Heat load in Refrigeration System's

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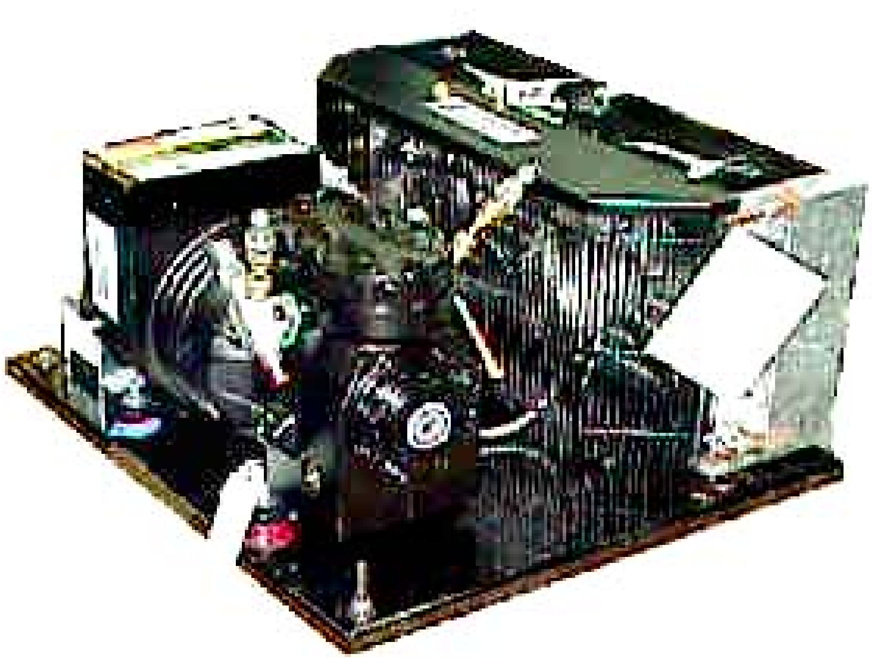

The more complete the information, the better the calculation. Good calculations are the first step in assuring adequate selection in refrigeration equipment for the project.

Heat load in Refrigeration system

Survey

The person involved in heat transfer calculations needs accurately information to predict the heat load on a refrigerated system. The more complete the information, the better the calculation. Good calculations are the first step in assuring adequate selection in refrigeration equipment for the project.

Design ambient temperatures

This would be the ambient surrounding the box necessary for the load calculations. Another ambient to consider is the one surrounding the condensing unit, which will affect equipment selection.

Storage Temperature and Humidity Requirements

Refrigeration equipment by its nature is a dehumidification process. To minimize the drying effect of the refrigeration equipment, by selecting the appropriate temperature difference (T.D.) between the saturated suction temperature of the evaporator and the room air. The T.D. selected approximates the desired relative humidity.

Temperature Difference in Refrigeration Space

The preservation of food and other products in optimum condition by refrigeration depends not only upon the temperature of the refrigerated space but also upon the humidity of the space. When relative humidity in the refrigerated space is too high, the growth of mold, fungus, and bacteria is encouraged. Mold and slime conditions may occur particularly on meats that are in a refrigerated space with higher than 95% relative

humidity and/or low airflow across the product. When relative humidity in the refrigerated space is too low and/or there is an excessive of airflow across the refrigerated product, excessive dehydration will occurs.

Table1

Class	T.D.	Approximately R H %	Description of product classes
1	7º to 9º	90%	Results in a minimum amount of moisture evapo- ration during storage. Includes vegetables, pro- duce, flowers, unpack- aged ice and chill rooms.
2	10º to12º	80 – 85%	Includes general storage and convenience store coolers, pack- aged meats and vegetables, fruits and similar pro- ducts. Prod- ucts require slightly lower relative humidity levels than those in Class I.
3	12ºto16º	65- 80%	Includes beer, wine, pharmaceuticals, potatoes and onions, tough skin fruits such as melons and short-term pack- aged products. These products require only moderate relative hu- midities.
4	17ºto22º	50- 65%	Includes prep and cutting rooms, beer warehouses, candy or film storage and loading docks. These applications need only low, relative humidities or are unaffected by humidity.

The most important factor governing the humidity in the refrigerated space is the temperature difference of the evaporator. The greater the temperature difference of the evaporator the lower is the relative humidity in the refrigerated space. Likewise, the smaller the temperature difference of the evaporator and the closer the temperature of the leaving air of the evaporator is to the refrigerated space, the higher is the relative humidity in the refrigerated space.

Evaporators Temperature Difference in Refrigeration

For humidity control

TABLE 2

Relative humidity %	Natural Convection	Forced Convection
99 - 95	5º - 6ºF	4º - 5ºF
95 – 91	7º - 8ºF	5º - 6ºF
90 – 86	8º - 9ºF	5º - 7ºF
85 – 81	9º - 10ºF	8º - 10ºF
80 – 76	10º - 11ºF	10º - 12ºF
75 – 71	11º - 12ºF	12º - 14ºF
70 - 66	12º - 14ºF	14º - 16ºF
65 - 61	14º - 16ºF	16º - 18ºF
60 – 56	16º - 18ºF	18º - 20ºF
55 – 50	18º - 20ºF	20º - 22ºF

For temperature and relative humidity for refrigerated product spaces see ASHRAE 2002 Refrigeration Handbook (Chapter 10) Commodity Storage Requirements

Dimension, Insulation, Type of Construction, Exposure

This criterion lends itself to well-established, straightforward calculations, but the information, while elementary, often omitted from the initial job survey. The transmission load for 4" Styrofoam is double the transmission load for4" formed in place urethane.

Infiltration or Air Change Load

Heats, both sensible and latent, enter an enclosure through door openings whenever the air surrounding the enclosure is warmer than the box temperature. Knowing the location, size and number of the door openings and the temperature to, which they are exposed will greatly aid in determining the heat load of the infiltrating air.

TOTAL HEAT LOAD

Regardless of its size or complexity, a refrigeration system has one basic function. That function is to remove heat from a place or substance where it is not wanted, and transport it to a location where it can be diffused into air or water. In order to select the proper equipment for a given application, you must carefully estimate the amount of heat to be moved.

The *total heat load* to be handled in any application is the sum of the heat from four sources:

- **The heat leakage load is heat that infiltrates the refrigerated area through**
- **walls, ceilings, roofs, and floors**
- **The product load is heat from warm food or other solids or liquids that are being refrigerated.**
- **Type- storage requirements**
- **Weight**
- **Entering temperature**
- **Pull down time**
- **The *miscellaneous heat load* is heat introduced by lights, motors, and other heat-producing devices located in the refrigerated area. Manufacturing processes and human occupancy also may contribute to the miscellaneous heat load.**
- **Lights**
- **Motors including fan motors**
- **fork lifts, conveyers**
- **People**
- **Glass doors**
- **The *service load* is heat that enters the refrigerated area when doors or other access means are opened. The door may be opened to put in or take out a product, for example, or for a variety of other reasons. This source is often called the "usage load."**

- **Operation**
- **Holding cooler or freezer**
- **Blast cooling or freezing**
- **Preparation, processing or cutting rooms**
- **Distribution warehouses**
- **Reach-in or walk-in boxes**

The relative importance of each of these heat sources varies considerably from one application to another, as does the amount of each heat load. These factors also vary with the application of different types of equipment. With some types of equipment, very little heat may be derived from one of the four sources. If so, that source is of minor importance in estimating the total heat load. Nevertheless, with other types of equipment, the same source may be the major contributor to the total heat load.

As a service technician, you may have to estimate the heat load and select the refrigeration equipment for a prospective job. Alternatively, you may need to make similar calculations when troubleshooting a problem application. In any case, you must consider each of the four sources of heat individually. Then you add the four values together for an accurate estimate of the total heat load.

HEAT LEAKAGE LOAD

The heat leakage load is generally a major factor in refrigeration systems, regardless of whether the application is residential, commercial, or industrial. Before you try to estimate the heat leakage load, you need to know several things:

- **How to calculate heat flow through an insulated wall**
- **The extent of the temperature change within the insulation**
- **The function of a vapor barrier**
- **The amount of insulation required to prevent "sweating" (condensation) in or on the insulation.**

You can use the following equation to calculate the heat leakage load:

Q=UxAxTD

where:

- **Q = total heat transfer, in Btuh**
- ***U* = the rate of heat flow through the walls, floor, and ceiling of the refrigerated space, in Btuh per square foot of area per degree of temperature change**
- **A = the total outside area of the refrigerated space, in square feet**
- **TΔ = the difference, in degrees Fahrenheit, between the temperature outside the refrigerated space and the average temperature inside the refrigerated space.**

Calculating area

For maximum accuracy in estimating the heat leakage load, measure each wall, the floor, and the ceiling separately. Then add your findings together to get the total area. For example, assume that a walk-in cooler is 8 ft high, 8 ft long and 6 ft wide. Then:

- **the area of the floor is 6 ft x 8 ft = 48 ft^2**
- **the area of the ceiling is also 6 ft x 8 ft = 48 ft^2**
- **the area of each end wall is likewise 6 ft x 8 ft =48 ft^2, or 96 ft^2 for both end walls**
- **The area of each sidewall is 8 ft x 8 ft = 64 ft^2, or 128 ft^2 for both sidewalls.**

The total outside area of the walk-in refrigerator, therefore, is:

Floor 48 ft^2

Ceiling 48 ft^2

End walls 96 ft^2

Sidewalls 128 ft^2

Total area = 320 ft^2

Calculating temperature difference

Outside daytime and nighttime temperatures can vary greatly, especially during the summer months. In temperature difference calculations, it is customary to use an *average* outside summer temperature for a specific geographical location. This figure is generally a few degrees below the maximum. If you do not know the average outside summer temperature for a given area, the nearest weather bureau can provide this information. Obviously, this practice of using an average outside temperature is not appropriate in all cases. The refrigerator may be located in a hot kitchen, for example, or in a completely air conditioned space. In such applications, calculations must be based on hourly conditions (the temperature in a hotel kitchen, for instance, will be much higher during the hours when the restaurant is open than when it is closed).

Calculating heat flow

Next, you must calculate the rate of heat flow through the floor, ceiling, and walls of the refrigerated space. You must consider several factors in performing this calculation, including the type of insulation used, the thickness of the insulation, and its condition. You also must determine the condition of the existing vapor seal.

For an existing cabinet or walk-in refrigerator, the thickness and type of insulation used should be known. You must evaluate its condition for an accurate estimate of the heat leakage load. Of particular importance is the vapor seal. If broken, it permits the insulation to become damp or even wet. Such a condition can be a critical factor in low-temperature applications, such as freezers or frozen storage compartments. Vapor pressure, which tends to force moisture into insulation, is twice as high in a -10°F frozen food storage room as it is in a 36°F fresh meat cooler (assuming a 90°F ambient temperature in both cases).

Example.

Assume that the 8 ft x 6 ft x 8 ft walk-in cooler mentioned previously is located in a warm climate area. It is situated in a corner of a store, so that two of its walls are exterior walls. The two remaining walls are in a conditioned space. There is an upper level storage space (not fully conditioned) above the ceiling. The floor rests on a 6-in. concrete slab poured over gravel. In order to determine the total heat gain from the cooler's surroundings, you must make calculations for four different conductance’s (indoor walls, outdoor walls, ceiling, floor) and four corresponding temperature differences.

Except for the floor, the entire interior of the cooler is lined with stainless steel. The 3/4-in. hardwood floor is laid over 2 in. of expanded extruded polystyrene (EPS), which rests directly on the slab (ignoring the foil and polymer film vapor barrier).

The ceiling and all of the walls of the cooler consist of a 6-in. thickness of well-sealed, expanded extruded polystyrene. A single door of similar construction is centered in the longer interior wall. The two store-side walls are faced with *1/8-in.* tempered hardboard. During the cooling season, the surrounding conditioned space is kept at 75°F (±3°F). The out- side walls of the building are constructed of medium-weight aggregate, S-in. concrete block with molded EPS core inserts, sealed on both the inside and outside faces.

The ceiling is covered with sealed batts of 7-in. glass fiber insulation. The temperature in the partly conditioned space above the ceiling rarely exceeds 90°F.

In order to determine the U-value for each of the cooler's surfaces, you first must find the conductivities and conductances of the materials involved. These values can be found in Table 1 at the end of this chapter. You may find it helpful to list your findings in chart form, as shown above. Note that the stainless steel liner is not listed. This is because metal sheeting has no significant insulating value.

The U-value is the reciprocal of the total resistance. Resistance, in turn, is the reciprocal of conductance. For the indoor walls, therefore, you can calculate the U-value as follows:

Table 3

Material	C-Value or K-Value	C-Value per Component
Indoor wall: 1/8=in tempered hardboard	K = 1.00	C = 1.00 / 1/8 = 8
Outdoor walls 8-in concrete block	C = 0.37	C = 0.37
Walls and ceiling: 6-in extruded expanded polystyrene	K = 0.20	C = 0.20 / 6 = 0.033
Ceiling: 7-in glass fiber batts	C = 0.045	C = 0.045
Floor: 2-in extruded ex-panded polystyrene	K = 0.20	C = 0.20 / 2 = 0.10
Floor: ¾-in hardwood	C = 1.47	C = 1.47
Floor: 6-in sand and gravel Concrete slab (D= 130 lb/ft²)	K = 13.0	C = 13.0 / 6 = 2.17

R = 1/8 + 1/0.033 = 0.125+30 = 30.125

U = 1/30.125 = 0.0332

The two indoor walls measure 8 ft x 8 ft, (64 ft2) and 8 ft x 6 ft (48 ft2), for a total area of 112 ft2. Since the temperature on the warm side is never higher than 78°F, and the set point for storing product is 36°F, the maximum temperature difference (TD) across these walls is 42°F. This gives you the information you need to calculate the rate of heat gain through these walls:

Q = *U* x area x temperature difference = 0.0332 x 112 x 42 = 156.2 Btuh

Now you can make a series of similar calculations for the outdoor walls:

R = 1/0.37 + 1 / 0.033 = 2.7 + 30 = 32.7

U = 1 / 32.7 =0.0306

Like the indoor walls, the two outdoor walls have a combined area of 112 ft2. Let us assume that outside temperatures regularly reach and often exceed 100°F. For load calculations, 100°F is selected as the design temperature. Subtracting the product set point of 36°F from 100°F gives you a temperature difference of 64°F across the outdoor walls. The rate of heat gain through the outdoor walls, therefore, is:

Q=UxAxTD

= 0.0306 x 112 x 64 = 219.3 Btuh

Now try making your own calculations for the ceiling and floor. Using the procedure explained above, you should arrive at a U-value of 0.019 for the ceiling and 0.09 for the floor. You know the area of the ceiling (48 ft2), so assuming a warm-side temperature of 90°F, you can calculate a TO of 54°F and a resulting heat gain *(0)* through the ceiling of 49.2 Btuh.

What about the floor? Its area is the same as that of the ceiling, of course, which leaves the TD as the remaining unknown. Since the desired temperature for the product is 36°F, all you need now is the temperature of the soil or rock below the cooler. A direct measurement with a thermometer can provide a usable temperature if the thermometer bulb is in con- tact with earth 12 to 18 in. below the surface, and if the measurement is taken after a few seasonally warm days. If this is not convenient, consult a local agricultural extension service for soil temperatures. Let us assume that even on hot days in the cooling season, the ground temperatures remain at about 70°F. Your calculations should give you a TO of 34°F and a Q-value of 146.88 Btuh.

