Refrigeration Load Estimating Manual (RLE)

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Engineering Manual

Refrigeration Load Estimating

Krack Corporation

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This Krack Manual was published for the purpose of providing a concise, complete and convenient load estimating reference volume for the commercial refrigeration industry. Application suggestions and unit cooler selection examples are representative for halocarbon direct expansion fed systems.

Load estimating data can be used for industrial refrigeration systems using ammonia or brine as the refrigerant.

Estimating guidelines and rules of thumb, are necessarily general in nature, and should not be utilized as the sole design criteria.

Product freezing and cooling data was developed in the Krack product testing laboratory. Other data has been extracted by permission from various ASHRAE Guide and Data Book publications.

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PRELIMINARY CONSIDERATIONS

Calculation of the heat transfer through the walls, floor and ceiling of a refrigerated space requires determination of the overall coefficient of heat transmission (or **'U' value**, as it is commonly called) for the building structure.

Accordingly, the procedures utilized to determine this coefficient, and the several factors which affect its value, are briefly discussed below.

It is to be noted that rapidly increasing energy costs have made obvious the desirability of optimum insulation efficiency. First-versus-operating cost comparisons are therefore worthwhile, and will often justify an increase in the indicated insulation thickness.

Letter symbols utilized herein are those most commonly employed to designate the various heat transfer factors.

THERMAL CONDUCTIVITY (K)

Thermal conductivity is defined as the rate of heat transfer through a homogeneous material in Btu per hour per square foot of area per °F temperature differential per inch of thickness (NOTE: A homogeneous material is one whose thermal conductivity is essentially unaffected by a change in surface area or thickness).

Conduction heat transfer varies directly with thermal conductivity, surface area, temperature differential and time, and varies inversely with material thickness. Accordingly, the heat transfer into a refrigerated space may be reduced either by selecting an insulating medium with a lower K value, or by increasing the insulation thickness.

The daily heat transfer through any homogeneous material of a given thickness may be calculated by utilizing the following formula:

$$Q_{\text{Btu}/24\text{ hrs}} = \frac{K \times \text{Area}_{\text{sq ft}} \times TD_{°F} \times 24}{\text{Thickness}_{\text{in}}}$$

K always expresses a heat transfer value per inch of thickness in air conditioning and refrigeration considerations.

CONDUCTANCE (C)

Thermal conductance (C) differs from thermal conductivity (K) only in that it is a heat transfer factor for a specific building material having a standard thickness. All non-homogeneous materials are necessarily rated in this manner (as opposed to K), examples being tile & concrete block. Building boards and paper, flooring materials, air spaces and various materials common in general construction are also rated by C values.

Thermal conductance is by definition, therefore, the rate of heat transfer through a specific material in Btu per hour per square foot of area per °F temperature differential.

Conductances for various material categories are tabulated in Table 1B in the Appendix.

It is to be noted that the formula listed above for calculating heat transfer through various thicknesses of homogeneous substances would not apply for materials rated by conductance.

SURFACE FILM CONDUCTANCE (f)

The surface of any material offers an additional resistance to heat flow, with the absolute value being dependent upon its reflectivity, degree of roughness, attitude (vertical or horizontal), length and the air velocity over the surface.

The reciprocal of this resistance is the surface film conductance (f) which is expressed in the same units as conductance (ie, Btu per hour per square foot of area per °F temperature differential.)

Inside surface film conductance is designated by f_i, and may usually be estimated at **1.60** for walls in still air not exposed to outdoor conditions.

Outside surface film conductance is designated by f_o, and may be approximated at **6.0** for outdoor walls not exposed to winds in excess of 15 MPH.

THERMAL RESISTANCE (R)

Thermal resistance is the resistance of a material to heat flow and is, by definition, the reciprocal of a given heat transfer coefficient (ie, C, f_i, f_o etc.):

$$R = \frac{1}{C}$$

As an example, the conductance (C) of ½ inch plaster board (as obtained from Table 1B) is 2.25 Btu per hour per °F temperature differential per sq. ft. Accordingly, its resistance is:

$$R = \frac{1}{2.25} = 0.449\,°F\ TD\ /\ sq\ ft\ /\ Btu\ /\ hr$$

This means that a temperature differential of 0.449°F would be required to transfer 1 Btu of heat across 1 square foot of ½ inch plasterboard surface in 1 hour.

The practical significance of resistance (R) is that its values are additive thereby enabling the calculation of overall coefficients of heat transfer for compound structures, ie:

$$R_{Total} = R_1 + R_2 + R_3\ (etc)$$

OVERALL COEFFICIENT OF HEAT TRANSFER (U)

The overall coefficient of heat transfer of a given material or compound structure with parallel surfaces is commonly known as the U factor, and is expressed in the same units as conductance (ie, Btu per hour per square foot of area per °F temperature differential). It is most generally applied to compound structures such as roofs or walls.

As stated previously, resistance is the reciprocal of conductance and the individual resistances of a structure are additive. Accordingly, it is necessary to determine the overall resistance to heat transfer, and then its reciprocal, to calculate the U factor.

Overall resistance in a compound structure is:

$$R_{Total} = \frac{1}{C} + \frac{X_1}{K_1} + \frac{X_2}{K_2} + \frac{1}{f_i} + \frac{1}{f_o}$$

Where,

- C is the conductance (if it applies.)
- X_1, X_2, etc. are material thicknesses.
- K_1, K_2, etc. are conductivities.
- f_i is the inside film conductance.
- f_o is the outside film conductance.

The U factor is then calculated as follows:

$$U = \frac{1}{R_{Total}}$$

An example is useful in illustrating the above. A representative compound structure with parallel surfaces as depicted in Figure A has been selected for this purpose since it is dealt with frequently in refrigeration applications.

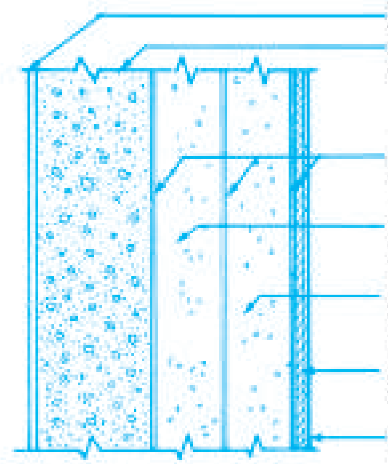


FIGURE A: EXAMPLE CROSS SECTION

In the above example, R_{Total} would equal:

$$R_{Total} = \frac{1}{0.90} + \frac{4}{0.38} + \frac{4}{0.38} + \frac{0.5}{0.80} + \frac{1}{1.60} + \frac{1}{6.0}$$

or,

$$R_{Total} = 23.58$$

and,

$$U_{Overall} = \frac{1}{R_{Total}} = \frac{1}{23.58} = 0.042$$

JOB SURVEY

Part II of Krack Survey and Load Estimate Form LE-1 is devoted to the job survey. All factors which affect the **rate** of heat gain must be detailed. It is suggested that each application be thoroughly reviewed with the operating personnel to determine facility operational characteristics, product pulldown requirements, packaging specifics and such other details as are peculiar to a given application.

Particular attention should be given to the means and frequency of product entrance, adjacent area pressure differentials, existing or required ventilation systems, and related operating characteristics which may produce infiltration loading above the norm (the average air changes detailed in Tables 4A and 4B are intended for standard applications only, and should not be used when specialized conditions prevail).

The product entrance rate, condition and type packaging must be determined to assure an accurate product load estimate. If an individual product is treated as a heat exchanger, the product refrigeration load is then dependent upon its shape, size and type of packaging, as well as the more usual considerations of entering and leaving temperature differential, product type, entrance rate into the cooler, air temperature and velocity over the product and process duration. A prime purpose of the survey, therefore, is to determine the **rate of product heat evolution** (or rate of heat transfer from the product to the room). Specific examples of various product situations are given in the section devoted to the load estimate.

Part IV of Form LE-1 provides for a sketch of the refrigerated space. All relevant construction features such as column, door and partition locations, ceiling clearances, adjacent area conditions, etc. should be detailed. Supplemental photographs of significant building features are often part of a good survey. Additional survey requirements such as ambient design, room temperature, dimensional data, insulation type & thickness, electrical service and the various miscellaneous loads are self-explanatory.

LOAD ESTIMATE

GENERAL

Part III of Krack Form LE-1 is devoted to calculation of the refrigeration load. Five sources of heat gain must be estimated:

- **Wall, floor, & ceiling transmission load**
- **Solar load**
- **Infiltration load**
- **Product load**
- **Supplemental load**

Optimum and efficient equipment selection is dependent upon an accurate determination of each of the above loads.

A brief discussion of each heat gain source follows, with references made where appropriate to factors and data charted in the appendix.

TRANSMISSION LOAD

The heat transmission into a refrigerated space through its ceiling, floor and walls is a function of the outside surface area, the temperature differential between the room and its surrounding area and the thermal conductivity of the insulation utilized.

Table 1A converts thermal conductivity ('K' in Btu / hour / sq ft / °F temperature differential / inch of thickness) to 24 hour heat gain factors for various thicknesses of commonly used insulation materials at temperature differentials from 1 to 130°F. These factors should be inserted where indicated in Part III, Section A of Form LE-1, and multiplied by surface area to obtain the 24 hour transmission heat gain.

For materials other than those tabulated, or for compound structures, refer to Table 1B for the appropriate thermal conductivities and calculate the overall coefficient of heat transfer (U) as illustrated in the foregoing section. This is then converted to a daily heat gain factor by utilizing the following formula:

$$\textbf{Heat Gain Factor}_{\text{Btu / sq ft / 24 hrs}} = 24 \times U \times TD_{\,^{\circ}F}$$

It is common practice in calculating heat transmission for low temperature rooms to ignore the resistances of both surface films and the building structure proper since their overall effect is quite nominal.

Heat gain factors for various floor designs are tabulated at the bottom of Table 1A. It is the usual practice to assume a factor of 1 Btu / sq ft / °F / 24 hrs for freezer floors with conventional insulation.

SOLAR LOAD

The heat gain through solar radiation is a function of the exposure, type of surface, latitude, altitude, time of year, time of day and other factors. For load estimating purposes, however, this sun effect can be compensated for by adding the degrees shown in Table 2 to the normal temperature differential as indicated in Section A of the load calculation form.

In instances where the refrigerated facility is on (or adjacent to) a highly reflective surface such as sand or water, the allowances shown in Table 2 should be increased by 50%

INFILTRATION LOAD

Infiltration into a refrigerated room will occur when a door is opened as a result of the difference in density between the warm and cold air.

Since door openings vary widely, it the usual practice to estimate infiltration in air changes per 24 hours as shown in Tables 4-A and 4-B. This may then be factored by the room volume and the heat removed in cooling outside air to storage conditions in Btu/cu ft as tabulated in Table 5 to obtain the infiltration load. Space is provided in Part III, Section B of Form LE-1 for computation of this load.

Infiltration may be determined more precisely by calculating the air velocity through the door, the door area and the heat removed in cooling entering air to room conditions, and then estimating the average number of minutes per hour that the door will be open.

The average air velocity in either half of a door 7 feet high at a 60°F temperature differential is 100 feet per minute. Since velocity varies directly with the square root of the doorway height and the square root of the temperature differential across the door, actual air velocity for any set of conditions may be calculated by utilizing the following formula:

$$\text{Vel}_{\text{fpm}} = 100 \times \frac{\sqrt{H}}{\sqrt{7}} \times \frac{\sqrt{TD}}{\sqrt{60}}$$

or,

$$\textbf{Vel}_{\textbf{fpm}} = 4.88 \times \sqrt{H} \times \sqrt{TD}$$

As an example, the velocity thru a door 8 ft wide and 9 ft high, with a temperature differential of 100°F, is:

$$\text{Vel} = 4.88 \times \sqrt{9} \times \sqrt{100}$$

$$\text{Vel} = 146.4 \text{ fpm}$$

Were the door in this example open 15 min per hour in a 12 hour shift operation, the 24 hour infiltration would be computed as follows:

$$\textbf{Cu ft} = \textbf{Vel}_{\textbf{fpm}} \times \frac{\textbf{Door Area}_{\textbf{ft}^2}}{2} \times \textbf{Time Open}_{\textbf{min}}$$

or,

$$\text{Cu ft} = 146.4 \times \frac{(8 \times 9)}{2} \times 180 = 948{,}672$$

This would then be factored by the heat gain per cu ft from Table 5 in the usual way. An alternate approach is to determine the enthalpy difference between room and entering air from the psychrometric chart, and utilize the following formula:

$$\text{Heat Gain}_{\text{Btu / 24 hrs}} = 24 \times 4.5^{1} \times \text{Cfm} \times \Delta h$$

or,

$$\textbf{Heat Gain}_{\textbf{Btu / 24 hrs}} = 108 \times \textbf{Cfm} \times \Delta\textbf{h}$$

In cases where **positive ventilation** is applied to a space, this load would then replace the infiltration load (if greater).

Note 1: Converts Cfm to lbs/hr (refer to Table 48, Pg. 47).

PSYCHROMETRICS

The Psychrometric Chart is utilized to determine the infiltration heat gain for specialized conditions, or for temperature changes not tabulated in Table 5.

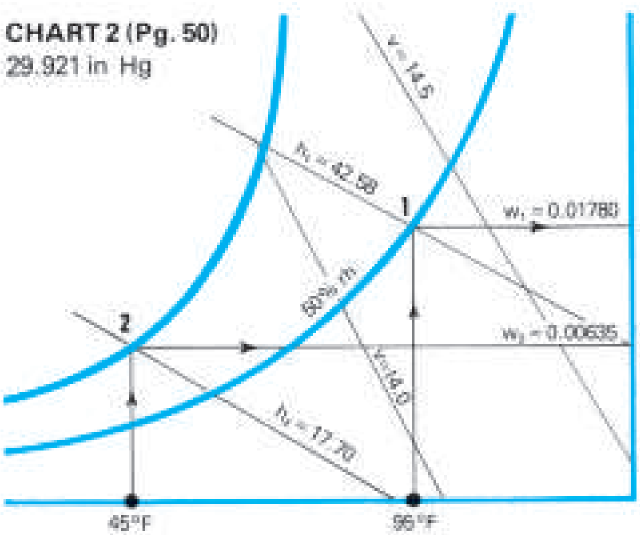
Charts 2 and 3 at the rear of the Appendix are applicable to normal temperature (32°F to 130°F) and low temperature (−40°F to 50°F) conditions, respectively. Both charts are based on a standard atmospheric (or sea level) pressure of 29.921 in Hg, and must be corrected for other altitudes.

For purposes of approximating infiltration loads at higher altitudes, it may be assumed that:

- Relative humidity (rh) remains constant,
- Enthalpy (h) and humidity ratio (w) increase 2% and 5% respectively per 1000 ft increase in altitude, and,
- Volume (v) for a given dry bulb and humidity ratio is inversely proportional to atmospheric pressure.

Atmospheric pressures at various altitudes are tabulated at the bottom of Chart 3.

An example is useful in demonstrating the use of the psychrometric chart in the calculation of infiltration heat gain. Assuming an infiltration rate of 500 Cfm, an entering air condition of 95°F dbt & 50%rh and a cooler temperature of 45°F, characteristics of the entering and cooled air are first determined as in Figure B:



SCHEMATIC SOLUTION OF EXAMPLE

As indicated in Figure B, the properties of the entering and cooled air are:

$h_1 = 42.58$ Btu / lb of dry air
$w_1 = 0.01780$ lb H_2O / lb of dry air
$v_1 = 14.25$ Cu ft / lb of dry air
$h_2 = 17.70$ Btu / lb of dry air
$w_2 = 0.00635$ lb H_2O / lb of dry air

Infiltration heat gain may then be calculated as follows:

$$\text{Heat Gain}_{\text{Btu / hr}} = 4.5 \times \text{Cfm} \times (h_1 - h_2)$$

or,

$$Q = 4.5 \times 500 \times (42.58 - 17.70) = 55{,}980 \text{ Btu / hr}$$

For an 8 hour shift operation, the 24 hr infiltration heat gain would therefore be 447,840 Btu, and this load would be inserted in the space provided in Part III, Section B of Form LE-1.

The above calculation provides a conservative load estimate since it presupposes that the total heat removed from the entering air is transferred to the evaporated refrigerant. This is not the case in as much as heat leaves the coil box as well via the heat content of the condensate. Accordingly, precise calculation of the refrigeration load in any instance in which entering air is cooled below its dew point would be calculated as follows:

$$Q_{\text{Btu / hr}} = 4.5 \times \text{Cfm} \left[(h_1 - h_2) - (w_1 - w_2)\, h_W\right]$$

This effect is illustrated by comparing the 1.746 Btu / cu ft $\left(\frac{42.58 - 17.70}{14.25}\right)$ heat removal indicated with the 1.710 Btu / cu ft tabulated in Table 5 for comparable conditions.

Additionally, the factor of 4.5 utilized to convert Cfm to lbs / hr incorporates the standard (70°F) dry air conversion factor of 13.33 cu ft / lb. Obviously, therefore, additional safety is built into the sample calculation since utilization of the actual entering volume of 14.25 cu ft/lb would result in a lower mass flow.

It is to be noted that the psychrometric chart is useful in calculating numerous other processes involving the conditioning or mixing of moist air, and that no attempt was made in this manual to fully develop the subject.

PRODUCT LOAD

The heat gain from product loading may consist of one or more of the following:

- **Sensible heat removal above freezing**
- **Latent heat**
- **Sensible heat removal below freezing**
- **Heat of respiration**

Sensible heat is calculated by factoring the **daily rate** of product in lbs per 24 hours by the temperature reduction and the product specific heat (the specific heat being the number of Btu's required to lower 1 lb of a substance 1 degree fahrenheit).

Latent heat is calculated by factoring the **daily rate** of product in lbs per 24 hours by the product latent heat of fusion (the latent heat being the number of Btu / lb required to freeze the product).

Applicable formulas are:

$$Q_{Sens\ Btu/24\ hrs} = \text{Daily Rate} \times \Delta T \times \text{Sp. Ht.}$$

$$Q_{Lat\ Btu/24\ hrs} = \text{Daily Rate} \times h_{L\ Btu/lb}$$

Specific heats (above and below freezing) and the latent heats of fusion for commonly encountered products are detailed in Table 9. Product loads may be figured in the space provided under Part III, Section C of Form LE-1.

As stressed in prior comments relating to the job survey, it is imperative that the rate of product heat evolution be accurately determined. Therein is the significance of **daily rate**, since it is, by definition, the amount of product cooled or frozen per hour multiplied by 24 hours. This may be illustrated by considering two freezers, each of which has been loaded with 10,000 lbs of unfrozen product. In the first instance, eviscerated chickens are to be blast frozen in 2 hours, with the resultant **daily rate** being:

$$\text{Daily Rate}_{\text{lbs/24 hrs}} = \frac{10{,}000}{2} \times 24 = 120{,}000$$

In the second case, the product is packaged, boxed, and palletized, and therefore requires 16 hours to give up its heat. Accordingly, the **daily rate** is:

$$\text{Daily Rate}_{\text{lbs/24 hrs}} = \frac{10{,}000}{16} \times 24 = 15{,}000$$

PRODUCT CHILLING

Product chilling is a process wherein product temperatures are rapidly reduced to a level acceptable for processing or shipment. Examples are freshly slaughtered carcasses and recently harvested fruits or vegetables. The benefits of rapid temperature reduction, in each instance, are a reduction in shrinkage and the deterrence of bacterial growth.

The introduction of hot product into a chill room results in the concentration of a significant load segment during the initial cooling period. This initial high rate of product heat evolution is caused by the high temperature and vapor pressure differentials between the product and the room. The effect is illustrated in Figure H, Page 29, wherein temperature reduction versus chill time for hogs is graphically depicted.

Load factors (or chill factors as they are sometimes called) have been developed to compensate for the non-uniform distribution of product load which results. These are utilized to increase the average hourly product load which would otherwise apply. Factors for the products most commonly encountered in chilling applications are charted in Table 10, and should be inserted in the space provided in Part III, Section C of Form LE-1 when applicable. The overall refrigeration requirements for beef and pork chilling rooms are charted in Page 28, Tables 11 and 12, respectively.

As an example, laboratory testing has shown that hogs tend to give up their heat during the initial portion of their chill at a 45% greater rate than is average for the complete period. Accordingly, the load factor indicated is 1.45.

PRODUCT CHILLING (CON'T.)

Failure to apply a load factor to the average hourly load (when applicable) will result in an unacceptably high initial room temperature, and an extension of the chill time required.

The substantial reduction in product load during the latter portion of the chill (**15-25%** of peak load) makes it mandatory that the refrigeration system be designed for proper function under a wide variance in load condition. Properly staged capacity reduction, in conjunction with evaporator pressure regulating valves, is commonly employed. Other approaches include the application of multi-circuit DX coils, and the combining of other (and more constant) side loads with the basic chill room load to enable high side equipment to stay on line and track the chill load as it tails off.

Suction accumulators and **liquid-suction heat exchangers** are strongly recommended with close coupled DX halocarbon systems.

PRODUCT CHILLING & HOLDING

Frequently, the same room is utilized to accommodate both the product chilling and long term storage requirements. This is particularly true in the case of apples and pears.

In such rooms, the peak load varies with the duration of the loading period and the maximum percentage loaded on any given day. Normally, however, it is **neither necessary nor advisable** to apply a load factor to the average hourly load since an unacceptable disparity between the peak and holding requirements will result (see Note 5, Table 10).

A common load estimating technique for combined fruit chilling and storage applications is to add the 24-hour pulldown requirement for the last day's loading to the normal room holding load (the apple storage loads charted in Table 16 were computed on this basis).

A prime consideration in this regard is that the on-hand pre-chilled product produces a flywheel effect which minimizes the increase in room temperature which would otherwise result.

Combined chilling and holding facilities may require that existing prechilled product be segregated (either by physical partition or zoned air distribution) from the newly introduced hot product. Otherwise, the significant increase in room relative humidity which results upon the introduction of hot product will produce condensation on the prechilled product. Meat, for example, will sweat and slime, and the bacterial growth rate will be greatly enhanced (meat processed under such conditions would not meet with USDA acceptance).

As is the case with rooms applied for product chilling only, particular attention must be given in the refrigeration plant design to the wide disparity between the peak and normal holding loads. In a fruit storage facility, for example, the winter holding load will approximate 10 to 15% of the peak refrigeration requirement, and the coil TD under holding conditions may, therefore, be only 2-3°F (versus the 15°F and higher TD's experienced under peak pulldown conditions).

Accordingly, flooded or recirculated refrigerant systems are the most frequently utilized since they adapt well to the wide control variance required. When a DX halocarbon system is applied, the comments detailed above under "Product Chilling" apply. Unit coolers with multi-speed fans are sometimes utilized, but should be applied with discretion given the necessity for positive air circulation through the load during storage.

As a final consideration, the refrigeration design engineer should remember that his responsibility is confined to the creation and maintenance of a specific room environment. It is neither his function or purpose, nor is it within his capability, to guarantee a given product core temperature within a specified time frame given the many variables (product condition, packaging, wrapping, entrance rate, means of storage, etc).

PRODUCT BLAST FREEZING

Air blast freezing offers an alternative to the conventional contact method wherein the product is placed in direct contact with pipes or plates thru which refrigerant or brine is piped.

Batch freezing is a process wherein the complete product load is placed in the room and frozen in one loading. The resultant load profile approximates that previously described for chill rooms in that a major portion of the load is concentrated during the initial freezing period[1]. Accordingly, a **factor of 1.5** is applied to the average hourly load, and the Daily Rate on Form LE-1 is computed by:

$$\text{Daily Rate} = \frac{\text{Product Load}_{\text{lbs}}}{\text{Freezing Period}_{\text{hrs}}} \times 24 \times 1.5$$

The 1.5 factor is **not** to be used when products are frozen over an extended period (these usually being products which are packaged or otherwise not susceptible to significant moisture loss during freezing).

Continuous load freezing is a process wherein the product is fed continuously thru the freezer via a conveyor or systemized manual feed. In this type of application, the estimated time of product heat removal has little effect on the total refrigeration load (it does, however, affect room size, conveyor belt size and speed, etc).

Accordingly, **no load factor is applicable** and the Daily Rate is computed by:

$$\text{Daily Rate} = \frac{\text{Product Load}_{\text{lbs}}}{\text{Process Duration}_{\text{hrs}}} \times 24$$

Air temperature, air velocity, product loading technique, and space requirements are critical considerations in the design of blast freezing systems (it seems that adequate space for both the equipment and product is never available). Additional comments, and general guidelines, are detailed in the preamble to Example II, Pg. 14.

Figures C, D & E depict typical room layouts for batch and conveyor-fed blast freezers.

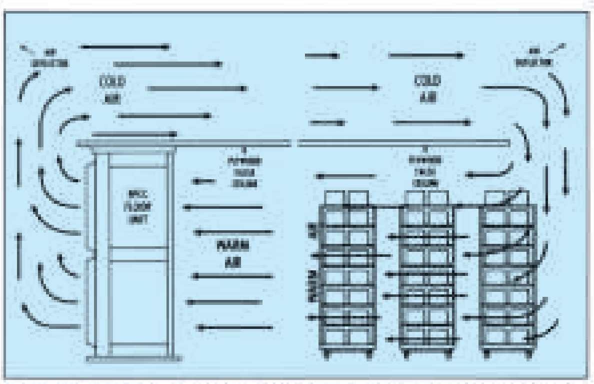


FIGURE C: BATCH FREEZING (FLOOR MOUNT)

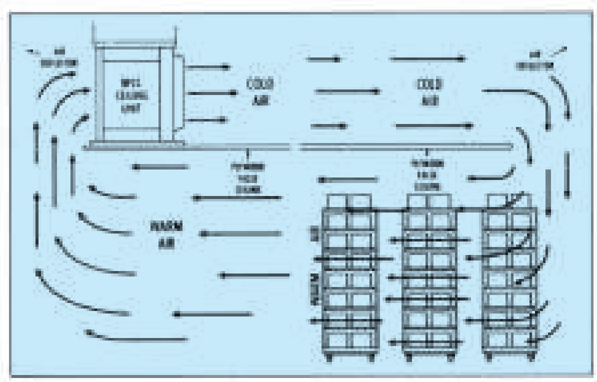


FIGURE D: BATCH FREEZING (CEILING MOUNT)

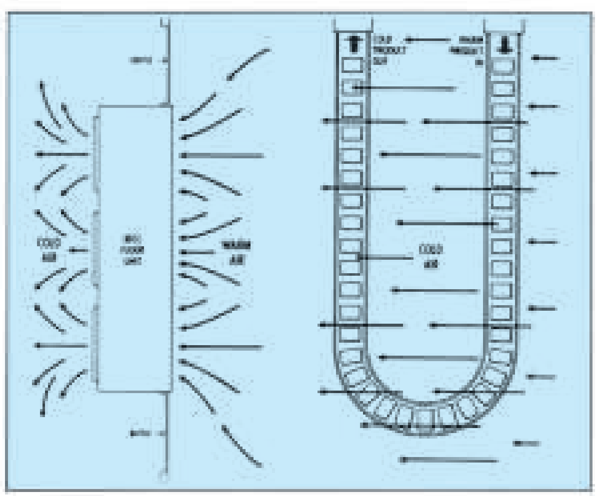


FIGURE E: PROCESS BLAST FREEZING

Note 1: As a product freezes, its outer frozen portion becomes an insulator and its rate of heat evolution decreases accordingly.

RESPIRATION

Fruits and vegetables are living organisms which continue to respire and carry on certain other life processes after harvesting. The carbon in the product combines with the oxygen in the air with the resulting chemical process being exothermic. This, in turn, results in an additional room heat gain.

The heats of respiration for various products in Btu/lb/24 hrs are tabulated in Table 9 at the temperatures recommended for both long and short term storage. Respiration heat (or reaction heat as it is sometimes called) varies with temperature, and decreases significantly with a reduction in storage temperature. There is no correlation, however, between respiration and relative humidity.

Since living organisms are involved, the temperature in long term storage rooms should be controlled within 1°F; otherwise, the physiology of the product will be affected, and the dormant state in which it has been maintained will be disturbed.

Meats and fish have no continuing life process, and therefore generate no heat in storage.

The respiration heat in controlled atmosphere (CA) storage will be less than the values charted in Table 9 as a result of the reduction in room oxygen content.

SUPPLEMENTAL LOAD

All additional heat dissipated in the refrigerated space must be accounted for in computing the overall load. This includes energy utilized for motors, heaters, lights, people, forklifts and related miscellaneous heat sources. Supplemental loads of this type are computed in Part III, Section D of Form LE-1.

Occupancy loads are tabulated in Table 6. The heat equivalents noted should be increased by 20% if occupancy periods are of short duration. Utilize the average number of personnel in the space.

Heat equivalents for **electric motors** are listed in Table 3 for each possible application (ie, motor and connected load in the refrigerated space, connected load only in the refrigerated space and motor only in the refrigerated space). Equivalent horsepower is determined by multiplying the motor horsepower by the fraction of each hour operated.

Storage room **lighting** may usually be assumed at 1 to 1½ watts/sq ft. Doors, offices and work rooms require 2½ to 3 watts / sq ft. **Forklifts** may be estimated at 4 to 5 hp if more precise data is unavailable, and should be converted to equivalent horsepower as above.

The **defrost heat load** in a refrigerated space varies with the rate and time which heat is required, and, in some cases, with the unit cooler design[1]. In section D of Form LE-1, 25% of the heat imposed is arbitrarily allocated to room load (the assumption being that this amount is either radiated to the room or retained by the coil mass, with the remainder leaving via the coil condensate.

Charts, trays, racks, pallets, etc. seldom contribute a significant load, but must be accounted for in high volume operations.

Electric energy from any source may be estimated by multiplying the applicable wattage by 82 (24 hrs × 3.4 Btu / Watt / hr).

HOURLY LOAD CONVERSION

The 24 hour total obtained by adding Sections A thru D of Part III, Form LE-1 is converted to design refrigeration load in Btu/hr by applying time cycle and safety factors.

