operation during the same period. The product, 2000 lb of beef, is to be cooled from 60 F to 40 F between 6 P.M. and 6 A.M.

Solution: The gross surface area of the outside walls is (15 x 9 + 11 x 9 + 15 x 11) x 2 = 798 sq ft. The glass area is 8 x 5 x 2 = 80 sq ft. The net insulated surface area is 798 - 80 = 718 sq ft. From Table 1, the heat gain factor for the insulated wall is found to be 90 Btu per (sq ft) (24 hr), while the factor for the glass area is 350 Btu per (sq ft) (24 hr), for a 50 F deg temperature difference. The heat gain through the walls is 718 x 90 = 64,620 Btu per 24 hr, and the heat gain through the glass is 80 x 350 = 28,000 Btu per 24 hr.

The internal volume of the room is 14 x 10 x 8 = 1120 cu ft. From Table 4, the number of air changes per 24 hr is found to be 16.6. The heat required to cool air from 90 F to 40 F is 2.26 Btu per cu ft (from Table 5). The air change load is 1120 x 16.6 x 2.26 = 42,000 Btu per 24 hr.

The product load is (2000 x 0.77 x 20) (24 + 12) = 61,600 Btu per 24 hr.

The load due to people is 2 x 750 x 24 = 36,000 Btu per 24 hr. The electrical load is 800 x 3.41 x 24 = 65,500 Btu per 24 hr. In order to determine the hourly load requirements, a comparison of the day and night loads is necessary.

Item	Btu per 24 Hr	
	NIGHT	DAY
Wall Load	87,400	87,000
Air Change Load	42,000	42,000
Product	61,600	—
People	—	36,000
Electrical	—	65,500
Calculated Load	191,000	230,500
10% Safety Factor	19,100	23,100
Total	210,200	253,600

The day load is greater and should be used in selecting equipment.

Example 4: Determine the load for a banana storage room,