In order to determine the total heat load due to conduction from the environment, simply add the heat leakage loads from all of the surfaces:

Indoor walls 156.2 Btuh + Outdoor walls 219.3 Btuh + Ceiling 49.2 Btuh +

Floor 146.9 Btuh = 571.6 Btuh

To find the daily load, multiply 571.6 Btuh times 24 hr to get 13,718.4 Btu per day.

THERMAL CONDUCTIVITY

The letter *"K"* represents thermal conductivity, which is the rate of heat transfer through a material as measured in Btuh per square foot of area per degree Fahrenheit of temperature difference per inch of thickness. The total heat transferred by conduction, therefore, varies *directly* with time, area, and temperature difference, and *inversely* with the thickness of the material through which it passes.

Different materials offer varying resistances to heat. Assume, for example, that you want to calculate the heat transfer through a material with a thermal conductivity (K-value) of 0.25. The material in question has an area of 2ft² and is 3 in. thick. If the average temperature difference across the material is 70°F, you will be able to calculate the total quantity of heat transferred (Q) over a 24-hr period with this simple equation:

Q = 0.25 *(K)* x 2 (ft^2) X 24 (hr) x 70°F (ΔT) / 3 (in. of thickness)

Q = 840 / 3 = 280 Btu

It should be apparent from the example that in order to reduce heat transfer, the thermal conductivity must be as low as possible and the material as thick as possible. *Note:* In some technical literature, K-values are based on thickness per foot instead of per inch. Unless otherwise specified, all references to K-values in this chapter are based on heat transfer per inch of thickness.

CONDUCTANCE

The letter *"C"* represents thermal conductance, which, like conductivity, is a measure of the rate of heat transfer through a material or heat barrier. Conductance is used frequently with specific building materials, air spaces, etc., and differs from conductivity in one significant way. Thermal *conductance* is a specific factor for a given thickness of material or structural member. Thermal *conductivity* is a heat transfer factor *per inch* of thickness.

SURFACE FILM CONDUCTANCE

Heat transfer through any material is affected by the resistance to heat flow offered by its surface. The degree of resistance depends on the type of surface, its relative roughness or smoothness, its vertical or horizontal position, its reflective properties, and the rate of airflow over it. It is similar to conductance in that its value is expressed in Btuh per square foot of area per degree Fahrenheit of temperature difference

THERMAL RESISTANCE

The letter *"R"* represents thermal resistance. By definition, the resistance of a material to the flow of heat is the reciprocal of its heat transfer coefficient. In other words, the *R-value* is the reciprocal of either the K-value or the C-value. For example, if a material has a conductance (C-value) of 0.25, then resistance is R = 1/C = 1/0.25 = 4

You can see, then, that for this material it would take a 4°F temperature difference across a 1ft² area, or a 1°F temperature difference across a 4ft² area, to result in a heat flow of 1 Btuh. Thermal resistance is important primarily because individual resistance values can be added numerically:

R total = R1 + R2 + R3

This makes the use of R-values very convenient in calculating overall heat transfer coefficients.

OVERALL COEFFICIENT OF HEAT TRANSFER

The letter *"U"* represents the overall coefficient of heat transfer, which is the overall rate of heat transfer through a material. U-values usually applied to compound structures, such as walls, ceilings, and roofs, and must include. The additional insulating effect of the air film that exists on either side of the surface.

The U-value of a wall is the reciprocal of its total resistance. Resistance, in turn, is the reciprocal of conductivity. Nevertheless, calculating the U-value is complicated by the fact that the *total* resistance to the flow of heat through a wall made of several layers is the sum of the resistances of the individual layers. In order to calculate the overall heat transfer coefficient, you first must find the overall resistance to heat flow. The various heat transfer factors must be taken into consideration when you calculate the total resistance:

CALCULATING HEAT LOADS

For load calculation purposes, the heat transferred through a wall can be determined by using the basic heat transfer equation:

Q = *U* x *A* x TD

where:

- **Q = the total heat transfer (Btuh)**
- ***U* = the overall heat transfer coefficient**
- ***A* = the area (ft2)**
- **TD = the temperature differential (sometimes also signified by the symbol 11 T) between the outside design temperature and the design temperature of the refrigerated space (ºF).**

Consider the wall in the previous example (with a U-value of 0.114). The heat transmission per hour through a 90-ft2 area with an inside temperature of 0°F and an outside temperature of 80°F is calculated as follows:

Q = *U* x *A* x TD

= 0.114 x 90 x 80 = 821 Btuh

You can determine the amount of heat gained by transmission into a refrigerated space in a similar manner. Calculate the U-value for each part of the structure around the refrigerated space, and then proceed with the equation shown above.

Extensive tests have been conducted to determine accurate values for heat transfer through all common building and structural materials. Certain materials have a high resistance to heat flow (a low thermal conductivity). They are used as insulation to reduce the level of heat transfer into a refrigerated space. Many good insulation materials have K-values of 0.25 or less, and some foam insulations have thermal conductivities of 0.12 to 0.15.

Table 4A

Description	Density, lb/ft³	Conductivity (*K*)	Conductance (*C*)	Resistance (*R*) per inch (1/*K*)	Resistance (*R*) overall (1/*C*)	Specific heat, Btu/lb/°F
BUILDING BOARD						
Asbestos-cement board	120	4.0	—	0.25	—	0.24
Asbestos-cement board. . . . 0.125 in.	120	—	33.00	—	0.03	—
Asbestos-cement board. . . . . 0.25 in.	120	—	16.50	—	0.06	—
Gypsum or plaster board . . . 0.375 in.	50	—	3.10	—	0.32	0.26
Gypsum or plaster board . . . . . 0.5 in.	50	—	2.22	—	0.45	—
Gypsum or plaster board . . . 0.625 in.	50	—	1.78	—	0.56	—
Plywood (Douglas fir)	34	0.80	—	1.25	—	0.29
Plywood (Douglas fir) . . . . . . 0.25 in.	34	—	3.20	—	0.31	—
Plywood (Douglas fir) . . . . . 0.375 in.	34	—	2.13	—	0.47	—
Plywood (Douglas fir) . . . . 0.5 in.	34	—	1.60	—	0.62	—
Plywood (Douglas fir) . . . . . 0.625 in.	34	—	1.29	—	0.77	—
Plywood or wood panels . . . . 0.75 in.	34	—	1.07	—	0.93	0.29
Vegetable fiber board						
Sheathing,						
regular density . . . . 0.5 in.	18	—	0.76	—	1.32	0.31
. . . . 0.78125 in.	18	—	0.49	—	2.06	—
Sheathing,						
intermediate density . . . . 0.5 in.	22	—	0.92	—	1.09	0.31
Nail-base sheathing. . . . . . . 0.5 in.	25	—	0.94	—	1.06	0.31
Shingle backer. . . . . 0.375 in.	18	—	1.06	—	0.94	0.31
Shingle backer. . . . . 0.3125 in.	18	—	1.28	—	0.78	—
Sound deadening board . . . 0.5 in.	15	—	0.74	—	1.35	0.30
Tile and lay-in panels,						
plain or acoustic	18	0.40	—	2.50	—	0.14
. . . . 0.5 in.	18	—	0.80	—	1.25	—
. . . . 0.75 in.	18	—	0.53	—	1.89	—
Laminated paperboard	30	0.50	—	2.00	—	0.33
Homogeneous board						
from repulped paper	30	0.50	—	2.00	—	0.28
Hardboard						
Medium density	50	0.73	—	1.37	—	0.31
High density, service-tempered						
grade and service grade	55	0.82	—	1.22	—	0.32
High density, standard-tempered						
grade	63	1.00	—	1.00	—	0.32
Particle board						
Low density	37	0.71	—	1.41	—	0.31
Medium density	50	0.94	—	1.06	—	0.31
High density	62	0.5	1.18	—	0.85	—
Underlayment . . . . 0.625 in.	40	—	1.22	—	0.82	0.29
Waferboard	37	0.63	—	1.59	—	—
Wood subfloor . . . . 0.75 in.	—	—	1.06	—	0.94	0.33
BUILDING MEMBRANE						
Vapor—permeable felt	—	—	16.70	—	0.06	—
Vapor—seal, two layers of mopped						
15-lb felt	—	—	8.35	—	0.12	—
Vapor—seal, plastic film	—	—	—	—	Negligible	—
FINISH FLOORING MATERIALS						
Carpet and fibrous pad	—	—	0.48	—	2.08	0.34
Carpet and rubber pad	—	—	0.81	—	1.23	0.33
Cork tile . . . . 0.125 in.	—	—	3.60	—	0.28	0.48
Terrazzo . . . . 1 in.	—	—	12.50	—	0.08	0.19
Tile—asphalt, linoleum, vinyl, rubber	—	—	20.00	—	0.05	0.30

Table 4B

Description	Density, lb/ft³	Conductivity (*K*)	Conductance (*C*)	Resistance (*R*) per inch (1/*K*)	Resistance (*R*) overall (1/*C*)	Specific heat, Btu/lb/°F
Tile—vinyl asbestos	—	—	—	—	—	0.24
Tile—ceramic	—	—	—	—	—	0.19
Wood, hardwood finish . . . . . 0.75 in.	—	—	1.47	—	0.68	
INSULATING MATERIALS						
Blanket and batt						
Mineral fiber, fibrous form processed from rock, slag, or glass						
approx 3 to 4 in.	0.4 to 2.0	—	0.091	—	11	—
approx 3.5 in.	0.4 to 2.0	—	0.077	—	13	—
approx 3.5 in.	1.2 to 1.6	—	0.067	—	15	—
approx 5.5 to 6.5 in.	0.4 to 2.0	—	0.053	—	19	—
approx 5.5 in.	0.6 to 1.0	—	0.048	—	21	—
approx 6 to 7.5 in.	0.4 to 2.0	—	0.045	—	22	—
approx 8.25 to 10 in.	0.4 to 2.0	—	0.033	—	30	—
approx 10 to 13 in.	0.4 to 2.0	—	0.026	—	38	—
Board and slabs						
Cellular glass	8.0	0.33	—	3.03	—	0.18
Glass fiber, organic bonded	4.0 to 9.0	0.25	—	4.00	—	0.23
Expanded perlite, organic bonded	1.0	0.36	—	2.78	—	0.30
Expanded rubber (rigid)	4.5	0.22	—	4.55	—	0.40
Expanded polystyrene, extruded (smooth skin surface) (CFC-12 exp)	1.8 to 3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, extruded (smooth skin surface) (HCFC-142b exp)	1.8 to 3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, molded beads	1.0	0.26	—	3.85	—	—
	1.25	0.25	—	4.00	—	—
	1.5	0.24	—	4.17	—	—
	1.75	0.24	—	4.17	—	—
	2.0	0.23	—	4.35	—	—
Cellular polyurethane/polyisocyanurate (CFC-11 exp) (unfaced)	1.5	0.16 to 0.18	—	6.25 to 5.56	—	0.38
Cellular polyisocyanurate (CFC-11 exp) (gas-permeable facers)	1.5 to 2.5	0.16 to 0.18	—	6.25 to 5.56	—	0.22
Cellular polyisocyanurate (CFC-11 exp) (gas–impermeable facers)	2.0	0.14	—	7.04	—	0.22
Cellular phenolic (closed cell) (CFC-11, CFC-113 exp)	3.0	0.12	—	8.20	—	—
Cellular phenolic (open cell)	1.8 to 2.2	0.23	—	4.40	—	—
Mineral fiber with resin binder	15.0	0.29	—	3.45	—	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16 to 17	0.34	—	2.94	—	—
Acoustical tile	18.0	0.35	—	2.86	—	0.19
Acoustical tile	21.0	0.37	—	2.70	—	—
Mineral fiberboard, wet molded						
Acoustical tile	23.0	0.42	—	2.38	—	0.14
Wood or cane fiberboard						
Acoustical tile. . . . . 0.5 in.	—	—	0.80	—	1.25	0.31
Acoustical tile. . . . . 0.75 in.	—	—	0.53	—	1.89	—
Interior finish (plank, tile)	15.0	0.35	—	2.86	—	0.32
Cement fiber slabs (shredded wood with Portland cement binder)	25 to 27	0.50 to 0.53	—	2.0 to 1.89	—	—
Cement fiber slabs (shredded wood with magnesia oxysulfide binder)	22.0	0.57	—	1.75	—	0.31

Table 4C

Description	Density, lb/ft³	Conductivity (*K*)	Conductance (*C*)	Resistance (*R*) per inch (1/*K*)	Resistance (*R*) overall (1/*C*)	Specific heat, Btu/lb/°F
Loose fill						
Cellulosic insulation (milled paper or wood pulp)	2.3 to 3.2	0.27 to 0.32	—	3.70 to 3.13	—	0.33
Perlite, expanded	2.0 to 4.1	0.27 to 0.31	—	3.7 to 3.3	—	0.26
	4.1 to 7.4	0.31 to 0.36	—	3.3 to 2.8	—	—
	7.4 to 11.0	0.36 to 0.42	—	2.8 to 2.4	—	—
Mineral fiber (rock, slag, or glass)						
approx 3.75 to 5 in.	0.6 to 2.0	—	—	—	11.0	0.17
approx 6.5 to 8.75 in.	0.6 to 2.0	—	—	—	19.0	—
approx 7.5 to 10 in.	0.6 to 2.0	—	—	—	22.0	—
approx 10.25 to 13.75 in.	0.6 to 2.0	—	—	—	30.0	—
Mineral fiber (rock, slag, or glass) approx 3.5 in. (closed sidewall application)	2.0 to 3.5	—	—	—	12.0 to 14.0	—
Vermiculite, exfoliated	7.0 to 8.2	0.47	—	2.13	—	0.32
	4.0 to 6.0	0.44	—	2.27	—	—
Spray applied						
Polyurethane foam	1.5 to 2.5	0.16 to 0.18	—	6.25 to 5.56	—	—
Ureaformaldehyde foam	0.7 to 1.6	0.22 to 0.28	—	4.55 to 3.57	—	—
Cellulosic fiber	3.5 to 6.0	0.29 to 0.34	—	3.45 to 2.94	—	—
Glass fiber	3.5 to 4.5	0.26 to 0.27	—	3.85 to 3.70	—	—
Reflective insulation						
Reflective material (ε<0.5) in center of ¾-in. cavity forms two ⅜-in. vertical air spaces	—	—	0.31	—	3.2	—
ROOFING						
Asbestos-cement shingles	120	—	4.76	—	0.21	0.24
Asphalt roll roofing	70	—	6.50	—	0.15	0.36
Asphalt shingles	70	—	2.27	—	0.44	0.30
Built-up roofing . . . . 0.375 in.	70	—	3.00	—	0.33	0.35
Slate . . . . 0.5 in.	—	—	20.00	—	0.05	0.30
Wood shingles, plain and plastic film faced	—	—	1.06	—	0.94	0.31
PLASTERING MATERIALS						
Cement plaster, sand aggregate	116	5.0	—	0.20	—	0.20
Sand aggregate . . . . 0.375 in.	—	—	13.3	—	0.08	0.20
Sand aggregate . . . . 0.75 in.	—	—	6.66	—	0.15	0.20
Gypsum plaster						
Lightweight aggregate . . . . . 0.5 in.	45	—	3.12	—	0.32	—
Lightweight aggregate . . . 0.625 in.	45	—	2.67	—	0.39	—
Lightweight aggregate on metal lath . . . . 0.75 in.	—	—	2.13	—	0.47	—
Perlite aggregate	45	1.5	—	0.67	—	0.32
Sand aggregate	105	5.6	—	0.18	—	0.20
Sand aggregate . . . . 0.5 in.	105	—	11.10	—	0.09	—
Sand aggregate . . . . 0.625 in.	105	—	9.10	—	0.11	—
Sand aggregate on metal lath . . . . 0.75 in.	—	—	7.70	—	0.13	—
Vermiculite aggregate	45	1.7	—	0.59	—	—
MASONRY MATERIALS						
Masonry units						
Brick, fired clay	150	8.4 to 10.2	—	0.12 to 0.10	—	—
	140	7.4 to 9.0	—	0.14 to 0.11	—	—