Time cycle factors for various applications are charted in Table 8. The divisors listed in column 1 represent anticipated operating hours under various frost conditions. The operating times noted are **average,** and are not applicable to all applications. Some freezers, for example, may require defrosting only once daily (or, in extreme cases, once weekly). The factor selected, therefore, represents a judgment consideration based upon the amount of moisture expected to enter the space from infiltration, product shrinkage, etc.

A **safety factor** correction of 5 to 10% to the hourly load resulting above is suggested. The figure selected is, again, a judgment consideration. Factors in excess of 10% should not be necessary.

OTHER CONSIDERATIONS

Data herein, and the overall format of Form LE-1, both presuppose a "total load" estimating approach (ie, the combining of sensible and latent loads). Accordingly, evaporative loads such as those resulting from product moisture loss, wash water, etc. have not been considered since they have no net effect on the total room load (the resultant latent heat gains serve as credits to the sensible heat load due to the evaporative cooling effect).

This approach satisfies the requirements of most applications. This is particularly the case with freezers at 15°F or below since variation of the Apparatus Dew Point (ie, the average coil surface temperature) has little or no effect on the sensible heat factor, or the moisture removal capability of the coil.

Further, adherence to the guidelines charted in Tables 17 and 18 for recommended coil TD will produce required room relative humidities in most instances. In those cases where long storage under close humidity control is indicated, however, the possible requirement for reheat or re-humidification must be investigated.

Note: One series of Krack unit coolers, for example, incorporates a door on the unit discharge which automatically closes upon the initiation of a defrost cycle, and thereby minimizes both heat absorption by the unit and direct heat transmission to the room.

I. FRUIT CHILLING AND STORAGE:

The example below illustrates the load profile for a typical combination chilling/holding facility. Three common product load estimating techniques are shown, with the pre-calculated values charted in Table 16 offering the simplest approach (note that respiration heat is neglected when a load factor is applied to the average hourly pulldown load).

Room design dry bulb varies with product variety. The control temperature for apples, as an example, ranges from **38°F** for McIntosh (as shown) to **32°F** for Golden Delicious. Relative humidity is maintained at **85% for apples, and 92-95% for pears.** Room condition is not significantly affected by daily product loading due to the flywheel affect of the on-hand pre-chilled fruit. (Note that **room temperature only** should be guaranteed, and that no commitment as to time required for product pulldown should be made due to the many uncontrollable factors. (ie, type of packaging, position in the load, method of stacking, etc.).

Fruit stored for extended periods (over 3 months) is usually maintained under controlled atmosphere (or C.A.) storage conditions wherein the O_2 concentration is reduced from the normal 20% to a level of 3-7%, with a corresponding increase in the CO_2 level from a trace to 2-5% (the purpose of C.A. storage being to minimize product deterioration during storage). Respiration heat is reduced to a fraction of the normal rate as a result of the low O_2 concentration. C.A. storage facilities are commonly sub-divided into 50' × 100' × 20' modules to enable product availability in saleable quantities when the room seals are broken. Water defrost and 460V TENV motors are frequently utilized to maximize reliability, and control devices are externally mounted for serviceability given the non-accessible environment.

Apples are usually containerized in lug or wood boxes, or in fiber cartons. The fruit may be individually tissue wrapped, or placed in poly-bags. Ungraded fruit is stored in 1000 lb 2½' × 4' × 4' tote bins. Product **loading density** averages **25 lb/cu ft.**

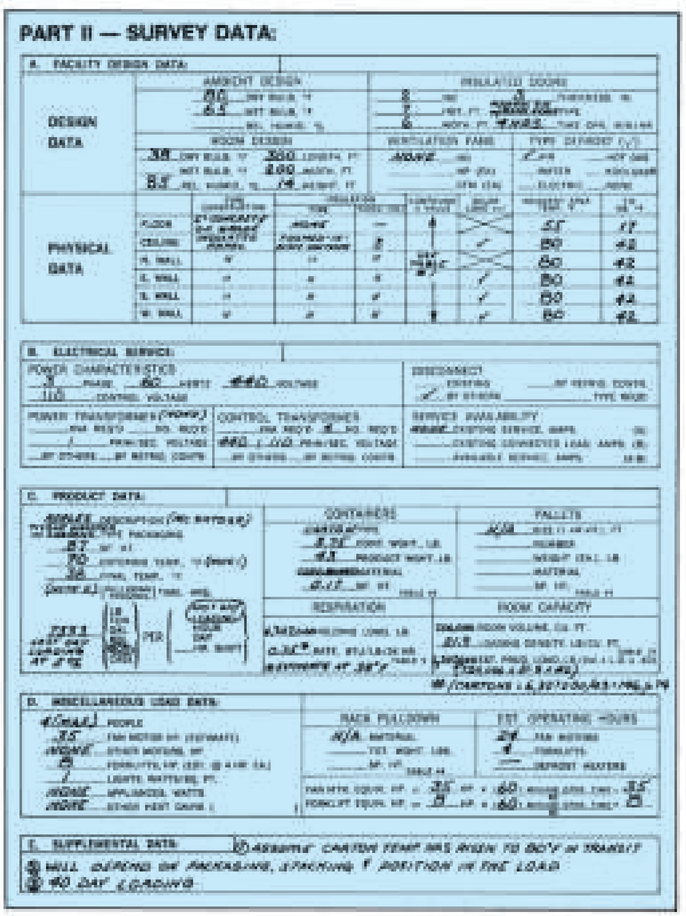
The refrigeration system for a combination chilling/holding facility must be specifically designed for adequate function under the widely divergent pulldown and winter holding loads. Since operational coil TD's will range from 15°F (or higher) during pulldown to 2°F (or less) with the winter holding load, flooded or recirculated systems are the most readily adapted to fruit storage applications.

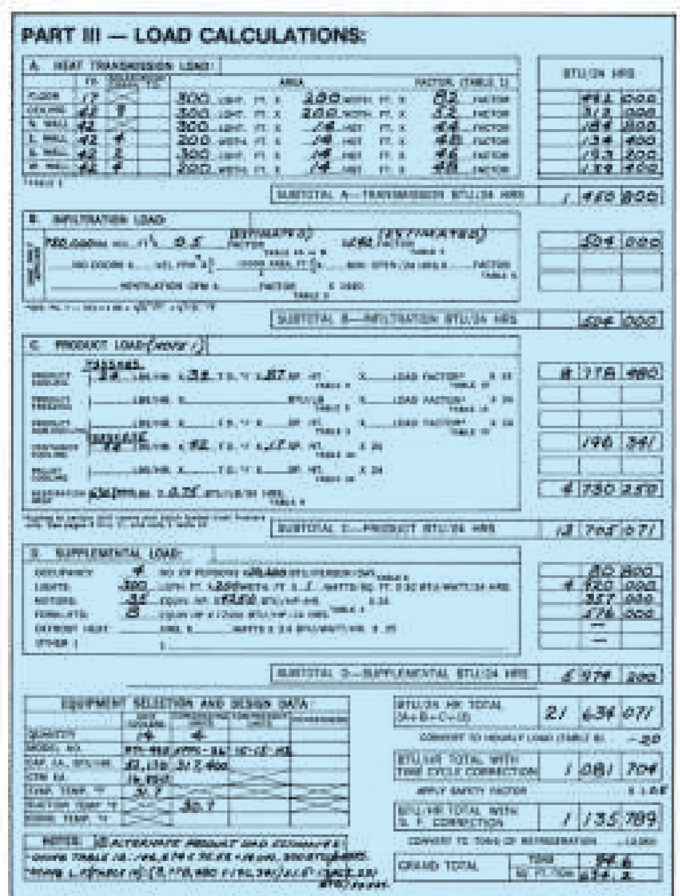
When a DX system is applied, it must incorporate properly staged capacity reduction in consideration of the wide load variance. Multi-speed fan motors may also be applied, but have an obvious adverse effect on air movement thru the load.

Coils should be selected for a **6-8°F TD** to maintain required humidity. Since all rooms require defrosting, a **4 FPI** coil design is recommended.

Refer to the text, Pg. 10, for more detailed information.

FORM LE-1





II. BLAST FREEZING:

As illustrated in the example, the load profile of a batch blast freezing process dictates the application of a **load factor** to the average hourly load which would otherwise apply. The result is a refrigeration system properly adapted to the initial high rate of product heat evolution. The usual factor is **1.5**, but a lower number is sometimes applied based on experience. In general, products with high surface-to-weight ratios freeze in 2 to 4 hours, and lower factors are therefor applicable when an extended freezing period is allowed. Note that **no load factor should be applied to conveyor fed blast freezers, or to rooms equipped with single halocarbon refrigeration systems** (in the latter, freezing time should be extended, and the room temperature allowed to rise).

Special design considerations include the provision for room pressure relief, and the consistent problem of obtaining adequate space to accommodate both the equipment and product. Provision for heater pull space must be made with electric defrost units. Utilization of coils with variable fin spacing minimizes the defrost requirement.

The following procedure should be followed in arriving at a blast freezer design:

STEP 1: Determine whether a conveyor or batch loaded freezer is best applied. This judgment is usually based on product test data wherein freezing time with various air temperatures and velocities has been determined. In general, batch loaded freezing is applied with products requiring 1 ½ hours or more to freeze satisfactorily; products which freeze in less than 1 ½ hours are conveyor fed.

STEP 2: Determine the space limitations of the room (remember that the space initially allocated by others is frequently insufficient to accomodate both the equipment and the product).

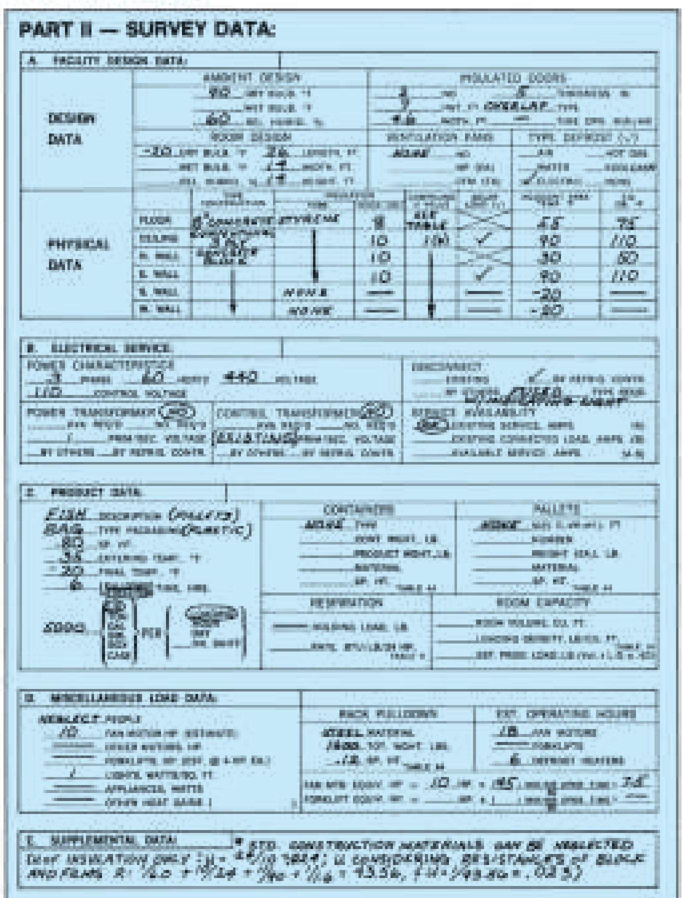
STEP 3: Finalize the room design criteria, keeping in mind that design air velocity and temperature are most critical, and that these factors are the prime considerations in the selection of a blast freezing unit.

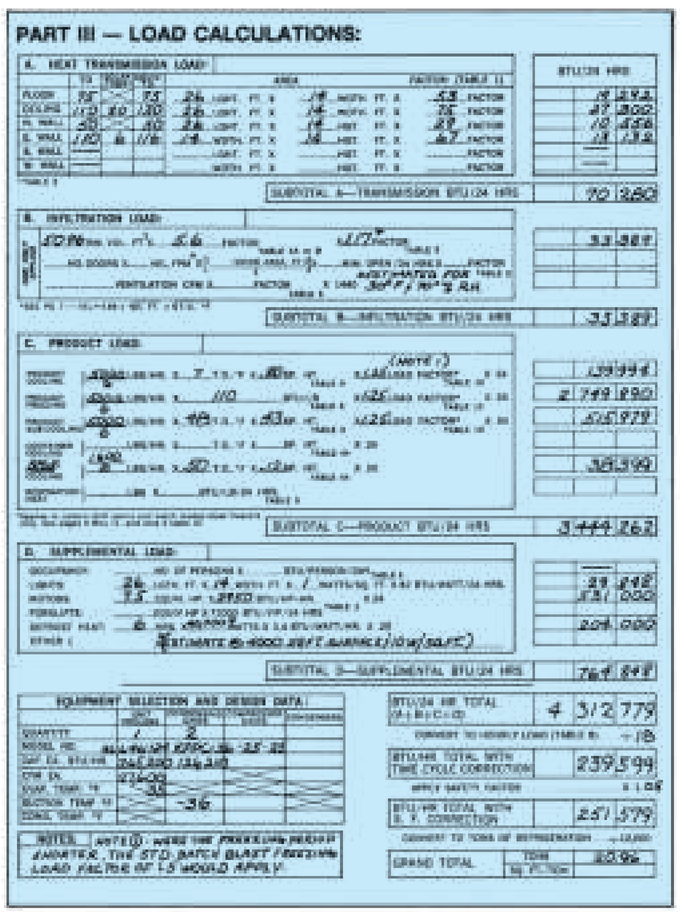
STEP 4: Select equipment as dictated by room size and product mass, and which is in conformance with the required air temperature and velocity as finalized in Step 3 (following review of the pilot freezing test results). The equipment employed should be specifically designed for blast freezing application, and should be capable of producing extremely high air velocities and volumes.

STEP 5: The last step is to position the unit in the room. Refer to Figures C & D, Pg. 11, for typical batch loaded blast freezers. Note that the air travels from right to left in these diagrams, passing thru the product and gradually warming up before being returned to the coil. A critical requirement in blast freezing of this type is that product be loaded across the complete room width thereby precluding the cold air bypass which would otherwise destroy the effectiveness of the freezer.

Refer to the text, Pg 10, for further discussion, and to Table 13, pg. 28, for test blast freezing data on selected products.

FORM LE-1





III. BEEF CARCASS CHILLING:

The load characteristics of a carcass chill room (or the "Hot" cooler, as it is commonly called) are such that the application of a load factor to the average hourly product load is mandatory. The initial rate of heat evolution has been shown by test to exceed the average hourly rate by 50%. **Hence the load factor applicable is 1.50.** The typical load profile is illustrated in figure H, Page 29, wherein time/temperature curves for Hot Chilling are plotted.

Other specialized design and operational requirements apply. Rail height as dictated by USDA must be 11'2", and a 4 to 5 ft. clearance above the rails is required for supporting structure and equipment placement; accordingly ceiling height should be 16 ft. at a minimum. BTR units are specifically designed for this application, and should be utilized whenever possible (these units will accommodate 2 rails on either side).

Small plants can present particular problems. Frequently,12 or 14 ft ceiling heights are encountered, as is the placement of structural steel within the envelope. In an application of this type, it is essential that the refrigeration be coordinated with the structure to assure a clear air flow at the discharge of the unit coolers. Hite-saver® or draw-thru type unit coolers must be flush mounted with the ceiling around the periphery of the room.

An additional USDA requirement is that drain pans be insulated to prevent drippage on the product; stainless enclosures as found on the BTR series are optimum.

Unit coolers should be of 4 FPI coil construction, and be selected for a 10-12°F TD (the initial TD will approach 18-20°F, but will drop rapidly with the fall-off in load). Variable fin spacing (wherein the first 2 rows are of 2 FPI construction) minimizes the defrost requirement, but is not recommended for DXF applications since a 2 fin per inch coil face produces marginal superheat.

Defrost is usually accomplished 4 times daily, with each cycle being of 15 to 20 min. duration. Small rooms usually approximate 40 sq. ft./ton, with large facilities approaching 65-70 sq. ft./ton. The following guidelines may be applied:

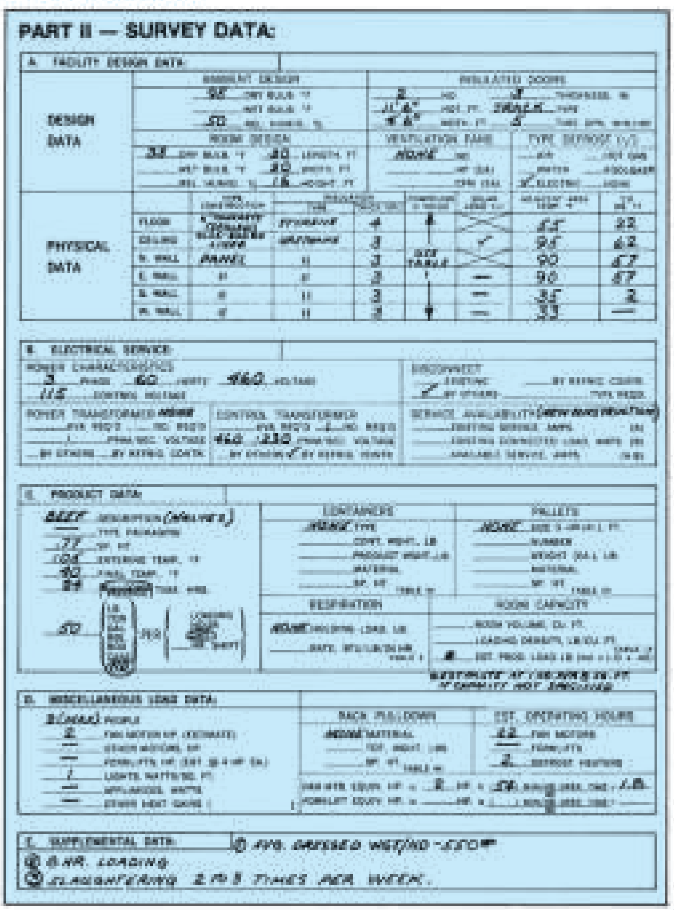
- **5 head per ton**
- **8 sq. ft. per head**

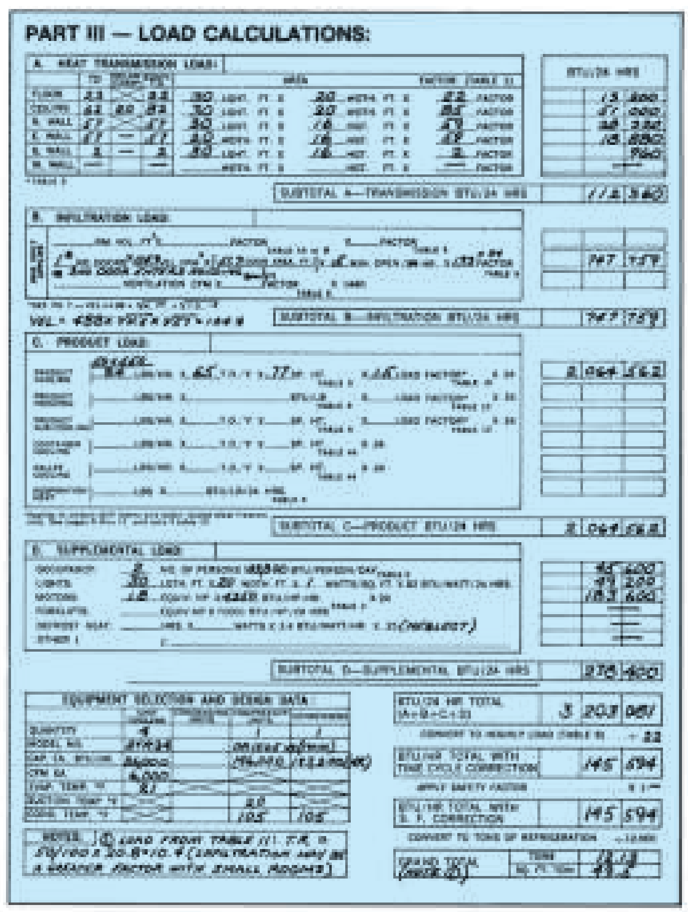
The refrigeration plant should be designed to adapt to the wide load variance. Multiple compressors with unloaders are recommended (a twin unit is illustrated in the example). Improperly applied equipment will short cycle, pump-down the coils, and thereby dry out the product.

As a final consideration, it should be noted that round temperature cannot be pulled down in 18-24 hours. Accordingly, a product load must be estimated for the **holding cooler** which will approximate a 15 degree, 24 hour pull-down of 10% of the carcass weight (utilize 20% of the overall weight for small rooms).

Refer to USDA handbook 191 for detailed meat packing-plant design guidelines, and to tables 11 & 12, Pg. 28, for pre-calculated chill room loads.

FORM LE-1


PART II — SURVEY DATA:


PART III — LOAD CALCULATIONS:

APPLICATION EXAMPLE

IV. BEER STORAGE:

Beer storage facilities are refrigerated for the purpose of maintaining product quality with an extended shelf life (from the usual 90 days, to as much as 180 days at 40°F). The expense is justified by the cyclical nature of industry sales. Storage temperatures vary from **40°F to 76°F**, with the control point being adjusted in accordance with the dew point profile of a given area (the reason being that cartoning would otherwise disintegrate upon exposure to ambient conditions). Draught beer (kegs) is stored in a separate cooler since it must be maintained at a constant temperature year-round (the range being from **34°F to 38°F**).

The product leaves the brewery's pasteurizer at a maximum temperature of 85°F, with its temperature range prior to arrival at the distribution point increasing (decreasing) 1°F if shipment is by truck, or 1°F per day if shipment is by rail.

Beer is shipped by pallet, with a rail car containing 50 pallets. Car loadings are mixed in accordance with a distributor's sales profile. Kegs may be included with a can or bottle load behind a bulkhead packed with dry ice. Pallets are wood, and vary in weight with location from 36 to 44 lbs. (for cans), to 55 lbs. (for kegs); 42 lbs. is the most common weight encountered with cans or bottles. Dimensions are 32" × 37" × 73".

Pallet refrigeration loads based on a 45°F/24 hour product pulldown are as follows:

TYPE CONTAINER	CASES/ PALLET	BTU/45°F/ 24 HR
• 12 oz tray steel can	98	85,000
• 12 oz tray alum. can	98	84,800
• 12 oz Mich*, N.R.	56	54,000
• 12 oz N.R., 4/6	77	75,400
• 12 oz ret, 24	49	51,200
• 16 oz tray steel can	77	89,500
• Quart, N.R.	49	63,200

The following procedure should be followed in estimating the refrigeration load:

STEP 1: Determine facility operational specifics such as method of truck loading (end or side), the percent of pre-sold/scheduled deliveries vs. driver sales, the required number of pallet facings, a 5 year sales projection, the average number of inbound car loads/day, etc.

STEP 2: Following review of the above with operating personnel, define the space to be refrigerated (the primary concern being whether the loading and staging areas should be refrigerated). It is the usual practice to size for expansion planned over a 5 year period.

STEP 3: Determine the distributor's annual sales profile by product category, and compute the average pallet refrigeration load on a weighted average basis.

STEP 4: Obtain the area dew point profile, and subsequently establish minimum storage temperature by month.

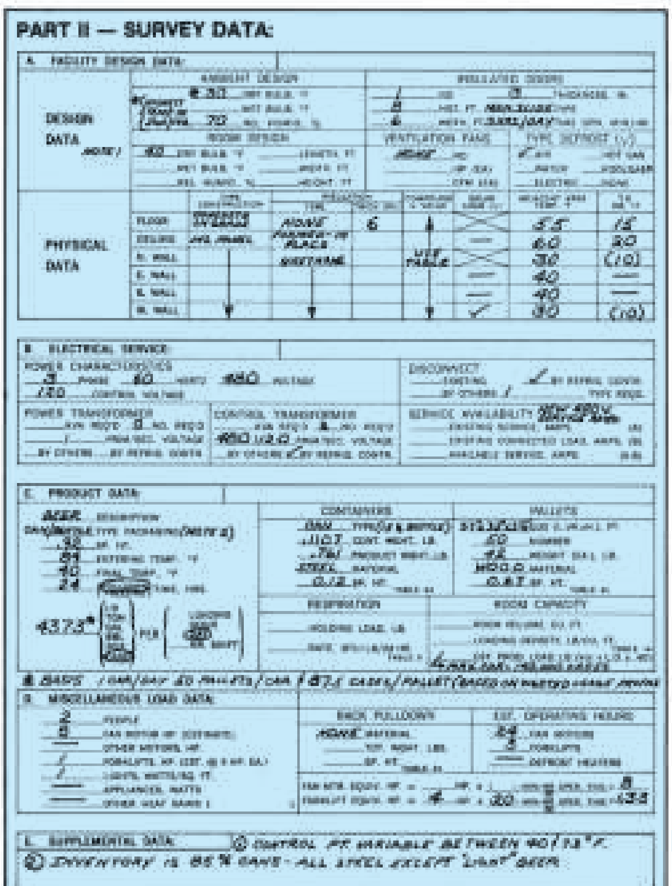
STEP 5: Estimate the heat gain for each of several representative months to determine the peak load. (NOTE: As illustrated in the example, the peak load will occasionally occur during a winter month due to maximum product pulldown requirements).

STEP 6: Review alternate insulation options to those assumed in Step 5 above. A compound U value of .080 is a commonly accepted design, but values as low as .035 are sometimes justified.

STEP 7: Design the refrigeration system for proper function under the load variance determined in Step 5 above. Coil TD is not critical; utilize 6 FPI construction.

See Tables 29 thru 32, Page 37, for additional product load and container data.

FORM LE-1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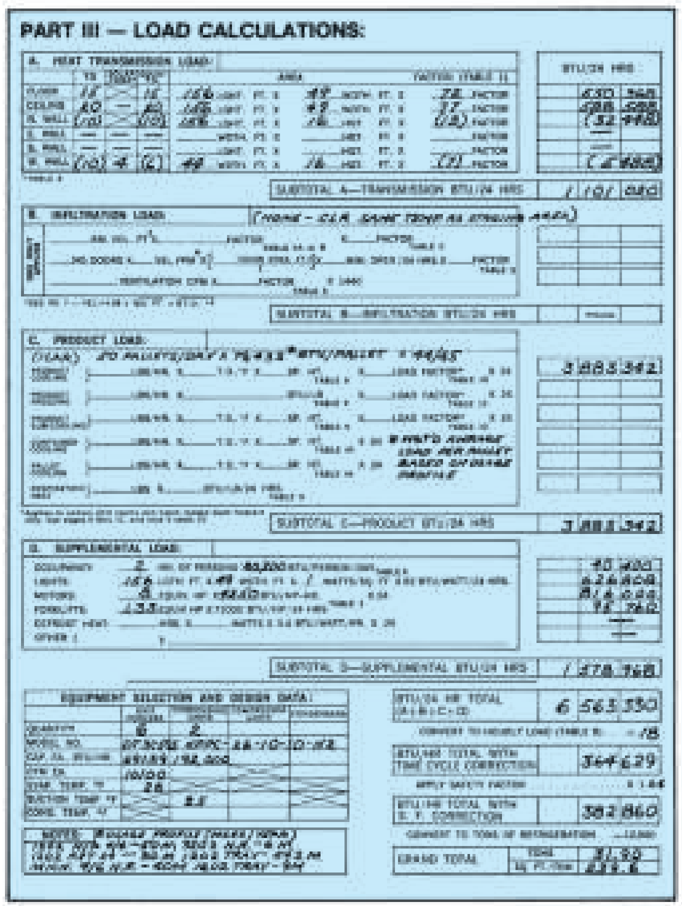

PART III — LOAD CALCULATIONS:

 Note: Michelob* is a registered trademark of Anheuser Busch, Inc., St. Louis, Mo.

V. NUT STORAGE:

Nuts are received from growers during the October thru February harvest season packed in burlap bags. Bag weights vary from 90 lb (for high quality) to 150 lb (for small size, or seedlings); average bag weight is 125 lb, with a truck load being 360 to 400 bags.

Upon receipt at the processing and storage facility, the product is cleaned, sized, and graded, with miscellaneous shells, trash, etc. being removed. It is then segregated into 7 or 8 categories by size, and packed loose in 60" × 42" × 42" wood tote boxes for transfer to storage. Box weights average 170 lbs, with each containing 1800 to 2000 lbs of product. Entrance rate into the cooler is a function of the grading machinery capacity (and **not** the rate of inbound shipments from growers).

Tote boxes are generally stacked 4 high (or 20 ft). The box bottoms and sides are perforated with small holes, and these, in combination with the loosely packed nature of the product, enable adequate air movement thru the load.

Customer orders are filled from storage, with the appropriate size and grade nuts being transferred to the plant area where shelling, cutting and repackaging for customer shipment occur.