Table 4D

Description	Density, lb/ft³	Conductivity (K)	Conductance (C)	Resistance (R) per inch ($1/K$)	Resistance (R) overall ($1/C$)	Specific heat, Btu/lb/°F
Brick, fired clay (continued)	130	6.4 to 7.8	—	0.16 to 0.12	—	—
	120	5.6 to 6.8	—	0.18 to 0.15	—	0.19
	110	4.9 to 5.9	—	0.20 to 0.17	—	—
	100	4.2 to 5.1	—	0.24 to 0.20	—	—
	90	3.6 to 4.3	—	0.28 to 0.24	—	—
	80	3.0 to 3.7	—	0.33 to 0.27	—	—
	70	2.5 to 3.1	—	0.40 to 0.33	—	—
Clay tile, hollow						
1 cell deep .... 3 in.	—	—	1.25	—	0.80	0.21
1 cell deep .... 4 in.	—	—	0.90	—	1.11	—
2 cells deep .... 6 in.	—	—	0.66	—	1.52	—
2 cells deep .... 8 in.	—	—	0.54	—	1.85	—
2 cells deep .... 10 in.	—	—	0.45	—	2.22	—
3 cells deep .... 12 in.	—	—	0.40	—	2.50	—
Concrete blocks						
Limestone aggregate						
• 8 in., 36 lb, 1.38 lb/ft³ concrete, 2 cores	—	—	—	—	—	—
• Same with perlite filled cores	—	—	0.48	—	2.1	—
• 12 in., 55 lb,138 lb/ft³ concrete, 2 cores	—	—	—	—	—	—
• Same with perlite filled cores	—	—	0.27	—	3.7	—
Normal weight aggregate (sand and gravel)						
• 8 in., 33 to 36 lb, 126 to 136 lb/ft³ concrete, 2 or 3 cores	—	—	0.90 to 1.03	—	1.11 to 0.97	0.22
• Same with perlite filled cores	—	—	0.50	—	2.0	—
• Same with vermiculite filled cores	—	—	0.52 to 0.73	—	1.92 to 1.37	—
• 12 in., 50 lb,125 lb/ft³ concrete, 2 cores	—	—	0.81	—	1.23	0.22
Medium weight aggregate (combinations of normal weight and lightweight aggregate)						
• 8 in., 26 to 29 lb, 97 to 112 lb/ft³ concrete, 2 or 3 cores	—	—	0.58 to 0.78	—	1.71 to 1.28	—
• Same with perlite filled cores	—	—	0.27 to 0.44	—	3.7 to 2.3	—
• Same with vermiculite filled cores	—	—	0.30	—	3.3	—
• Same with molded EPS (beads) filled cores	—	—	0.32	—	3.2	—
• Same with molded EPS inserts in cores	—	—	0.37	—	2.7	—
Lightweight aggregate (expanded shale, clay, slate or slag, pumice)						
• 6 in., 16 to 17 lb, 85 to 87 lb/ft³ concrete, 2 or 3 cores	—	—	0.52 to 0.61	—	1.93 to 1.65	—
• Same with perlite filled cores	—	—	0.24	—	4.2	—
• Same with vermiculite filled cores	—	—	0.33	—	3.0	—
• 8 in., 19 to 22 lb, 72 to 86 lb/ft³ concrete	—	—	0.32 to 0.54	—	3.2 to 1.90	0.21
• Same with perlite filled cores	—	—	0.15 to 0.23	—	6.8 to 4.4	—
• Same with vermiculite filled cores	—	—	0.19 to 0.26	—	5.3 to 3.9	—
• Same with molded EPS (beads) filled cores	—	—	0.21	—	4.8	—
• Same with UF foam filled cores	—	—	0.22	—	4.5	—
• Same with molded EPS inserts in cores	—	—	0.29	—	3.5	—

Table 4E

Description	Density, lb/ft³	Conductivity (K)	Conductance (C)	Resistance (R) per inch $(1/K)$	Resistance (R) overall $(1/C)$	Specific heat, Btu/lb/°F
Lightweight aggregate (expanded shale, clay, slate or slag, pumice) (continued)						
• 12 in., 32 to 36 lb, 80 to 90 lb/ft³ concrete, 2 or 3 cores	—	—	0.38 to 0.44	—	2.6 to 2.3	—
• Same with perlite filled cores	—	—	0.11 to 0.16	—	9.2 to 6.3	—
• Same with vermiculite filled cores	—	—	0.17	—	5.8	—
Stone, lime, or sand	180	72	—	0.01	—	—
Quartzitic and sandstone	160	43	—	0.02	—	—
	140	24	—	0.04	—	—
	120	13	—	0.08	—	0.19
Calcitic, dolomitic, limestone, marble, and granite	180	30	—	0.03	—	—
	160	22	—	0.05	—	—
	140	16	—	0.06	—	—
	120	11	—	0.09	—	0.19
	100	8	—	0.13	—	—
Gypsum partition tile						
3 by 12 by 30 in., solid	—	—	0.79	—	1.26	0.19
3 by 12 by 30 in., 4 cells	—	—	0.74	—	1.35	—
4 by 12 by 30 in., 3 cells	—	—	0.60	—	1.67	—
Concretes						
Sand and gravel or stone aggregate concretes (concretes with more than 50% quartz or quartzite sand have conductivities in the higher end of the range)	150	10.0 to 20.0	—	0.10 to 0.05	—	—
	140	9.0 to 18.0	—	0.11 to 0.06	—	0.19 to 0.24
	130	7.0 to 13.0	—	0.14 to 0.08	—	—
Limestone concretes	140	11.1	—	0.09	—	—
	120	7.9	—	0.13	—	—
	100	5.5	—	0.18	—	—
Gypsum-fiber concrete (87.5% gypsum, 12.5% wood chips)	51	1.66	—	0.60	—	0.21
Cement/lime, mortar, and stucco	120	9.7	—	0.10	—	—
	100	6.7	—	0.15	—	—
	80	4.5	—	0.22	—	—
Lightweight aggregate concretes						
Expanded shale, clay, or slate; expanded slags; cinders; pumice (with density up to 100 lb/ft³); and scoria (sanded concretes have conductivities in the higher end of the range)	120	6.4 to 9.1	—	0.16 to 0.11	—	—
	100	4.7 to 6.2	—	0.21 to 0.16	—	0.20
	80	3.3 to 4.1	—	0.30 to 0.24	—	0.20
	60	2.1 to 2.5	—	0.48 to 0.40	—	—
	40	1.3	—	0.78	—	—
Perlite, vermiculite, and polystyrene beads	50	1.8 to 1.9	—	0.55 to 0.53	—	—
	40	1.4 to 1.5	—	0.71 to 0.67	—	0.15 to 0.23
	30	1.1	—	0.91	—	—
	20	0.8	—	1.25	—	—
Foam concretes	120	5.4	—	0.19	—	—
	100	4.1	—	0.24	—	—
	80	3.0	—	0.33	—	—
	70	2.5	—	0.40	—	—

Table 4F

Description	Density, lb/ft³	Conductivity (*K*)	Conductance (*C*)	Resistance (*R*) per inch (1/*K*)	Resistance (*R*) overall (1/*C*)	Specific heat, Btu/lb/°F
Foam concretes and cellular concretes	60	2.1	—	0.48	—	—
	40	1.4	—	0.71	—	—
	20	0.8	—	1.25	—	—
SIDING MATERIALS (on flat surface)						
Shingles						
Asbestos-cement	120	—	4.75	—	0.21	—
Wood, 16 in., 7.5-in. exposure	—	—	1.15	—	0.87	0.31
Wood, double, 16-in., 12-in. exposure	—	—	0.84	—	1.19	0.28
Wood plus insulated backer board, 0.312 in.	—	—	0.71	—	1.40	0.31
Siding						
Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	0.21	0.24
Asphalt roll siding	—	—	6.50	—	0.15	0.35
Asphalt insulating siding (0.5-in. bed)	—	—	0.69	—	1.46	0.35
Hardboard siding, 0.4375 in.	—	—	1.49	—	0.67	0.28
Wood, drop, 1 by 8 in.	—	—	1.27	—	0.79	0.28
Wood, bevel, 0.5 by 8 in., lapped	—	—	1.23	—	0.81	0.28
Wood, bevel, 0.75 by 10 in., lapped	—	—	0.95	—	1.05	0.28
Wood, plywood, 0.375 in., lapped	—	—	1.69	—	0.59	0.29
Aluminum, steel, or vinyl over sheathing						
• Hollow-backed	—	—	1.64	—	0.61	0.29
• Insulating-board backed, nominal 0.375 in.	—	—	0.55	—	1.82	0.32
• Insulating-board backed, nominal 0.375 in., foil backed	—	—	0.34	—	2.96	—
Architectural (soda-lime float) glass	158	6.9	—	—	—	0.21
WOODS (12% moisture content)						
Hardwoods						0.39
Oak	41.2 to 46.8	1.12 to 1.25	—	0.89 to 0.80	—	—
Birch	42.6 to 45.4	1.16 to 1.22	—	0.87 to 0.82	—	—
Maple	39.8 to 44.0	1.09 to 1.19	—	0.92 to 0.84	—	—
Ash	38.4 to 41.9	1.06 to 1.14	—	0.94 to 0.88	—	—
Softwoods						0.39
Southern pine	35.6 to 41.2	1.00 to 1.12	—	1.00 to 0.89	—	—
Douglas fir-larch	33.5 to 36.3	0.95 to 1.01	—	1.06 to 0.99	—	—
Southern cypress	31.4 to 32.1	0.90 to 0.92	—	1.11 to 1.09	—	—
Hemlock-fir, spruce-pine-fir	24.5 to 31.4	0.74 to 0.90	—	1.35 to 1.11	—	—
West Coast woods, cedars	21.7 to 31.4	0.68 to 0.90	—	1.48 to 1.11	—	—
California redwood	24.5 to 28.0	0.74 to 0.82	—	1.35 to 1.22	—	—

Table 4G

Table 18
Rapid load selection for back bars
(Based on 2" glass fiber or equivalent insulation and 50° F. T.D.)

Back Bar Length in feet	BTU/Hour Load Based on 16 Hour Compressor Operation
6 Feet	1,060
8 Feet	1,416
10 Feet	1,770
12 Feet	2,120
15 Feet	2,650
20 Feet	3,540

Table 19
Refrigeration requirements for hardening ice cream

Overrun, Percent	Hardening Load, BTU per Gal. Ice Cream
60	532
70	500
80	470
90	447
100	425
110	405
120	386

Table 4H

Table 9
Heat loads of keg and bottled beer BTU/24 HR

Type and Size of Container	Temperature Reduction of Beer Only, °F.							
	60	50	40	30	20	15	10	5
Wood								
One keg	—	—	12000	9000	6000	4500	3000	1500
Half keg	—	—	5600	4650	3100	2325	1550	775
Quarter keg	—	—	3200	2400	1600	1200	800	400
Eight keg	—	—	1640	1230	820	615	410	205
Aluminum								
Half keg	—	—	5200	3900	2600	1950	1300	650
Quarter keg	—	—	2560	1920	1280	960	640	320
Eight keg	—	—	1400	1050	700	525	350	175
Steel								
Half keg	—	—	4800	3600	2400	1800	1200	600
Quarter keg	—	—	2400	1800	1200	900	600	300
Bottles oz.								
6	32	27	22	16	10.8	8.1	5.4	2.7
7	37	31	25	20	12.4	9.3	6.2	3.1
8	42	35	28	21	14.0	10.5	7.0	3.5
9	47	38	30	23	15.2	11.4	7.6	3.8
12	60	50	40	30	20	15	10	5.0
Case of 24-12 oz. bottles/cans	1920	1600	1280	960	640	480	320	160

Table 10
Carcass weights

Carcass	Average Weight Lbs.	Specific Heat	Entering Carcass Temp. °F.	Final Carcass Temp. °F.
Cattle	550	.77	106	35
Calves	150	.76	104	35
Sheep	45	.76	101	33
Hogs	180	.54	106	35

Table 11
Heat equivalent of electric motors

Motor HP	BTU Per (HP) (HR)		
	Connected Load In Refr Space[1]	Motor Losses Outside Refr Space[2]	Connected Load Outside Refr Space[3]
1/8 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.

Table 12
Heat equivalent of occupancy

Cooler Temperature F	Heat Equivalent/Person BTU/24 Hrs.
50	17,280
40	20,160
30	22,800
20	25,200
10	28,800
0	31,200
-10	33,600

Table 13
General standards for insulation thickness in storage rooms

Storage Temperature		Desirable Insulation Thickness in Inches	
°F.	°C.	Styrofoam	Urethane
-50° to -25°	-45° to -32°	8	6
-25° to -6°	-32° to -18°	6	4
0° to 25°	-18° to -4°	4	4
25° to 40°	-4° to 5°	4	3-4
40° and up	+5° and up	2	2

Table 14
Heat gain due to operation of battery operated lift trucks

Battery operated, load capacity, lb.	Heat Gain per hour of truck operation, BTU/hr.*	Approximate total weight of lift truck, lb.
2,000	14,000	6,000
4,000	21,000	8,000
6,000	23,000	12,000
8,000	26,000	14,000

*Heat gain from lift trucks with internal co mbustion engines can be approximated by muliplying the engine horsepower by 2,545 by the number of hours of operation (BTU/24 hrs.)

Table 15
Specific heats of various liquids and solids

Name	Specific Heat	
	BTU/Lb./°F.	Temp.°F.
Liquids		
Acetic Acid	0.522	79-203
Alcohol-Ethyl	0.680	32-208
Alcohol-Methyl	0.610	59-68
Calcium Chloride Brine (20% by Wt.)	0.744	68
Carbon Tetrachloride	0.201	68
Chloroform	0.234	68
Gasoline	0.500	32-212
Glycerine	0.575	59-120
Olive Oil	0.471	44
Toluene	0.404	68
Turpentine	0.420	68
Solids		
Aluminum	0.214	—
Asphalt	0.220	—
Bakelite	0.350	—
Brickwork	0.200	—
Brass	0.090	—
Bronze	0.104	—
Concrete	0.156	—
Glass	0.200	—
Ice	0.465	-4
Ice	0.487	32
Iron (cast)	0.120	—
Lead	0.031	—
Paper	0.320	—
Porcelain	0.180	—
Rubber Goods	0.480	—
Sand	0.191	—
Steel	0.120	—
Woods		
Fir	0.650	—
Oak	0.570	—
Pine	0.670	—

OUTDOOR DESIGN TEMPERATURES

In refrigeration and air conditioning applications, maximum load conditions generally occur during the “warmest weather. Nevertheless, it is neither economical nor practical to design equipment for the highest possible temperature that might occur in a given area. After all, the temperature may be at that record level for only a few hours over a period of several years. National Weather Service records spanning many years have been used to establish suitable outdoor design temperatures for specific geographical areas. The outdoor design temperature is a temperature that, according to past data, will not be exceeded more than a given percentage of the time during the summer season in that area. Table 5 at the end of this chapter lists typical summer design temperatures. Actual temperatures should equal or exceed those listed only during 1% of the hours of the four-month summer season.

Table5A

Location	Dry bulb, °F	Wet bulb, °F
CANADA		
ALBERTA		
Calgary	83	60
Edmonton	82	63
Fort McMurray	84	64
Grande Prairie	81	62
Medicine Hat	90	63
Red Deer	82	62
Vermilion	83	64
BRITISH COLUMBIA		
Abbotsford	85	67
Fort Nelson	82	62
Port Hardy	68	59
Prince George	81	60
Vancouver	76	65
Victoria	79	63
Williams Lake	83	59
MANITOBA		
Brandon	87	67
Churchill	77	62
Winnipeg	87	68
NEW BRUNSWICK		
Chatham	86	69
Moncton	83	68
Saint John	78	65
NEWFOUNDLAND		
Battle Harbour	65	58
Cartwright	75	62
Deer Lake	81	66
Gander	79	65
Saint John's	76	65
Stephenville	74	64
Wabush Lake	76	60
NORTHWEST TERRITORIES		
Cape Parry	58	53
Fort Smith	82	63
Norman Wells	80	62
Yellowknife	77	60
NUNAVUT		
Baker Lake	69	57
Cambridge Bay	60	53
Chesterfield	66	54
Coral Harbour	64	53
Hall Beach	56	50
NOVA SCOTIA		
Greenwood	84	69
Halifax	80	68
Sable Island	70	67
Shearwater	78	66
Sydney	81	68
Truro	79	69
Yarmouth	73	66
ONTARIO		
Armstrong	81	66
Earlton	85	69
London	85	71
North Bay	81	67
Ottawa	86	70
Sault Sainte Marie	83	69
Thunder Bay	84	68
Toronto	87	71
Trenton	84	71
Windsor	89	73
PRINCE EDWARD ISLAND		
Charlottetown	79	69
QUEBEC		
Bagotville	84	67
Montreal	85	71
Quebec	84	70
Riviere du Loup	79	68
Roberval	83	68
Sherbrooke	84	70
Val d'Or	83	67
SASKATCHEWAN		
Moose Jaw	90	64
North Battleford	86	64
Prince Albert	84	65
Regina	89	64
Saskatoon	87	64
Yorkton	86	65
YUKON		
Burwash	73	57
Whitehorse	77	57

Table 5B

Location	Dry bulb, °F	Wet bulb, °F
ALABAMA		
Birmingham	94	75
Mobile	94	77
Montgomery	95	76
Tuscaloosa	95	77
ALASKA		
Anchorage	71	59
Fairbanks	81	61
Juneau	74	60
Nome	69	57
ARIZONA		
Flagstaff	85	56
Phoenix	110	70
Tucson	104	65
ARKANSAS		
Fayetteville	95	75
Fort Smith	99	76
Little Rock	97	77
CALIFORNIA		
Bakersfield	104	70
Fresno	103	71
Long Beach	92	67
Los Angeles	85	64
Sacramento	100	69
San Diego	85	67
San Francisco	83	63
San Jose	93	67
Santa Barbara	83	64
COLORADO		
Colorado Springs	90	58
Denver	93	60
Pueblo	97	62
CONNECTICUT		
Bridgeport	86	73
Hartford	91	73
DELAWARE		
Dover	93	76
Wilmington	91	75
D.C.		
Washington	95	76
FLORIDA		
Cape Canaveral	92	78
Daytona Beach	92	77
Fort Lauderdale	92	78
FLORIDA (continued)		
Fort Myers	94	77
Jacksonville	94	77
Key West	90	79
Miami	91	77
Pensacola	93	78
Saint Petersburg	94	80
Tampa	92	77
West Palm Beach	91	78
GEORGIA		
Athens	94	75
Atlanta	93	75
Fort Benning	97	76
Macon	96	76
Marietta	94	74
Savannah	95	77
HAWAII		
Honolulu	89	73
IDAHO		
Boise	96	63
ILLINOIS		
Chicago	91	74
Decatur	94	76
Moline	93	76
Peoria	92	76
Rockford	91	74
Springfield	93	76
INDIANA		
Evansville	94	77
Fort Wayne	90	74
Indianapolis	91	75
Lafayette	93	75
South Bend	90	73
Terre Haute	93	76
IOWA		
Cedar Rapids	93	75
Des Moines	93	76
Fort Dodge	92	75
Mason City	91	74
Sioux City	94	75
Waterloo	91	75
KANSAS		
Dodge City	100	70
Topeka	96	75
Wichita	100	73

Table 5C

Location	Dry bulb, °F	Wet bulb, °F
KENTUCKY		
Bowling Green	94	76
Fort Knox	94	76
Lexington	91	74
Louisville	93	76
LOUISIANA		
Baton Rouge	94	78
Lafayette	94	78
Lake Charles	93	78
New Orleans	93	79
Shreveport	97	77
MAINE		
Augusta	87	71
Bangor	87	71
Brunswick	87	71
Portland	86	71
MARYLAND		
Baltimore	93	75
MASSACHUSETTS		
Boston	91	73
Worcester	85	71
MICHIGAN		
Detroit	90	73
Flint	88	73
Grand Rapids	89	73
Lansing	89	73
Marquette	86	69
Saginaw	90	74
Traverse City	89	71
MINNESOTA		
Brainerd	88	70
Duluth	84	69
Hibbing	85	70
International Falls	86	69
Minneapolis-Saint Paul	91	73
Rochester	88	72
Saint Cloud	91	72
MISSISSIPPI		
Biloxi	92	79
Jackson	95	77
Tupelo	96	76
MISSOURI		
Columbia	95	75
Kansas City	96	75
Saint Louis	95	76
MONTANA		
Billings	93	63
Bozeman	91	61
Butte	86	57
Helena	90	60
Missoula	91	62
NEBRASKA		
Lincoln	97	74
Omaha	95	75
NEVADA		
Las Vegas	108	66
Reno	95	61
NEW HAMPSHIRE		
Concord	90	71
Lebanon	88	71
Mount Washington	60	56
NEW JERSEY		
Atlantic City	91	74
Newark	93	74
Trenton	93	75
NEW MEXICO		
Albuquerque	96	60
Carlsbad	101	65
Roswell	98	65
Santa Fe	90	65
NEW YORK		
Albany	90	71
Buffalo	86	70
New York	91	74
Niagara Falls	87	72
Poughkeepsie	92	75
Rochester	89	73
Syracuse	88	72
White Plains	89	74
NORTH CAROLINA		
Asheville	88	72
Charlotte	94	74
Fort Bragg	96	77
Greensboro	92	75
Raleigh/Durham	93	76
Wilmington	93	79
Winston-Salem	92	74
NORTH DAKOTA		
Bismarck	93	68
Fargo	91	71

Table 5D

Location	Dry bulb, °F	Wet bulb, °F
OHIO		
Akron	88	72
Cincinnati	93	74
Cleveland	89	73
Columbus	90	74
Dayton	90	74
Toledo	90	73
Youngstown	88	72
OKLAHOMA		
Oklahoma City	98	74
Tulsa	100	76
OREGON		
Eugene	91	67
Pendleton	97	64
Portland	90	67
Salem	92	67
PENNSYLVANIA		
Allentown	90	73
Altoona	89	72
Erie	85	72
Harrisburg	92	74
Philadelphia	92	75
Pittsburgh	89	72
Wilkes-Barre/Scranton	88	71
RHODE ISLAND		
Providence	89	73
SOUTH CAROLINA		
Charleston	94	78
Greenville	93	74
Myrtle Beach	93	79
SOUTH DAKOTA		
Pierre	99	70
Rapid City	95	65
Sioux Falls	94	73
TENNESSEE		
Chattanooga	94	75
Knoxville	92	74
Memphis	96	78
Nashville	94	76
TEXAS		
Abilene	99	71
Amarillo	96	67
Austin	98	74
Beaumont/Port Arthur	94	79
Brownsville	95	78

Location	Dry bulb, °F	Wet bulb, °F
TEXAS (continued)		
Corpus Christi	95	78
Dallas	100	74
El Paso	101	64
Fort Worth	100	75
Galveston	91	82
Houston	96	77
Laredo	102	73
Lubbock	97	67
San Antonio	98	73
Waco	101	75
Wichita Falls	103	74
UTAH		
Ogden	93	61
Salt Lake City	96	62
VERMONT		
Burlington	87	71
Montpelier	85	70
VIRGINIA		
Hampton	94	78
Lynchburg	93	74
Newport News	95	78
Norfolk	93	77
Quantico	94	77
Richmond	94	76
Roanoke	92	73
WASHINGTON		
Olympia	87	67
Seattle	85	65
Spokane	92	62
Takoma	86	65
Walla Walla	98	66
Yakima	95	65
WEST VIRGINIA		
Charleston	91	73
WISCONSIN		
Green Bay	88	73
La Crosse	91	74
Madison	90	73
Milwaukee	89	74
Wausau	88	71
WYOMING		
Casper	92	59
Cheyenne	87	58
Cody	91	59
Rock Springs	86	54

MAKING ALLOWANCES FOR SOLAR HEAT RADIATION

Radiant heat from the sun contributes significantly to heat gain. The heat load is much greater if the walls of a refrigerated space are exposed to the sun's rays, either directly or indirectly. In the northern hemi- sphere, the sun's ray's fall on east, south, and west walls. To allow for solar radiation in heat load calculations, simply increase the temperature differential by the applicable figure shown in Table 6 on the next page (or in a similar table). Note that the figures given in Table 6 are for the summer season, and are to be used for refrigeration load calculations only. They are not accurate for estimating air conditioning loads.

Table 6

Type of surface	East wall	South wall	West wall	Flat roof
Dark surfaces Slate roofing Tar roofing Black paints	8	5	8	20
Medium surfaces Unpainted wood Brick Red tile Dark cement Red, gray, green paint	6	4	6	15
Light surfaces White stone Light-colored cement White paint	4	2	4	9
Figures are to be added to the normal temperature differentials for heat leakage calculations in order to compensate for sun effect. *Not* to be used for air conditioning design.				

Table 6. Allowance for sun effect, in °F

MAKING QUICK HEAT LOAD CALCULATIONS

There may be times when you need to make a non-critical heat load calculation, either for basic cost- estimating purposes or for some other reason. Table 7 at the bottom of the next page will help you make a quick calculation of heat transmission through insulated walls. It lists the heat gain for various thick- nesses of common insulations. The values given in Table 7 are in Btu per degree Fahrenheit of temperature difference per square foot of surface area per 24 hours. Note that the "thickness of insulation" refers to the insulation itself, not the thickness of the overall wall.

For example, assume that you are asked to find the heat transfer over a 24-hr period through a 6-ft x 8-ft wall insulated with 4 in. of fiberglass. The wall's outside surface is exposed to an ambient temperature of 95°F. The temperature inside the refrigerated space is 0°F. Refer to Table 7 and calculate as follows:

Q = heat transfer value x area x 11 T = 1.5 x 48 ft2 x 95°F = 6,840 Btu

Table 7

Insulation	Thickness of insulation, in.										
	2	3	4	5	6	7	8	9	10	11	12
K-value approximately 0.17 Expanded polyurethane	2.04	1.36	1.02	0.815	0.68	0.58	0.51	0.45	0.41	0.37	0.34
K-value approximately 0.25 Glass fiber, cork, mineral wool fill and board, expanded polystyrene	3.0	2.0	1.5	1.2	1.0	0.86	0.75	0.67	0.60	0.55	0.50

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Table 7. Quick-estimate values for heat transmission through insulated walls (Btu per 1°F temperature difference per ft^2 of area per 24 hours)

AIR INFILTRATION

Outside air enters a refrigerator or other refrigerated space whenever a door is opened. Reducing the temperature of this outside air to the level inside the enclosure increases the refrigeration load. If the moisture content of the entering air is above that of the refrigerated space, the excess moisture will condense out of the air. The latent heat of condensation also adds to the overall heat load.

Because of the many variables involved, it is difficult to calculate the additional heat gain due to air infiltration. Traffic in and out of a refrigerated area usually varies with the area's size or volume. The number of doors is not important, but the number of times the doors are opened must be considered.

Table 8 lists estimated average air changes per 24 hours for refrigerated areas of various sizes. These figures assume that the storage temperature is above 32°F. "Average air changes" are due to door openings and infiltration. As noted previously, how- ever, it is difficult to estimate these figures accurately. You may have to modify the values as shown if you find that the use of the area is very heavy or very light. Another method of calculating air infiltration into a refrigerated space is to determine the velocity of airflow through an open door. When the door to a refrigerated space is opened, the difference in density between the cold air inside and the warm air outside creates a pressure differential. This pres- sure differential causes cold air to flow out at the bottom of the doorway, and warm air to flow in at the top. Velocities vary from a maximum value at the top and bottom of the doorway to zero at the vertical center of the opening. The average velocity in either half of a 7-ft doorway, for example, is 100 ft/ min when the temperature difference is 60°F. The velocity varies with the square root of the height of the door- way, and with the square root of the temperature difference.

Air change per 24 Hours for room above 32ºF by average due to doors and infiltration

Table 8A

Volume, ft^3	Air changes Per 24 hours		Volume, ft^3	Air changes Per 24 hours
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			

TABLE 8B

Air change per 24 Hours for room below 32ºF by average due to doors and infiltration

Volume CU. FT	Air Changes Per 24 Hrs.	Volume Cu. Ft	Air Changes Per 24 Hrs	Volume Cu. Ft	Air Changes Per 24 Hrs
200	33.5	2,000	9.3	25,000	2.3
250	29.0	3,000	7.4	30,000	2.1
300	26.2	4,000	6.3	40,000	1.8
400	22.5	5,000	5.6	50,000	1.6
500	20.0	6,000	5.0	75,000	1.3
600	18.0	8,000	4.3	100,00	1.1
800	15.3	10,000	3.8	150,000	1.0
1,000	13.5	15,000	3.0	200,000	0.9
1,500	11.0	20,000	2.6	300,000	0.85

Table 8. Average air changes per 24 hours due to door opening and infiltration, for storage room above 32ºF

Note: For heavy usage, multiply the above values by 2.0, for undisturbed long periods of storage multiply the above values by 0.6.

Here is a sample calculation. Assume that you wish to estimate the rate of infiltration through a door 8 ft high and 4 ft wide. There is a 100°F temperature difference between the refrigerated space and the outside air. Use the 7-ft doorway and the 60°F temperature difference as reference figures, and find the velocity as follows:

Velocity = 100 ft/mln x (√ 8 / √7) x (√100 / √*60*) = 100 X (2.83 / 2.65) X (10 / 7.75)

= 100 x 1.07 x 1 .29

= 138 ft/min

Now, using this value for velocity, you can calculate the estimated rate of infiltration in cubic feet per minute (cfm):

138 ft/mln x (.8ftx4ft / 2) = 2,208 cfm

For refrigerated spaces in which ventilation is provided by supply and/or exhaust fans, the ventilation load replaces the infiltration load (if the ventilation load is greater). You can calculate heat gain based on the ventilating air volume.