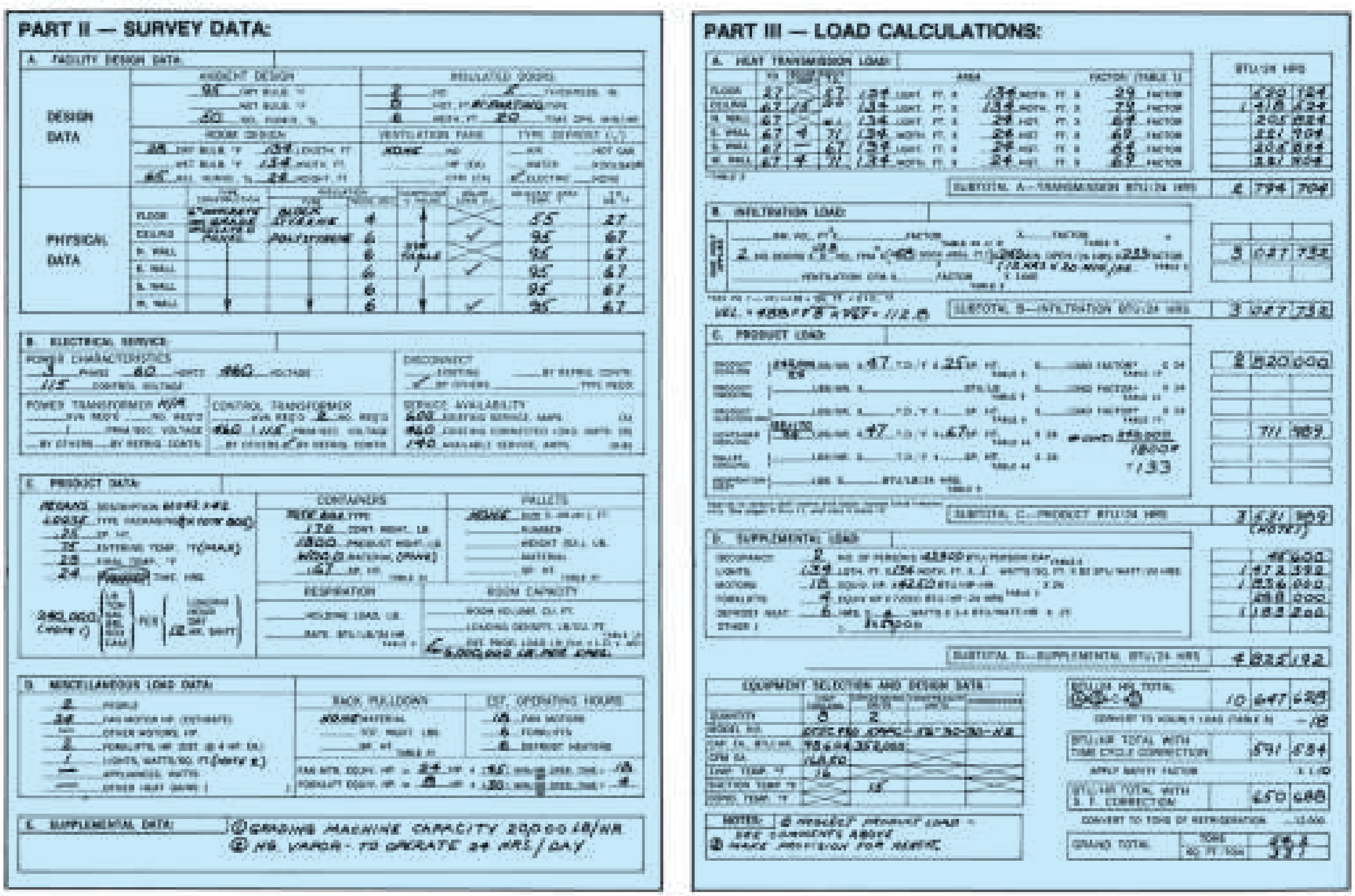
Proper storage room design is **28°F to 32°F** with a **65%** relative humidity; **maintainance of constant humidity is critical**. Processing and plant areas are not usually air conditioned. Since the product enters storage during the fall and winter months, the peak pulldown, transmission and infiltration loads are not coincident (note that incoming product during the summer months usually represents inter-warehouse transfer, and is pre-refrigerated).

The usual practice, therefore, is to estimate the load on the basis of the maximum transmission, infiltration and miscellaneous loads only, with the product load neglected. An alternate load estimating technique is to compute the product load based on 24 hr pulldown at the maximum entrance rate, and add the usual transmission, infiltration and miscellaneous loads recomputed for a lower design ambient (were the example refigured on this basis with a 75°F outdoor design, the net effect would be to reduce the transmission and infiltration loads to 1.8 million and 1.6 million Btu/24 hrs, respectively, with the overall load becoming slightly overstated at 60 tons).

Coils should be selected for a **12°F TD**, and may be of 4 or 6 FPI construction. Multiple compressors are recommended to adapt to the widely divergent peak and holding loads.

Provision for reheat is usually necessary to assure maintenance of constant humidity under light load conditions. The simplest approach is to de-energize one refrigeration system while continually operating all unit fans, lights, and a predetermined number of defrost heaters (the net effect being to false load the operative refrigeration unit). This approach requires the addition of a humidistat and humidity relay (the function of the latter being to de-energize the required refrigeration circuitry and to activate the defrost heaters).

FORM LE-1


PART II — SURVEY DATA:

A. FACILITY DESIGN DATA

B. ELECTRICAL SERVICE

C. PRODUCT DATA

D. MISCELLANEOUS LOAD DATA

E. SUPPLEMENTAL DATA: ① GRADING MACHINE CAPACITY 20000 LB/HR ② HG. VAPOR - TO OPERATE 24 HRS/DAY

PART III — LOAD CALCULATIONS:

A. HEAT TRANSMISSION LOAD

B. INFILTRATION LOAD

C. PRODUCT LOAD

D. SUPPLEMENTAL LOAD

EQUIPMENT SELECTION AND DESIGN DATA

VI. DISTRIBUTION CENTERS:

The refrigeration load in a food distribution facility differs substantially from that common to holding rooms utilized for the extended (or, long term) storage of seasonal and process foods. Product movement, and the activity level in general, is high, with the result being significantly increased infiltration and supplemental heat gains.

The **produce cooler** depicted in the example is illustrative of the application in general. Rooms of this type are maintained at 32-35°F with high humidity, and open into a staging or loading area most frequently controlled at 50-55°F. There is a significant infiltration heat gain resulting from the high frequency of product movement (it is not uncommon for the entrance doors to be open 50% or more of the time). Vestibule and air doors, or strip curtains, appreciably reduce this load, but are often not employed. Consequently, the infiltration load can approach **2 to 2.5 tons per door**. An additional characteristic of this type room is the significant product load resulting from reaction heat; this load may usually be estimated at **.003 to .004 tons/sq ft**, and the room load overall will generally fall between **150 and 200 sq ft/ton**. Proper equipment application dictates unit coolers selected for a **6-9°F** coil T.D., with face velocities not in excess of **600 FPM for wet coil operation**, or **700 FPM for light frosted operation**. The over-riding design consideration in these rooms is the prevention of product damage from shrinkage, drying, or mold growth.

Deli coolers are generally maintained at a slightly lower temperature (30-33°F), and represent an even more severe application from the standpoint of infiltration. In many rooms, the doors are never closed, with the resulting infiltration gain being **3.5 to 4 tons/door**. The overall room load usually approximates **200 to 225 sq ft/ton**.

The load in **holding freezers** is dependent in large measure on the condition of the inbound product. Frequently, a 10 to 15°F pulldown load is imposed, and, since movement is heavy, this load is significant. Infiltration can be estimated at **2 tons/door**. A load estimating guideline of **200 to 300 sq ft/ton** applies due to the wide variance in product load.

The refrigeration requirements for **loading docks** are difficult to estimate. The activity level is high (personnel, forklifts, etc.), as is the rate of infiltration. Dock seals may be either worn or damaged, or not adaptable to certain trailer cavities. Forced ventilation is sometimes utilized to evacuate exhaust fumes, and, when present, will supplant the usual infiltration load (if greater). Docks are maintained at 35 to 55°F, with the lower temperatures affording the dual advantage of increased flexibility and decreased load imposition on adjacent rooms. Unit coolers should have face velocities under 650 FPM, and be placed such that they blow toward and above the doors to create an air curtain effect. The load range is **150 to 175 sq ft/ton.**

Ripening rooms are usually located at the rear of the loading area, and may be of ½, 1 or 2 car capacity. The load range is **3 to 12 tons per room**, and is accommodated most effectively with individual halocarbon systems specifically designed for this application. Since the full complement of rooms are seldom (if ever) in simultaneous service, a load diversity factor of .75 can be applied if a central refrigeration plant is utilized.

FORM LE-1

PART II — SURVEY DATA:

A. FACILITY DESIGN DATA:

DESIGN DATA — Ambient design: 95 dry bulb °F; 60 wet bulb °F. Room design: 35 dry bulb °F; 85 rel. humid. %; 100 length ft; 75 width ft; 20 height ft. Ventilation fans: NONE. Type defrost: ✓ (hot gas).

PHYSICAL DATA:

	Insulation thick.	Adjacent area temp. °F	T.D. °F
FLOOR	6	55	20
CEILING	4	95	60
N. WALL	4	95	60
E. WALL	4	95	60
S. WALL	4	55	20
W. WALL	4	-10	(45)

B. ELECTRICAL SERVICE: 3 phase, 60 hertz, 460 voltage; 115 control voltage. Control transformer: 460 / 115 primary-sec. voltage.

C. PRODUCT DATA: PRODUCE; CARTON; 90 (AVG.); 40 entering temp. °F; 35 final temp. °F; 24 pulldown time hrs; 200,000 lbs per day. Containers: carton; AVG. 2.5 cont. wght. lb; 35 product wght. lb; FIBER material; 0.34 sp. ht. Respiration: 4.5 rate BTU/LB/24 HR (AVERAGE). Room capacity: 4,700,000 LB (SPECIFIED).

D. MISCELLANEOUS LOAD DATA: 2 people; 16 fan motor HP (estimate); 3 forklifts; 1 lights, watts/sq ft. Est. operating hours: 20 fan motors; 4 forklifts; 3 defrost heaters. Fan mtr. equiv. HP = 16 HP × .80 = 13.4; forklift equiv. HP = 3 HP × .40 = 5.4?

E. SUPPLEMENTAL DATA: STORAGE PERIOD MAY EXTEND FROM 10 TO 15 DAYS · HUMIDITY CRITICAL — USE 7°F COIL T.D.

PART III — LOAD CALCULATIONS:

A. HEAT TRANSMISSION LOAD:

	T.D.	Solar	Total	Area	Factor	BTU/24 HRS
FLOOR	20	—	20	100 × 75	.19	142 500
CEILING	60	20	80	100 × 75	.36	570 000
N. WALL	60	—	60	100 × 20	.58	116 000
E. WALL	60	4	64	75 × 20	.62	93 000
S. WALL	20	—	20	100 × 20	.19	38 000
W. WALL	(45)	—	(45)	75 × 20	(.93)	(63 000)

SUBTOTAL A — TRANSMISSION BTU/24 HRS: 895 000

B. INFILTRATION LOAD: 487 516

SUBTOTAL B — INFILTRATION BTU/24 HRS: 487 516

C. PRODUCT LOAD: 900 000; 24 285; 5 100 000

SUBTOTAL C — PRODUCT BTU/24 HRS: 6 024 285

D. SUPPLEMENTAL LOAD: Occupancy 2; Lights 100 × 75; Motors 13.4; Forklifts 5.4; Defrost heat 3 — 43 200; 615 000; 1 366 800; 388 800; 367 200

SUBTOTAL D — SUPPLEMENTAL BTU/24 HRS: 2 780 200

EQUIPMENT SELECTION AND DESIGN DATA: Quantity 8; Model No. BTC4090

BTU/24 HR TOTAL (A+B+C+D)	10 187 001
CONVERT TO HOURLY LOAD	20
BTU/HR TOTAL WITH TIME CYCLE CORRECTION	509 350
APPLY SAFETY FACTOR	× 1.10
BTU/HR TOTAL WITH S.F. CORRECTION	560 318
CONVERT TO TONS OF REFRIGERATION	12,000
GRAND TOTAL — TONS	46.6
GRAND TOTAL — SQ FT/TON	160.9

VII. WALK-IN COOLERS:

GENERAL

Pre-fabricated walk-in coolers and freezers are utilized for a wide variety of refrigerated storage, chilling and freezing applications, the most common of which is the point-of-sale holding room.

Since standard configurations with an extensive experience factor are involved, loads may be precalculated and charted as a matter of convenience.

A brief description of the precalculated walk-in cooler data included herein is as follows:

TABLE NO.	DESCRIPTION
40	Tabulates transmission, infiltration, lighting, occupancy and related miscellaneous loads for 8' and 10' prefabricated coolers in the 40 most common configurations. Note that product load is **excluded** for the purpose of enabling greater applicational flexibility. Loads are based on: • 95°F ambient design • Average usage • Indoor installation • 3" urethane (or equivalent) insulation • 18 hour compressor operation. Correction factors are noted for other ambients, and for light or heavy usage situations.
41	Tabulates average product loads by room volume. Data is based on actual Hussmann experience with field applications, and is intended for use with holding rooms **only** when the specific product loading is unknown.
42	Tabulates specific product loads on the basis of 24 hour pulldown with 18 hour operation. This table should be used for all pulldown coolers and freezers, or when the specific product entering rate and condition is known. Note: batch blast freezing, and certain other specialized applications such as ice cream hardening, require adjustment of the 24 hr pulldown data. The applicable formula is:

$$Q_{\text{Btu / 24 hrs}} = \frac{\text{Charted Value} \times 24}{\text{Pulldown or Freezing Time}_{\text{hrs}}}$$

TABLE NO.	DESCRIPTION
43	Tabulates additional infiltration loads for glass display doors.

Additionally, Table 32 tabulates the total capacity requirements for walk-in beer storage coolers.

Product loads not tabulated in Table 42, or loads for specialized applications, may be estimated in the usual manner utilizing Form LE-1.

SPECIFIC EXAMPLES:

I. Cooler — Average Product Load:

- 10' W × 12' L × 8' H @ 36°F
- 95°F ambient design

- Refrig. load less product (Table 40) .... 7,000 Btu/hr
- Average product load (Table 41) .... 1,800 Btu/hr

Total refrig. load .... 8,800 Btu/hr

II. Milk Cooler — Specific Product Load:

- 10' W × 12' L × 8' H @ 35°F
- 300 gal/day entering @ 45°F
- 10 hour pulldown
- 80°F ambient design (air cond. space)
- (3) 30" × 66" glass display doors

- Refrig. load less product (Table 40) 7125 × 0.75 (C.F. @ 80°F) .... 5,444 Btu/hr
- Product load (Table 42)

456 Btu/hr /100 gal $\times \frac{300}{100} \times \frac{24}{10}$ .... 3,283 Btu/hr

- Display door infiltration (Table 43) 960 × 3 .... 2,880 Btu/hr

Total refrig. load .... 11,607 Btu/hr

III. Holding/Pulldown Freezer:

- 16' W × 32' L × 10' H @ −20°F
- 2000 lbs fish/day entering @ 35°F
- 100°F ambient design
- Product packaged & boxed
- 16 hour pulldown

- Refrig. load less product (Table 40) 26,600 Btu/hr × 1.10 (C.F. @ 100°F) .... 29,260 Btu/hr
- Product load (Table 42)

817 Btu/hr/100 lbs $\times \frac{2000}{100} \times \frac{24}{16}$ .... 24,510 Btu/hr

Total refrig. load .... 53,770 Btu/hr

IV. Ice Cream Hardening/Storage Freezer:

- 30' W × 30' L × 10' H @ −20°F
- Soft mix @ 28°F
- Assume maximum daily capacity
- 100% overrun; wgt/gal = 4.6 lbs
- 95°F ambient design

- Refrig. load less product (Table 40) .... 37,000 Btu/hr
- Product load (Table 42)

Assuming 3.3 gal/sq ft (see Table 7, Note 7), the no. of gal to be hardened is:

900 sq ft × 3.3 gal/sq ft = 2970 gal,

and the product load based on a 10 hr hardening time is therefore:

3284 Btu/hr/100 gal × 2970/100 × 24/10 .... 234,083 Btu/hr

Total refrig. load .... 271,083 Btu/hr

V. Beer Cooler:

- 12' W × 20' L × 10' H @ 35°F
- 900 case capacity with 20% daily turn
- Product entering temp. of 50°F
- 95°F ambient design

- Refrig. load less product assuming heavy usage (Table 40) 11,100 × 1.15 (C.F. @ heavy usage) .... 12,765 Btu/hr
- Product load (Table 42) 2670 Btu/hr/100 Cases ×

$\frac{900}{5 \times 100}$ .... 4,806 Btu/hr

Total refrig. load .... 17,571 Btu/hr

APPENDIX—TABLES

TABLE 1A

HEAT GAIN FACTORS IN BTU/SQ FT /24 HRS FOR COMMON INSULATING & BUILDING MATERIALS

TEMPERATURE DIFFERENCE — °F (AMBIENT LESS STORAGE TEMPERATURE)

	K Factor	Inches	1	10	20	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130
FOAMGLASS	.38	3	3.85	39	77	116	135	154	173	193	212	232	250	270	288	306	327									
		4	2.28	23	46	68	80	92	103	114	125	136	148	160	171	184	194	206	217	228	239	250	262	272	285	296
		5	1.82	18	36	55	64	72	82	91	100	110	118	128	137	144	155	164	173	182	191	200	209	220	228	236
		6	1.52	15	30	46	53	61	68	76	84	92	99	106	114	122	129	136	144	152	160	168	175	184	190	198
		7	1.30	13	26	39	46	52	59	65	72	78	85	92	98	104	110	118	124	130	137	144	150	156	163	170
		8	1.14	11	23	34	40	46	51	57	63	68	74	80	86	92	97	102	106	114	120	126	131	136	143	148
		9	1.01	10	20	30	35	40	45	50	55	61	65	71	76	81	86	91	96	101	106	111	116	121	126	131
		10	0.91	9	18	27	32	36	41	46	50	54	59	64	68	72	77	82	86	91	96	100	105	108	114	118
		11	0.83	8	17	25	29	34	37	42	46	50	54	58	62	68	71	74	79	83	87	92	95	100	104	108
		12	0.76	7.6	15	23	27	30	34	38	42	46	49	54	57	60	65	68	72	76	80	84	87	91	95	99
CORKBOARD	.30	3	2.40	24	48	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	312
		4	1.80	18	36	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180	189	198	207	216	225	234
		5	1.44	14	28	42	50	58	65	72	79	87	94	101	108	115	122	130	137	144	151	158	166	173	180	188
		6	1.20	12	24	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	160	176
		7	1.03	10	20	30	35	41	46	52	57	62	67	72	77	82	88	93	98	103	108	113	118	124	129	134
		8	0.90	9	18	27	32	36	41	45	50	54	59	63	68	72	77	81	86	90	95	99	104	108	113	118
		9	0.80	8	16	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104
		10	0.72	7	14	21	25	29	32	36	40	43	47	50	54	58	61	65	68	72	76	79	83	86	90	94
		11	0.66	6.5	13	19.5	23	26	30	33	36	40	43	46	50	53	56	60	63	66	69	73	76	79	82	86
		12	0.60	6	12	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78
EXPANDED POLYSTYRENE OR FIBERGLASS	.24	1	5.76	58	115	173	201	230	260	290	320															
		2	2.88	29	58	86	101	115	130	144	158	173	187	202	216	231	245	260	274	288	303					
		3	1.92	19	38	58	68	77	86	96	106	115	125	135	145	154	163	173	182	192	202	212	221	231	240	251
		4	1.44	14	29	43	50	58	65	72	79	86	94	101	108	115	123	130	137	144	151	159	166	173	181	188
		5	1.15	11	23	34	40	46	51	58	63	68	75	80	86	92	98	102	109	115	121	126	132	136	143	150
		6	0.96	9.8	19	29	34	38	43	48	53	58	62	68	72	77	82	87	91	96	101	106	111	115	120	125
		7	0.84	8.4	17	25	29	34	38	42	46	50	55	59	63	68	72	76	80	84	88	92	97	101	105	109
		8	0.72	7.2	14	22	25	29	32	36	39	43	46	50	54	57	61	65	69	72	76	80	83	86	90	93
		9	0.64	6.4	13	19	22	26	29	32	35	38	42	44	48	52	54	58	61	64	67	70	74	76	80	84
		10	0.58	5.8	12	17	20	24	26	29	32	34	38	40	44	48	49	52	55	58	61	64	67	69	73	75
EXTRUDED POLYSTYRENE	.185	1	4.44	44	89	133	155	178	200	222	244	266	289	311	333											
		2	2.22	22	44	67	78	89	100	111	122	133	145	156	167	177	189	200	211	222	233	244	255	266	278	289
		3	1.48	15	30	44	52	60	67	74	81	89	96	104	111	118	126	133	141	148	155	163	170	178	185	192
		4	1.11	11	22	34	39	45	50	56	61	67	73	78	84	89	95	100	106	111	117	122	128	133	139	145
		5	0.89	9	18	27	31	36	40	45	49	54	58	62	67	71	76	80	85	89	93	98	102	107	111	116
		6	0.74	7.4	15	22	26	30	33	37	40	44	48	52	56	59	63	67	70	74	78	81	85	89	92	96
		7	0.63	6.3	13	19	22	25	28	32	35	38	41	44	47	50	53	57	60	63	66	69	72	76	79	82
		8	0.56	5.6	11	17	19	23	25	28	31	34	37	39	42	45	48	50	53	56	59	61	64	67	69	72
SLAB URETHANE-FOAMED IN-PLACE URETHANE PANELS	.16	1	3.84	38	77	115	134	154	173	192	211	230	250	268	288	307	326									
		2	1.92	19	38	58	67	77	87	96	106	115	124	135	144	154	163	173	183	192	202	212	221	231	240	249
		3	1.28	13	26	38	45	51	58	64	71	77	83	90	96	102	109	115	122	128	135	141	147	154	160	167
		4	0.96	9.6	19	29	34	38	43	48	53	58	63	68	72	76	82	87	91	96	101	106	111	115	119	125
		5	0.75	7.5	15	23	26	30	34	38	41	46	49	52	56	60	64	68	71	75	79	83	86	90	94	98
		6	0.64	6.4	13	19	22	26	29	32	35	38	42	45	48	51	54	57	61	64	67	70	74	77	80	83
	.13	3	1.04	10	21	31	36	42	47	52	57	62	68	73	78	83	88	94	99	104	109	114	120	125	130	135
		4	0.78	7.8	16	23	27	32	35	38	43	46	51	55	59	63	66	70	74	78	82	86	89	94	98	101
		5	0.62	6.2	12	19	22	24	28	31	34	37	40	43	47	50	53	56	59	62	65	68	71	74	78	8
BUILDING MATERIALS	Single Glass		27	270	540	810																				
	Double Glass		11	110	220	330	385	440	495	550	600	660	715	770	825	880	935	990								
	Triple Glass		7	70	140	210	245	280	320	350	390	420	454	490	525	560	595	630	665	700	740	770	810	840	875	910
	6" Conc. on Grade		4.8	48	96	144																				
	6" Conc. & 4" Extrud. Styrene		1.08	11	22	32	38	43	49	54	59	65	70	76												
	8" Conc. & 6" Expand. Styrene or 4" Urethane		0.96	9.6	19	28	33	38	43	48	53	57	62	67												
	8" Conc. & 8" Expand. Styrene		0.71	7.1	14	21	25	28	32	36	39	43	46	50	53	57	60	64								

Note 1: 4" sub floor & 4" wearing surface enclosing intermediate insulation slab.

APPENDIX—TABLES

TABLE 1B — HEAT TRANSMISSION COEFFICIENTS FOR OTHER INSULATING AND BUILDING MATERIALS

	MATERIAL	DENSITY LB/CU FT	MEAN TEMP °F	CONDUCTIVITY K	CONDUCTANCE C	RESISTANCE PER IN	R OVERALL
BUILDING BOARD	Asbestos-Cement Board	120	75	4.0	—	0.25	—
	Plaster Board, 1/2"	50	75	—	2.25	—	0.45
	Plywood	34	75	0.80	—	1.25	—
	Insulating Board, Sheathing, 1/2"	22	75	—	0.82	—	1.22
	Sound Deadening Board, 1/2"	15	—	—	0.74	—	1.35
	Hardboard, Siding 7/16"	40	75	—	1.49	—	0.67
	Particleboard, Med. Dens.	50	75	0.94	—	1.06	—
BUILDING PAPER	Vapor, Permeable Felt	—	75	—	16.70	—	0.06
	Vapor, Seal, 2 Layers of Mopped 15 lb Felt	—	75	—	8.35	—	0.12
	Vapor, Seal, Plastic Film	—	75	—	—	—	Negl.
FLOORING	Carpet & Fiber Pad	—	75	—	0.48	—	2.08
	Carpet & Rubber Pad	—	75	—	0.81	—	1.23
	Cork Tile, 1/8"	—	75	—	3.60	—	0.28
	Terrazzo, 1"	—	75	—	12.50	—	0.08
	Tile, Asphalt Vinyl or Linoleum	—	75	—	20.00	—	0.05
	Wood Subfloor, 25/32"	—	—	—	1.05	—	0.95
	Wood Flooring	—	—	—	1.45	—	0.69
INSULATION	Blanket, Fiberglass	1.0	75	0.29	—	3.45	—
	Blanket, Mineral Wool	0.5	75	0.32	—	3.12	—
	Loose Fill, Perlite, Expanded	5.0-8.0	75	0.37	—	2.70	—
	Loose Fill, Glass Fiber	2.5	75	0.28	—	3.46	—
	Loose Fill, Vermiculite, Exp.	7.0-8.2	75	0.47	—	2.12	—
	Insulating Roof Deck, 2"	—	75	—	0.18	—	5.56
	Mineral Fiber Board, Accoustical Tile	23	75	0.42	—	2.38	—
	Roof Insulation, 2" (Note 1)	—	75	—	0.19	—	5.56
MISC.	Sawdust	—	75	0.45	—	2.22	—
	Snow	—	—	1.2-3.6	—	0.83-0.27	—
	Soil	—	—	7.2-12.0	—	0.14-0.08	—
	Water	—	—	4.2	—	0.24	—
MASONRY	Brick, Common	120	75	5.0	—	0.20	—
	Brick, Face	130	75	9.0	—	0.11	—
	Concrete (Sand & Gravel)	140	—	12.0	—	0.08	—
	Concrete Block (Sand & Gravel — 8")	—	75	—	0.90	—	1.11
	Concrete Block, Cinder, 8"	—	75	—	0.58	—	1.72
	Concrete Block, Cinder, 12"	—	75	—	0.53	—	1.89
	Gypsum Plaster (Sand)	105	75	5.6	—	0.18	—
	Stone, Lime or Sand	—	75	12.50	—	0.08	—
	Tile, Hollow 2 Cell, 6"	—	75	—	0.66	—	1.52
ROOFING	Asphalt Roll Roofing	70	75	—	6.5	—	0.15
	Roofing, Built-Up, 3/8"	70	75	—	3.0	—	0.33
	Shingles, Asbestos Cement	120	75	—	4.76	—	0.21
	Shingles, Asphalt	70	75	—	2.27	—	0.44
SIDING	Asphalt Insul. Siding, 1/2"	—	75	—	0.69	—	1.46
	Wood, Bevel, 1/2" × 8" Lapped	—	75	—	1.23	—	0.81
	Aluminum or Steel (Sheathed)	—	—	—	1.61	—	0.61
	Insulating-Board Backed, 3/8"	—	—	—	0.55	—	1.82
WOOD	Hardwoods (Maple, Oak)	45	75	1.10	—	0.91	—
	Softwoods (Fir, Pine)	32	75	0.80	—	1.25	—
	Softwoods (Fir, Pine), 3/4"	32	75	—	1.06	—	0.94

Note 1: Various thicknesses to meet U.S. Department of Commerce Standard.

TABLE 2 SOLAR RADIATION ALLOWANCE

	SURFACE TYPE	°F TO BE ADDED TO NORMAL T.D. (NOTE 1)			
		East Wall	South Wall	West Wall	Flat Roof
DARK	Slate Roofing Tar Roofing Black Paints	8	5	8	20
MEDIUM	Unpainted Wood Brick Red Tile Dark Cement Red, Grey, or Green Paint	6	4	6	15
LIGHT	White Stone Light Colored Cement White Paint	4	2	4	9

Notes: 1. The F degrees noted are to be added to the normal temperature difference to compensate for sun effect in calculating transmission heat gain.
2. Not to be used for air conditioning design.
3. Add 50% to charted values for buildings adjacent to highly reflective surfaces such as sun, water, or heat-repellent glass.

TABLE 3 MOTOR EQUIVALENCIES

HORSE-POWER	BTU PER HORSEPOWER-HOUR		
	Connected Load And Motor In Refrigerated Space (Note 1)	Connected Load Only In Refrigerated Space	Motor Only In Refrigerated Space
1/8 to ½	4250	2545	1700
¾-3	3700	2545	1150
5-20	2950	2545	400

Note 1: Use for forced circulation unit coolers.

TABLE 4A AVERAGE AIR CHANGES PER 24 HRS FOR MED. TEMPERATURE (ABOVE 32°F) ROOMS DUE TO INFILTRATION AND DOOR OPENINGS

VOLUME CU FT	AIR CHANGES PER 24 HR	VOLUME CU FT	AIR CHANGES PER 24 HR	VOLUME CU FT	AIR CHANGES PER 24 HR	VOLUME CU FT	AIR CHANGES PER 24 HR
200	44.0	1000	17.5	6000	6.5	30000	2.7
300	34.5	1500	14.0	8000	5.5	40000	2.3
400	29.5	2000	12.0	10000	4.9	50000	2.0
500	26.0	3000	9.5	15000	3.9	75000	1.6
600	23.0	4000	8.2	20000	3.5	100000	1.4
800	20.0	5000	7.2	25000	3.0	200000	0.9

Note: For heavy usage, multiply above values by 2. For long storage, multiply the above values by 0.60. Not valid if ventilating ducts or grilles are used.

TABLE 4B AVERAGE AIR CHANGES PER 24 HRS FOR LOW TEMPERATURE (BELOW 32°F) ROOMS DUE TO INFILTRATION AND DOOR OPENINGS

VOLUME CU FT	AIR CHANGES PER 24 HR	VOLUME CU FT	AIR CHANGES PER 24 HR	VOLUME CU FT	AIR CHANGES PER 24 HR	VOLUME CU FT	AIR CHANGES PER 24 HR
250	29.0	1000	13.5	5000	5.6	25000	2.3
300	26.2	1500	11.0	6000	5.0	30000	2.1
400	22.5	2000	9.3	8000	4.3	40000	1.8
500	20.0	2500	8.1	10000	3.8	50000	1.6
600	18.0	3000	7.4	15000	3.0	75000	1.3
800	15.3	4000	6.3	20000	2.6	100000	1.1

Note: For heavy usage, multiply above values by 2. For long storage, multiply the above values by 0.6. Not valid if ventilating ducts or grilles are used.

TABLE 5 HEAT REMOVED IN COOLING AIR TO STORAGE CONDITIONS (BTU PER CU FT)

STORAGE ROOM TEMP. °F	TEMPERATURE OF OUTSIDE AIR, °F							
	85		90		95		100	
	RELATIVE HUMIDITY, PERCENT							
	50	60	50	60	50	60	50	60
65	0.32	0.52	0.58	0.81	0.85	1.12	1.15	1.46
60	0.58	0.78	0.83	1.06	1.10	1.37	1.39	1.70
55	0.80	1.00	1.05	1.28	1.32	1.59	1.61	1.92
50	1.01	1.21	1.26	1.49	1.53	1.79	1.82	2.13
45	1.20	1.40	1.45	1.68	1.71	1.98	2.00	2.31
40	1.37	1.57	1.62	1.85	1.88	2.15	2.17	2.48
35	1.54	1.74	1.78	2.01	2.04	2.31	2.33	2.64
30	1.78	2.01	2.05	2.31	2.33	2.64	2.65	3.00

STORAGE ROOM TEMP. °F	TEMPERATURE OF OUTSIDE AIR, °F							
	40		50		90		100	
	RELATIVE HUMIDITY, PERCENT							
	70	80	70	80	50	60	50	60
30	0.21	0.26	0.55	0.62	2.06	2.31	2.65	3.00
25	0.37	0.43	0.71	0.78	2.20	2.46	2.79	3.14
20	0.52	0.58	0.86	0.93	2.33	2.60	2.93	3.28
15	0.66	0.72	1.00	1.07	2.46	2.72	3.05	3.40
10	0.80	0.85	1.13	1.20	2.58	2.84	3.17	3.52
5	0.92	0.97	1.25	1.32	2.69	2.95	3.28	3.63
0	1.04	1.09	1.36	1.43	2.80	3.06	3.38	3.74
−5	1.15	1.20	1.47	1.55	2.90	3.16	3.48	3.84
−10	1.26	1.31	1.58	1.65	3.00	3.26	3.58	3.93
−15	1.37	1.42	1.69	1.76	3.10	3.36	3.68	4.03
−20	1.47	1.52	1.79	1.86	3.19	3.46	3.77	4.12
−25	1.57	1.62	1.89	1.96	3.29	3.55	3.86	4.21
−30	1.67	1.72	1.99	2.06	3.38	3.64	3.95	4.30

From 1972 ASHRAE Handbook of Fundamentals — Reprinted by Permission

TABLE 6 OCCUPANCY HEAT

ROOM TEMPERATURE °F	HEAT PER PERSON BTU/24 HRS
50	17,300
40	20,200
30	22,800
20	25,200
10	28,800
0	31,200
−10	33,600

Derived from 1972 ASHRAE Handbook of Fundamentals — Reprinted by Permission

TABLE 7 ICE CREAM DATA

PERCENT OF OVERRUN	HARDENING LOAD BTU/GAL ICE CREAM
60	532
70	500
80	470
90	447
100	425
110	405
120	386

Notes:

1. $\% \text{ overrun} = \dfrac{(\text{wgt/gal of mix}) - (\text{wgt/gal ice cream})}{\text{wgt/gal of ice cream}}$
2. Values based on entering temp. of 25°F (30% frozen).
3. Formula: $\text{Product Load (Btuh)} = \dfrac{\text{no. of gal} \times \text{Btu/gal}}{\text{hardening time (hrs.)}}$
4. 8-10 hr hardening time should be used with forced air circulation; adjust the calculated load for 18-20 hr compressor operation.
5. See Table 42 for prefigured 24 hr hardening loads at 28°F ent. temp. & 18 hr comp. operation (the values charted in Table 42 must be adjusted for the desired hardening time — i.e., 8 or 10 hrs).
6. At 100% overrun, avg. wgt/gal is 4.6 lb with 60% water content.
7. Estimate hardening rooms at a peak daily production rate of 3.3 gal/sq ft and for a storage capacity of 10 gal/sq ft, if sized to stock all flavors.
8. Estimate storage rooms @ 25 gal/sq ft when stacked solid 6 ft high (including aisles).

Extracted from 1971 ASHRAE Guide & Data Book — Reprinted by Permission

TABLE 8 TIME CYCLE FACTORS

APPLICATION	RECOMMENDED FACTORS	
	24 HOUR (DIVIDE BY)	HOURLY (MULTIPLY BY)
Coil Temp. Above 32°F — No Frost Accumulation	24	1.0
Light Frost With Positive Defrost Systems	22	1.1
Med. Temp. With Positive Defrost Systems	20	1.2
Low Temp. With Positive Defrost Systems	18	1.3
Off Cycle Defrost, 35°F or Higher Storage Temp., With Evap. Temp. Below 32°F	16	1.5

Note: Factors noted are for average frosting. For heavier frost, or lower than normal evap. temps., use 1-2 hrs less oper. time.

APPENDIX—TABLES

TABLE 9 PROPERTIES AND STORAGE DATA FOR PERISHABLE PRODUCTS

PRODUCT	SP. HEAT BTU/LB/°F ABOVE FREEZE POINT	SP. HEAT BTU/LB/°F BELOW FREEZE POINT	LATENT[1] HEAT OF FUSION BTU/LB	HIGHEST FREEZE POINT °F	WATER CONTENT %	SHORT STORAGE TEMP °F	SHORT STORAGE RH% MIN-MAX	SHORT STORAGE RESPIRATION HEAT BTU/LB/24 HR	LONG STORAGE TEMP °F	LONG STORAGE RH% MIN-MAX	LONG STORAGE RESPIRATION HEAT BTU/LB/24 HR	APPROX STORAGE LIFE
DAIRY PRODUCTS			(See Tables 24-28 for additional Milk / Cheese Data)									
Butter	.64	.34	15	30.0	15.0	40	75-80	—	-5 to -10	80-85	—	6 Mos
Cheese												
• American	.64	.36	79	17.0	55.0	40[8]	75-80	—	32[8]	75-80	—	12 Mos
• Limburger	.70	.40	86	19.0	60.0	40[8]	80-85	—	32[8]	80-85	—	2 Mos
• Roquefort	.65	.32	79	3.0	55.0	45[8]	75-80	—	30[8]	75-80	—	2 Mos
• Swiss	.64	.36	79	15.0	55.0	40[8]	75-80	—	32[8]	75-80	—	2 Mos
Cream	.85	.40	90	28.0	55.0	35	—	—	-5 to -10	—	—	4 Mos
Eggs												
• Crated	.75	.42	96	30.0[4]	66.0	40[8]	80-85	—	31[8]	85-88	—	12 Mos
• Frozen	—	.42	96	30.0[4]	—	—	—	—	-5 to -10	—	—	18 Mos
• Whole Solid	.22	.21	4	—	3.0	40[8]	80	—	40[8]	80	—	12 Mos
Ice Cream	.75	.42	89	28.0	61.0	-15	—	—	-15	—	—	3-4 Mos
Milk												
• Fluid Whole	.92	.48	125	31.0	88.0	35	—	—	—	—	—	5 Days
• Condensed	.42	—	40	—	28.0	40	—	—	40	—	—	3 Mos
• Evaporated	.72	—	106	—	74.0	—	—	—	Rm Temp	—	—	12 Mos
• Dried	.22	—	4	—	3.0	—	—	—	50	80	—	3 Mos
Oleo	.32	.25	22	—	15.5	45	60-70	—	35	60-70	—	8 Mos
FRUIT												
Apples	.87	.45	121	29.3	84.1	35[8]	85-88[8]	.72	30[8]	85-88[8]	.48	3-8 Mos
Apricots	.88	.46	122	30.1	85.4	35	80-85	.96	31	80-85	.48	2 Wks
Avocados	.81	.45	118	31.5	82.0	50[8]	85-90[8]	—	45[8]	85-90[8]	—	3 Wks
Bananas												
• Green	.80	.42	108	30.6	74.8	56	90-95	.17	—	—	—	—
• Ripe	.80	.42	108	30.6	74.8	—	—	—	56	85-90	.17	8 Days
Berries (Gen)	.88	.45	120	30.0	84.0	35	80-85	2.90	31	80-85	2.90	8 Days
Cherries	.86	.45	116	28.8	80.4	35	80-85	1.35	31	80-85	.75	2 Wks
Coconuts	.58	.34	67	30.4	46.9	35	80-85	—	32	80-85	—	2 Mos
Cranberries	.90	.46	124	30.4	87.4	40	85-90	.48	36	85-90[8]	.48	3 Mos
Currants	.88	.45	120	30.2	84.7	36	85-90	—	32	85-90	—	2 Wks
Dates (Cured)	.36	.26	29	3.7	20.0	35[8]	65-75	—	28[8]	65-70	—	6 Mos
Dried fruit	.42	.28	39	—	28.0	35	50-60	—	32	50-60	—	12 Mos
Figs (Fresh)	.82	.43	112	27.6	78.0	40	65-75	—	32	65-75	—	12 Days
Grapefruit	.91	.46	126	30.0	88.8	45	85-90	.48	32	85-90[8]	.24	6 Wks
Grapes (Calif)	.86	.44	116	28.1	81.6	35	80-90	.48	31	85-90[8]	.24	5 Mos
Lemons	.91	.47	127	29.4	89.3	55[8]	85-90[8]	1.44	55	85-90[8]	.96	3 Mos
Limes	.86	.45	118	29.7	82.9	45	85-90[8]	1.44	45	85-90[8]	.96	8 Wks
Melons	.94[3]	.48[3]	120[3]	30.0	87.0[3]	45	85-90	1.68	40	85-90	.96	3 Wks
Olives (Fresh)	.80	.42	108	29.4	75.2	50	85-90	—	45	85-90	—	5 Wks
Oranges	.90	.46	124	30.6	87.2	40[8]	85-90	.72	32[8]	85-90[8]	.48	3-12 Wks
Peaches	.90	.46	124	30.3	89.1	35	80-85	.96	32	80-85[8]	.48	2-4 Wks
Pears	.86	.45	118	29.2	82.7	35[8]	90-95	.72	30[8]	90-95[8]	.48	2-7 Mos
Pineapples												
• Green	.88	.45	122	30.2	85.3	50	85-90[8]	—	—	—	—	4 Wks
• Ripe	.88	.45	122	30.0	85.3	40	85-90[8]	—	—	—	—	3 Wks
Plums	.88	.45	118	30.5	82.3	40	80-85	1.44	31	80-85[8]	.72	2-6 Wks
Prunes	.88	.45	118	30.5	82.3	40	80-85	1.44	31	80-85[8]	.72	2-6 Wks
Quinces	.88	.45	122	28.4	85.3	35	80-85	.72	31	80-85[8]	.48	2-3 Mos
Raisins (Dried)	.47	.33	45	—	—	45	85-90	—	40	85-90	—	3-6 Mos
Raspberries	.84	.44	122	30.0	80.6	31	85-90	2.40	—	—	—	3 Days
Strawberries	.92	.42	129	30.6	89.9	31	85-90	1.80	—	—	—	5-7 Days
Tangerines	.90	.46	125	30.1	87.3	40	85-90	1.63	32	85-90	1.14	2-4 Wks
MEAT												
Bacon (Cured)	.43	.29	39	—	28.0	55	55-65	—	—	—	—	15 Days
Beef												
• Dried	—	—	—	—	—	—	—	—	55	65-70	—	6 Mos
• Fresh	.77	.42	99	30.0[3]	70.0	34[8]	85-90	—	32[8]	85-90	—	3 Wks
• Brined	—	—	—	—	—	40	80-85[11]	—	32	80-85[11]	—	6 Mos
Liver/Tongue	.77	.44	102	—	72.0	34	85-90	—	32	85-90	—	3 Wks
Ham/Shoulder												
• Fresh	.61	.35	80	30.0[3]	54.0	34[8]	85-88	—	28[8]	85-88	—	3 Wks
• Smoked	.56	.33	64	—	—	55	55-65	—	55	55-65	—	6 Mos/up
Hides	—	—	—	—	—	—	—	—	34	55-70	—	3-5 Yrs

Footnote references above may be found at conclusion of Table on Page 26.

APPENDIX—TABLES

TABLE 9 PROPERTIES AND STORAGE DATA FOR PERISHABLE PRODUCTS

PRODUCT	SP HEAT BTU/LB/°F ABOVE FREEZE POINT	SP HEAT BTU/LB/°F BELOW FREEZE POINT	LATENT[1] HEAT OF FUSION BTU/LB	HIGHEST FREEZE POINT °F	WATER CONTENT %	SHORT STORAGE TEMP °F	SHORT STORAGE RH% MIN-MAX	SHORT STORAGE RESPIRATION HEAT BTU/LB/24 HR	LONG STORAGE TEMP °F	LONG STORAGE RH% MIN-MAX	LONG STORAGE RESPIRATION HEAT BTU/LB/24 HR	APPROX. STORAGE LIFE
Lamb[8]	.76	.45	100	28.0[3]	70.0	34	85-90	—	28	85-90	—	2 Wks
Lard	—	—	—	—	0	45	75-80	—	32	75-80	—	6-8 Mos
Pork[8]	.53	.32	60	28.0[3]	42.0	34	85-90	—	—	—	—	15 Days
Sausage												
• Fresh	.87	.56	92	26.0[3]	65.0	35	85-90[8]	—	—	—	—	7 Days
• Smoked	.83	.54	87	29.0[3]	61.0	40	80-85	—	32	70-75	—	6 Mos
Veal[8]	.75	.40	98	28.0[3]	65.0	34	85-90	—	28	85-90	—	15 Days
Frozen Meats	—	.42[3]	—	—	—	—	—	—	−10	90-95	—	9 Mos
POULTRY												
Chicken	.80	.42	106	27.0[3]	74.0	28	85-90	—	—	—	—	10 Days
Game	.80	.42	114	27.0[3]	77.0	28	85-90	—	—	—	—	10 Days
Goose	.58	.35	69	28.0	48.0	28	85-90	—	—	—	—	10 Days
Turkey	.66	.38	82	28.0	57.0	28	85-90	—	—	—	—	10 Days
Frozen Fowl	—	.40[3]	—	27.0[3]	—	−5	85-90	—	−10	85-90	—	10 Mos
SEA FOOD												
Clams												
• In Shell	.84	.44	115	27.0	80.0	32	—	—	—	—	—	15 Days
• Shucked	.90	.46	125	27.0	87.0	32	70-75	—	—	—	—	10 Days
Crabs (Boiled)	.83	.44	115	—	80.0	25	80-90	—	—	—	—	10 Days
Fish												
• Fresh	.80[3]	.43[3]	110[3]	28.0[3]	80.0[3]	30	80-95[8]	—	—	—	—	15 Days
• Frozen	—	.43[3]	—	—	—	−5	—	—	−10	—	—	8 Mos
• Smoked	.70	.39	92	—	—	45	50-60	—	40	50-60	—	6 Mos
Lobsters	.83	.44	113	—	79.0	25	80-90	—	—	—	—	10 Days
Oysters												
• In Shell	.84	.44	115	27.0	80.0	32	—	—	—	—	—	15 Days
• Shucked	.90	.46	125	27.0	87.0	32	70-75	—	—	—	—	10 Days
Shrimp/ Scallops	.83	.45	119	28.0	75.0	32	70-75	—	—	—	—	7-10 Days
VEGETABLES												
Artichokes	.87	.45	120	29.9	83.7	40	90-95	7.24	31	90-95	5.07	1-2 Wks
Asparagus	.94	.48	134	30.9	93.0	32	85-90	.84	32	85-90[8]	.84	3-4 Wks
Beans												
• Green	.91	.47	128	30.7	88.9	45	85-90	4.80	45	85-90[8]	4.80	7-10 Days
• Lima	.73	.40	94	31.0	66.5	40	85-90	7.20	32	85-90[8]	4.80	1-2 Wks
Beets												
• Bunch	.90	.46	126	31.3	87.6	40	85-90	2.40	32	95[8]	1.44	10-14 Days
• Topped	.90	.46	126	30.1	87.6	40	85-90	2.40	32	85-90	1.44	3 Mos
Broccoli	.92	.47	130	30.9	89.9	40	90-95	2.40	32	90-95	1.44	9-12 Days
Brussel Sprouts	.88	.46	130	30.9	89.9	40	90-95	2.40	32	90-95[8]	1.44	3-5 Wks
Cabbage	.94	.47	132	30.4	92.4	35	90-95	2.40	32	90-95[8]	1.44	3-4 Mos
Carrots												
• Bunch	.88	.46	126	29.5	88.2	40	85-90	1.92	32	85-90[8]	1.20	10-14 Days
• Topped	.90	.46	126	29.5	88.2	40	85-90	1.92	32	95	1.20	4-5 Mos
Cauliflower	.93	.47	132	30.6	91.7	35	85-90	2.40	32	85-90[8]	1.44	2-4 Wks
Celery	.95	.48	135	31.1	93.7	35	85-90	2.40	32	90-95[8]	1.44	3-4 Mos
Collards	.90	—	—	30.6	86.9	35	85-90	2.40	32	90-95[8]	1.44	2 Wks
Corn (Fresh)	.82	.42	106	30.9	73.9	35	85-90	4.08	32	85-90[8]	0.96	4-8 Days
Cucumbers	.97	.49	137	31.1	96.1	50	85-95	4.32	45	85-95	2.40	10-14 Days
Egg Plant	.94	.48	132	30.6	92.7	50	85-90	—	45	85-90	—	7 Days
Endive	.94	.48	132	31.9	93.3	35	90-95	4.80	32	90-95[8]	3.60	2-3 Wks
Garlic (Dry)	.69	.40	89	30.5	61.3	35	85-90	—	32	65-70	—	6 Mos
Greens (Leafy)	.90[3]	.47	126[3]	31.1[3]	86.0[3]	35	90-95	2.40	32	90-95	1.44	10-14 Days
Kale	.89	.46	124	31.1	86.6	35	90-95	—	32	90-95[8]	—	10-14 Days
Lettuce	.96	.48	136	31.7	94.8	35	90-95	7.92	32	90-95[8]	6.00	2-3 Wks
Leeks (Fresh)	.88	.46	126	30.7	85.4	35	90-95	.96	32	90-95[8]	.48	2-3 Mos
Mushrooms	.93	.47	130	30.4	91.1	32	90	3.05	—	—	—	3-4 Days
Mushroom (Grain Spawn)	—	—	—	—	—	40	75-80	—	32	75-80	—	2 Wks
Okra	.92	.46	128	28.7	89.8	50	90-95	9.00	45	90-95	6.50	7-10 Days
Onions	.90	.46	124	30.6	87.5	50	70-75	.96	32	65-70	.48	4-8 Mos
Parsley	.88	.45	122	30.0	85.1	35	90-95	2.40	32	90-95	1.44	1-2 Mos
Parsnips	.84	.44	112	30.4	78.6	35	90-95	1.68	32	90-95	1.20	4-5 Mos
Peas, Green	.79	.42	106	29.2	82.7	35	85-90	6.00	32	85-90[8]	4.80	1-3 Wks
Peppers	.94	.47	132	30.7	92.4	50	90-95	3.25	45	90-95	2.80	2-3 Wks
Potatoes												
• Irish	.85	.44	116	30.9	81.2	50	85-90	1.44	38	85-90[8]	.72	—
• Sweet[8]	.83	.42	100	29.7	68.5	55[8]	85-90	2.40	55[8]	85-90[8]	2.40	4-6 Mos
Pumpkins	.92	.47	130	30.5	90.5	55	70-75	—	50	70-75	—	2-3 Mos
Radishes	.95	.48	134	30.7	93.6	35	90-95	—	32	90-95	—	2-4 Mos
Rhubarb	.96	.48	134	30.3	94.9	35	95	—	32	95	—	2-4 Wks
Rutabagas	.91	.47	127	30.1	89.1	35	95	—	32	95	—	2-4 Mos
Sauerkraut (In Kegs)	.92	.52	128	26.0	89.2	45	75-80	—	32	75-80	—	4-5 Mos

Footnote references above may be found at conclusion of Table on Page 26.

TABLE 9 PROPERTIES AND STORAGE DATA FOR PERISHABLE PRODUCTS

PRODUCT	SP HEAT BTU/LB/°F[1] ABOVE FREEZE POINT	SP HEAT BTU/LB/°F[1] BELOW FREEZE POINT	LATENT[2] HEAT OF FUSION BTU/LB	HIGHEST FREEZE POINT °F	WATER CONTENT %	SHORT STORAGE TEMP °F	SHORT STORAGE RH% MIN-MAX	SHORT STORAGE RESPIRATION HEAT BTU/LB/24 HR	LONG STORAGE TEMP °F	LONG STORAGE RH% MIN-MAX	LONG STORAGE RESPIRATION HEAT BTU/LB/24 HR	APPROX. STORAGE LIFE
Spinach	.94	.48	132	31.5	92.7	35	90-95[8]	4.80	32	90-95[8]	2.88	10-14 Days
Squash												
• Acorn	.92	.47	131	30.5	90.5	50	70-75	—	45	70-75	—	6-8 Wks
• Summer	.95	.48	135	31.1	94.0	50	85-95	—	32	85-95	—	5-14 Days
• Winter	.91	.47	127	30.3	88.6	55	70-75	—	50	70-75	—	4-6 Mos
Tomatoes												
• Green	.95	.48	134	31.0	93.0	55	85-90	3.12	55	85-90	3.12	3-4 Wks
• Ripe	.94	.48	134	31.1	94.1	50	85-90[8]	.72	—	—	—	5-7 Days
Turnips	.93	.47	130	30.1	91.5	35	90-95	1.20	32	90-95[8]	.96	4-5 Mos
Vegetable Seed	.29	.23	16	—	12.0[3]	45	55-65	—	32	50-60	—	—
Vegetables (Mixed)	.92[3]	.47[3]	130[3]	30.0[3]	92.0[3]	35	90-95	2.40[3]	32	90-95	1.60[3]	—
MISCELLANEOUS												
Beer												
• Metal Keg	.92	—	129	28.0	90.2	40	—	—	35	—	—	3 Mos
• Wood Keg	.92	—	129	28.0	90.2	40	85-90[11]	—	35	85-90[11]	—	3 Mos
Bread	.74	.34	53	20.0	34.0[3]	0	—	—	0	—	—	3 Mos
Candy	.93	—	—	—	—	34	40-50	—	0	40-50	—	6 Mos
Chocolate (Coatings)	.56	.35	40	90.0	—	65	40-50	—	60	40-50	—	6 Mos
Canned Foods	—	—	—	—	—	60	70	—	32	70	—	1 Yr
Cocoa	—	—	—	—	—	40	70	—	32	50	—	1 Yr
Coffee (Green)	.30	.24	20	—	15.0	37	80-85	—	35	80-85	—	3 Mos
Dried Foods	—	—	—	—	—	70	40-50	—	32	40-50	—	1 Yr
Flour	.38	.28	—	—	14.0	82	60-65	—	78	60-65	—	6 Mos
Flowers	See Table 15 for Data on Cut Flowers, Greens, Bulbs, and Nursery Stock											
Frozen Pack Fruits & Vegetables	—	—	—	—	—	0	—	—	−10	—	—	12 Mos
Furs & Fabrics	—	—	—	—	—	40	45-55[12]	—	34	45-55[12]	—	Yrs
Honey	.35	.26	26	—	18.0	40	60-70	—	31	60-70	—	1 Yr
Hops	—	—	—	—	—	32	50-60	—	29	50-60	—	3 Mos
Maple Sugar	.24	.21	7	—	5.0	45	65-70	—	31	65-70	—	4 Mos
Maple Syrup	.48	.31	51	—	35.5	45	65-70	—	31	65-70	—	4 Mos
Nursery Stock	See Table 15 For Various Varieties											
Nuts												
• In Shells	.25	.22	8[3]	—	6.0[3]	40-45	65-75	—	28-32	65-75	—	10 Mos
• Shelled	.30	.24	10[3]	—	8.0[3]	40-45	65-75	—	28-32	65-75	—	8 Mos
Oil (Vegetable)	—	—	—	—	0	70	—	—	70	—	—	1 Yr
Oleo	.32	.25	22	—	15.5	45	75-80	—	35	70-75	—	6 Mos
Orange Juice (Chilled)	.91	.47	128	—	89.0	35	—	—	30	—	—	6 Wks
Popcorn (Unpopped)	.31	.24	19	—	13.5	40	85	—	32	85	—	—
Precooked Frozen Food	—	—	—	—	—	0	—	—	−10	—	—	10 Mos
Seed (Vegetable)	.29	.23	16	—	12.0[3]	50	55-65	—	32	50-55	—	—
Serums/ Vaccines	—	—	—	—	—	45	70	—	40	70	—	—
Yeast (Compressed Bakers)	.77	.41	102	—	70.9	35	80-85	—	31	75-80	—	—

Notes: 1. Specific heats for products not listed may be estimated as follows:
Specific heat above freezing = 0.20 + (0.008 × % water)
Specific heat below freezing = 0.20 + (0.003 × % water)
2. Latent heats of fusion for products not listed may be estimated as follows:
Heat of fusion = % water × 143.4 Btu/lb
3. Average value.
4. Eggs with weak albumen freeze just below 30°F.
5. Lemons in terminal markets are customarily stored @ 50-55°F; sometimes, 32°F is used.
6. Optimum storage temperature varies widely with variety and/or section where grown. Recommended temperatures for apples, as an example, range from 32°F (Golden Delicious) to 38°F (McIntosh). See USDA handbook #66.
7. Permissable storage period varies widely with variety. See USDA handbook #66.
8. Room design conditions critical.
9. Sweet potatoes must be cured for 10 to 14 days @ 85°F & 85-90% rh for successful storage.
10. Relative humidity is left blank (—) in cases where the product is sealed from the air, or the rh % is otherwise non-critical.
11. High humidity required with wood kegs to prevent drying and resulting leaks.
12. Constant humidity desirable.

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TABLE 10 PRODUCT CHILLING DATA

PRODUCT	TEMPERATURE[3] ENT. °F	TEMPERATURE[3] FINAL °F	CHILLING DATA TIME, HRS	CHILLING DATA LOAD FACTOR
DAIRY				
Eggs (crated)	45	30	10	1.20
Eggs (frozen)	40	0	24	1.50
Ice Cream (5 gal cans)	28	– 10	10	1.38
Milk (cartons)	45	35	10	1.20
FRUIT				
Apples	80	35	24	1.50
Apricots	80	35	22	1.50
Avocados	80	46	22	1.50
Berries	80	35	22	1.50
Grapes	70	34	20	1.27
Grapefruit	75	35	22	1.45
Lemons	75	56	20	1.05
Limes	75	52	20	1.13
Oranges	75	33	22	1.45
Peaches	85	35	24	1.60
Pears	70	35	24	1.25
Pineapples	85	42	3	1.50
Plums	80	35	20	1.50
Prunes	80	35	20	1.20
Quinces	80	33	24	1.50
MEAT				
Bacon	105	28	24	1.00
Beef[1]	100	35	18	1.40
(carcass)	100	35	24	1.50
Ham	105	38	18	1.00
Hogs[1]	100	35	18	1.40
(carcass)	100	35	24	1.50
Lamb	100	35	8	1.35
Liver	90	35	18	1.44
Poultry	85	35	6	1.00
Sausage	70	35	2	1.00
Smoked (small cuts)	70	35	2	1.00
Tongue	90	35	18	1.44
Weiners	70	35	2	1.00
Veal	100	35	7	1.36
VEGETABLES				
Asparagus	60	34	24	1.12
Beets[2] (with tops)	70	34	24	1.26
Broccoli	80	34	24	1.26
Brussel Sprouts	80	34	24	1.26
Cabbage	70	34	24	1.26
Cantaloupes	80	45	24	1.10
Carrots[2] (with tops)	70	34	24	1.26
Cauliflower	70	34	24	1.26
Corn	70	34	24	1.26
Cucumbers	70	50	24	1.00
Onions	70	34	24	1.26
Parsnips	70	34	24	1.26
Peas	78	34	22	1.45
String Beans	80	45	22	1.45
Tomatoes	80	55	40	1.00
Turnips	70	34	24	1.26

Notes: 1. See Tables 11 & 12 for data on typical beef and pork chilling rooms.
2. Load factor of beets or carrots withouts tops is 1.
3. Design room temperatures at the completion of the chilling process are generally 2°F below the final product temperature.
4. The following factors apply to **any blast freezing** operation: **batch freezing-1.5; continuous process (ie, conveyor fed) freezing-1.0.**
5. **Important:** Utilization of load factors results in sufficient refrigeration capacity to accommodate the high initial rates of product heat evolution; room temperature rise is thereby minimized. It is to be noted, however, that the application of load factors necessitates a system design compatible with the diverse pulldown & holding requirements. These factors are **not** to be applied to: (1) small rooms, (2) rooms loaded over an extended period of time, & (3) rooms equipped with single rooftop halocarbon systems.
In cases (1), (2) & (3) above, the chill period should be extended, and the room temperature allowed to rise. (See Page 9 for a more detailed discussion of this subject).

TABLE 11 BEEF CHILLING • • MINIMUM REFRIGERATION REQUIREMENTS IN TONS[1]

TOTAL ROOM CAPACITY — HEAD	FLOOR AREA SQ. FT.	18 HOUR CHILL TIME[2] 4 HR LOADING	18 HOUR CHILL TIME[2] 8 HR LOADING	24 HOUR CHILL TIME 4 HR LOADING	24 HOUR CHILL TIME 8 HR LOADING
75	650	23.2	18.2	17.9	15.6
100	800	31.0	24.2	23.8	20.8
250	2000	77.5	60.5	59.5	52.1
450	3600	139.5	109.0	107.2	93.8

Notes: 1. Refrigeration tonnages noted allow for normal room heat gain and defrosting, and are based upon a 65°F temperature pulldown of 550 lb cattle.
2. An 18 hour chill time requires additional air circulation and lower than normal room temperatures (32-34°F).

TABLE 12 PORK CHILLING • • MINIMUM REFRIGERATION REQUIREMENTS IN TONS[1]

TOTAL ROOM CAPACITY — HEAD	FLOOR AREA SQ. FT.	18 HOUR CHILL TIME[2] 4 HR LOADING	18 HOUR CHILL TIME[2] 8 HR LOADING	24 HOUR CHILL TIME 4 HR LOADING	24 HOUR CHILL TIME 8 HR LOADING
75	200	7.9	6.3	6.2	5.5
100	250	10.5	8.4	8.2	7.3
250	625	26.2	20.9	20.6	18.3
450	1125	47.2	37.8	37.0	33.0

Notes: 1. Refrigeration tonnages noted allow for normal room heat gain and defrosting, and are based upon a 65°F temperature pulldown of 200 lb hogs.
2. An 18 hour chill time requires additional air circulation and lower than normal room temperatures (32-34°F).