Table 9

Heat (BTU per cu. Ft) going into Storage room

Storage Room Temperature		Temperature of Outside Air of box											
		40ºF (4.4ºC)		50ºF (10ºC)		85ºF (29ºC)		90ºF (32.2ºC)		95ºF (35ºC)		100ºF (37.8C)	
		Relative Humidity of Outside Air of the box%											
ºF	ºC	70	80	70	80	50	60	50	60	50	60	50	60
55	12.8					1.12	1.34	1.41	1.66	1.72	2.01	2.06	2.44
50	10.0					1.32	1.54	1.62	1.87	1.93	2.22	2.28	2.65
45	7.2					1.50	1.73	1.80	2.06	2.12	2.42	2.47	2.85
40	4.4					1.69	1.92	2.00	2.26	2.31	2.62	2.67	3.65
35	1.7			0.36	0.41	1.86	2.09	2.17	2.43	2.49	2.79	2.85	3.24
30	-1.1	0.24	0.29	0.58	0.66	2.00	2.24	2.26	2.53	2.64	2.94	2.95	3.35
25	-3.9	0.41	0.45	0.75	0.83	2.09	2.42	2.44	2.71	2.79	3.16	3.14	3.54
20	-6.7	0.56	0.61	0.91	0.99	2.27	2.61	2.62	2.90	2.97	3.35	3.33	3.73
15	-9.4	0.71	0.75	1.06	1.14	2.45	2.74	2.80	3.07	3.16	3.54	3.51	3.92
10	-12.2	0.85	0.89	1.19	1.27	2.57	2.87	2.93	3.20	3.29	3.66	3.64	4.04
5	-15.0	0.98	1.03	1.34	1.42	2.76	3.07	3.12	3.40	3.48	3.87	3.84	4.27
0	-17.0	1.12	1.17	1.48	1.56	2.92	3.23	3.28	3.56	3.64	4.03	4.01	4.43
-5	-20.6	1.23	1.28	1.59	1.67	3.04	3.36	3.41	3.69	3.78	4.18	4.15	4.57
-10	-23.3	1.35	1.41	1.73	1.81	3.19	3.49	3.56	3.85	3.93	4.33	4.31	4.74
-15	-26.1	1.50	1.53	1.85	1.92	3.29	3.60	3.67	3.96	4.05	4.46	4.42	4.86
-20	-28.9	1.63	1.68	2.01	2.00	3.49	3.72	3.88	4.18	4.27	4.69	4.66	5.10
-25	-31.7	1.77	1.80	2.12	2.21	3.61	3.84	4.00	4.30	4.39	4.80	4.78	5.21
-30	-34.4	1.90	1.95	2.29	2.38	3.86	4.05	4.21	4.51	4.56	5.00	4.90	5.44

Once you know the rate of infiltration, you can calculate the heat load from the heat gain per cubic foot of infiltration. For conditions not covered by available data, you can find the infiltration heat load by determining the difference in enthalpy between the entering air and the air inside the refrigerated space. You can do this most easily by using a psychrometric chart.

PRODUCT LOAD

The second factor to be considered in estimating the total heat load is the product load. The term "product" covers a wide variety of materials and substances. The nature of the product can determine the design of the enclosure in which it will be kept chilled or frozen. For example, there is a wide difference between freezing and storing bakery products in an insulated cabinet and chilling water in a continuous, tubular water chiller. Even in air conditioning there is a "product"-two, in fact, since both the dry air and the water vapor mixed with it are cooled.

In order to estimate the product load accurately, you must know several things about the product. What kinds of foods will be kept in the cooler, and at what temperatures? Where is the product coming from, and how is it being transported? How much of the product is to be placed in the cooler, on average, per day or per week?

From this information, you can estimate the amount of heat that must be removed from the product. The object is to cool it from the temperature at which it enters the cooler to the temperature at which it will be stored (and then to keep that temperature constant).

Assume that the following amounts of meats, vegetables, fruits, milk, and other dairy products represent an average daily product load:

Meats.

It is estimated that approximately 300 lb of fresh meat and 85 lb of poultry are handled on an average day. These meats are obtained from a local packinghouse. They are delivered pre-chilled, but not down to 36°F. Delivery temperature depends on the time of arrival, but averages about 50°F, which then must be reduced about 15°F to reach an acceptable storage temperature.

When larger quantities of meat products are involved, you must calculate the heat load factor for each different kind of fresh meat separately. How- ever, the limited capacity of the walk-in cooler used in this example makes this unnecessary. The meats can be grouped together as far as their specific heats are concerned.

Let us assume that most of the meat involved is beef. The specific heat of fresh beef at an above-freezing temperature, as shown in Table 2 at the end of this chapter, ranges from 0.70 to 0.84 Btu/lb/ºF. If the beef is relatively lean; you can use 0.77, the midpoint of this range, for your calculations. Simple math then tells you that to cool 300 lb of fresh meat through 15°F will require 3,465 Btu of refrigeration per day (300 x 15 x 0.77 = 3,465).

The specific heat of fresh poultry is 0.79 Btu/lb/ºF. Make the same kind of calculation as you did for the beef, and you find that 1,007 Btu of heat must be removed from the 85 lb of poultry per day (85 x 15 x 0.79 = 1,007).

Milk and dairy products

It is estimated that 25 gallons of milk are handled daily. A gallon weighs roughly 8 lb, so 25 gallons of milk would weigh approximately 200 lb. The specific heat of milk, again from Table 2, is 0.93 Btu/lb/ºF. Assuming a similar 15°F temperature change, the heat load from this product comes to about 2,790 Btu per day (200 x 15 x 0.93 = 2,790).

Vegetables and fruits

Included in this category are cabbage, lettuce, string beans, peas, rhubarb, carrots, apples, peaches, pears, oranges, grapefruit, etc. About 100 lb of these items are handled daily. However, they are on display during regular business hours and are only in the storage cooler overnight. Since they represent a minimum load, and then only at a time when there is no traffic in or out of the cooler, they may be disregarded as part of the product load. *(Note:* For larger applications, such as cold-storage warehouses, individual product loads can never be disregarded. When estimating the total heat load for such applications, you must make separate computations for each product, and for its respective temperature and specific heat.)

From the preceding calculations, you can now find the total product load:

Fresh meats 3,465 Btu per day + Poultry 1,007 Btu per day Milk + 2,790 Btu per day

Total product load = <u>7,262 Btu per day</u>

If the product to be stored in the refrigerated space is delivered pre-cooled, the product load is usually negligible, especially in small walk-in cooler installations. For large-volume applications, however, the product load may be substantial enough to require separate calculations for each product. This requires knowing the freezing point, specific heat, percent water, etc. of each product.

The *product load,* whether it is heavy or light, is defined as any heat gain resulting from the products that are being stored in the refrigerated space. The heat given off depends on the specific product and its storage temperature.

Product heat gain consists of some or all of:

- **the heat released from products that were initially stored and/or transported at a higher temperature than that maintained in the refrigerated space**
- **.the heat removed in the process of freezing or chilling the products**
- **The heat of respiration from chemical reactions that take place in products.**

Note that the values resulting from the last item vary with the storage temperature.

CALCULATING SENSIBLE HEAT

Above-freezing temperatures

Most products are at a higher temperature than the storage temperature when they are first placed in the refrigerated space. Many food products have a high percentage of water content. Their reaction to a loss of heat is quite different above the freezing point than it is below the freezing point. Above the freezing point, the water continues to exist as liquid. Below the freezing point, it changes to ice.

The *specific heat* of a product is defined, as the amount of heat (Btu) required raising the temperature of 1 lb of the substance 1°F. Note that the specific heat of a product differs depending on whether the temperature is above freezing or below freezing. The freezing point, which in most cases is below 32°F, also varies among products.

The heat to be removed from a stored product to lower its temperature to a point above freezing can be calculated as follows:

$$Q = W \times C \times (T1 - T2)$$

where:

Q = the quantity of heat (Btu) to be removed

W = the weight of the product (lb)

C = the specific heat of the product above freezing

***T1* = the initial temperature (OF)**

***T2* = the final temperature, at or above the freezing point (OF).**

For example, assume that you want to calculate the heat that must be removed in order to cool 1,000 lb of veal from 42°F to 29°F. The highest freezing point of veal is 29° F. The specific heat, taken from Table 2 at the end of the previous chapter, is 0.76 Btu/ lb/ºF. Proceed as follows:

Q = 1,000 lb x 0.76 x (42°F -29°F)

= 1 ,000 x 0.76 x 13 = 9,880

Btu Below-freezing temperatures

Once the water content of a product has been frozen, sensible cooling occurs again, just as it did when the product was above freezing. Now the ice in the product causes the specific heat to change. For example, the specific heat of veal *above* freezing is 0.76. Its specific heat *below* freezing is 0.41.

The heat to be removed from a stored product to lower its temperature to a point *below* freezing can be calculated as follows:

Q = W x C1 x (T1 -*T* 3)

where:

Q = the quantity of heat (Btu) to be removed

W = the weight of the product (lb)

C1 = the specific heat of the product below freezing

71 = the freezing temperature (OF)

***T* 3 = the final temperature, below the freezing point (OF).**

For example, to calculate the heat that must be removed from the same 1,000 lb of veal in order to cool it from its freezing point (29°F) to 0°F, you would proceed as follows:

Q = 1,000lb x 0.41 x (29°F-0°F)

= 1,000 x 0.41 x 29 = 11,890 Btu

CALCULATING THE LATENT HEAT OF FREEZING

Most refrigerated food products contain a high percentage of water. When calculating the amount of heat that must be removed in order to freeze a product, you need to know its water content.

The *latent heat of freezing* (also called the *latent heat of fusion)* is defined as the amount of heat (Btu) that must be removed in order to change 1 lb of a liquid to 1 lb of solid at the same temperature. You can find a product's latent heat of freezing by multiplying the latent heat of water (144 Btu/lb) times the percentage of water in the product. It also shows the latent heat of fusion for veal to be 100 Btu/lb, but you could have arrived at approximately the same figure by calculating as follows:

0.70 x 144 Btu/lb = 100 Btu/lb

To calculate the amount of heat that must be removed from a product in order to freeze it, then, simply proceed as follows:

Q = *W x hf*

where:

Q = the quantity of heat (Btu) to be removed

***W* = the weight of the product (lb)**

***hf* = the product's latent heat of fusion (Btu/lb).**

Therefore, the latent heat of freezing 1,000lb of veal at 29°F is:

Q = *W* x *hf*

= 1,000 lb x 100 Btu/lb = 100,000 Btu

CALCULATING THE TOTAL PRODUCT LOAD

The *total product load* is the sum of the individual calculations just completed. It includes the sensible heat above freezing, the latent heat of freezing, and the sensible heat below freezing. Using the previous calculations as an example, if 1,000 lb of veal is cooled from 42ºF to 0ºF, the total product load would be:

Sensible heat above freezing 9,880 Btu + Latent heat of freezing 100,000 Btu + Sensible heat below freezing 11 ,890 Btu = 121,770 Btu total.

Table 10A

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT
Vegetables								
Artichokes								
Globe	32º	95 to 100	2 week	29.8º	0.93	0.48	122	-
Jerusalem	31º to 32º	90 to 95	4 to 5 months	27.5º	0.87	0.54	112	
Asparagus	32º to 35º	95 to 100	2 to 3 weeks	30.9º	0.94	0.48	134	25
Beans								
Snap or Green	40º to 45º	95	7 to 10 days	30.7º	0.91	0.47	128	14
Lima	34º to 40º	95	3 to 5 day	31.0º	0.73	0.40	94	
Dried	50º	70	6 to 8 months					
Beets								
Roots	32º	95 to 100	4 to 6 months	30.1º	0.90	0.46	126	23
Bunch	32º	98 to 100	10 to 14 days					
Broccoli	33º	95	10 to 14 days	30.9	0.96	0.43		
Brussels sprouts	32º	95 to 100	3 to 5 weeks	30.5	0.88	0.46	122	
Cabbage, Late	32º	98 to 100	5 to 6 months	30.4º	0.94	0.47	132	17
Carrots								
Topped-immature	32º	98 to 100	4 to 6 weeks	29.5º	0.90	0.46	126	22
Topped-mature	32º	98 to 100	7 to 9 months	29.5º	0.90	0.46	126	22
Cauliflower	32º	95 to 98	3 to 4 weeks	29.0º	0.93	0.47	132	16
Celeriac	32º	95 to 100	6 to 8 months	30.3º	0.91	0.46	126	
Celery	32º	98 to 100	2 to 3 months	31.1º	0.95	0.48	135	30
Collards	32º	95 to 100	10 to 14 days	30.6º	0.94	0.44	130	
Corn, Sweet	32º	95 to 98	4 to 8 days	30.9º	0.79	0.42	106	16
Cucumbers	45º to 50º	95	10 to 14 days	31.1º	0.97	0.49	137	20
Eggplant	45º to 50º	90 to 95	7 to 10 days	30.6º	0.94	0.48	132	
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT

Table 10B

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT
Endive (Escarole)	32º	95	2 to 3 weeks	31.9º	0.94	0.48	132	
Frozen Vegetables	-10º to 0º		6 to 12 months					
Garlic	33º	70	1 to 2 months	30.6º	0.76	0.52	84	
Garlic, dry	32º	65 to 70	6 to 7 weeks	30.5º	0.69	0.40	89	
Greens, leafy	32º	95	10 to 14 days	30.0º	0.91	0.48	136	32
Ginger, root	34º	90 to 95	1 to 2 months	29.0º	0.90	0.46	117	
Horseradish	30º to 32º	95 to 100	10 to 12 months	28.7º	0.78	0.42	104	
Jicama	55º to 65º	65 to 70	1 to 2 months					
Kale	32º	95	3 to 4 months	31.1º	0.89	0.46	124	
Kohlrabi	32º	95	2 to 4 weeks	30.2º	0.92	0.47	124	
Leeks, green	32º	95	1 to 3 months	30.7º	0.88	0.46	126	
Lettuce head	34º	95 to 100	2 to 3 weeks	31.7º	0.96	0.48	136	25
Mushrooms	32º	90	3 to 4 days	30.4º	0.93	0.47	130	
Okra	45º to 50º	90 to 95	7 to 10 days	28.7º	0.92	0.46	128	
Onions								
Green	32º	95	3 to 4 weeks	30.4º	0.91			22
Dry, and onion sets	32º	65 to 70	1 to 8 months	30.6º	0.90	0.46	124	
Parsley	32º	95	1 to 2 months	30.0º	0.88	0.45	122	
Parsnips	32º	98 to 100	4 to 6 months	30.4º	0.84	0.44	112	36
Peas								
Green	32º	95	1 to 3 weeks	30.9º	0.79	0.42	106	23
Dried	50º	70	6 to 8 months					
Peppers								
Dried chili	32º to 50º	60 to70	6 months		0.30	0.24	17	
Sweet	45º to 50º	90 to 95	2 to 3 weeks	30.7º	0.94	0.47	132	41
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT

Table 10C

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT
Potatoes								
Early	38º to 40º	90 to 95	4 to 5 months	30.9º	0.85	0.43	111	
Main crop	38º to 40º	90 to 95	5 to 8 months	30.9º	0.82	0.44	116	
Spring	32º	95 to 100	3 to 4 weeks	30.7º	0.95	0.48	134	
Winter	32	95 to 100	2 to 4 months	30.2º	0.95	0.48	134	
Rhubarb	32º	95	2 to 4 weeks	30.3º	0.96	0.48	134	
Rutabagas	32º	98 to 100	4 to 6 months	30.1º	0.91	0.47	127	
Salsify	32º	98 to 100	2 to 4 months	30.0º	0.83	0.44	133	
Seed, vegetable	32º to 50º	50 to 65	10 to 12 months		0.29	0.23	16	
Spinach	32º	95	10 to 14 days	31.5º	0.94	0.48	132	
Squash	-	-	-	-	-	-	-	-
Acorn	45º to 50º	70 to 75	5 to 8 weeks	30.5º				
Summer	32º to 50º	85 to 95	5 to 14 days	31.1º	0.95	0.48	135	
Winter	50º to 55º	70 to 75	4 to 6 months	30.3º	0.91	0.48	127	
Tamarillos	37º to 40º	85 to 95	10 weeks					
Tomatoes	-	-	-	-	-	-	-	-
Mature green	55º to 70º	85 to 90	1 to 3 weeks	31.0º	0.95	0.48	134	25
Firm, ripe	45º to 50º	85 to 90	4 to 7 days	31.1º	0.94	0.48	134	21
Turnips	-	-	-	-	-	-	-	-
Roots	32º	95	4 to 5 months	30.1º	0.93	0.47	130	
Greens	32º	95 to 100	10 to 14 days	30.6º	0.92	0.48		
Watercress	32º	95 to 100	2 to 3 weeks					
Yams	60º	85 to 90	3 to 60 months	28.5º	0.79	0.40	105	
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT

Table 10D

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/ Fº	Specific Heat Below Freezing BTU/Lb/ Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/ Cu FT
Fruit and Melons								
Apples	30º to 40º	90	3 to 8 months	29.3 º	0.87	0.45	121	28
Apples dried	41º to 48º	55 to 60	5 to 8 months					
Apricots	31º to 32 º	90	1 to 2 weeks	30.1 º	0.88	0.46	122	30
Avocados	45º to 55º	85 to 90	2 to 4 weeks	31.5º	0.72	0.40	94	19
Bananas	55º to 65º	85 to 95		30.6º	0.80	0.42	108	
Blackberries	31º to 32º	95	3 days	30.5º	0.88	0.46	122	19
Blueberries	31º to 32º	90 to 95	2 weeks	29.7º	0.86	0.45	118	19
Cantaloupes	36º to 40º	95	5 to 15 days	29.8º	0.94	0.46	129	
Casaba melons	45º to 50º	85 to 95	4 to 6 weeks					
Cherries	-	-	-	-	-	-	-	-
Sour	31º to 32º	90 to 95	3 to 7 days	29.0º	0.87	0.49	124	18
Sweet	30º to 31º	90 to 95	2 to 3 weeks	28.8º	0.89	0.51	116	
Coconuts	32º to 35º	80 to 85	1 to 2 months	30.4º	0.58	0.34	67	
Cranberries	36º to 40º	90 to 95	2 to 4 months	30.4º	0.90	0.46	124	22
Crenshaw melons	45º to 50º	75 to 80	2 to 4 weeks					
Currants	31º to 32º	90 to 95	10 to 14 days	30.2º	0.88	0.45	120	
Dates, cured	0º to 32º	75 or less	6 to 12 months	3.7º	0.36	0.26	29	24
Dewberries	31º to 32º	90 to 95	3 days	27.0º	0.88			
Elderberries	31º to 32º	90 to 95	1 to 2 weeks					
Figs	-	-	-	-	-	-	-	-
Dried	32º to 40º	50 to 60	9 to 12 months		0.36	0.27	34	45
Fresh	31º to 32º	85 to 90	7 to 10 days	27.6º	0.82	0.43	112	21
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/ Fº	Specific Heat Below Freezing BTU/Lb/ Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/ Cu FT

Table 10E

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/ Fº	Product Loading Density Approx. Lb/ Cu FT
Frozen fruits	-12º to 0º	90 to 95	18 to 24 months					
Grapefruit	50º to 60º	85 to 90	4 to 6 weeks	30.0º	0.91	0.46	126	30
Grapes	-	-	-	-	-	-	-	-
American type	31º to 32º	85 to 90	2 to 8 weeks	29.7º	0.86	0.44	116	29
European type	30º to 31º	90 to 95	3 to 6 months	28.1º	0.86	0.44	116	29
Vinifera	30º to 31º	90 to 95	3 to 6 months					
Guavas	45º to 50º	90	2 to 3 weeks		0.86			
Honeydew mel- ons	41º to 50º	90 to 95	2 to 3 weeks	30.4º	0.94	0.44	129	
Kiwifruit	31º to 32º	90 to 95	3 to 5 months					
Lemons	32º to 58º	85 to 90	1 to 6 months	29.4º	0.91	0.46	127	33
Limes	45º to 48º	85 to 90	6 to 8 weeks	29.1º	0.89	0.46	122	32
Loganberries	31º to 32º	90 to 95	2 to 3 days					
Loquats	32º	90	3 weeks					
Lychees	35º	90 to 95	3 to 5 weeks					
Mangoes	55º	85 to 90	2 to 3 weeks	30.3º	0.85	0.44	117	
Melons, Casaba	45º to 48º	75 to 80	2 to 4 weeks	30.0º	0.95	0.45	132	
Nectarines	31º to 32º	90	2 to 4 weeks	30.4º	0.90	0.49	119	
Olives, fresh	45º to 50º	85 to 90	4 to 6 weeks	29.4º	0.80	0.42	108	
Oranges Juice	32º to 35º		3 to 6 weeks	30.6º	0.91	0.47	128	
Oranges CA and AZ	38º to 40º	85 to 90	3 to 6 weeks	30.6º	0.90	0.46	124	
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/ Fº	Product Loading Density Approx. Lb/ Cu FT

Table 10F

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/ Fº	Product Loading Density Approx. Lb/ Cu FT
Oranges FL and TX	32º to 34º	85 to 90	8 to 12 weeks	28.6º	0.91	0.46	126	
Papayas	45º	85 to 90	1 to 3 weeks	30.4º	0.82	0.47	130	
Peaches	31º to 32º	90	2 to 4 weeks	30.3º	0.90	0.46	124	33
Peaches dried	32º to 41º	55 to 60	5 to 8 months		0.61	0.83	46	
Pears	29º to 31º	90 to 95	2 to 7 months	29.2º	0.86	0.45	118	47
Persian melons	45º to 50º	90 to 95	2 weeks		0.81	0.43	112	
Persimmons	30º	90	3 to 4 months	28.1º	0.84	0.43	112	
Pineapples, ripe	45º	85 to 90	2 to 4 weeks	30.0º	0.88	0.45	122	25
Plums	31º to 32º	90 to 95	2 to 4 weeks	30.5º	0.88	0.45	118	22
Pomegranates	32º	90	2 to 4 weeks	26.6º	0.87	0.48	112	
Prunes	-	-	-	-	-	-	-	-
Fresh	31º to 32º	90 to 95	2 to 4 weeks	30.5º	0.84	0.34	112	
Dried	32º to 41º	55 to 60	5 to 8 months					
Quinces	31º to 32º	90	2 to 3 months	28.4º	0.88	0.45	122	
Raisins	40º	60 to 70	9 to 12 months		0.47	0.32	43	45
Raspberries, black	31º to 32º	90 to 95	2 to 3 days	30.0º	0.84	0.44	122	
Raspberries, red	31º to 32º	90 to 95	2 to 3 days	30.9º	0.87	0.45	121	
Strawberries	31º to 32º	90 to 95	5 to 7 days	30.6º	0.92	0.42	129	40
Tangerines	32º to 38º	85 to 90	2 to 4 weeks	30.1º	0.90	0.46	125	
Watermelons	40º to 50º	80 to 90	2 to 3 weeks	31.3º	0.97	0.48	132	27
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/ Fº	Product Loading Density Approx. Lb/ Cu FT

Table 10G

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT
Haddock, Cod Perch	30º to 35º	90 to 95	12days	28º	0.82	0.43	112	35
Hake, Whiting	32º to 34º	95 to 100	10 days	28º	0.86	0.45	118	
Halibut	31º to 34º	95 to 100	18 days	28.0º	0.75	0.45	110	
Herring	-	-	-	-	-	-	-	-
Kippered	32º to 36º	80 to 90	10 days	28.0º	0.76	0.41	100	
Smoked	40º to 50º	50 to 60	6 to 8 months		0.70	0.39	92	
Tuna	30º to 35º	90 to 95	15 days	28º	0.76	0.41	100	35
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freez-ing BTU/Lb/ Fº	Specific Heat Below Freez-ing BTU/Lb/ Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/ Cu FT
Mackerel	32º to 34º	95 to 100	6 to 8 days	28.0º	0.66	0.37	82	
Salmon	40º to 50º	50 to 60	15 days	28º	0.71	0.39	92	
Scallop meat	32º to 34º	95 to 100	12 days	28º	0.84	0.44	115	
Shrimp	31º to 34º	95 to 100	12 to 14 days	28º	0.86	0.45	119	35
Lobster American	41º to 50º	In sea water	indefinitely	28º	0.87	0.51	113	
Oysters, Clams								
(meat and liquid)	32º to 36º	100	5 to 8 days	28º	0.90	0.46	125	
Oyster in shell	41º to 50º	95 to 100	5 days					
Frozen shellfish	-30º to -4º	90 to 95	3 to 8 months			0.46	110	
Beef								
Beef, Aging	34º	85 to 90	45 days	29º	0.75	0.40	110	
Beef, fresh, average	32º to 34º	88 to 92	1 to 6 weeks	28º to 29º	0.70 to 0.84	0.38 to 0.43	89 to 110	
Beef carcass								
Choice 60% lean	32º to 39º	85 to 90	1 to 3 weeks	28.5º	0.84	0,43	110	
Prime 54% lean	32º to 34º	85	1 to 3 weeks	29º	0.70	0.38	89	
Sirloin cut (choice)	32º to 34º	85	1 to 3 weeks	28º	0.75	0.40	100	
Round cut (choice)	32º to 34º	85	1 to 3 weeks	28º	0.75	0.40	100	
Dried, chipped	50º to 59º	15	6 to 8 weeks	28º	0.87	0.51	110	
Liver	32º	90	5 days	28.9º	0.83	0.52	99	
Veal, lean	28º to 34º	85 to 95	3 weeks	27º	0.85	0.45	89	
Beef, frozen	-10º to 0º	90 to 95	6 to 12 months			0.41	100	
Pork								
Fresh, average	32º to 43º	85 to 90	3 to 7 days	28º to 29º	0.46 to 0.55	0.30 to 0.33	46 to 63	
Carcass, 47% lean	32º to 34º	85 to 90	3 to 5 days	28º	0.74	0.75	65	
Bellies, 35% lean	32º to 34º	85	3 to 5 days	28º	0.67	0.0.81	65	
Backfat, 100% fat	32º to 34º	85	7 to 12 days	28º to 29º	0.58 to 0.63	0.34 to 0.36	67 to 77	37
Shoulder, 67% lean	32º to 34º	85 to 90	3 to 5 days	28º	0.60	0.35	65	
Pork frozen	-10º to 0º	90 to 95	4 to 8 months					
Ham								
74% lean	32º to 34º	80 to 85	3 to 5 days	28º	0.56	0.33	60	
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freez-ing BTU/Lb/ Fº	Specific Heat Below Freez-ing BTU/Lb/ F	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/ Cu FT

Table 10H

Table 10I

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/F	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT
cured	60º to 65º	50 to 60	0 to 2 years	28º	0.52 to 0.56	0.32 to 0.33	57 to 64	
Country cure	50º to 59º	65 to 70	3 to 5 months	29º	0.54	0.33	60	
Frozen	-10º to 0º	90 to 95	6 to 8 months	29º	0.54	0.33	60	
Bacon								
Medium fat class	37º to 41º	80 to 85	2 to 3 weeks	29º	0.40	0.26	38	
Curd, farm style	61º to 64º	85	4 to 6 months	29º	0.30 to 0.43	0.24 to 0.29	18 to 41	57
Cured, packer style	34º to 39º	85	2 to 6 weeks	29º	0.40	0.26	38	
Frozen	-10º to 0º	90 to 95	2 to 4 months	29º	0.40	0.26	38	
Sausage								
Links or bulk	32º to 34º	85	1 to 7 days	29º	0.75	0.59	39	
Country, smoked	32º	85	1 to 3 weeks	28º	0.75	0.59	39	
Braunschweiger	32º	85	1 to 3 weeks	29º	0.72	0.57	69	
Frankfurter	32º	85	1 to 3 weeks	28º	0.75	0.55	77	
Italian	32º	85	1 to 3 weeks	29º	0.74	0.57	74	
Polish	32º	85	1 to 3 weeks	29º	0.75	0.56	77	
Pork	32º	85	1 to 3 weeks	29º	0.70	0.58	64	
Smoked links	32º	85	2 to 3 months	28º	0.67	0.59	56	
Frankfurters								
Average	32º	85	1 to 3 weeks	28º	0.43	0.26	40	
Polish style	32º	85	1 to 3 weeks	28º	0.43	0.26	40	
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/F	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT

Table 10J

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/ Fº	Specific Heat Below Freezing BTU/Lb/ Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/ Cu FT
Meat (Lamb)								
Fresh, average	32º to 34º	85 to 90	5 to 12 days	28º to 29º	0.68 to 0.76	0.38 to 0.51	86 to 100	
Choice, lean	32º	85	5 to 12 days	29º	0.74	0.40	95	
Fresh, average	28º to 32º	95 to 100	1 to 3 weeks	28º to 29º	0.46 to 0.55	0.30 to 0.33	46 to 63	
Chicken all classes	28º to 32º	95 to 100	1 to 4 weeks	28	1,04	0.79	95	
Turkey, all classes	28º to 32º	95 to 100	1 to 4 weeks	28	0.84	0.54	101	
Turkey breast roll	-4º to -1º		6 to 12 months	28	0.83	0.53	101	
Turkey frankfurters	0º to 15º		6 to 16 months	29º				
Duck	28º to 32º	95 to 100	1 to 4 weeks	26º	0.73	0.59	70	
Poultry, frozen	-10º to 0º	90 to 95	12 months					
Meat Misc.								
Rabbits, fresh	-10º to 0º	90 to 95	6 to 10 months	28	0.50	0.35	89	
Dairy Products								
Butter	40º	75 to 85	1 months	-4º to 31º	0.50	0.25	23	
Butter, frozen	-10º	70 to 85	12 to 20 months					
Cheese, Cheddar				18º to 29º				
Long storage	32º to 34º	65 to 70	12 months		0.65	0.62		
Short storage	40º	65 to 70	6 months		0.65			
Processed	40º	65 to 70	12 months		0.65			
Grated	40º	65 to 70	12 months		0.65			
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/ Fº	Specific Heat Below Freezing BTU/Lb/ Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/ Cu FT