TABLE 13 BLAST FREEZING • • PRODUCT LOAD ESTIMATES

PRODUCT	SUPPLY AIR TEMP, °F	SUPPLY AIR VELOCITY, FPM	PRODUCT TEMP., °F ENTERING	PRODUCT TEMP., °F LEAVING	HEAT REMOVED BTU/LB	ESTIMATED TIME OF HEAT REMOVAL HOURS: MINUTES
4 Oz. Hamburger Patties (unwrapped)	−17	400	55	25	119	0:22
2 Oz. Hamburger Patties (unwrapped)	−18	400	40	16	112	0:13
6 Lbs. Ground Beef In Plastic Wrapper (not lean)	−20	1250	39	0	119	9:00
1 Oz. Fresh Pork Sausage (unwrapped)	−13	1000	41	15	101	0:20
12 Oz. — 1¼" Thick Strip Steak In Plastic Wrapper	−20	1000	40	0	119	1:03
1 Lb. — 6 Oz. Cooked Chop Suey In Plastic Container	−21	800	64	0	147	2:13
16 Lb. Fresh Turkey In Plastic Wrapper	−24	2600	44	0	130	5:24
12 — 1 Lb.-7 Oz. Containers Of Bar-B-Que Beef In Cardboard Box	−21	1450	78	0	158	10:00

Notes: 1. For a continuous loading operation such as a conveyor or systemized manual feed, the product load in Btu per 24 hrs equals:

$$Q_{Btu/24\,hrs} = Btu/lb \times \frac{\text{Product per Shift}_{lbs}}{\text{Shift time}_{hrs}} \times 24;$$ this equation does not apply to "batch loading".

2. The usual transmission, infiltration, lighting, motor and defrosting loads must be added to the product loads listed.
3. In continuous loading operations, the rate of product heat evolution has a negligible effect on the refrigeration load (it does, however, affect room sizing, conveyor size and speed, etc).

FIG. F RELATION BETWEEN FREEZING TIME AND AIR TEMPERATURE

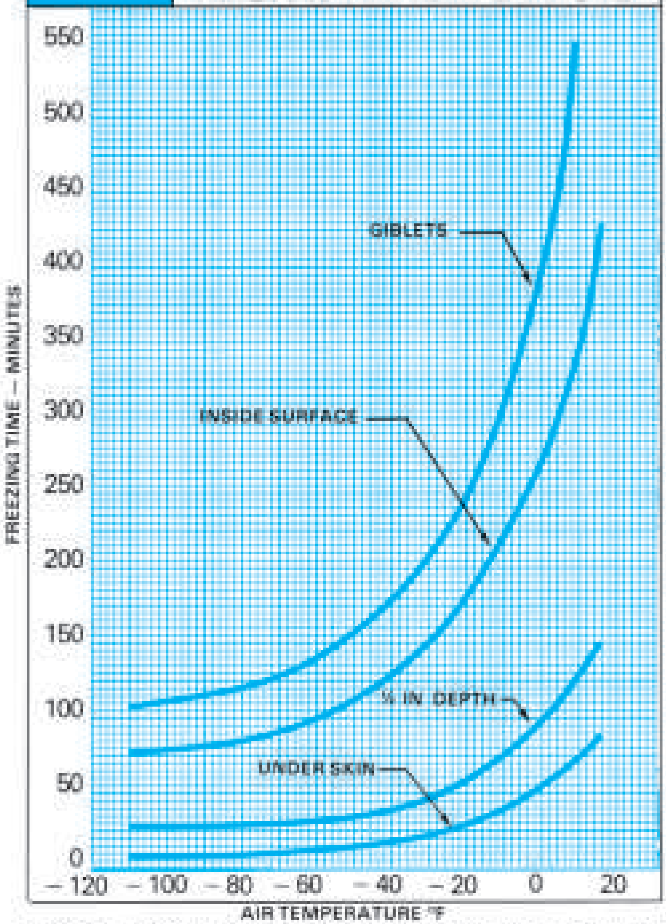
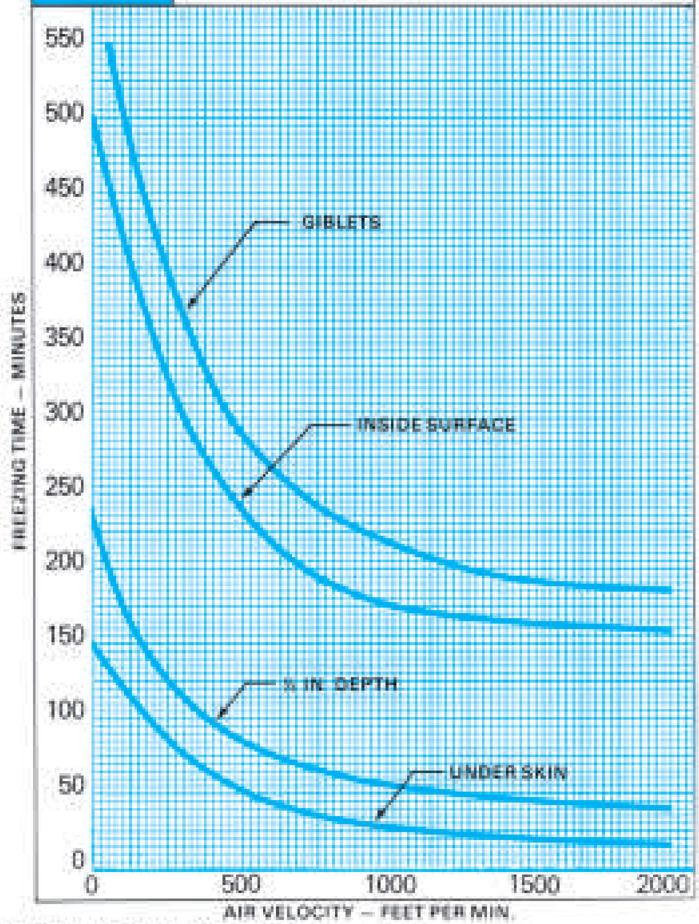


FIG. G RELATION BETWEEN FREEZING TIME AND AIR VELOCITY



Notes (Fig. F & G): 1. Freezing time is the time required for product temperature to fall from 32°F to 25°F.
2. Fig. F based on 5-8 lb. chickens with an initial temperature of 32-35°F, and an air velocity of 450-550 ft./min.
3. Fig. G based on 5-8 lb. chickens with an initial temperature of 32-35°F, and an air temperature of – 20°F

FIG. H HOG CHILLING • • TIME-TEMPERATURE CURVES

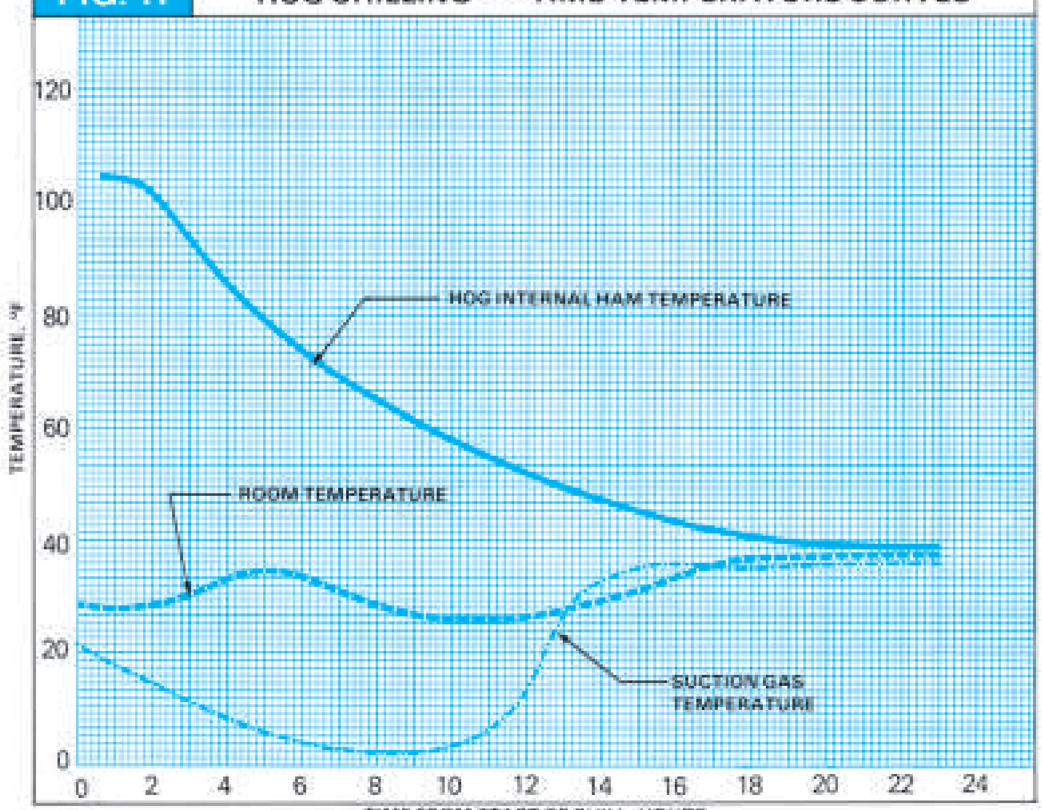


Fig. F, G & H from ASHRAE 1971 Applications Guide & Data Book — Reprinted by Permission

TABLE 14 PHYSICAL DATA OF PERISHABLE PRODUCT CONTAINERS

	CONTAINER DATA					LOADING DENSITY[1] LB/CU FT
	TYPE	OUTSIDE DIMENSIONS[2] H × W × L – INCHES	APPROX. WEIGHTS — LBS			
			PRODUCT	CONTAINER	TOTAL	
DAIRY PRODUCTS						
Cheese	Hoops	13 × 16 × 16	78	6.0	84.0	40.5
Cheese	Wood Box (Export)	14 × 17 × 17	76	11.0	87.0	32.5
Cheese, Swiss	Wheels	7 × 32½ × 32½	171	—	171.0	40.0
Eggs, Shell	Wood Cases	13 × 26 × 12	45	10.0	55.0	19.1
Eggs, Frozen	Cans	12½ × 10 × 10	30	2.0	32.0	41.5
Milk, Condensed	Barrels	36 × 25½ × 25½	600	70.0	670.0	45.6
	See Table 23 for Data on Milk Cartons and Bottles					
FROZEN FRUITS, JUICES & VEGETABLES						
Asparagus	24/12 oz Carton	8¼ × 13½ × 11⅞	18	3.0	21.0	23.8
Beans (Green)	36/10 oz Carton	8 × 12½ × 11	22.5	3.0	25.5	35.3
Blueberries	24/12 oz Carton	8 × 12 × 11½	18	2.0	20.0	28.2
Broccoli	24/12 oz Carton	8½ × 12½ × 11½	15	3.5	18.5	21.2
Citrus Concentrates	48/6 oz Fiber Carton	7½ × 13 × 8¾	26	1.0	27.0	52.7
Peaches	24/1 lb Carton	7½ × 13½ × 11½	24	3.0	27.0	36.4
Peas	6/5 lb Carton	9½ × 17 × 11	30	2.0	32.0	28.2
Peas	48/12 oz Carton	12½ × 21½ × 8½	36	2.0	38.0	27.2
Spinach	24/14 oz Carton	8¼ × 12½ × 11	21	3.0	24.0	31.0
Strawberries	30 lb Can	12½ × 10 × 10	30	2.0	32.0	41.5
Strawberries	24/1 lb Carton	8 × 13 × 11	24	4.0	28.0	36.2
Strawberries	450 lb Barrel	35 × 25 × 25	450	—	—	35.5
FRUIT						
Apples						
• Eastern	Lug Box	11⅛ × 14½ × 18⅛	59	5.0	64.0	31.4
• Western	Wood Box	12 5/16 × 19½ × 11	42	8.0	50.0	27.8
• General	Fiber Tray Carton	13¼ × 20½ × 12½	43	3.8	46.8	21.9
• General	Fiber Bulk Carton	13 × 19 × 12½	41	3.8	44.8	22.9
• General	Tote Bin	2½ × 4 × 4	1000	150.0	1150.0	25.0
Apricots	Box	5½ × 13 × 17½	22	3.0	25.0	30.4
Avocados	Box	4¾ × 14 × 17½	13	3.0	16.0	19.3
Berries (Gen.)	Crate (24 qt)	11¾ × 11¾ × 24	36	4.0	40.0	18.8
Coconut (Shredded)	Bags	8 × 38 × 18½	100	1.0	101.0	30.7
Cranberries	Fiber Carton	10½ × 15¾ × 11¾	24	2.0	26.0	22.2
Dried Fruit						
• Dates	Fiber Carton	11 × 14 × 14	30	2.0	32.0	24.0
• Raisins, Prunes, Figs	Fiber Carton	7 × 15 × 11	30	2.0	32.0	44.9
Figs (Fresh)	Box	2½ × 11½ × 17½	6	2.0	8.0	20.6
Grapes						
• Eastern	Wood Lug Box	7¼ × 14 × 17½	28	3.5	31.5	27.3
• Western	Wood Lug Box	6½ × 15 × 18	28	3.0	31.0	29.2
Grapefruit	Box	12⅝ × 12 × 26	68	7.0	75.0	30.4
Lemons	Box	10⅝ × 13½ × 27	72	6.0	78.0	32.9
Oranges						
• California	Box	12⅝ × 12 × 26	76	6.0	82.0	34.0
• Florida	Bruce Box	12¾ × 12¾ × 26	82	6.0	88.0	33.5
• California	Fiber Carton	10½ × 16⅝ × 10 5/16	37	3.0	40.0	35.2
• Florida	Fiber Carton	8 × 18¾ × 12½	37	8.0	45.0	33.9
Peaches	Wood Lug Box	5¾ × 18⅛ × 11½	23	3.0	26.0	33.1
Pears	Wood Box	8½ × 18 × 11½	48	4.0	52.0	47.1
Plums & Prunes	Crate	5⅝ × 16½ × 17⅝	20	5.0	25.0	22.4
Quinces	Bushel	See Note 2	48	3.0	51.0	18.3
ICE CREAM[3]						
Can, Welded	Standard — 8 qt	6⅝ Diam. × 14⅝	9.2	5.5	14.7	24.8
Can, Welded	Standard — 10 qt	8⅝ Diam. × 10⅝	11.5	8.0	19.5	24.1
Can, Welded	Standard — 20 qt	8⅝ Diam. × 20⅝	23.0	12.0	35.0	25.2
Pressboard, Waxed	Tall — 1 qt	3 5/16 Diam. × 7 5/16	1.2	0.1	1.3	25.9
Pressboard, Waxed	Tall — 2 qt	4 5/16 Diam. × 8⅝	2.3	0.2	2.5	24.4
Pressboard, Waxed	Squat — 2 qt	7 Diam. × 4	2.3	0.3	2.6	20.3
Pressboard, Waxed	Squat — 4 qt	7 Diam. × 7¼	4.6	0.4	5.0	22.4
Pressboard, Waxed	Squat — 10 qt	9¼ Diam. × 9½	11.5	0.4	11.9	25.1
Pressboard, Waxed	Squat — 20 qt	9¼ Diam. × 19½	23.0	0.5	23.5	24.5
MEAT						
Beef						
• Boneless	Fiber Carton	6 × 28 × 18	140	6.0	146.0	80.0
• Fores	Loose	—	—	—	—	22.2
• Hinds	Loose	—	—	—	—	22.2
Lamb, Boneless	Fiber Box	5 × 20 × 15	53	4.0	57.0	61.0
Pork						
• Bellies	Bundles	7 × 23½ × 10½	57	—	57.0	57.0
• Loins, Regular	Wood Box	10 × 28 × 10	54	6.0	60.0	33.3
• Loins, Boneless	Fiber Box	5 × 20 × 15	52	5.0	57.0	59.9
Veal, Boneless	Fiber Carton	5 × 20 × 15	53	4.0	57.0	61.0

Notes: 1. Loading density for products packaged in bushel baskets, bushel hampers, or barrels is computed on the basis of actual warehouse cubage utilized.

2. Approximate weights and dimensions of bushel baskets and hampers are as follows:
- ½ Bushel Basket — Wgt: 2 lb; 14½ in top diam. × 11½ in bottom diam. × 10 in high
- 1 Bushel Basket — Wgt: 3 lb; 18 in top diam. × 14 in bottom diam. × 12 in high
- 1 Bushel Hamper — Wgt: 3 lb; 16 in top diam. × 10 in bottom diam. × 20 in high
- 1½ Bushel Hamper — Wgt: 5 lb; 17 in top diam. × 12 in bottom diam. × 24 in high

TABLE 14 PHYSICAL DATA OF PERISHABLE PRODUCT CONTAINERS

	CONTAINER DATA					LOADING DENSITY[4] LB/CU FT
	TYPE	OUTSIDE DIMENSIONS[3] H × W × L — INCHES	APPROX. WEIGHTS — LBS PRODUCT	CONTAINER	TOTAL	
POULTRY, FRESH						
Fryers (Whole: 24-30)	Crate	7 × 24 × 10	60	5.0	65.0	25.4
Fryers (Parts)	Crate	12½ × 17¾ × 10	50	4.0	54.0	38.5
POULTRY, FROZEN						
Ducks, 6 to Pkg.	Fiber Carton	4 × 22 × 16	31	1.5	22.5	38.0
Fowl, 6 to Pkg.	Fiber Carton	5½ × 20¾ × 18	31	2.5	33.5	26.1
Fryers, Cut Up, 12 to Pkg.	Fiber Carton	4¾ × 17¼ × 15¾	28	2.5	30.5	41.7
Roasters, 8 to Pkg.	Fiber Carton	5½ × 20¾ × 18	30	2.5	32.5	25.2
TURKEYS						
3-6 lb, 6 to Pkg.	Fiber Carton	8½ × 21 × 17	27	3.0	30	20.1
6-10 lb, 6 to Pkg.	Fiber Carton	7 × 26 × 21½	48	4.5	52.5	21.2
10-13 lb, 4 to Pkg.	Fiber Carton	7½ × 26½ × 16	46	4.0	50.0	25.0
13-16 lb, 4 to Pkg.	Fiber Carton	9 × 29 × 18½	62	5.5	67.5	22.2
16-20 lb, 2 to Pkg.	Fiber Carton	9 × 17 × 16	36	3.0	39.0	25.4
20-24 lb, 2 to Pkg.	Fiber Carton	9½ × 19 × 16½	44	3.5	47.5	25.5
SEA FOOD — FROZEN						
Blocks	4/13½ lb Carton	6¾ × 20¾ × 12⅛	54	2.0	56.0	55.0
	4/16½ lb Carton	11¼ × 19¾ × 10¾	66	2.0	68.0	47.8
Fillets	12/16 oz Carton	3 15/16 × 12¾ × 8⅝	12	1.5	13.5	49.6
	10/5 lb Carton	14 × 14½ × 10	50	2.3	52.3	42.7
	5/10 lb Carton	14 × 14½ × 10	50	2.2	52.2	42.7
Fish Sticks	12/8 oz Carton	3⅞ × 11 × 8½	6	0.9	6.9	29.3
	24/8 oz Carton	4⅝ × 16 5/16 × 8 9/16	12	1.8	13.8	32.9
Panned Fish	None (Glazed)	Wood Boxes	—	—	—	35.0
Portions	2, 3, 5 or 6 lb Cartons	Custom Packing	—	—	—	29-33
Round Ground Fish	None (Glazed)	Stacked Loose	—	—	—	33-35
Round Halibut	None (Glazed)	Wood Box, Loose	—	—	—	30-35
		Stacked Loose	—	—	—	38.0
Round Salmon	None (Glazed)	Stacked Loose	—	—	—	33-35
Shrimp	2½ or 5 lb Cartons	Custom Packing	—	—	—	35.0
Steaks	1, 5 or 10 lb Packages	Custom Packing	—	—	—	50-60
VEGETABLES						
Asparagus	Crate	11½ × 9½ (top) × 12½ (bot.) × 17½	32	6.5	38.5	25.0
Beans	Bushel	See Note 2	32	3.0	35.0	14.2
Beets (Topped)	Bushel	See Note 2	53	3.0	56.0	23.6
Broccoli	Crate	13¾ × 19 × 24½	48	10.0	58.0	13.0
Cabbage	Hamper (1½ bu)	See Note 2	50	5.0	55.0	17.7
Carrots (Topped)	Bushel	See Note 2	50	3.0	53.0	22.2
Cauliflower	Crate	14½ × 16 × 25½	55	9.0	64.0	16.0
Celery	Crate	9¾ × 20¾ × 16	55	5.0	60.0	30.0
Corn (Green)	Bushel	See Note 2	35	3.0	38.0	15.6
Cucumbers	Bushel	See Note 2	46	3.0	49.0	20.4
Lettuce (Head)	Fiber Carton	9½ × 20½ × 13½	35	2.5	37.5	25.2
Melons						
• General	Crate	13 × 12¾ × 23½	60	1.1	71.0	26.7
• Cantaloupe	Crate	5 9/16 × 14¾ × 23½	27	4.0	31.0	25.7
• Honeydew	Crate	7½ × 16⅝ × 23½	42	6.0	48.0	24.4
Onions (Dry)	Sack	—	50	1.5	51.5	—
Onions	Bushel	See Note 2	50	3.0	56.0	22.2
Peas (Unshelled)	Bushel	See Note 2	30	3.0	33.0	13.3
Potatoes	Bushel	See Note 2	60	3.0	63.0	26.7
Sweet Potatoes	Bushel	See Note 2	55	3.0	58.0	24.4
Tomatoes						
• General	Fiber Box	10¾ × 19 × 10⅞	40	3.0	43.0	31.0
• California	Lug Box	7¾ × 17½ × 14	30	4.0	34.0	27.3
• Florida	Crate	11 13/16 × 18¾ × 11 13/16	60	4.0	64.0	38.7
• Texas	Lug Box	6⅝ × 17½ × 14	30	4.0	34.0	31.9
MISCELLANEOUS						
Beverages[6]						
Lard (2/28 lb)	Wood Box (Export)	7¾ × 18 × 13½	56	8.0	64.0	52.5
Nuts						
• Almonds (In Shell)	Sacks	33 × 24 × 15	90	1.5	91.5	13.1
• Almonds (Shelled)	Cases	6¾ × 23½ × 11	28	4.0	32.0	27.7
• English Walnuts (In Shell)	Sacks	31 × 25 × 11	100	3.0	103.0	20.3
• English Walnuts (Shelled)	Fiber Carton	10 × 14 × 14	25	2.0	27.0	22.0
• Peanuts (Shelled)	Burlap Bag	35 × 10 × 15	125	2.0	127.0	38.6
• Pecans (In Shell)	Burlap Bag	35 × 22 × 12	125	1.5	126.5	23.4
• Pecans (Shelled)	Fiber Carton	11 × 13 × 13	30	2.0	32.0	27.9
• Pecans (In Shell)	Tote Box	60 × 42 × 42	1800	170.0	1970.0	29.4

Notes: 3. Tabulated figures are the true dimensional characteristics of the various containers when empty, and make no allowance for bulging tops or sides when filled.

4. Weights of various products at point of sale holding facilities may vary substantially from the figures noted due to moisture loss during processing or storage.

5. Ice cream assumed at 100% overrun and 4.6 lb/gal.

6. Refer to Table 29 for beer and soda data.

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TABLE 15 STORAGE CONDITIONS FOR CUT FLOWERS AND NURSERY STOCK

	STORAGE CONDITIONS TEMP., °F	STORAGE CONDITIONS REL. HUM., %	APPROXIMATE STORAGE LIFE	METHOD OF HOLDING	HIGHEST FREEZE POINT, °F
CUT FLOWERS					
Calla lily	40	90-95	1 week	Dry pack	—
Camellia	45	90-95	3-6 days	Dry pack	30.6
Carnation	32-36	90-95	1 month	Dry pack	30.8
Chrysanthemum	32-35	90-95	3-6 weeks	Dry pack	30.5
Daffodil (Narcissus)	32-33	90-95	1-3 weeks	Dry pack	31.8
Dahlia	40	90-95	3-5 days	Dry pack	—
Gardenia	32-33	90-95	2-3 weeks	Dry pack	31.0
Gladiolus	35-40	90-95	1 week	Dry pack	31.4
Iris, tight buds	31-32	90-95	2 weeks	Dry pack	30.6
Lily, Easter	32-35	90-95	2-3 weeks	Dry pack	31.1
Lily-of-the-Valley	31-32	90-95	2-3 weeks	Dry pack	—
Orchid	45-50	90-95	2 weeks	Water	31.4
Peony (tight buds)	32-35	90-95	4-6 weeks	Dry pack	30.1
Rose (tight buds)	32	90-95	1-2 weeks	Dry pack	31.2
Snapdragon	31-32	90-95	3-4 weeks	Dry pack	30.4
Sweet peas	31-32	90-95	2 weeks	Dry pack	30.4
Tulips	31-32	90-95	4-8 weeks	Dry pack	—
GREENS					
Asparagus (plumosus)	32-40	90-95	4-5 months	Polylined cases	26.0
Fern (dagger and wood)	30-32	90-95	4-5 months	Dry pack	28.9
Holly	32	90-95	4-5 weeks	Dry pack	27.0
Huckleberry	32	90-95	1-4 weeks	Dry pack	26.7
Laurel	32	90-95	1-4 weeks	Dry pack	27.6
Magnolia	35-40	90-95	1-4 weeks	Dry pack	27.0
Rhododendron	32	90-95	1-4 weeks	Dry pack	27.6
Salal	32	90-95	1-4 weeks	Dry pack	26.8
BULBS					
Amaryllis	38-45	70-75	5 months	Dry	30.8
Crocus	48-63	—	2-3 months	—	—
Dahlia	40-45	70-75	5 months	Dry	28.7
Gladiolus	38-50	70-75	8 months	Dry	28.2
Hyacinth	55-70	—	2-5 months	—	29.3
Iris, Dutch, Spanish	80-85	70-75	4 months	Dry	—
Lily					
Gloriosa	63	70-75	3-4 months	Poly liner	—
• Candidum	31-33	70-75	1-6 months	Poly liner & peat	—
• Croft	31-33	70-75	1-6 months	Poly liner & peat	—
• Longiflorum	31-33	70-75	1-10 months	Poly liner & peat	28.9
• Speciosum	31-33	70-75	1-6 months	Poly liner & peat	—
Peony	33-35	70-75	5 months	Dry	—
Tuberose	40-45	70-75	4 months	Dry	—
Tulip	31-32	70-75	5-6 months	Dry	27.6
NURSERY STOCK					
Trees and Shrubs	32-36	80-85	4-5 months		—
Rose Bushes	32	85-95	4-5 months	Bare rooted with poly liner	—
Strawberry Plants	30-32	80-85	8-10 months	Bare rooted with poly liner	29.9
Rooted Cuttings	33-40	85-95	—	Poly wrap	—
Herbaceous Perennials	27-28 or 33-35	80-85	—		—
Christmas trees	22-32	80-85	6-7 weeks	—	—

Note: Refer to USDA Handbook No. 66 for additional data relating to flower and nursery stock storage.

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TABLE 16 APPLE STORAGE CAPACITY REQUIREMENTS @ 35°F

ENTERING FRUIT* TEMPERATURE, °F	MAXIMUM (NOTE 3) RESPIRATION BTU/LB/24 HRS	BTU PER 24 HR PER BOX (NOTES 1, 5 & 8) PERCENTAGE LOADED ON LAST DAY					
		5	10	15	20	25	30
100	9.0	164.6	298.6	432.8	576.9	701.1	835.3
95	7.5	154.0	277.7	401.4	525.1	648.9	772.6
90	6.5	143.5	256.8	370.1	483.4	596.6	709.9
85	5.5	133.1	235.9	338.7	441.6	544.4	647.2
80	4.9	122.6	215.0	307.4	399.8	492.2	584.6
75	4.4	112.2	194.1	276.1	358.0	439.9	445.3
70	3.8	101.7	173.3	244.7	316.2	387.7	459.2
65	3.3	91.4	152.6	213.8	275.0	336.1	397.3
60	2.6	81.0	131.7	182.4	233.2	283.9	334.6
55	2.0	70.5	110.8	151.1	191.4	231.6	271.9
50	1.5	60.1	89.9	119.7	149.6	179.4	209.2
45	1.1	49.6	69.0	88.4	107.8	127.1	146.6
40	0.8	39.2	48.1	57.0	65.0	74.9	83.9

Notes: 1. The Btu's noted per box represent product load **only**. The usual transmission, infiltration, and miscellaneous loads must be added.
2. One box equals one bushel: gross weight — 50 lbs; net weight — 42 lbs.
3. Respiration heat at 35°F: 0.72 Btu/lb/24 hrs; at 30°F: 0.48 Btu/lb/24 hrs.
4. Sp. heats: apples: 0.88 Btu/lb/°F; boxes: 0.60 Btu/lb/°F; weighted average: 0.835 Btu/lb/°F.
5. Loads will be less under C. A. storage conditions.
6. See Table 10 and Text, Page 9, for applications involving chilling only.
7. Example: 10000 box storage with ent. temp. of 95°F and last day loading of 15 percent: Product Load = 10000 × 401.4 = 4,014,000 Btu/24 hrs.
8. Apply a **0.95** factor to charted loads if containers are 3.75 lb cardboard cartons in lieu of 8 lb wood boxes.
9. Hydrocoolers generally pre-cool the fruit to 40°F or 45°F.

TABLE 17 RECOMMENDED COIL T D BY PRODUCT CLASS

COIL TYPE	TEMPERATURE DIFFERENTIAL — °F			
	CLASS 1	CLASS 2	CLASS 3	CLASS 4
FORCED AIR	6 to 9	9 to 12	12-20	20-25
GRAVITY	12 to 16	14 to 18	16-22	20-25

Class 1 Includes products which require very high relative humidities in order to minimize moisture loss during storage. Examples of this category include unpackaged cheese or butter, eggs, and most vegetables if held for comparatively long periods.

Class 2 Includes products which require reasonably high relative humidities (but not as high as those included in Class 1). Examples of this category include fruits & cut meats in retail storage[1].

Class 3 Includes products which require only moderate relative humidities, and includes such products as mushrooms, carcass meats, hides, smoked fish, and fruits such as melons having tough skins.

Class 4 Includes products which are either unaffected by humidity, or which require specialized storage conditions in which the maximum relative humidity is limited thru use of a reheat system. Examples of the first group are furs, woolens, milk, beer (steel or aluminum kegs), bottled beverages, canned goods & similar products having a protective coating; nuts and chocolates are good examples of the second group.

Note 1: Some supermarket fixtures for cut meat display are designed to operate with lower TD's.

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TABLE 18 COMMERCIAL ESTIMATING GUIDELINES[1]

APPLICATION		TEMP. °F	CEILING HEIGHT, FT	COIL TD, °F	SQ FT /TON	COMMENTS
DISTRIBUTION CENTER	Storage Cooler	28-40	16-24	Dry Room 9-15 Wet Room 6-9	150-250	Maximum face velocity for light frosted application is 700 fpm; for wet coil operation, face velocity should not exceed 600 fpm; centrifugal or propeller fans are applicable.
	Storage Freezer	−10	16-24 / 24-40	10-15	200-300 7000-10000 cu ft/Ton	Maximum fin spacing of 3-4 fpi; propeller fan units with high face velocities and long air throw are normally used.
	Loading Dock	40-55	16-20	10-12	150-175	Low face velocity units (under 650 fpm) are required. Units should blow toward and above the doors to create an air curtain effect. Between-the-rail units are ideal for narrow docks.
MEAT CHILL COOLER	Hogs[2]	28-34	16-20	10-12	25-40 10-16 hd/ton	Coil face velocity should not exceed 750 fpm. Between-the-rail units are specifically designed for this application and should be used whenever possible.
	Beef[3]				30-45 3-5 hd/ton	
Work Rooms Cutting & Grinding Rooms		35-45	10-12	15-25	125-175	Units with low noise level which distribute air with low velocity or in an umbrella pattern optimize worker comfort.

Notes: 1. Above guidelines are for budgeting purposes only, and should not be used as the sole design criteria.
2. Hog chill rooms average 2-2.5 sq ft per head.
3. Beef chill rooms average 6-8 sq ft per head.

TABLE 19 BANANA ROOM DESIGN PARAMETERS

ROOM SIZE	NO. OF BOXES	WEIGHT, LBS		EVAPORATOR		REFRIGERATION[4,5] LOAD-BTU/HR	HEATING LOAD-KW
		GROSS	NET	T.D.	CFM		
½ Car	432	20304	18144	15	6000	36,000	4
1 Car	864	40608	36288	15	12000	72,000	8

Notes: 1. Evaporator fan should have ½" ext. static pressure capability.
2. Weights per box: gross-47 lb; net-42 lb.
3. Specific heats: bananas-0.8 Btu/lb/°F; cartons-0.4 Btu/lb/°F.
4. To calculate load, assume pulldown of 1°F per hour, and peak respiration of 12 Btu/lb/24 hr.
5. Tabulated loads represent **total heat removal**.
6. Heat is required only to warm a cold load and may not be required.

TABLE 20 U VALUE REVISIONS

EXISTING SECTION PROPERTIES		REVISED U VALUE AT ADDITIONAL RESISTANCE OF						
U	R	4	6	8	12	16	20	24
1.00	**1.00**	0.20	0.14	0.11	0.08	0.06	0.05	0.04
0.90	**1.11**	0.20	0.14	0.11	0.08	0.06	0.05	0.04
0.80	**1.25**	0.19	0.14	0.11	0.08	0.06	0.05	0.04
0.70	**1.43**	0.19	0.13	0.11	0.07	0.06	0.05	0.04
0.60	**1.67**	0.19	0.13	0.10	0.07	0.06	0.05	0.04
0.50	**2.00**	0.18	0.13	0.10	0.07	0.06	0.05	0.04
0.40	**2.50**	0.16	0.12	0.10	0.07	0.05	0.05	0.04
0.30	**3.33**	0.14	0.11	0.09	0.07	0.05	0.04	0.04
0.20	**5.00**	0.11	0.09	0.08	0.06	0.05	0.04	0.03
0.10	**10.00**	0.06	0.06	0.06	0.05	0.04	0.04	0.03
0.08	**12.50**	0.06	0.06	0.05	0.04	0.04	0.03	0.03

Example: Given an existing structure with a U value of 0.50, determine the revised U following the addition of insulation having a resistance of 12: enter Column 1 at 0.50 and move horizontally to the column headed by 12; the revised U value may then be read at 0.07.

From 1972 ASHRAE Handbook of Fundamentals
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TABLE 21 FOOD STORAGE ESTIMATING GUIDELINES

	PRODUCT CATEGORY	AVERAGE HEAT CONTENT: SP HT ABOVE FREEZING	AVERAGE HEAT CONTENT: SP HT BELOW FREEZING	AVERAGE HEAT CONTENT: LATENT HEAT BTU/LB	HIGHEST FREEZING POINT, °F	RECOMMENDED STORAGE CONDITIONS: TEMPERATURE, °F[1] SHORT TERM	RECOMMENDED STORAGE CONDITIONS: TEMPERATURE, °F[1] LONG TERM	RECOMMENDED STORAGE CONDITIONS: RELATIVE HUMIDITY %
DAIRY	Butter	.64	.34	15	30	40	−5	80-85
	Cheese, Cream, Eggs, Milk	.85	.40	100	31	35-40	33-35	70-85
	Bananas (Ripe)	.80	.42	108	30.6	56	56	85-90
FRUIT	Dried Figs/Raisins	.41	.29	36	−4	40-50	40	60
	Avocados	.76	.41	101	30	50-55	45-50	85-90
	Citrus	.90	.46	123	30	50-55	32	85-90
	Apples/Apricots/Pears					35	30-38	85-90[3]
MEAT	Bacon (Cured)	.43	.29	39	27	55	34-40	55-65
	Fresh Game	.80	.42	114	27	34	28	85-90
	Beef, Ham, Lamb, Pork Sausage, Veal	.76	.40	95	29	34	28-32	85-90
FOWL	Chicken	.79	.42	106	30	34	28	85-90
	Turkey	.63	.36	78				
SEA FOOD	Boiled Lobsters or Crabs	.84	.44	14	—	25	—	85-90
	All Other (Fresh)	.84	.44	14	28	32	—	85-95
VEGETABLES	Beans (Green), Cucumbers, Eggplant, Garlic (Dry), Melons, Okra, Onions (Dry), Peppers, Potatoes, Pumpkins, Squash (Hard Shell), Sweet Potatoes, Tomatoes (Ripe)	.94	.47	136	31	50	50	80
	Most Other	.94	.47	136	31	35	31-32	90-95

Notes: 1. Values are averages by product group, and may be used for estimating rooms in which the exact product loading is unknown.
2. Refer to Table 9 for specific properties and storage requirements of individual products.
3. Pears require a relative humidity of 92-95%.

TABLE 22 RECOMMENDED INSULATION THICKNESS

INSULATION TYPE AND 'K' VALUE		COOLER					HOLDING FREEZER									SHARP FREEZER		
		50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130
Foamglass	.38	3	4	5	6	6	7	8	8	9	9	9	10	11	11	12	12	12
Corkboard	.30	3	4	4	4	5	5	5	6	6	7	7	8	9	9	10	10	10
Expanded Polystyrene	.24	2	3	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8
Fiberglass	.24	2	3	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8
Extruded Polystyrene	.185	2	3	3	4	4	5	5	5	6	6	6	6	6	6	7	7	7
Slab Urethane	.16	2	3	3	3	3	3	4	4	4	4	5	5	5	6	6	6	6
Foamed-In-Place Urethane	.13	2	2	2	3	3	3	3	3	4[2]	4[2]	4[2]	4[2]	4[2]	4	5	5	5

TEMPERATURE DIFFERENCE (ROOM LESS AMBIENT), °F

Notes: 1. Thicknesses shown are for general guidance only. Requirements for a given installation will vary in accordance with operating versus first cost projections.
2. 3 inch foamed-in-place urethane is adequate for short term walk-in freezer applications.

APPENDIX—TABLES

TABLE 23 MILK CONTAINER DATA

TYPE CONTAINER	CAPACITY OZ	CAPACITY GAL	DIMENSIONS, IN. LENGTH	DIMENSIONS, IN. WIDTH OR MAX. DIAM	DIMENSIONS, IN. HEIGHT	CONTAINER DATA WEIGHT LBS	CONTAINER DATA SP. HT. B/LB/°F	CONTAINER DATA MATERIAL	BOTTLES OR CARTONS PER CASE	LIQUID WEIGHT LBS	BTU REQ'D TO COOL 1°F WHEN FULL
Carton											
Quart	32	—	—	2.81	9.00	0.075	0.50	Paper	—	2.15	2.06
Half Gallon	64	—	—	3.81	9.375	0.142	0.50	Paper	—	4.30	4.11
Gallon	—	1	—	5.56	9.50	0.245	0.50	Paper	—	8.60	8.20
Bottle											
Half Pint	8	—	—	2.375	5.375	0.500	0.20	Glass	—	0.537	0.61
Pint	16	—	—	3.00	7.75	0.810	0.20	Glass	—	1.075	1.18
Quart	32	—	—	4.00	9.75	2.000	0.20	Glass	—	2.15	2.42
Cases[3]											
Quart Cartons	—	—	13.0	13.00	11.00	7.0	0.12	Steel	16	34.40	33.80
Half Gal Cartons	—	—	13.0	13.00	11.00	7.0	0.12	Steel	9	38.70	37.92
Gallon Cartons	—	—	13.0	13.00	11.00	7.0	0.12	Steel	4	34.40	33.80
Half Pint Bottles	—	—	18.5	14.50	6.75	11.0	0.60	Wood	30	16.11	24.90
Pint Bottles	—	—	18.5	14.50	8.50	14.0	0.60	Wood	20	21.50	32.00
Quart Bottles	—	—	18.5	14.50	10.50	16.0	0.60	Wood	12	25.80	38.70
Cans											
5 Gallon	—	5	—	10.50	19.50	15.0	0.12	Steel	—	43.00	42.20
10 Gallon	—	10	—	13.00	25.00	26.0	0.12	Steel	—	86.00	84.00

Notes: 1. Sp. Ht.: 0.94; weight per quart — 2.15 lbs ; weight per gallon — 8.60 lbs.
2. Storage areas may be estimated on the basis of 70 lb of milk in glass bottles or 100 lb of milk in paper quart cartons per sq ft, with ⅓ additional area being allowed for aisles. Cases are usually stacked 5 high.
3. Weights for cases empty (no bottles included).

Extracted in part from ASRE (now ASHRAE) Application Data Section. Some data obtained by actual weighing & measuring.

TABLE 24 CHEESE MAKE & CURE DATA

CHEESE	PART OF PROCESS	TEMP. °F	RELATIVE HUMIDITY %	TIME DAYS
Blue	Form Room	68-72	80-90	3-5
	Curing Room	48-50	95	90
	Holding Room	40-45	70	30-180
Cheddar	Curing Room	32-34	70	12-18(mos)
		38-40	70	8-10(mos)
		45-55	85-90	60
		55-70	85-90	indeterminate
Swiss	Salting Room	50-54	In Brine	4-6
	Cool Room	40-45	70	10-14
	Warm Room	68-77	80-85	14
	Curing Room	60	80-85	14-28
	Holding Room	35-40	70	60-180

TABLE 25 SPECIFIC HEATS[1] OF MILK AND MILK DERIVATIVES

PRODUCT	TEMPERATURE, °F 32	59	104	140
Whey	0.978	0.976	0.974	0.972
Skim Milk	0.940	0.943	0.952	0.963
Whole Milk	0.920	0.938	0.930	0.918
15% Cream	0.750	0.923	0.899	0.900
20% Cream	0.723	0.940	0.880	0.886
30% Cream	0.673	0.983	0.852	0.860
45% Cream	0.606	1.016	0.787	0.793
60% Cream	0.560	1.053	0.721	0.737
Butter	0.512	0.527	0.556	0.580
Milk Fat	0.445	0.467	0.500	0.530

Note 1: Sp. heat in Btu/lb/°F

TABLE 26 OTHER CHEESE CURE DATA

CHEESE	CURE TEMP. °F	RELATIVE HUMIDITY %	CURE TIME DAYS
Brick	60-65	90	60
Limburger	60-65	95	42
Camembert	53-59	90	21
Cream	No Cure		
Cottage			
Neufchatel			

TABLE 27 CHEESE FREEZE POINTS

CHEESE	FREEZE POINT, °F
Brick	16.3
Cheddar	8.8
Cottage	29.8
Limburger	18.7
Process American	16.6
Process Swiss	17.5
Roquefort	3.7
Swiss, Domestic	14.0
Swiss, Imported	14.7

TABLE 28 CHEESE STORAGE TEMPERATURES

CHEESE	OPTIMUM STORAGE TEMP., °F	MAXIMUM STORAGE TEMP., °F	CHEESE	OPTIMUM STORAGE TEMP., °F	MAXIMUM STORAGE TEMP., °F
Brick	30-34	50	Process American	40-45	75
Camembert	30-34	50	Process Brick	40-45	75
Cheddar	30-34	60	Process Limburger	40-45	75
Cottage	32-34	45	Process Swiss	40-45	75
Cream	32-34	45	Roquefort	30-34	50
Limburger	30-34	50	Swiss	30-34	60
Neufchatel	32-34	45	Cheese Foods	40-45	55

Tables 24 thru 28 extracted from 1971 ASHRAE Applications Guide and Data Book — Reprinted by Permission

APPENDIX—TABLES

TABLE 29 BEVERAGE CONTAINER DATA

TYPE CONTAINER	CAPACITY FLUID OZ	CAPACITY GAL	DIMENSIONS, IN. LENGTH	DIMENSIONS, IN. WIDTH OR MAX. DIAM.	DIMENSIONS, IN. HEIGHT	CONTAINER DATA WEIGHT LBS	CONTAINER DATA SP. HT. BTU/LB/°F	CONTAINER DATA MATERIAL	BOTTLES OR CANS PER CASE	LIQUID WEIGHT LBS	BTU REQ'D TO COOL 1°F WHEN FULL
Bottles											
Beer, Tall, Ret.	12	—	—	2.50	9.50	0.75	0.20	Glass	—	0.76	0.91
Beer, Squat, N.R.	12	—	—	2.60	5.75	0.40	0.20	Glass	—	0.76	0.84
Beer, Quart, N.R.	32	—	—	3.63	11.25	1.03	0.20	Glass	—	2.03	2.24
Coca Cola	6	—	—	2.37	7.75	0.86	0.20	Glass	—	0.38	0.55
Soda- 6	6	—	—	2.50	7.75	0.88	0.20	Glass	—	0.38	0.56
Soda- 7	7	—	—	2.37	7.87	0.88	0.20	Glass	—	0.44	0.62
Soda- 8	8	—	—	2.50	7.25	0.88	0.20	Glass	—	0.50	0.68
Soda- 9	9	—	—	2.75	9.13	0.88	0.20	Glass	—	0.56	0.74
Soda-12	12	—	—	2.67	9.75	1.00	0.20	Glass	—	0.75	0.96
Soda-32	32	—	—	3.67	11.50	1.88	0.20	Glass	—	2.03	2.41
Cans											
12 oz. Beer, Steel	12	—	—	2.63	4.59	0.111	0.12	Steel	—	0.76	0.77
12 oz. Beer, Alum.	12	—	—	2.55	4.59	0.047	0.214	Alum.	—	0.76	0.77
Pint Beer, Steel	16	—	—	2.63	6.22	0.134	0.12	Steel	—	1.02	1.03
Cases											
Beer											
Tall, 12 oz. Ret.	—	—	15.87	10.63	10.06	1.81	0.34	Corr. Paper	24	18.26	22.48
Tall, 12 oz. Ret.	—	—	16.19	10.63	9.69	3.19	0.40	Fiber[3]	24	18.26	23.14
Squat, 12 oz. N.R.	—	—	17.31	11.56	6.50	1.38	0.34	Corr. Paper	24	18.26	20.65
Quart, N.R.	—	—	15.94	12.00	10.63	1.81	0.34	Corr. Paper	12	24.34	25.16
Can, 12 oz Tray	—	—	16.00	10.50	4.75	0.27	0.34	Corr. Paper	24	18.26	18.67
Coca Cola	—	—	18.50	12.13	8.25	5.25	0.60	Wood	24	9.12	12.27
Soda											
6 oz	—	—	14.50	11.00	8.25	6.90	0.60	Wood	24	9.12	13.28
8 oz	—	—	14.50	11.00	7.75	6.50	0.60	Wood	24	12.00	15.90
12 oz	—	—	18.00	11.75	10.25	9.25	0.60	Wood	24	18.00	23.55
Quart	—	—	16.67	12.25	12.50	8.00	0.60	Wood	12	24.00	28.80
Kegs — Wood											
⅛	—	4	—	13.5	16.0	22	0.60	Wood	—	33	41
¼	—	8	—	17.0	21.0	36	0.60	Wood	—	70	80
½	—	15	—	20.0	24.0	65	0.60	Wood	—	130	155
Full	—	31	—	24.0	31.0	105	0.60	Wood	—	260	300
Kegs — Insulated Steel											
¼	—	8	—	16.0	17.25	33	0.12	Steel	—	62	60
½	—	16	—	19.0	23.5	60	0.12	Steel	—	124	120
Kegs — Cast Aluminum											
⅛	—	4	—	13.0	15.0	22	0.21	Aluminum	—	31	35
¼	—	8	—	16.0	17.25	32	0.21	Aluminum	—	62	64
½	—	16	—	19.25	23.5	70	0.21	Aluminum	—	124	130

Notes: 1. Specific heats of beer and carbonated beverages estimated at 1 Btu/lb/°F.
2. Storage areas may be estimated on the basis of 24 cans per one half cubic foot, and 24 bottles per 2 cubic feet; one third additional area should be allowed for aisles.
3. Fiber is utilized for returnable bottle cartons in southern climates.
4. Case weights include partitions, but no bottles or cans.

TABLE 30 INFILTRATION LOADS WHEN STORING BEER CONTAINERS[1]

TYPE AND SIZE OF CONTAINER	TEMPERATURE REDUCTION °F (OUTSIDE TEMPERATURE MINUS STORAGE TEMPERATURE)					
	60	55	50	45	40	35
Full keg	3200	2600	2100	1700	1400	1100
Half keg	2800	2100	1700	1400	1100	900
Quarter keg	2200	1900	1600	1300	1000	800
Case 24 12 oz. bottles	2100	1800	1500	1200	900	700

Note 1: Loads are in Btu/24 hr. Multiply the number of kegs delivered per day by the appropriate load per keg, and utilize the resultant number as the total 24 hr infiltration heat gain in Part III B, Form LE-1

TABLE 31 HEAT LOADS OF KEG AND BOTTLED BEER

TYPE AND SIZE OF CONTAINER	TEMPERATURE REDUCTION, °F							
	65	50	40	30	20	15	10	5
Keg — 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
Eigth Keg	–	–	1640	1230	820	615	410	205
Keg — Aluminum								
Half Keg	–	–	5200	3900	2600	1950	1300	650
Quarter Keg	–	–	2560	1920	1280	960	640	320
Eigth Keg	–	–	1400	1050	700	525	350	175
Keg — Steel								
Half Keg	–	–	4800	3600	2400	1800	1200	600
Quarter Keg	–	–	2400	1800	1200	900	600	300
Bottles								
6 oz[2]	32	27	22	16	10.8	8.1	5.4	2.7
7 oz[2]	37	31	25	20	12.4	9.3	6.2	3.1
8 oz[2]	42	35	28	21	14.0	10.5	7.0	3.5
9 oz[2]	47	38	30	23	15.2	11.4	7.6	3.8
12 oz[2]	60	50	40	30	20.0	15.0	10.0	5.0
Cases								
12 Oz Tray, Can	1214.2	934.0	746.8	560.4	373.4	280.2	186.7	93.4
Tall, 12 Oz. Ret.	1502.8	1156.0	924.8	693.6	462.4	346.8	231.2	115.6
Squat, 12 Oz. N.R.	1341.6	1032.0	826.0	619.2	413.0	309.6	206.5	103.2

Notes: 1. Specific heat of beer estimated at 1 Btu/lb/°F. 2. Tabulated values may be utilized for carbonated beverages.

TABLE 32 WALK-IN BEER COOLER STORAGE LOADS

WALK-IN COOLER SIZE	CAPACITY CASES OF 24 — 12 OZ BOTTLES	TOTAL LOAD INCLUDING PRODUCT IN BTU/HR	WALK-IN COOLER SIZE	CAPACITY CASES OF 24 — 12 OZ BOTTLES	TOTAL LOAD INCLUDING PRODUCT IN BTU/HR
6′ × 6′	110	5400	10′ × 14′	470	13960
6′ × 8′	150	6470	10′ × 16′	540	15400
6′ × 10′	190	7450	10′ × 18′	610	16820
6′ × 12′	230	8520	10′ × 20′	680	18150
8′ × 10′	260	9080	12′ × 16′	650	17500
8′ × 12′	315	10330	12′ × 18′	740	19260
8′ × 14′	370	11880	12′ × 20′	820	20800
8′ × 16′	425	13130	12′ × 30′	1240	28690

Note: Loads are based on 10′ cooler heights, 35°F holding temp., 20°F product temp. reduction and a 75°F environment, and have been adjusted for 18 hr compressor operation. A 20% daily inventory turn was assumed.

Tables 29, 30 & 31 extracted in part from the ASRE (now ASHRAE) Application Data Section, additional data was obtained by actual weighing and measurement.

TABLE 33 DOMESTIC OUTDOOR DESIGN DATA[1]

LOCATION	DB °F	WB °F
Alabama		
Birmingham	97	79
Mobile	95	80
Montgomery	98	80
Tuscaloosa	98	81
Alaska		
Anchorage	73	63
Fairbanks	82	64
Juneau	75	66
Arizona		
Douglas	100	70
Phoenix	108	77
Tucson	105	74
Arkansas		
Fort Smith	101	79
Little Rock	99	80
California		
Bakersfield	103	72
Blythe	111	78
Fresno	101	73
Los Angeles	94	72
Oakland	85	65
Sacramento	100	72
San Francisco	80	64
Colorado		
Denver	92	65
Connecticut		
Hartford	90	77
New Haven	88	77
Delaware		
Wilmington	93	79
Dist. Of Columbia		
Washington	94	78
Florida		
Jacksonville	96	80
Miami	92	80
Orlando	96	80
Tallahassee	96	80
Tampa	92	81
Georgia		
Atlanta	95	78
Savannah	96	81
Hawaii		
Honolulu	87	75
Idaho		
Boise	96	68
Illinois		
Champaign	96	79
Chicago	94	78
Springfield	95	79
Indiana		
Evansville	96	79
Fort Wayne	93	77
Indianapolis	93	78
Terre Haute	95	79
Iowa		
Cedar Rapids	92	78
Des Moines	95	79
Kansas		
Dodge City	99	74
Topeka	99	79
Wichita	102	77
Kentucky		
Lexington	94	78
Louisville	96	79
Louisiana		
Baton Rouge	96	81
New Orleans	93	81
Shreveport	99	81
Maine		
Portland	88	75
Maryland		
Baltimore	94	79
Hagerstown	94	77
Massachusetts		
Boston	91	76
Springfield	91	76
Worcester	89	75
Michigan		
Detroit	92	76
Grand Rapids	91	76
Lansing	89	76
Minnesota		
Duluth	85	73
St. Paul	92	77
Minneapolis	92	77
Mississippi		
Jackson	98	79
Missouri		
Kansas City	100	79
St. Louis	96	79
Springfield	97	78
Montana		
Billings	94	68
Helena	90	65
Nebraska		
Omaha	97	79
Nevada		
Las Vegas	108	72
Reno	94	64
New Hampshire		
Concord	91	75
New Jersey		
Newark	94	77
Trenton	92	78
New Mexico		
Albuquerque	96	66
Santa Fe	90	65
New York		
Albany	91	76
Buffalo	88	75
New York	94	77
Rochester	91	75
Syracuse	90	76
North Carolina		
Asheville	91	75
Charlotte	96	78
North Dakota		
Bismarck	95	74
Fargo	92	76
Ohio		
Cincinnati	94	78
Cleveland	91	76
Dayton	92	77
Oklahoma		
Oklahoma City	100	78
Lawton	103	78
Tulsa	102	79
Oregon		
Portland	91	69
Pennsylvania		
Erie	88	76
Philadelphia	93	78
Pittsburg	90	75
Rhode Island		
Providence	89	76
South Carolina		
Charleston	95	81
South Dakota		
Rapid City	96	72
Sioux Falls	95	77
Tennessee		
Chattanooga	97	78
Knoxville	97	80
Memphis	98	80
Nashville	97	79
Texas		
Amarillo	98	72
Corpus Christi	95	81
Dallas	101	79
El Paso	100	70
Galveston	91	82
Houston	96	80
San Antonio	99	77
Utah		
Salt Lake City	97	67
Vermont		
Burlington	88	74
Virginia		
Norfolk	94	79
Richmond	96	79
Roanoke	94	76
Washington		
Seattle	81	67
Spokane	93	66
Yakima	94	69
West Virginia		
Charleston	92	76
Parkersburg	93	77
Wisconsin		
Green Bay	88	75
Madison	92	77
Milwaukee	90	77
Wyoming		
Caspar	92	63
Cheyenne	89	63
Canada		
Calgary	87	66
Edmonton	86	69
Goose Bay	86	69
Halifax	83	69
Hamilton	91	77
Montreal	88	76
Ottawa	90	75
Toronto	90	77
Vancouver	80	68
Winnipeg	90	75

Tables 33 & 34 extracted from 1972 ASHRAE Handbook of Fundamentals — Reprinted by Permission

TABLE 34 INTERNATIONAL OUTDOOR DESIGN DATA[1]

LOCATION	DB °F	WB °F
Afghanistan		
Kabul	98	66
Algeria		
Algiers	95	77
Argentina		
Buenos Aires	91	77
Tucuman	102	76
Australia		
Adelaide	98	72
Brisbane	91	77
Melbourne	95	71
Perth	100	76
Sydney	89	74
Austria		
Vienna	88	71
Bahamas		
Nassau	90	80
Belgium		
Brussels	83	70
Bermuda		
Kindley AFB	87	79
Bolivia		
La Paz	71	58
Brazil		
Brasilia	89	76
Porto Alegre	95	76
Rio de Janeiro	94	80
Salvador	88	79
Sao Paulo	86	75
British Honduras		
Belize	90	82
Burma		
Mandalay	104	81
Cambodia		
Phnom Penh	98	83
Ceylon		
Colombo	90	81
Chile		
Santiago	90	71
Valparaiso	81	67
Colombia		
Bogota	72	60
Cali	87	73
Medellin	84	70
Congo		
Kinasha	92	81
Stanleyville	92	81

LOCATION	DB °F	WB °F
Cuba		
Havana	92	81
Denmark		
Copenhagen	79	68
Dominican Republic		
Santo Domingo	92	81
Ecuador		
Guayaquil	92	80
Quito	73	63
El Salvador		
San Salvador	98	77
Ethiopia		
Addis Ababa	84	66
Finland		
Helsinki	77	66
France		
Marseilles	90	72
Paris	89	70
Germany		
Berlin	84	68
Hamburg	80	68
Munich	86	68
Ghana		
Accra	91	80
Greece		
Athens	96	72
Greenland		
Narssarssuaq	66	56
Guatemala		
Guatemala City	83	69
Guyana		
Georgetown	89	80
Haiti		
Port Au Prince	97	82
Honduras		
Tegucigalpa	89	73
Hong Kong		
Hong Kong	92	81
Iceland		
Reykjavik	59	54
India		
Bombay	96	82
Calcutta	98	83
New Delhi	110	83

LOCATION	DB °F	WB °F
Indonesia		
Djakarta	90	80
Makasser	90	80
Iran		
Abadan	116	82
Meshed	99	68
Tehran	102	75
Iraq		
Baghdad	113	73
Ireland		
Shannon	76	65
Israel		
Tel Aviv	96	74
Italy		
Naples	91	74
Rome	94	74
Japan		
Sapporo	86	76
Tokyo	91	81
Jordan		
Amman	97	70
Kenya		
Nairobi	81	66
Lebanon		
Beirut	93	78
Libya		
Bengasi	97	77
Malaysia		
Penang	93	82
Singapore	92	82
Mexico		
Guadalajara	93	68
Merida	97	80
Mexico City	83	61
Monterrey	98	79
Vera Cruz	91	83
Netherlands		
Amsterdam	79	65
New Zealand		
Auckland	78	67
Wellington	76	66
Nicaragua		
Managua	94	81
Nigeria		
Lagos	92	82

LOCATION	DB °F	WB °F
Pakistan		
Chittagong	93	82
Kaachi	100	82
Panama & Canal Zone		
Panama City	93	81
Paraguay		
Asuncion	100	81
Peru		
Lima	86	76
Philippines		
Manila	94	82
Puerto Rico		
San Juan	89	81
Saudi Arabia		
Dhahran	111	86
Riyadh	110	78
South Africa		
Capetown	93	72
Johannesburg	85	70
Spain		
Barcelona	88	75
Madrid	93	71
Sweden		
Stockholm	78	64
Syria		
Damascus	102	72
Thailand		
Bangkok	97	82
Tunisia		
Tunis	102	77
Turkey		
Ankara	94	68
Istanbul	91	75
United Arab Republic		
Cairo	102	76
United Kingdom		
Belfast	74	65
Birmingham	79	66
London	82	68
Uraguay		
Montevideo	90	73
Venezuela		
Caracas	84	73
Puerto Ordaz	95	82
Maracaibo	97	84
Valencia	95	80

Note 1: Design temperatures shown in Tables 33 & 34 are equalled or exceeded during 1% of summer months.