Table 10K

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/F	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT
Camembert					0.74	0.80	74	
Cheddar				8.8 º	0.66	0.73	53	
Cottage uncreamed				29.8 º	0.89	0.48	114	
Cream					0.75	0.70	77	
Gouda					0.69	0.66	59	
Limburger				18.7 º	0.72	0.67	70	
Mozzarella					0.75	0.59	78	
Parmesan, hard					0.62	0.70	42	
Processed American				19.6 º	0.67	0.66	56	
Roquefort				2.7 º	0.67	0.80	57	
Swiss				14.0 º	0.66	0.69	53	
Ice cream								
10% fat	-20º to -15º	90 to 95	3 to 23 months	21.0º	0.66 to 0.70	0.37 to 0.39	86	25
Premium	-30º to -20	90 to 95	3 to 23 months	22º	0.70	0.39	86	
Chocolate	-20	95	3 to 23 months	21.9	0.74	0.66	80	
Strawberry	-20	95	3 to 23 months	21.9	0.76	0.65	86	
Vanilla	-20	95	3 to 23 months	21.9	0.77	0.65	88	
Milk								
Fluid pasteurized	39º to 43º		7 days		0.93	0.43	124	64
Grade A (3.7% fat)	32º to 39º		7 to 14 days	31º	0.93	0.43	124	64
Raw	32º to 39º		2 days		0.93	0.43	124	64
Dried, Whole	70º	low	6 to 9 months				3	
Skim, dried	70º	low	16 months		0.43		5	
Dried, nonfat	45º to 70º	Low	16 months		0.44			
Evaporated	40º		24 months	29.5º	0.85	0.50	106	
Evaporated unsweetened	70º		12 months					
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/F	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT

Table 10L

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/Fº	Specific Heat Below Freezing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT
Condensed sweetened	40º		15 months					
Whey, dried	70º	low	12months					
Cream								
Half and half						0.89	0.52	116
Table					28.0 º	0.86	0.53	106
Heavy whipping						0.78	0.55	83
Shell, farm cooler	50º to 55º	70 to 75	2 to 3 weeks	28º	0.73	0.40	96	19
Frozen	0 or below		1 year +	28º	0.73	0.42	106	41
Whole	0º		1 year +					
Yolk	0º		1 year +					
White	0º		1 year +					
Whole egg solids	35º to 40º	low	6 to 12 months					
Yolk solids	35º to 40º	low	6 to 12 months					
Flake albumen solids		Low	1 year +					
Dry spray albumen solids		low	1 year +					
Candy								
Milk chocolate	0º to 34º	40	6 to 12 months		0.44		2	
Peanut brittle	0º to 34º	40	1.5 to 6 months		0.42		3	
Fudge	0º to 34º	65	5 to 12 months		0.45		15	
Marshmallows	0º to 34º	65	3 to 9 months					

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/ Fº	Specific Heat Below Freezing BTU/Lb/ Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/ Cu FT
Miscellaneous	-	-	-	-	-	-	-	
Alfalfa meal	0º	70 to 75	1 year +					
Beer								
Keg	35º to 40º		3 to 8 weeks	28º	0.92		129	
Bottles and cans	33º to 38º	65 or below	3 to 6 months	28º	0.92		129	
Body Box	34º	93	7 days	29º	0.84	0.43	110	
Bread	0º		3 to 13 weeks					
Canned goods	32º to 60º	70 or lower	1 year					
Cocoa	32º to 34º	50 to 70						
Coffee, green	35º to 37º	80 to 85	2 to 4 months		0.30	0.24	14 to 21	
Fur and Fabrics	34º to 40º	45 to 55	years					
Fur debugging	-10º to 0º	50 to 55	2 weeks					
Honey	38º to 50º	50 to 60	1 year +		0.35	0.26	26	
Hops	28º to 32º	50 to 60	6 months					
Lard (without Antioxidant)	45	90 to 95	4 to 8 months					
Maple syrup	75º to 80º	60 to 65	1 year +		0.24	0.21	7	
Nuts	32º to 50º	65 to 75	8 to 12 months		0.50 to 0.53	0.21 to 0.22	4 to 8	25
Oil, vegetable salad	70º		1 year +					
Oleomargarine	35º	60 to 70	1 year +					
Orange Juice	30º to 35º		3 to 6 weeks		0.91	0.47	128	
Popcorn, unpopped	32º to 40º	85	4 to 6 months		0.31	0.24	19	
Yeast, baker's compressed	31º to 32º		1 year +					
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freezing BTU/Lb/ Fº	Specific Heat Below Freezing BTU/Lb/ Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/ Cu FT

Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freez-ing BTU/Lb/Fº	Specific Heat Below Freez-ing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT
Tobacco								
Hogshead	50º to 65º	50 to 65	1 year +					
Bales	35º to 40º	70 to 85	1 year +					
Cigarettes	35º to 46º	50 to 55	6 months	25º				
Cigars	35º to 50º	60 to 65	2 months	25º				
Horseradish	30º to 32º	95 to 100	10 to 12 months	28.7º	0.78	0.42	104	
Commodity	Storage Temp. Fº	Relative Humidity %	Approximate Storage Life	Highest Freezing point Fº	Specific Heat above Freez-ing BTU/Lb/Fº	Specific Heat Below Freez-ing BTU/Lb/Fº	Latent Heat of Fusion BTU/Lb/Fº	Product Loading Density Approx. Lb/Cu FT

Flower

Commodity	Storage Temperature F°	Relative Humidity %	Approximate Storage Life	Method of Holding	Highest Freezing Point °F
Cut Flower					
Calla Lily	40°	90 to 95	1 week	Dry Pack	
Camellia	45 °	90 to 95	3 to 6 days	Dry Pack	30.6°
Carnation	31° to 32°	90 to 95	3 to 4 weeks	Dry Pack	30.8°
Chrysanthemum	31° to 32°	90 to 95	3 to 4 weeks	Dry Pack	30.5°
Daffodil (Narcissus)	32° to 33°	90 to 95	1 to 3 weeks	Dry Pack	31.8°
Dahlia	40°	90 to 95	3 to 5 days	Dry Pack	
Gardenia	32° to 34°	90 to 95	2 weeks	Dry Pack	31.0°
Gladiolus	36° to 42°	90 to 95	1 week	Dry Pack	31.4°
Iris, tight buds	31° to 32°	90 to 95	2 weeks	Dry Pack	30.6°
Lily, Easter	32° to 35°	90 to 95	2 to 3 weeks	Dry Pack	31.1°
Lily, of the valley	31° to 32°	90 to 95	2 to 3 weeks	Dry Pack	
Orchid	45° to 55°	90 to 95	2 weeks	Water	31.4°
Peony, tight buds	32° to 35°	90 to 95	4 to 6 weeks	Dry Pack	30.1
Rose tight buds	32	90 to 95	2 weeks	Dry Pack	31.2
Snapdragon	40° to 42°	90 to 95	1 to 2 weeks	Dry Pack	30.4
Sweet Peas	31 ° to 32 °	90 to 95	2 weeks	Dry Pack	30.4
Tulips	31 ° to 32 °	90 to 95	2 to 3 weeks	Dry Pack	
Greens					
Asparagus (plumosus)	35 ° to 40 °	90 to 95	2 to 3 weeks	Polylined cases	26.0
Fern, dagger and wood	30 ° to 32 °	90 to 95	2 to 3 months	Dry Pack	28.9 °

Commodity	Storage Temperature F°	Relative Humidity %	Approximate Storage Life	Method of Holding	Highest Freezing Point °F
Fern, Leatherleaf	43 °	90 to 95	1 to 2 months	Dry Pack	
Holly	32 °	90 to 95	4 to 5 weeks	Dry Pack	27.0 °
Huckleberry	32 °	90 to 95	1 to 4 weeks	Dry Pack	26.7 °
Laurel	32 °	90 to 95	2 to 4 weeks	Dry Pack	27.6 °
Magnolia	35 ° to 40 °	90 to 95	2 to 4 weeks	Dry Pack	27.0 °
Rhododendron	32 °	90 to 95	2 to 4 weeks	Dry Pack	27.6 °
Commodity	Storage Temperature F°	Relative Humidity %	Approximate Storage Life	Method of Holding	Highest Freezing Point °F

Commodity	Storage Temperature F°	Relative Humidity %	Approximate Storage Life	Method of Holding	Highest Freezing Point °F
Salal	32 °	90 to 95	2 to 3 weeks	Dry Pack	26.8 °
Bulbs					
Amaryllis	38 ° to 45 °	70 to 75	5 months	Dry	30.8 °
Caladium	70 °	70 to 75	2 to 4 months		29.7 °
Crocus	48 ° to 63 °		2 to 3 months		29.7 °
Dahlia	40 ° to 48 °	70 to 75	5 months	Dry	28.7 °
Gladiolus	45 ° to 50 °	70 to 75	5 to 8 months	Dry	28.2 °
Hyacinth	63 ° to 68 °		2 to 5 months		29.3 °
Iris, Dutch Spanish	68 ° to 77 °	70 to 75	4 months	Dry	29.3 °
Gloriosa	50 ° to 63 °	70 to 75	3 to 4 months	Polyliner	
Candidum	31 ° to 33 °	70 to 75	1 to 6 months	Polyliner and peat	
croft	31 ° to 33 °	70 to 75	1 to 6 months	Polyliner and peat	
Longiflorum	31 ° to 33 °	70 to 75	1 to 10 months	Polyliner and peat	28.9
Tuberose	40 ° to 45 °	70 to 75	4 to 12 months	Dry	
Tulip	63 °	70 to 75	2 to 6 months	Dry	
Commodity	Storage Temperature F°	Relative Humidity %	Approximate Storage Life	Method of Holding	Highest Freezing Point °F

Commodity	Storage Temperature F°	Relative Humidity %	Approximate Storage Life	Method of Holding	Highest Freezing Point °F
Rose bushes	31° to 36°	85 to 95	4 to 5 months	Bare Rooted	
Strawberry plants	30° to 32°	80 to 85	8 to 10 months	Bare Rooted	29.9°
Rooted cuttings	31° to 36°	85 to 95		Polywrap	
Herbaceous perennials	27° to 35°	80 to 85	3 to 8 months		
Christmas trees	22° to 32°	80 to 85	6 to 7 weeks		
Commodity	Storage Temperature F°	Relative Humidity %	Approximate Storage Life	Method of Holding	Highest Freezing Point °F

This Table is for Product Load

Specific Heat

Name	BTU/Lb./°F	Temperature °F
Liquid		
Acetic Acid	0.522	79 – 203
Alcohol- Ethyl	0.680	32 – 208
Alcohol-Methyl	0.610	59 – 68
Calcium Chloride Brine 20%	0.744	68
Carbon Tetrachloride	0.201	68
Chloroform	0.234	68
Gasoline	0.500	32 – 212
Glycerine	0.575	59 – 120
Olive Oil	0.471	44
Toluene	0.404	68
Turpentine	0.420	68
Solids		
Aluminum	0.214	
Asphalt	0.220	
Bakelite	0.350	
Brickwork	0.200	
Brass	0.090	
Bronze	0.104	
Concrete	0.156	
Glass	0.200	
Ice	0.465	-4
Ice	0.487	32
Iron (Cast)	0.120	
Lead	0.031	
Paper	0.320	
Porcelain	0.180	
Rubber Goods	0.480	
Sand	0.191	
Steel	0.120	
Woods		
Fir	0.650	
Oak	0.570	
Pine	0.670	

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ________ °F ________ RH Length ________ Volume ________

Ambient conditions ________ °F ________ RH Insulation: Thickness ________

Temperature difference (TD) ________ °F Type ________

Product load ______________________

____

Lights, motors ______________________

Occupancy, miscellaneous ______________________

Heat transmission load

Side walls	____ L	×	____ H × 2	=	____	area ×	____	TD ×	____	*U*-factor	=	____
End walls	____ W	×	____ H × 2	=	____	area ×	____	TD ×	____	*U*-factor	=	____
Ceiling	____ L	×	____ W	=	____	area ×	____	TD ×	____	*U*-factor	=	____
Floor	____ L	×	____ W	=	____	area ×	____	TD ×	____	*U*-factor	=	____
Glass					____	area ×	____	TD ×	____	*U*-factor	=	____
										Subtotal	=	____
										× 24 hours	=	____

Air infiltration

____ ft^3 volume × ____ air changes per 24 hours × usage factor × ____ Btu/ft^3 = ____

Product load

Product temperature reduction

____ lb × ____ specific heat × ____ TD = ____

____ lb × ____ specific heat × ____ TD = ____

____ lb × ____ specific heat × ____ TD = ____

Latent heat of freezing

____ lb × ____ specific heat × ____ TD = ____

____ lb × ____ specific heat × ____ TD = ____

Heat of respiration

____ lb × ____ Btu/24-hr heat of respiration = ____

____ lb × ____ Btu/24-hr heat of respiration = ____

Supplementary load

____ watts × ____ hours × 3.41 Btuh = ____

____ hp × ____ hours × ____ Btuh = ____

____ people × ____ hours × ____ Btuh = ____

Subtotal ____

____ % safety factor ____

Total 24-hr refrigeration load ____

Required hourly compressor capacity based on 16-hr operation ____

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ________ °F ________ RH Length ________ Volume ________

Ambient conditions ________ °F ________ RH Insulation: Thickness ________

Temperature difference (TD) ________ °F Type ________

Product load **Table 2** ______________________

Lights, motors ______________________

Occupancy, miscellaneous ______________________

Heat transmission load

Side walls ______ L × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

End walls ______ W × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

Ceiling ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Floor ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Glass **Table 4** ______ area × ______ TD × ______ *U*-factor = ______

Subtotal = ______

× 24 hours = ______

Air infiltration **Table 8** **Light Use 1.25** **Table 9**

______ ft³ volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft³ = ______

Product load **Table 10**

Product temperature reduction

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ______

______ lb × ______ Btu/24-hr heat of respiration = ______

Supplementary load

______ watts × ______ hours × 3.41 Btuh = ______

Table 11 ______ hp × ______ hours × ______ Btuh = ______

______ people × ______ hours × ______ Btuh = ______

People 345 to 450 Btuh

Subtotal ______

15% % safety factor ______

Total 24-hr refrigeration load ______

Required hourly compressor capacity based on 16-hr operation ______

MISCELLANEOUS HEAT LOAD

Heat introduced into the cooler from heat-producing devices such as lights, motors, etc., also must be considered when estimating the total heat load. Any electrical energy dissipated directly into the cooler is converted into heat, which must be included in your calculations.

One watt-hour of electrical energy is equivalent to 3.41 Btu of heat energy. This conversion ratio is accurate in dealing with any amount of electric power. Motor efficiency varies with the size of the motor-and the heat equivalent varies accordingly. Table 3 shows the heat load per horsepower for a variety of motor sizes. Although the values shown are useful approximations, the actual electric power input (in watts) is the only accurate measure for heat- estimating purposes.

Electric lights. Assume that the lighting in a cooler consists of two 60-W bulbs. They will add 409 Btuh (120 x 3.41) to the heat load. This is not much, true, but small loads can add up.

Electric motors. Electric motors may be used inside the refrigerated space to drive fans, pumps, or other equipment. They represent another example of miscellaneous heat load. The electrical energy that a motor consumes. is first converted to mechanical energy, but ultimately it is converted to heat.

Heat of motors
BTU Per (HP) per (HR)

Motor HP	Connected load in Refrigeration space	Motor losses out-side Refrigeration space	Connected load outside Refrigeration space
1/8 to 1/2	4,250	2,548	1,710
½ to 3	3,701	2,547	1.160
3 to 20	2,955	2545	405

Table 11

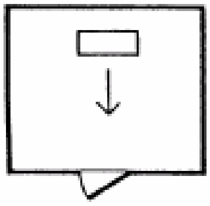
The power used by a motor driving the fan on a forced-draft evaporator is often overlooked. It should not be. Consider, for example, a small blower coil with a refrigerating capacity of approximately 5,000 Btuh. It incorporates a fan motor that consumes 225 W of power. While the fan is running (which is usually continuously), the motor is dissipating heat into the refrigerated space at the rate of 767 Btu per hour (225 x 3.41) .So the refrigerating capacity of the evaporator is, in reality, 5,000 Btuh *minus* 767 Btuh, or 4,233 Btuh-a reduction of more than 15%.

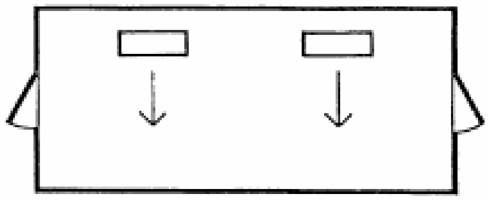
Human occupancy. **The people who live or work in a refrigerated space give off heat and moisture. The resulting refrigeration load will vary according to several conditions, including the duration of occupancy, the temperature of the refrigerated space, the type of work being done, and other factors 354 Btuh to 450 Btuh. These values are for extended occupancy periods. Stays of short duration, naturally, produce lower heat gains.**

Heat of respiration. There is one other heat load factor to consider when an application involves the storage of certain products, such as bananas, oranges, lemons, limes, green onions, lettuce, pears, apples, etc. This factor is the heat that these products give up as chemical changes take place over a period of time. The rate at which this heat is given up is usually expressed in Btu per 100 lb of product per 24 hours.

This chapter has demonstrated, through systematic explanation and calculation, the fundamentals of estimating the heat load. The application used as an example involved the maintenance of an above- freezing temperature in small, walk-in cooler and below-freezing temperature storage.

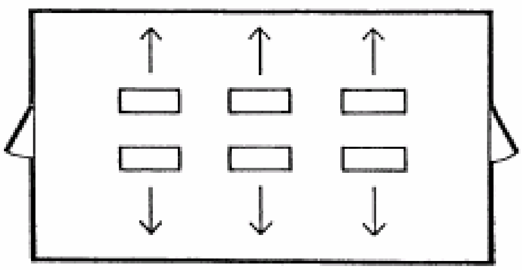
Unit Cooler Recommended Coil Replacement



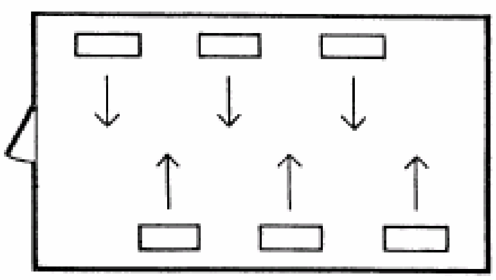


left
Large Cooler or Freezer

right
Large Cooler or Freezer



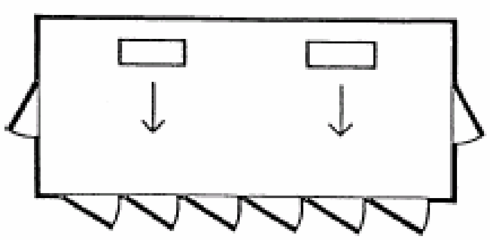
Large Cooler or Freezers where one wall will not accomodate all required evaporators or where air-throw distance must be considered.

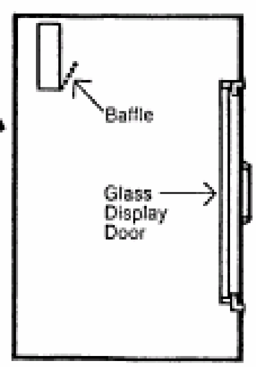


Note: Always avoid placement of Unit Coolers directly above doors and door openings where low temperature is being maintained and wherever possible for normal temperature.

Allow sufficient space between rear of Unit Cooler and wall to permit free return of air. Refer to Unit manufacturers' catalog for proper space.

Always trap drain lines individually to prevent vapor migration. Traps on low temperature units must be outside of refrigerated enclosures.





left
Cooler or Freezer with Glass Display Doors

right
Elevation view of Glass Display Door Cooler or Freezer. Be sure Air Discharge Blows above, not directly at doors. Provide baffle if door extends above Blower level.

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ______ °F ________ RH Length ________ Volume ________

Ambient conditions ______ °F ________ RH Insulation: Thickness ____________

Temperature difference (TD) ________ °F Type ______________

Product load ____

____

Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls ______ L × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

End walls ______ W × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

Ceiling ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Floor ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Glass ________ area × ________ TD × ________ *U*-factor = ________

Subtotal = ________

× 24 hours = ________

Air infiltration

________ ft³ volume × ________ air changes per 24 hours × usage factor × ______ Btu/ft³ = ________

Product load

Product temperature reduction

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

Latent heat of freezing

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

Heat of respiration

________ lb × ________ Btu/24-hr heat of respiration = ________

________ lb × ________ Btu/24-hr heat of respiration = ________

Supplementary load

________ watts × ________ hours × 3.41 Btuh = ________

________ hp × ________ hours × ________ Btuh = ________

________ people × ________ hours × ________ Btuh = ________

Subtotal ________

________ % safety factor ________

Total 24-hr refrigeration load ________

Required hourly compressor capacity based on 16-hr operation ________

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ______ °F ________ RH Length ________ Volume ________

Ambient conditions ______ °F ________ RH Insulation: Thickness ____________

Temperature difference (TD) ________ °F Type ______________

Product load ____

____

Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls ______ L × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

End walls ______ W × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

Ceiling ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Floor ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Glass ________ area × ________ TD × ________ *U*-factor = ________

Subtotal = ________

× 24 hours = ________

Air infiltration

______ ft^3 volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft^3 = ________

Product load

Product temperature reduction

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

Latent heat of freezing

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

Heat of respiration

________ lb × ________ Btu/24-hr heat of respiration = ________

________ lb × ________ Btu/24-hr heat of respiration = ________

Supplementary load

________ watts × ________ hours × 3.41 Btuh = ________

________ hp × ________ hours × ________ Btuh = ________

________ people × ________ hours × ________ Btuh = ________

Subtotal ________

________ % safety factor ________

Total 24-hr refrigeration load ________

Required hourly compressor capacity based on 16-hr operation ________

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ________ °F ________ RH Length ________ Volume ________

Ambient conditions ________ °F ________ RH Insulation: Thickness ____________

Temperature difference (TD) ________ °F Type ____________

Product load ____

____

Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls ______ L × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

End walls ______ W × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

Ceiling ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Floor ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Glass ______ area × ______ TD × ______ *U*-factor = ______

Subtotal = ______

× 24 hours = ______

Air infiltration

______ ft³ volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft³ = ______

Product load

Product temperature reduction

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ______

______ lb × ______ Btu/24-hr heat of respiration = ______

Supplementary load

______ watts × ______ hours × 3.41 Btuh = ______

______ hp × ______ hours × ______ Btuh = ______

______ people × ______ hours × ______ Btuh = ______

Subtotal ______

______ % safety factor ______

Total 24-hr refrigeration load ______

Required hourly compressor capacity based on 16-hr operation ______

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ________ °F ________ RH Length ________ Volume ________

Ambient conditions ________ °F ________ RH Insulation: Thickness ________

Temperature difference (TD) ________ °F Type ________

Product load ______________________

____

Lights, motors ______________________

Occupancy, miscellaneous ______________________

Heat transmission load

Side walls ______ L × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

End walls ______ W × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

Ceiling ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Floor ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Glass ______ area × ______ TD × ______ *U*-factor = ______

Subtotal = ______

× 24 hours = ______

Air infiltration

______ ft³ volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft³ = ______

Product load

Product temperature reduction

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ______

______ lb × ______ Btu/24-hr heat of respiration = ______

Supplementary load

______ watts × ______ hours × 3.41 Btuh = ______

______ hp × ______ hours × ______ Btuh = ______

______ people × ______ hours × ______ Btuh = ______

Subtotal ______

______ % safety factor ______

Total 24-hr refrigeration load ______

Required hourly compressor capacity based on 16-hr operation ______

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ______ °F ________ RH Length ________ Volume ________

Ambient conditions ______ °F ________ RH Insulation: Thickness ______________

Temperature difference (TD) ________ °F Type ______________

Product load ____

____

Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls ______ L × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

End walls ______ W × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

Ceiling ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Floor ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Glass ________ area × ________ TD × ________ *U*-factor = ________

Subtotal = ________

× 24 hours = ________

Air infiltration

______ ft³ volume × ________ air changes per 24 hours × usage factor × ______ Btu/ft³ = ________

Product load

Product temperature reduction

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

Latent heat of freezing

________ lb × ________ specific heat × ________ TD = ________

________ lb × ________ specific heat × ________ TD = ________

Heat of respiration

________ lb × ________ Btu/24-hr heat of respiration = ________

________ lb × ________ Btu/24-hr heat of respiration = ________

Supplementary load

________ watts × ________ hours × 3.41 Btuh = ________

________ hp × ________ hours × ________ Btuh = ________

________ people × ________ hours × ________ Btuh = ________

Subtotal ________

________ % safety factor ________

Total 24-hr refrigeration load ________

Required hourly compressor capacity based on 16-hr operation ________

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ________ °F ________ RH Length ________ Volume ________

Ambient conditions ________ °F ________ RH Insulation: Thickness ____________

Temperature difference (TD) ________ °F Type ____________

Product load ____

____

Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls ______ L × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

End walls ______ W × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

Ceiling ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Floor ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Glass ______ area × ______ TD × ______ *U*-factor = ______

Subtotal = ______

× 24 hours = ______

Air infiltration

______ ft³ volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft³ = ______

Product load

Product temperature reduction

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ______

______ lb × ______ Btu/24-hr heat of respiration = ______

Supplementary load

______ watts × ______ hours × 3.41 Btuh = ______

______ hp × ______ hours × ______ Btuh = ______

______ people × ______ hours × ______ Btuh = ______

Subtotal ______

______ % safety factor ______

Total 24-hr refrigeration load ______

Required hourly compressor capacity based on 16-hr operation ______

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ________ °F ________ RH Length ________ Volume ________

Ambient conditions ________ °F ________ RH Insulation: Thickness ________

Temperature difference (TD) ________ °F Type ________

Product load ____

____

Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls ______ L × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

End walls ______ W × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

Ceiling ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Floor ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Glass ______ area × ______ TD × ______ *U*-factor = ______

Subtotal = ______

× 24 hours = ______

Air infiltration

______ ft^3 volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft^3 = ______

Product load

Product temperature reduction

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ______

______ lb × ______ Btu/24-hr heat of respiration = ______

Supplementary load

______ watts × ______ hours × 3.41 Btuh = ______

______ hp × ______ hours × ______ Btuh = ______

______ people × ______ hours × ______ Btuh = ______

Subtotal ______

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Room conditions ________ °F ________ RH Length ________ Volume ________

Ambient conditions ________ °F ________ RH Insulation: Thickness ________

Temperature difference (TD) ________ °F Type ________

Product load ______________________

____

Lights, motors ______________________

Occupancy, miscellaneous ______________________

Heat transmission load

Side walls ______ L × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

End walls ______ W × ______ H × 2 = ______ area × ______ TD × ______ *U*-factor = ______

Ceiling ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Floor ______ L × ______ W = ______ area × ______ TD × ______ *U*-factor = ______

Glass ______ area × ______ TD × ______ *U*-factor = ______

Subtotal = ______

× 24 hours = ______

Air infiltration

______ ft³ volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft³ = ______

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______ lb × ______ specific heat × ______ TD = ______

Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ______

______ lb × ______ specific heat × ______ TD = ______

Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ______

______ lb × ______ Btu/24-hr heat of respiration = ______

Supplementary load

______ watts × ______ hours × 3.41 Btuh = ______

______ hp × ______ hours × ______ Btuh = ______

______ people × ______ hours × ______ Btuh = ______

Subtotal ______

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Room conditions ______ °F ________ RH Length ________ Volume ________

Ambient conditions ______ °F ________ RH Insulation: Thickness ____________

Temperature difference (TD) ______ °F Type ____________

Product load ____

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Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls ______ L × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

End walls ______ W × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

Ceiling ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Floor ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Glass ________ area × ________ TD × ________ *U*-factor = ________

Subtotal = ________

× 24 hours = ________

Air infiltration

______ ft³ volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft³ = ________

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______ lb × ______ specific heat × ______ TD = ________

Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ________

______ lb × ______ specific heat × ______ TD = ________

Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ________

______ lb × ______ Btu/24-hr heat of respiration = ________

Supplementary load

______ watts × ______ hours × 3.41 Btuh = ________

______ hp × ______ hours × ______ Btuh = ________

______ people × ______ hours × ______ Btuh = ________

Subtotal ________

______ % safety factor ________

Total 24-hr refrigeration load ________

Required hourly compressor capacity based on 16-hr operation ________

REFRIGERATION LOAD ESTIMATE FORM

Application ______________________ Room: Height ________ Width ________

Room conditions ______ °F ________ RH Length ________ Volume ________

Ambient conditions ______ °F ________ RH Insulation: Thickness ____________

Temperature difference (TD) ________ °F Type ____________

Product load ____

____

Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls	______ L × ______ H × 2 =	______ area ×	______ TD ×	______ *U*-factor	=	______
End walls	______ W × ______ H × 2 =	______ area ×	______ TD ×	______ *U*-factor	=	______
Ceiling	______ L × ______ W =	______ area ×	______ TD ×	______ *U*-factor	=	______
Floor	______ L × ______ W =	______ area ×	______ TD ×	______ *U*-factor	=	______
Glass		______ area ×	______ TD ×	______ *U*-factor	=	______
				Subtotal	=	______
				× 24 hours	=	______

Air infiltration

______ ft^3 volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft^3 = ______________

Product load

Product temperature reduction

______ lb × ______ specific heat × ______ TD = ______________

______ lb × ______ specific heat × ______ TD = ______________

______ lb × ______ specific heat × ______ TD = ______________

Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ______________

______ lb × ______ specific heat × ______ TD = ______________

Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ______________

______ lb × ______ Btu/24-hr heat of respiration = ______________

Supplementary load

______ watts × ______ hours × 3.41 Btuh = ______________

______ hp × ______ hours × ______ Btuh = ______________

______ people × ______ hours × ______ Btuh = ______________

Subtotal ______________

______ % safety factor ______________

Total 24-hr refrigeration load ______________

Required hourly compressor capacity based on 16-hr operation ______________

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Application ______________________ Room: Height ________ Width ________

Room conditions ______ °F ________ RH Length ________ Volume ________

Ambient conditions ______ °F ________ RH Insulation: Thickness ____________

Temperature difference (TD) ______ °F Type ____________

Product load ____

____

Lights, motors ____

Occupancy, miscellaneous ____

Heat transmission load

Side walls ______ L × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

End walls ______ W × ______ H × 2 = ________ area × ________ TD × ________ *U*-factor = ________

Ceiling ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Floor ______ L × ______ W = ________ area × ________ TD × ________ *U*-factor = ________

Glass ________ area × ________ TD × ________ *U*-factor = ________

Subtotal = ________

× 24 hours = ________

Air infiltration

______ ft^3 volume × ______ air changes per 24 hours × usage factor × ______ Btu/ft^3 = ________

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Latent heat of freezing

______ lb × ______ specific heat × ______ TD = ________

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Heat of respiration

______ lb × ______ Btu/24-hr heat of respiration = ________

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Supplementary load

______ watts × ______ hours × 3.41 Btuh = ________

______ hp × ______ hours × ______ Btuh = ________

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