APPENDIX—TABLES

TABLE 35 — SI METRIC CONVERSION FACTORS

AREA			
Acre	× 4.047E + 03	=	Metre^2 (m^2)
ft^2	× 9.290E − 02	=	Metre^2 (m^2)
in^2	× 6.452E − 04	=	Metre^2 (m^2)
mi^2	× 2.590E + 06	=	Metre^2 (m^2)
yd^2	× 8.361E − 01	=	Metre^2 (m^2)
ENERGY			
Btu	× 1.055E + 03	=	Joule (J)
Calorie	× 4.187E + 00	=	Joule (J)
Kilocalorie	× 4.187E + 03	=	Joule (J)
kw-h	× 3.600E + 06	=	Joule (J)
w-h	× 3.600E + 03	=	Joule (J)
ENERGY PER UNIT TIME			
Btu/(ft^2 • s)	× 1.136E + 04	=	Watt Per Metre^2 (w/m^2)
Btu/(ft^2 • min)	× 1.893E + 02	=	Watt Per Metre^2 (w/m^2)
Btu/(ft^2 • h)	× 3.155E + 00	=	Watt Per Metre^2 (w/m^2)
Cal/(cm^2 • min)	× 6.978E + 02	=	Watt Per Metre^2 (w/m^2)
w/cm^2	× 1.000E + 04	=	Watt Per Metre^2 (w/m^2)
w/ft^2	× 3.281E + 00	=	Watt Per Metre^2 (w/m^2)
w/in^2	× 1.550E + 03	=	Watt Per Metre^2 (w/m^2)
HEAT			
Heat Density:			
Btu/ft^2	× 1.136E + 04	=	Joule Per Metre^2 (j/m^2)
Cal/cm^2	× 4.187E + 04	=	Joule Per Metre^2 (j/m^2)
Heat Flux Density:			
Btu/(ft^2 • h)	× 3.155E + 00	=	Watt Per Metre^2 (w/m^2)
Cal/(cm^2 • s)	× 4.187E + 04	=	Watt Per Metre^2 (w/m^2)
Heat Transfer Coefficient (U):			
Btu/(h • ft^2 • °F)	× 5.678E + 00	=	Watt Per Metre^2 — Kelvin (w/(m^2 • K))
Btu/(s • ft^2 • °F)	× 2.044E + 04	=	Watt Per Metre^2 — Kelvin (w/(m^2 • K))
Specific Enthalpy (Latent Heat):			
Btu/lb	× 2.326E + 03	=	Joule Per Kilogram (j/kg)
Cal/g	× 4.187E + 03	=	Joule Per Kilogram (j/kg)
Specific Heat (C):			
Btu/(lb • °F)	× 4.187E + 03	=	Joule per Kg • Kelvin (j/(kg • K))
Cal/(g • °C)	× 4.187E + 03	=	Joule per Kg • Kelvin (j/(kg • K))
Thermal Conductivity (K):			
(Btu • Ft)/(h • ft^2 • °F)	× 1.731E + 00	=	Watt Per Metre — Kelvin (w/(m • K))
(Btu • In)/(S • ft^2 • °F)	× 5.192E + 02	=	Watt Per Metre — Kelvin (w/(m • K))
(Btu • In)/(h • ft^2 • °F)	× 1.442E − 02	=	Watt Per Metre — Kelvin (w/(m • K))
Cal/(cm • s • °C)	× 4.187E + 02	=	Watt Per Metre — Kelvin (w/(m • K))
Thermal Diffusivity:			
ft^2/h	× 2.581E − 05	=	Metre^2 Per Sec (m^2/s)
Thermal Resistance (R):			
(°F • h • ft^2)/Btu	× 1.761E − 01	=	Kelvin — Metre^2/Watt ((K • m^2)/w)
LENGTH			
ft	× 3.048E − 01	=	Metre (m)
in	× 2.540E − 02	=	Metre (m)
micron	× 1.000E − 06	=	Metre (m)
yd	× 9.144E − 01	=	Metre (m)
mile	× 1.609E + 03	=	Metre (m)
LIGHT			
Footcandle	× 1.076E + 01	=	Lux (lx)
Footlambert	× 3.426E + 00	=	Candela/Metre^2 (cd/m^2)
MASS			
Gram	× 1.000E − 03	=	Kilogram (kg)
Ounce (Avoir)	× 2.835E − 02	=	Kilogram (kg)
Pound (Avoir)	× 4.536E − 01	=	Kilogram (kg)
Tonne	× 1.000E + 03	=	Kilogram (kg)
Ton (long, 2240 lb)	× 1.016E + 03	=	Kilogram (kg)
Ton (Metric)	× 1.000E + 03	=	Kilogram (kg)
Ton (short, 2000 lb)	× 9.072E + 02	=	Kilogram (kg)
MASS PER UNIT TIME			
lb/h	× 1.260E − 04	=	Kilogram Per Second (kg/s)
lb/min	× 7.560E − 03	=	Kilogram Per Second (kg/s)
lb/sec	× 4.536E − 01	=	Kilogram Per Second (kg/s)
lb/(hp • h)	× 1.690E − 07	=	Kilogram Per Joule (kg/J)
DENSITY			
g/cm^3	× 1.000E + 03	=	Kilogram Per Metre^3 (kg/m^3)
Oz (Avoir)/Gal	× 7.489E + 00	=	Kilogram Per Metre^3 (kg/m^3)
lb/ft^3	× 1.602E + 01	=	Kilogram Per Metre^3 (kg/m^3)
lb/in^3	× 2.768E + 04	=	Kilogram Per Metre^3 (kg/m^3)
lb/gal	× 1.198E + 02	=	Kilogram Per Metre^3 (kg/m^3)
lb/yd^3	× 5.933E − 01	=	Kilogram Per Metre^3 (kg/m^3)
POWER			
Btu/h	× 2.931E − 01	=	Watt (w)
Btu/min	× 1.758E + 01	=	Watt (w)
Cal./m	× 6.978E − 02	=	Watt (w)
hp(550ft • lbf/s)	× 7.457E + 02	=	Watt (w)
hp (boiler)	× 9.810E + 03	=	Watt (w)
hp (electric)	× 7.460E + 02	=	Watt (w)
hp (metric)	× 7.355E + 02	=	Watt (w)
ton of refrig.	× 3.517E + 03	=	Watt (w)
PRESSURE			
Atmosphere	× 1.013E + 05	=	Pascal (pa)
Cm of Hg	× 1.333E + 03	=	Pascal (pa)
Cm of Water	× 9.806E + 01	=	Pascal (pa)
Ft of Water	× 2.989E + 03	=	Pascal (pa)
In of Hg	× 3.386E + 03	=	Pascal (pa)
In of Water	× 2.490E + 02	=	Pascal (pa)
Mm of Hg	× 1.333E + 02	=	Pascal (pa)
Psi[1]	× 6.895E + 03	=	Pascal (pa)
TEMPERATURE			
°F	− 32 ÷ 1.8	=	°C
°C	× 1.8 + 32	=	°F
°F	+ 459.67 ÷ 1.8	=	Kelvin
Kelvin	× 1.8 − 459.67	=	°F
°C	+ 273.15	=	Kelvin
Kelvin	− 273.15	=	°C
°Rankine	÷ 1.8	=	Kelvin

Notes:

1. No equivalents for the abbreviations "Psia" and "Psig" are utilized in the SI System (if necessary to so designate a given pressure, it would be defined as "an absolute pressure of 90kpa", or "25 kpa (Gage)", etc.

2. All factors have been rounded off to 4 significant digits and are, therefore, by SI definition "approximate."

3. The "E" notation is utilized for convenience in electronic data processing, and has no other significance.

4. SI equivalents are always shown as a number greater than 1 and less than 10. Examples: 1.055E + 03 joule per Btu (rather than 1055); 1.000 E − 03 kg per gram (rather than 0.001), etc.

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TABLE 36 WEIGHT EQUIVALENCY OF COMMON MEASURES

Product	Measure	Weight — Lbs
Apples	Bushel Or Box	50
	Barrel	125
Bananas	Bunch	50
Beef, Dressed	Head (Carcass)	550
Butter	Tub	60
Calves, Dressed	Head (Carcass)	150
Hogs, Dressed	Head (Carcass)	200
Ice	Bushel	50
Lamb, Dressed	Head (Carcass)	45
Peaches/Pears	Bushel	55
Potatoes	Bushel	60

TABLE 37 ENGLISH — METRIC CONVERSION FACTORS

Btu	× 252	= Calories
Cubic Feet	× 28.32	= Liters
Cubic Feet Per Minute	× 472	= Cubic Centimeters per Sec
Cubic Inches	× 16.39	= Cubic Centimeters
Cubic Meters	× 35.31	= Cubic Feet
	× 264.2	= Gallons (U.S. Liq.)
	× 1000	= Liters
Cubic Yards	× 764.6	= Liters
Drams	× 1.772	= Grams
Feet	× 30.48	= Centimeters
Feet Per Second	× 1.097	= Kilometers per Hour
Gallons	× 3.785	= Liters
Grams	× 15.43	= Grains
Grams Per Cubic Centimeter	×, 62.4	= Pounds per Cubic Foot
Grams Per Liter	× 1000	= Parts per Million
Grams Per Square Centimeter	× 2.05	= Pounds per Square Foot
Horsepower (English)	× 1.014	= Horsepower (Metric)
Horsepower	× 641.1	= Kilocalories
Inches	× 2.54	= Centimeters
Inches Of Mercury	× 34.53	= Grams per Sq. Centimeter
Kilograms	× 2.205	= Pounds
Kilograms Per Square Centimeter	× 28.96	= Inches of Mercury
	× 14.22	= Pounds per Sq In
Kilocalories	× 3.97	= Btu
Kilometers	× 3281	= Feet
Kilowatts	× 860.5	= Kilocalories per Hour
Liters	× 1.057	= Quarts (U.S. Liq.)
Meters	× 3.281	= Feet
Ounces (Avoir)	× 28.35	= Grams
Ounces (Troy)	× 31.10	= Grams
Pounds	× 453.6	= Grams
Pounds Per Cubic Foot	× 16.02	= Kilograms per Cubic Meter
Quarts	× 946.4	= Cubic Centimeters
Square Feet	× 929	= Square Centimeters
Square Inches	× 6.45	= Square Centimeters
Square Meters	× 10.76	= Square Feet
Tons (Short)	× 907.2	= Kilograms
Tons (Metric)	× 1.102	= Tons (Short)
Watts	× 860.5	= Calories per Hour

TABLE 38 ENGLISH CONVERSION FACTORS

Atmospheres	× 14.696	= Pounds per Sq In
Acres	× 43,560	= Square Feet
Barrels	× 31.5	= Gallons
Bushels	× 1.245	= Cubic Feet
Bushels	× 32	= Quarts (Dry)
Cubic Feet	× 1728	= Cubic Inches
Cubic Feet	× 7.48	= Gallons (U.S. Liq.)
Cubic Yards	× 27	= Cubic Feet
Cubic Yards	× 202	= Gallons (U.S. Liq.)
Gallons	× 231	= Cubic Inches
Grains (Avoir)	× 1.0	= Grains (Troy)
Horsepower	× 2547	= Btu/hr
Horsepower	× 745.7	= Watts
Kilowatts	× 3413	= Btu/hr
Kilowatts	× 1.34	= Horsepower
Kilowatts	× 1000	= Watts
Ounces (Avoir)	× 437.5	= Grains
Ounces (Fluid)	× 1.81	= Cubic Inches
Ounces (Troy)	× 480	= Grains
Ounces (Troy)	× 1.097	= Ounces (Avoir)
Pounds Per Sq In	× 27.686	= Inches of Water
Pounds Per Sq In	× 2.307	= Feet of Water
Pounds	× 7000	= Grains
Pounds	× 16	= Ounces (Avoir)
Pounds	× 14.58	= Ounces (Troy)
Pounds	× 1.22	= Pounds (Troy)
Pounds (Troy)	× 5760	= Grains
Pounds (Troy)	× 13.17	= Ounces (Avoir)
Pounds (Troy)	× 12	= Ounces (Troy)
Pounds Per Sq In	× 2.307	= Feet of Water
Quarts (Liquid)	× 57.75	= Cubic Inches
Square Feet	× 144	= Square Inches
Square Yards	× 1296	= Square Inches
Tons (Short)	× 2000	= Pounds
Tons (Long)	× 1.12	= Tons (Short)
Tons Of Refrigeration	× 12000	= Btu/hr
Watts	× 3.41	= Btu/hr

TABLE 39 METRIC CONVERSION FACTORS

Atmospheres	× 76	= Centimeters of Mercury
Centimeters	× 10	= Millimeters
Cubic Meters	× 1,000,000	= Cubic Centimeters
Cubic Meters	× 1,000	= Liters
Dekagrams	× 10	= Grams
Dekaliters	× 10	= Liters
Dekameters	× 10	= Meters
Grams	× 1,000	= Milligrams
Kilocalories	× 1,000	= Calories
Kilograms	× 1,000	= Grams
Kiloliters	× 1,000	= Liters
Kilometers	× 1,000	= Meters
Kilowatts	× 860.5	= Kilocalories per Hour
Liters	× 1,000	= Cubic Centimeters
Meters	× 100	= Centimeters
Meters	× 1,000	= Millimeters
Milliliters	× 1.0	= Cubic Centimeters
Square Centimeters	× 100	= Square Millimeters
Square Meters	× 10,000	= Square Centimeters
Watts	× 860.5	= Calories per Hour

APPENDIX—TABLES

TABLE 40 OUTSIDE AREA, ROOM VOLUME AND REFRIGERATION LOADS FOR WALK-IN COOLERS AND FREEZERS AT 95°F AMBIENT[3]

ROOM SIZE OUTSIDE W × L	8 FT HEIGHT[2]						10 FT HEIGHT[2]					
	OUTSIDE AREA SQ FT	ROOM VOLUME CU FT	CAPACITY REQUIREMENTS LESS PRODUCT LOAD-BTU/HR				OUTSIDE AREA SQ FT	ROOM VOLUME CU FT	CAPACITY REQUIREMENTS LESS PRODUCT LOAD-BTU/HR			
			−20°F	−10°F	28°F	36°F			−20°F	−10°F	28°F	36°F
6 × 6	228	234	5300	4900	4200	3600	276	294	6000	5600	4700	4100
6 × 8	272	319	6100	5700	4800	4200	328	402	6900	6500	5400	4700
6 × 10	316	404	6900	6500	5400	4700	380	509	7800	7300	6100	5200
6 × 12	360	490	7700	7200	6000	5100	432	616	8700	8100	6700	5800
8 × 10	368	552	8000	7500	6200	5400	440	694	9000	8400	7000	6000
8 × 12	416	668	8900	8300	6900	5900	496	840	10000	9300	7700	6600
8 × 14	464	784	10000	9400	7800	6800	552	987	11300	10500	8700	7500
8 × 16	512	900	10800	10100	8400	7300	608	1133	12200	11400	9300	8100
10 × 10	420	699	9000	8400	7000	6000	500	879	10200	9500	7800	6700
10 × 12	472	846	10300	9700	8000	7000	560	1065	11600	10800	8900	7700
10 × 14	524	993	11200	10500	8700	7500	620	1250	12600	11800	9700	8400
10 × 16	576	1141	12100	11300	9300	8100	680	1435	13600	12700	10400	9000
10 × 18	628	1288	13000	12100	9900	8600	740	1620	14500	13500	11000	9600
10 × 20	680	1435	13800	12900	10500	9100	800	1806	15400	14400	11700	10100
12 × 14	584	1203	12400	11600	9500	8200	688	1513	13800	12900	10600	9100
12 × 16	640	1381	13400	12500	10200	8800	752	1737	14900	13900	11300	9800
12 × 18	696	1559	14300	13400	10900	9400	816	1962	16000	14900	12100	10500
12 × 20	752	1737	15200	14200	11500	10000	880	2186	17000	15900	12800	11100
12 × 30	1032	2629	19600	18200	14500	12600	1200	3307	21900	20400	16100	14000
14 × 16	704	1621	14500	13500	11000	9600	824	2040	16200	15100	12300	10600
14 × 20	824	2040	16500	15400	12500	10800	960	2566	18400	17200	13900	12000
14 × 24	944	2458	18500	17200	13800	12000	1096	3093	20600	19200	15400	13300
14 × 28	1064	2877	20300	19000	15100	13100	1232	3619	22600	21100	16800	14500
14 × 32	1184	3295	22200	20700	16400	14200	1368	4146	24600	22900	18100	15700
16 × 16	768	1861	15700	14600	11800	10300	896	2342	17400	16300	13100	11400
16 × 20	896	2342	17800	16600	13400	11600	1040	2946	19800	18500	14800	12800
16 × 24	1024	2822	19900	18600	14800	12800	1184	3551	22200	20700	16500	14300
16 × 28	1152	3303	22000	20500	16200	14100	1328	4155	24300	22700	18000	15500
16 × 32	1280	3783	24000	22400	17700	15300	1472	4760	26600	24700	19400	16800
16 × 36	1408	4264	25800	24000	18900	16400	1616	5364	28600	26600	21000	18100
20 × 20	1040	2946	20300	18900	15100	13100	1200	3707	22500	21000	16700	14500
20 × 24	1184	3551	22700	21200	16900	14600	1360	4467	25200	23500	18600	16100
20 × 28	1328	4155	25000	23300	18400	15900	1520	5228	27700	25800	20400	17600
20 × 32	1472	4760	27300	25400	19900	17200	1680	5988	30200	28100	22100	19100
20 × 36	1616	5364	29500	27400	21500	18600	1840	6749	32600	30300	23600	20400
20 × 40	1760	5969	31700	29400	23000	19900	2000	7509	34900	32500	25300	21900
30 × 20	1400	4458	26200	24400	19200	16600	1600	5608	29000	27000	21200	18300
30 × 24	1584	5372	29300	27200	21400	18500	1800	6759	32400	30100	23400	20300
30 × 30	1860	6744	33800	31500	24300	21100	2100	8484	37000	34400	26700	23200
40 × 30	2320	9030	41100	38100	29200	25300	2600	11361	44800	41600	32000	27700
40 × 40	2880	12091	50300	46700	35300	30700	3200	15212	54800	50800	38500	33500

Notes:
1. Ratings based on 3" foamed-in-place urethane, average usage, indoor installation & 18 hour compressor operation
2. Heights represent internal clearance. Overall heights with floor: 8'6" & 10'6"
3. Correction Factors — **Other Ambients: 80°F — 0.75; 100°F — 1.10; 115°F — 1.35**
4. Correction Factors — **Other Usage: Light (Long-Term Storage) — 0.80; Heavy — 1.15-1.40**
5. **IMPORTANT:** Utilization of charted values requires application of properly rated equipment.

TABLE 41 AVERAGE PRODUCT LOADS IN BTU/HR FOR WALK-IN COOLERS AND FREEZERS

ROOM VOLUME CU FT	COOLERS		FREEZERS		ROOM VOLUME CU FT	COOLERS		FREEZERS	
	LBS/DAY	PRODUCT LOAD BTU/HR	LBS/DAY	PRODUCT LOAD BTU/HR		LBS/DAY	PRODUCT LOAD BTU/HR	LBS/DAY	PRODUCT LOAD BTU/HR
250	850	567	300	112	7000	15800	10500	3800	1425
500	1600	1067	600	225	7500	16100	10700	4000	1500
1000	3000	2000	1000	375	8000	16500	11000	4200	1575
1500	4200	2800	1400	525	8500	18000	12000	4400	1650
2000	5100	3400	1700	637	9000	21000	14000	4600	1725
2500	6900	4600	1900	713	9500	22500	15000	4900	1840
3000	8500	5700	2100	787	10000	24000	16000	5100	1910
3500	9800	6500	2250	844	15000	31000	20700	7600	2850
4000	11100	7400	2400	900	20000	40000	26700	9400	3525
4500	12000	8000	2500	938	30000	54000	36000	15000	5625
5000	12900	8600	2900	1090	40000	65000	43200	18000	6750
5500	13700	9100	3200	1200	60000	108000	72000	26000	9750
6000	14600	9700	3400	1275	80000	150000	100000	35000	13100
6500	15200	10100	3600	1350	100000 & up	190000 & up	127000 & up	53000 & up	19500 & up

Notes: 1. Values have been adjusted for **18 hour compressor operation**, and apply to **holding rooms only** with entering product at **15°F** above the refrigerator temperature.

2. This table is not to be used for unusual product loads, or if product specifics are known.

TABLE 42 SPECIFIC PRODUCT LOADS IN BTU/HR FOR WALK-IN COOLERS AND FREEZERS[1]

PRODUCT	DAILY PRODUCT QUANTITY	PRODUCT ENTERING TEMP. °F	FINAL PRODUCT TEMPERATURE – °F 60	40	35	32	0	–10	–20	–30
Bakery Goods	100 Lbs	80	82	164	185	197	545	564	583	602
		55	–	34	62	95	443	462	480	500
		35	–	–	4	16	365	384	403	421
Beef	1000 Lbs	100	1667	2500	2708	2833	9194	9422	9649	9877
		55	–	625	833	958	7319	7547	7774	8002
		34	–	–	–	83	6444	6672	6899	7127
Lamb & Veal	1000 Lbs	100	1824	2736	2964	3100	9477	9726	9965	10204
		55	–	684	912	1049	7436	7674	7913	8152
		34	–	–	–	91	6477	6716	6955	7194
Pork	1000 Lbs	100	1178	1766	1914	2002	6106	6283	6461	6639
		55	–	441	589	677	4781	4958	5136	5314
		34	–	–	–	59	4104	4281	4459	4637
Beer & Soda	100 Cases	80	3555	7110	8000	8530	–	–	–	–
		60	–	3555	4440	4980	–	–	–	–
		50	–	1775	2670	3200	–	–	–	–
Frozen Food	1000 Lbs	10	–	–	–	–	278	556	833	1111
		0	–	–	–	–	–	278	556	835
Ice Cream[3]	100 Gal • Soft Mix	28	–	–	–	–	2667	2962	3284	3631
	• Pre-Hardened	10	–	–	–	–	364	606	793	1160
Milk	100 Gal	45	–	228	456	547	–	–	–	–
Poultry & Fresh Game	1000 Lbs	55	–	658	879	1009	7747	7980	8214	8447
		50	–	439	658	790	7528	7761	7995	8228
		35	–	–	–	132	6870	7103	7337	7570
Pizza Meat Pies & TV Dinners	100 14 Oz Units	80	73	146	164	175	611	630	649	669
		60	–	73	91	102	537	557	576	596
		35	–	–	–	11	446	466	485	505
Sea Food	100 Lbs	70	47	141	165	179	933	957	982	1006
		50	–	47	71	85	838	862	887	911
		35	–	–	–	14	768	792	817	841
Vegetables	1000 Lbs	90	1500	2500	2750	2900	10409	10666	10922	11178
		75	750	1750	2000	2150	9659	9916	10172	10428
		55	–	750	1000	1150	8659	8916	9172	9428
		35	–	–	–	150	7659	7916	8172	8428

Notes: 1. Values are for **24 hour pulldown** and have been adjusted for **18 hour compressor operation.**

2. For shorter pulldown periods, or for continuous blast freezing operations, utilize the following formula:

$$\text{Product Load Btu/hr} = \frac{\text{Charted Value} \times 24}{\text{Pulldown or Shift Time}_{hrs}}$$

3. Ice cream loads must be modified for the preferred hardening period (usually 8-10 hrs) to prevent crystalization.

TABLE 43 GLASS DISPLAY DOOR LOADS IN BTU/HR FOR WALK-IN COOLERS AND FREEZERS

NO. OF DOORS[1]	COOLER@35°F 75°F AMBIENT	COOLER@35°F 90°F AMBIENT	FREEZER 80°F TD[4]	FREEZER 90°F TD[4]	FREEZER 110°F TD[4]
2 to 4	960	1200	1800	2100	2600
5 to 7	890	1100	1550	1800	2100
8 to 12	820	1000	1440	1500	2000
13 to 16	630	800	1330	1400	1800
16 to 20	550	700	1240	1300	1600

Notes: 1. Values are per door, and are based on standard 30" × 66" double glazed cooler, and triple glazed freezer, doors. Factors for other standard door sizes: **30" × 72": 1.11; 30" x 80": 1.26.**

2. Values do not apply to reach-in refrigerators.

3. Unit coolers should be placed opposite and above the doors (blowing toward the doors) to create an air curtain effect.

4. T D represents the difference between box and room temperatures.

TABLE 44 PROPERTIES OF SOLIDS

MATERIAL DESCRIPTION	SPECIFIC HEAT BTU/LB/°F	DENSITY LB/CU FT	THERMAL CONDUCTIVITY BTU • FT/HR/SQ FT/°F	EMISSIVITY RATIO	EMISSIVITY SURFACE CONDITION
Aluminum (alloy 1100)	0.214	171	128.00	0.09	Commercial sheet
				0.20	heavily oxidized
Aluminum Bronze					
(76% Cu, 22% Zn, 2% A1)	0.09	517	58.00		
Alundum (aluminum oxide)	0.186				
Asbestos:					
• fiber	0.25	150	0.097		
• insulation	0.20	36	0.092	0.93	"Paper"
Ashes, wood	0.20	40	0.041 (122)		
Asphalt	0.22	132	0.43		
Bakelite	0.35	81	9.70		
Bell metal	0.086 (122)				
Bismuth tin	0.040		37.60		
Brick, building	0.2	123	0.40	0.93	
Brass:					
• red (85% Cu, 15% Zn)	0.09	548	87.0	0.030	Highly polished
• yellow (65% Cu, 35% Zn)	0.09	519	69.0	0.033	Highly polished
Bronze	0.104	530	17 (32)		
Cadmium	0.055	540	53.70	0.02	
Carbon (gas retort)	0.17		0.20 (2)	0.81	
Cardboard	0.34		0.04		
Cellulose	0.32	3.4	0.033		
Cement (Portland clinker)	0.16	120	0.017		
Chalk	0.215	143	0.48	0.34	About 250 F
Charcoal (wood)	0.20	15	0.03 (392)		
Chrome Brick	0.17	200	0.67		
Clay	0.22	63			
Coal	0.3	90	0.098 (32)		
Coal Tars	0.35 (104)	75	0.07		
Coke (petroleum powdered)	0.36 (752)	62	0.55 (752)		
Concrete (stone)	0.156 (392)	144	0.54		
Copper (electrolytic)	0.092	556	227.00	0.072	Commercial, shiny
Cork (granulated)	0.485	5.4	0.028 (23)		
Cotton (fiber)	0.319	95	0.024		
Cryolite ($AlF_3 \cdot 3NaF$)	0.253	181			
Diamond	0.147	151	27.00		
Earth (dry and packed)		95	0.037	0.41	
Felt		20.6	0.03		
Fireclay brick	0.198 (212)	112	0.58 (392)	0.75	At 1832 F
Flourspar (CaF_2)	0.21	199	0.63		
German Silver (nickel silver)	0.09	545	19.00	0.135	Polished
Glass:					
• crown (soda-lime)	0.18	154	0.59 (200)	0.94	Smooth
• flint (lead)	0.117	267			
• pyrex	0.20	139	0.59 (200)		
• "wool"	0.157	3.25	0.022		
Gold	0.0312	1208	172.00	0.02	Highly polished
Graphite:					
• powder	0.165		0.106		
• "Karbate" (impervious)	0.16	117	75.00	0.75	
Gypsum	0.259	78	0.25	0.903	On a smooth plate
Hemp (fiber)	0.323	93			
Ice:					
• (32 F)	0.487	57.5	1.30	0.95	
• (−4 F)	0.465		1.41		
Iron:					
• cast	0.12 (212)	450	27.60 (129)	0.435	Freshly turned
• wrought		485	34.90	0.94	Dull, oxidized
Lead	0.0309	707	20.10	0.28	Gray, oxidized
Leather (sole)		62.4	0.092		
Limestone	0.217	103	0.54	0.36 to 0.90	At 145 to 380 F
Linen			0.05		
Litharge (lead monoxide)	0.055	490			
Magnesia:					
• powdered	0.234 (212)	49.7	0.35 (117)		
• light carbonate		13	0.034		
Magnesite brick	0.222 (212)	158	2.20 (400)		
Magnesium	0.241	108	91.00	0.55	Oxidized

Note: Values are for room temperature unless otherwise noted in brackets.

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TABLE 44 PROPERTIES OF SOLIDS

MATERIAL DESCRIPTION	SPECIFIC HEAT BTU/LB/°F	DENSITY LB/CU FT	THERMAL CONDUCTIVITY BTU • FT/HR/SQ FT/°F	EMISSIVITY	
				RATIO	SURFACE CONDITION
Marble	0.210	162	1.50	0.931	Light gray, polished
Nickel	0.105	555	34.40	0.045	Electroplated, polished
Paints:					
• White lacquer				0.800	
• White enamel				0.910	On rough plate
• Black lacquer				0.800	
• Black shellac		63	0.15	0.910	"Matte" finish
• Flat black lacquer				0.960	
• Aluminum lacquer				0.390	On rough plate
Paper	0.320	58	0.075	0.920	Pasted on tinned plate
Paraffin	0.690	56	0.14 (32)		
Plaster		132	0.43 (167)	0.910	Rough
Platinum	0.032	1340	39.90	0.054	Polished
Porcelain	0.180	162	1.30	0.920	Glazed
Pyrites (Copper)	0.131	262			
Pyrites (Iron)	0.136 (156)	310			
Rock Salt	0.219	136			
Rubber:					
• Vulcanized (soft)	0.480	68.6	0.08	0.860	Rough
• Vulcanized (hard)		74.3	0.092	0.950	Glossy
Sand	0.191	94.6	0.19		
Sawdust		12	0.03		
Silica	0.316	140	0.83 (200)		
Silver	0.0560	654	245.00	0.020	Polished and at 440 F
Snow					
• Freshly fallen		7	0.34		
• At 32°F		31	1.30		
Steel (mild)	0.120	489	26.20	0.120	Cleaned
Stone (quarried)	0.200	95			
Tar:					
• pitch	0.59	67	0.51		
• bituminous		75	0.41		
Tin	0.0556	455	37.50	0.060	Bright and at 122 F
Tungsten	0.032	1210	116.00	0.032	Filament at 80 F
Wood:					
• Hardwoods: (Most woods vary between)	0.450/0.650	23/70	0.085/0.148		
• Ash, white		43	0.0992		
• Elm, American		36	0.0884		
• Hickory		50			
• Mahogany		34	0.075		
• Maple, sugar		45	0.108		
• Oak, white	0.570	47	0.102	0.900	Planed
• Walnut, black		39			
• Softwoods:		22/46	0.061/0.093		
• Fir, white	0.650	27	0.068		
• Pine, white	0.670	27	0.063		
• Spruce		26	0.066		
Wool:					
• Fiber	0.325	82			
• Fabric		6.9/20.6	0.021/0.037		
Zinc:					
• Cast	0.092	445	65.00	0.050	Polished
• Hot-rolled	0.094	445	62.00		
• Galvanizing				0.230	Fairly bright

Note: Values are for room temperatures unless otherwise noted in brackets.

TABLE 45 PROPERTIES OF WATER[1]

Specific Heat of Water	=	1 Btu/lb/°F 1 Cal/Gram/°C
Specific Heat of Ice	=	0.5 Btu/lb/°F 0.5 Cal/Gram/°C
Latent Heat of Vaporization	=	970 Btu/lb @ 212°F & 1 ATM 540 Cal/Gram @ 100°C & 1 ATM
Latent Heat of Fusion	=	144 Btu/lb 80 Cal/Gram
One Cubic Foot	=	62.4 Pounds 7.48 Gallons
One Gallon	=	8.33 Pounds 3.77 Kilograms

Note: Water @ 39.2°F

TABLE 46 PROPERTIES OF AIR[1]

One Pound of Air	= 13.33 Cubic Feet
One Cubic Foot of Air	= 0.075 Pounds
One Cubic Foot Per Minute (Cfm)	= 4.5 Pounds per Hour

Note: Standard Dry Air @ 69.8F° and 1 Atmosphere Pressure.

TABLE 47 PROPERTIES OF LIQUIDS

NAME OR DESCRIPTION	NORMAL BOILING POINT °F AT 1 ATM	ENTHALPY OF VAPORIZATION BTU/LB	SPECIFIC HEAT, Cp		VISCOSITY		ENTHALPY OF FUSION BTU/LB	SPECIFIC GRAVITY OR DENSITY (P)		THERMAL² CONDUCTIVITY		FREEZING POINT °F
			BTU/LB/°F	TEMP °F	LB/(HR)(FT)	TEMP °F		LB/CU FT P	TEMP °F	K	TEMP °F	
Acetaldehyde	69.44	245.1			0.558	68		48.9	64.4			−192.3
Acetic Acid	245.3	174.1	0.522	79-203	2.956	68	84.0	65.49	68	0.099	68	61.9
Acetone	133.2	228.9	0.514	37-73	0.801	68	42.1	49.4	68	0.102	86	−139.6
Alcohol												
• Allyl	206.6	294.1	0.655	70-205	3.298	68		53.31	68	0.104	77-86	−200.2
• Amyl	280.6	216.3			9.686	73.4	48.0	51.06	59	0.094	86	−110.2
• Ethyl	173.3	367.5	0.680	32-208	2.889	68	46.4	50.0	68	0.082	68	−162.4
• Isobutyl	226.4	249	0.116	68	9.450	68		49.27	68	0.105	68	−179.1
• Methyl	148.9	473.0	0.601	59-68	1.434	68	42.7	49.40	68	0.124	68	−144.0
Ammonia	−28	583.2	1.099	32	0.643	−28.3	142.9	43.50	−50	0.290	5-86	−107.9
Aniline	363.8	186.6	0.512	46-180	10.806	68	48.8	63.77	68	0.100	32-68	20.84
Benzene	176.2	169.4	0.412	68	1.580	68	54.2	54.9	68	0.085	68	42.0
Bromine	137.8	79.4	0.107	68	2.390	68	28.5	194.7	68			19.0
Brine, $CaCl_2$ (20% by wt)			0.744	68	4.800	68		73.8	68	0.332	68	2.0
Carbon Disulfide	115.3	148.8	0.240	68	0.880	68	24.8	78.9	68	0.093	86	−168.0
Carbon Tetra-chloride	170.2	83.7	0.201	68	2.340	68	12.8	99.5	68	0.062	68	−9.0
Chloroform	142.3	106.0	0.234	68	1.360	68		92.96	68	0.075	68	−81.8
Ethyl Ether	94.06	151.0	0.541	68	0.560	68	42.4	44.61	68	0.081	68	−177.3
Ethyl Acetate	170.8	183.8	0.468	68	1.090	68	51.2	52.3	68	0.101	68	−116.3
Ethyl Chloride	54.2	165.9	0.368	32			29.68	56.05	68	0.179	33.6	−213.5
Ethylene Bromide	268.8	99.2	0.174	68	0.0694	68	24.82	136.05	68			49.2
Ethylene Chloride	182.3	153.4	0.301	68	0.0338	68	38.02	77.10	68			−31.64
Ethylene Glycol	388.4	344.0					77.86	69.22	68	0.100	68	12.7
Formic Acid	213.3	215.8	0.526	68	0.0719	68	118.89	76.16	68	0.104	33	47.1
Glycerine (glycerol)	359 (20 mm)				43.100	68		78.72	68	0.113	68	68.0
Heptane	209.2	138.0	0.532	68	0.990	68	60.4	42.7	68	0.0741	68	−132.0
Hexane	154	145.0	0.538	68	0.775	68	65.0	41.1	68	0.0720	68	−139.0
Hydrogen Chloride	−120.8	191.0					23.6	74.6	b.p.			−174.6
Kerosene	400-560		0.500	68	6.000	68		51.2	68	0.086	68	
Linseed Oil					104.000	68		58.0	68			−11.0[1]
Methyl Acetate	134.6	177.0	0.468	68		68		60.6	68	0.093	68	−144.6
Methyl Iodide	108.5	82.6			1.210	68		142.0	68			−87.7
Naphthalene	411.4	136.0	0.402	m.p.	2.180	m.p.	64.9	60.9	m.p.			176.4
Nitric Acid	186.8	270.0	0.420	68	2.200	68	71.5	94.45	68	0.160	68	−42.9
Nitrobenzene	411.6	142.0	0.348	68	5.200	68	40.28	75.2	68	0.960	68	42.3
Octane	258.3	131.7	0.510	68	1.360	68	77.70	43.9	68	0.084	68	−69.7
Petroleum		98-165	0.4-0.6	68	19-2900	68		40-66	68			
n-Pentane	96.8	153.6	0.558	68	0.546	68	50.1	39.1	68	0.066	68	−201.5
Sodium Chloride Brine												
• 20% by wt.	220.8		0.745	68	3.800	68		71.8	68	0.337	68	2.6
• 10% by wt.	215.5		0.865	68	2.850	68		66.9	68	0.343	68	20.6
Sulfuric Acid and Water												
• 100% by wt.	550.0		0.335	68	53.000	68		114.4	68			50.9
• 90% by wt.	500.0		0.390	68	60.000	68		113.4	68	0.220	68	15.0
Toluene ($C_6H_5CH_3$)	231.0	156.0	0.404	68	1.420	68	30.9	54.1	68	0.090	68	−139.0
Turpentine	303.0	123.0	0.420	68	1.320	68		53.9	68	0.073	68	
Water	212.0	970.3	0.999	68	2.390	68	143.5	62.32	68	0.348	68	32.018
Xylene $C_6H_4(CH_3)_2$												
• Ortho	291.0	149.0	0.411	68	2.010	68	55.1	55.0	68	0.900	68	−13.0
• Meta	283.0	147.0	0.400	68	1.520	68	46.9	54.1	68	0.900	68	−53.0
• Para	281.0	146.0	0.393	68	1.620	68	69.3	53.8	68			+56.0

Notes:
1. Approximate solidification temperature.
2. Thermal conductivity units are Btu/(hr)(sq ft)(°F per ft)

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TABLE 48 HEAT TRANSFER AND ELECTRICAL FORMULAS

HEAT TRANSFER FORMULAS

HEAT TRANSMISSION	Q_{Tot}	$= U \times A \times \Delta t$
PRODUCT LOADS	Q_{Tot}	$= Q_1 + Q_{Lat} + Q_2 + Q_{Res}$
	Q_{Sens}	$= W \times C_{1\,or\,2} \times \Delta t$
	Q_{Lat}	$= W \times h_L$
	Q_{Res}	$= W \times h_r$
COOLING COILS	Q_{Tot}	$= 4.5 \times Cfm \times \Delta h$
	Q_{Sens}	$= 1.08 \times Cfm \times \Delta t$
	Q_{Lat}	$= 0.68 \times Cfm \times \Delta SH$
	lbs/hr	$= \dfrac{4.5 \times Cfm \times \Delta SH}{7000\ gr/lb}$
HEATING COILS	Q_{Sens}	$= 1.08 \times Cfm \times \Delta t$
HEAT RECLAIM AND CONDENSER COILS	Q_{Sens}	$= 1.08 \times Cfm \times \Delta t$
WATER HEATING	Q_{Tot}	$= 500 \times Gpm \times (T_{LW} - T_{EW})$
WATER COOLING	Q_{Tot}	$= 500 \times Gpm \times (T_{EW} - T_{LW})$

KEY TO SYMBOLS

Q_{Tot} —	Total Heat in Btu/hr
U —	Heat Transfer Coefficient in Btu/hr/sq ft/°F
A —	Surface Area thru which Heat is Conducted
Δt —	Temperature Difference Between Initial & Final Product Temp., Storage and Outside Temp., or Entering & Leaving Air Temperature
Q_1 —	Sensible Product Heat Removal Above Freezing in Btu/hr
Q_2 —	Sensible Product Heat Removal Below Freezing in Btu/hr
Q_{Sens} —	Sensible Heat in Btu/hr
Q_{Lat} —	Latent Heat in Btu/hr
Q_{Res} —	Respiration Heat in Btu/hr
C_1 —	Specific Heat Above Freezing in Btu/lb/°F
C_2 —	Specific Heat Below Freezing in Btu/lb/°F
H_L —	Latent Heat Of Fusion in Btu/lb
H_R —	Heat Of Respiration in Btu/hr/lb
Cfm —	Cubic Feet per Minute
ΔH —	Enthalpy Difference Between Entering & Leaving Wet Bulb in Btu/lb
ΔSH —	Specific Humidity Difference (Grains of Water Removed per lb of Air).
Gpm —	Gallons per Minute
T_{EW} —	Entering Water Temp. in °F
T_{LW} —	Leaving Water Temp. in °F
W —	Product Weight in Pounds

ELECTRICAL FORMULAS

Full Load Current (Single Phase) $= \dfrac{\text{Watts}}{\text{Voltage}}$ $\qquad I = \dfrac{P}{E}$

Full Load Current (Three Phase) $= \dfrac{\text{Watts}}{1.732 \times \text{Voltage}}$ $\qquad I = \dfrac{P}{1.732 \times E}$

Volts = Amperage × Resistance $\qquad E = I \times R$

Watts = Amperage × Voltage $\qquad P = I \times E$

$P_2 = P_1 \left(\dfrac{E_2}{E_1}\right)^2$

Watts (@ Voltage E_2) = Watts (@ Voltage E_1) × (Volts$_2$/Volts$_1$)^2

CONVERSION FACTORS

4.5 — Converts Cfm to lbs/hr

$4.5 = \dfrac{60\ \text{Minutes}}{13.35\ ft^3\ \text{per lb (Spec. Vol.)}}$

1.08 — Combines 4.5 With Specific Heat

$1.08 = 4.5 \times 0.24\ Btu/lb/°F$

0.68 — Combines 4.5 With Heat of Vaporization & Grains per lb

$0.68 = \dfrac{4.5 \times 1054.3\ Btu/lb}{7000\ gr/lb}$

500 — Converts Gpm Water to lb/hr

$500 = \dfrac{60\ \text{Minutes} \times 62.4\ lb/cu\ ft}{7.48\ gal/cu\ ft}$

Note: Heat Transfer Formulas are valid for standard air @ 69.8°F & 14.7 Psig; Conversion Factors must be utilized for other conditions.

TABLE 49 FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION CHART

TEMPERATURE			TEMPERATURE			TEMPERATURE			TEMPERATURE		
CELS.	C OR F	FAHR.	CELS	C OR F	FAHR.	CELS	C OR F	FAHR.	CELS	C OR F	FAHR.
−40.0	**−40**	−40.0	−6.7	**+20**	+68.0	+26.7	**+80**	+176.0	+60.0	**+140**	+284.0
−39.4	**−39**	−38.2	−6.1	**+21**	+69.8	+27.2	**+81**	+177.8	+60.6	**+141**	+285.8
−38.9	**−38**	−36.4	−5.5	**+22**	+71.6	+27.8	**+82**	+179.6	+61.1	**+142**	+287.6
−38.3	**−37**	−34.6	−5.0	**+23**	+73.4	+28.3	**+83**	+181.4	+61.7	**+143**	+289.4
−37.8	**−36**	−32.8	−4.4	**+24**	+75.2	+28.9	**+84**	+183.2	+62.2	**+144**	+291.2
−37.2	**−35**	−31.0	−3.9	**+25**	+77.0	+29.4	**+85**	+185.0	+62.8	**+145**	+293.0
−36.7	**−34**	−29.2	−3.3	**+26**	+78.8	+30.0	**+86**	+186.8	+63.3	**+146**	+294.8
−36.1	**−33**	−27.4	−2.8	**+27**	+80.6	+30.6	**+87**	+188.6	+63.9	**+147**	+296.6
−35.6	**−32**	−25.6	−2.2	**+28**	+ 82.4	+31.1	**+88**	+190.4	+64.4	**+148**	+296.4
−35.0	**−31**	−23.8	−1.7	**+29**	+84.2	+31.7	**+89**	+192.2	+65.0	**+149**	+300.2
−34.4	**−30**	−22.0	−1.1	**+30**	+86.0	+32.2	**+90**	+194.0	+65.6	**+150**	+302.0
−33.9	**−29**	−20.2	−0.6	**+31**	+87.8	+32.8	**+91**	+195.8	+66.1	**+151**	+303.8
−33.3	**−28**	−18.4	.0	**+32**	+89.6	+33.3	**+92**	+197.6	+66.7	**+152**	+305.6
−32.8	**−27**	−16.6	+0.6	**+33**	+91.4	+33.9	**+93**	+199.4	+67.2	**+153**	+307.4
−32.2	**−26**	−14.8	+1.1	**+34**	+93.2	+34.4	**+94**	+201.2	+67.8	**+154**	+309.2
−31.7	**−25**	−13.0	+1.7	**+35**	+95.0	+35.0	**+95**	+203.0	+68.3	**+155**	+311.0
−31.1	**−24**	−11.2	+2.2	**+36**	+96.8	+35.6	**+96**	+204.8	+68.9	**+156**	+312.8
−30.6	**−23**	−9.4	+2.8	**+37**	+98.6	+36.1	**+97**	+206.6	+69.4	**+157**	+314.6
−30.0	**−22**	−7.6	+3.3	**+38**	+100.4	+36.7	**+98**	+208.4	+70.0	**+158**	+316.4
−29.4	**−21**	−5.8	+3.9	**+39**	+102.2	+37.2	**+99**	+210.2	+70.6	**+159**	+318.2
−28.9	**−20**	−4.0	+4.4	**+40**	+104.0	+37.8	**+100**	+212.0	+71.1	**+160**	+320.0
−28.3	**−19**	−2.2	+5.0	**+41**	+105.8	+38.3	**+101**	+213.8	+71.7	**+161**	+321.8
−27.8	**−18**	−0.4	+5.5	**+42**	+107.6	+38.9	**+102**	+215.6	+72.2	**+162**	+323.6
−27.2	**−17**	+1.4	+6.1	**+43**	+109.4	+39.4	**+103**	+217.4	+72.8	**+163**	+325.4
−26.7	**−16**	+3.2	+6.7	**+44**	+111.2	+40.0	**+104**	+219.2	+73.3	**+164**	+327.2
−26.1	**−15**	+5.0	+7.2	**+45**	+113.0	+40.6	**+105**	+221.0	+73.9	**+165**	+329.0
−25.6	**−14**	+6.8	+7.8	**+46**	+114.8	+41.1	**+106**	+222.8	+74.4	**+166**	+330.8
−25.0	**−13**	+8.6	+8.3	**+47**	+116.6	+41.7	**+107**	+224.6	+75.0	**+167**	+332.6
−24.4	**−12**	+10.4	+8.9	**+48**	+118.4	+42.2	**+108**	+226.4	+75.6	**+168**	+334.4
−23.9	**−11**	+12.2	+9.4	**+49**	+120.2	+42.8	**+109**	+228.2	+76.1	**+169**	+336.2
−23.3	**−10**	+14.0	+10.0	**+50**	+122.0	+43.3	**+110**	+230.0	+76.7	**+170**	+338.0
−22.8	**−9**	+15.8	+10.6	**+51**	+123.8	+43.9	**+111**	+231.8	+77.2	**+171**	+339.8
−22.2	**−8**	+17.6	+11.1	**+52**	+125.6	+44.4	**+112**	+233.6	+77.8	**+172**	+341.6
−21.7	**−7**	+19.4	+11.7	**+53**	+127.4	+45.0	**+113**	+235.4	+78.3	**+173**	+343.4
−21.1	**−6**	+21.2	+12.2	**+54**	+129.2	+45.6	**+114**	+237.2	+78.9	**+174**	+345.2
−20.6	**−5**	+23.0	+12.8	**+55**	+131.0	+46.1	**+115**	+239.0	+79.4	**+175**	+347.0
−20.0	**−4**	+24.8	+13.3	**+56**	+132.8	+46.7	**+116**	+240.8	+80.0	**+176**	+348.8
−19.4	**−3**	+26.6	+13.9	**+57**	+134.6	+47.2	**+117**	+242.6	+80.6	**+177**	+350.6
−18.9	**−2**	+28.4	+14.4	**+58**	+136.4	+47.8	**+118**	+244.4	+81.1	**+178**	+352.4
−18.3	**−1**	+30.2	+15.0	**+59**	+138.2	+48.3	**+119**	+246.2	+81.7	**+179**	+354.2
−17.8	**0**	+32.0	+15.6	**+60**	+140.0	+48.9	**+120**	+248.0	+82.2	**+180**	+356.0
−17.2	**+1**	+33.8	+16.1	**+61**	+141.8	+49.4	**+121**	+249.8	+82.8	**+181**	+357.8
−16.7	**+2**	+35.6	+16.7	**+62**	+143.6	+50.0	**+122**	+251.6	+83.3	**+182**	+359.6
−16.1	**+3**	+37.4	+17.2	**+63**	+145.4	+50.6	**+123**	+253.4	+83.9	**+183**	+361.4
−15.6	**+4**	+39.2	+17.8	**+64**	+147.2	+51.1	**+124**	+255.2	+84.4	**+184**	+363.2
−15.0	**+5**	+41.0	+18.3	**+65**	+149.0	+51.7	**+125**	+257.0	+85.0	**+185**	+365.0
−14.4	**+6**	+42.8	+18.9	**+66**	+150.8	+52.2	**+126**	+258.8	+85.6	**+186**	+366.8
−13.9	**+7**	+44.6	+19.4	**+67**	+152.6	+52.8	**+127**	+260.6	+86.1	**+187**	+368.6
−13.3	**+8**	+46.4	+20.0	**+68**	+154.4	+53.3	**+128**	+262.4	+86.7	**+188**	+370.4
−12.8	**+9**	+48.2	+20.6	**+69**	+156.2	+53.9	**+129**	+264.2	+87.2	**+189**	+372.2
−12.2	**+10**	+50.0	+21.1	**+70**	+158.0	+54.4	**+130**	+266.0	+87.8	**+190**	+374.0
−11.7	**+11**	+51.8	+21.7	**+71**	+159.8	+55.0	**+131**	+267.8	+88.3	**+191**	+375.8
−11.1	**+12**	+53.6	+22.2	**+72**	+161.6	+55.6	**+132**	+269.6	+88.9	**+192**	+377.6
−10.6	**+13**	+55.4	+22.8	**+73**	+163.4	+56.1	**+133**	+271.4	+89.4	**+193**	+379.4
−10.0	**+14**	+57.2	+23.3	**+74**	+165.2	+56.7	**+134**	+273.2	+90.0	**+194**	+381.2
−9.4	**+15**	+59.0	+23.9	**+75**	+167.0	+57.2	**+135**	+275.0	+90.6	**+195**	+383.0
−8.9	**+16**	+60.8	+24.4	**+76**	+168.8	+57.8	**+136**	+276.8	+91.1	**+196**	+384.8
−8.3	**+17**	+62.6	+25.0	**+77**	+170.6	+58.3	**+137**	+278.6	+91.7	**+197**	+386.6
−7.8	**+18**	+64.4	+25.6	**+78**	+172.4	+58.9	**+138**	+280.4	+92.2	**+198**	+388.4
−7.2	**+19**	+66.2	+26.1	**+79**	+174.2	+59.4	**+139**	+282.2	+92.8	**+199**	+390.2

Notes: 1. The numbers in bold-face type in the center column refer to the temperature, either in Celsius or Fahrenheit, which is to be converted to the other scale. If converting Fahrenheit to Celsius, the equivalent temperature will be found in the left column. If converting Celsius to Fahrenheit, the equivalent temperature will be found in the column on the right.

2. 1 Degree Celsius = 1 Kelvin

3. Formula: Temp °F = 9/5 Temp. °C + 32; Temp. °C = 5/9 (Temp. °F − 32)

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CHART 1 ESTIMATING UNIT COOLER CAPACITIES

GENERAL:

It is often necessary in the expansion or re-application of a cold storage room to estimate the capacity of existing equipment. Additionally, it is sometimes necessary to physically check evaporators to determine whether they are actually working. Chart 1 may be used for this purpose.

STEPS TO FOLLOW:

(1) Measure entering air temperature (t_1) and Leaving air temperature (t_2).

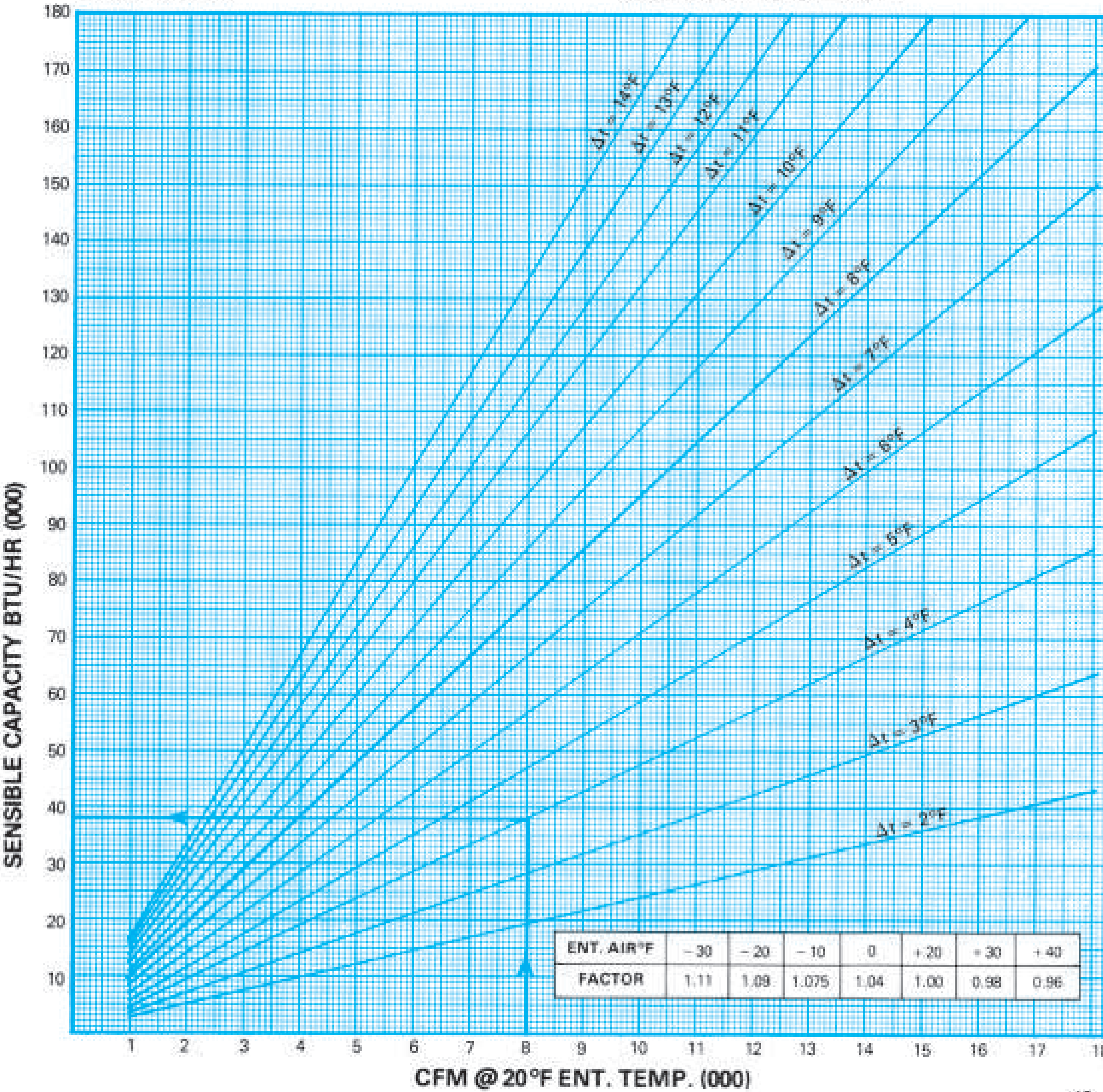
(2) Calculate Δt: $\Delta t = t_{1\,°F} - t_{2\,°F}$

(3) Measure face velocity and face area.

(4) Calculate Cfm: $\mathbf{Cfm} = \mathbf{Vel}_{fpm} \times \mathbf{Area}_{ft^2}$

(5) Enter chart on the x-axis at the calculated Cfm and move vertically to the Δt calculated above. Read indicated capacity on the y-axis.

(6) Apply the appropriate correction factor from the chart below to the indicated capacity for entering air temperatures other than +20°F.



ENT. AIR°F	−30	−20	−10	0	+20	+30	+40
FACTOR	1.11	1.09	1.075	1.04	1.00	0.98	0.96

CHART 2

NORMAL TEMPERATURE PSYCHROMETRIC CHART (32 TO 130°F)
STANDARD ATMOSPHERIC PRESSURE OF 29.921 IN HG

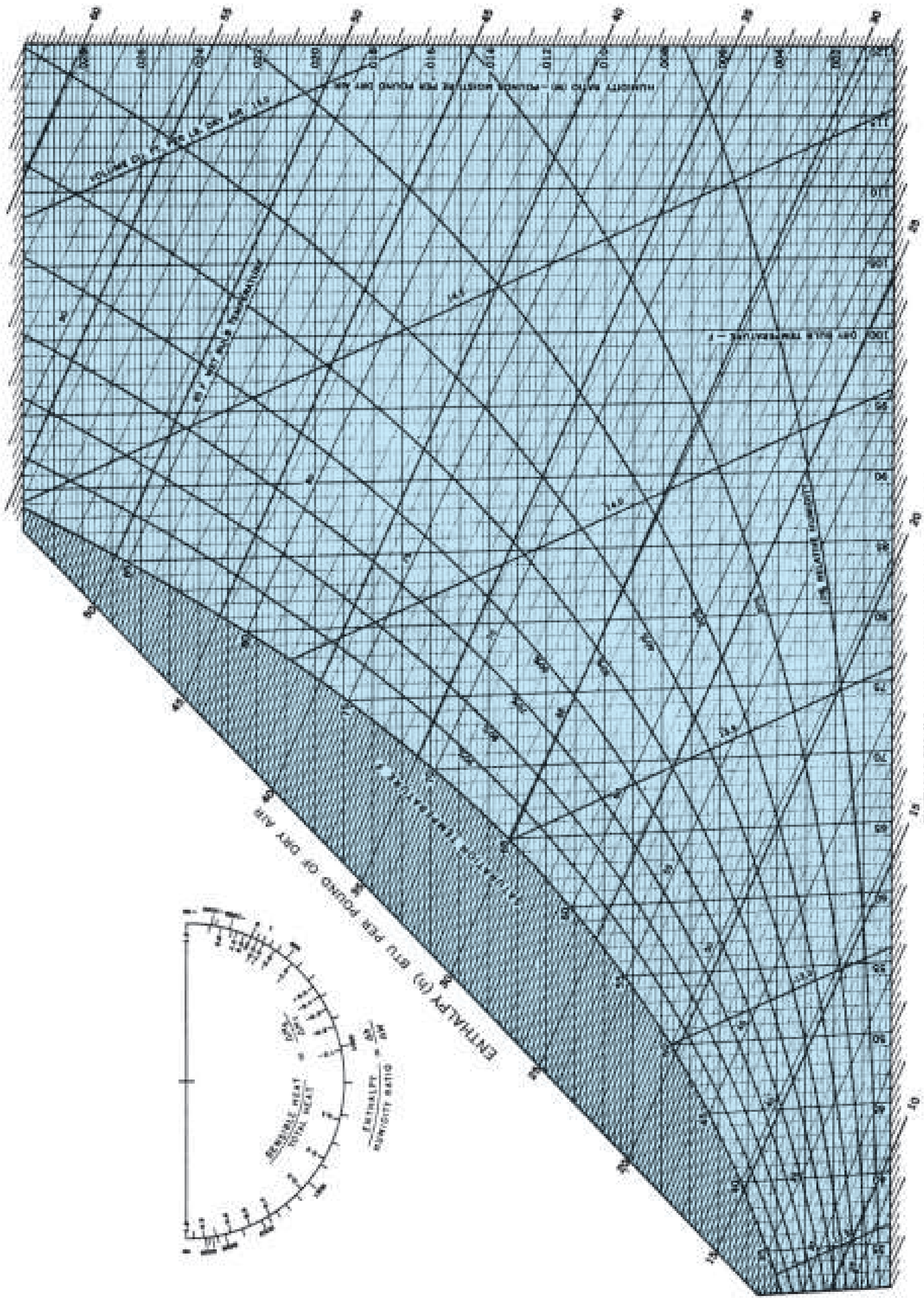


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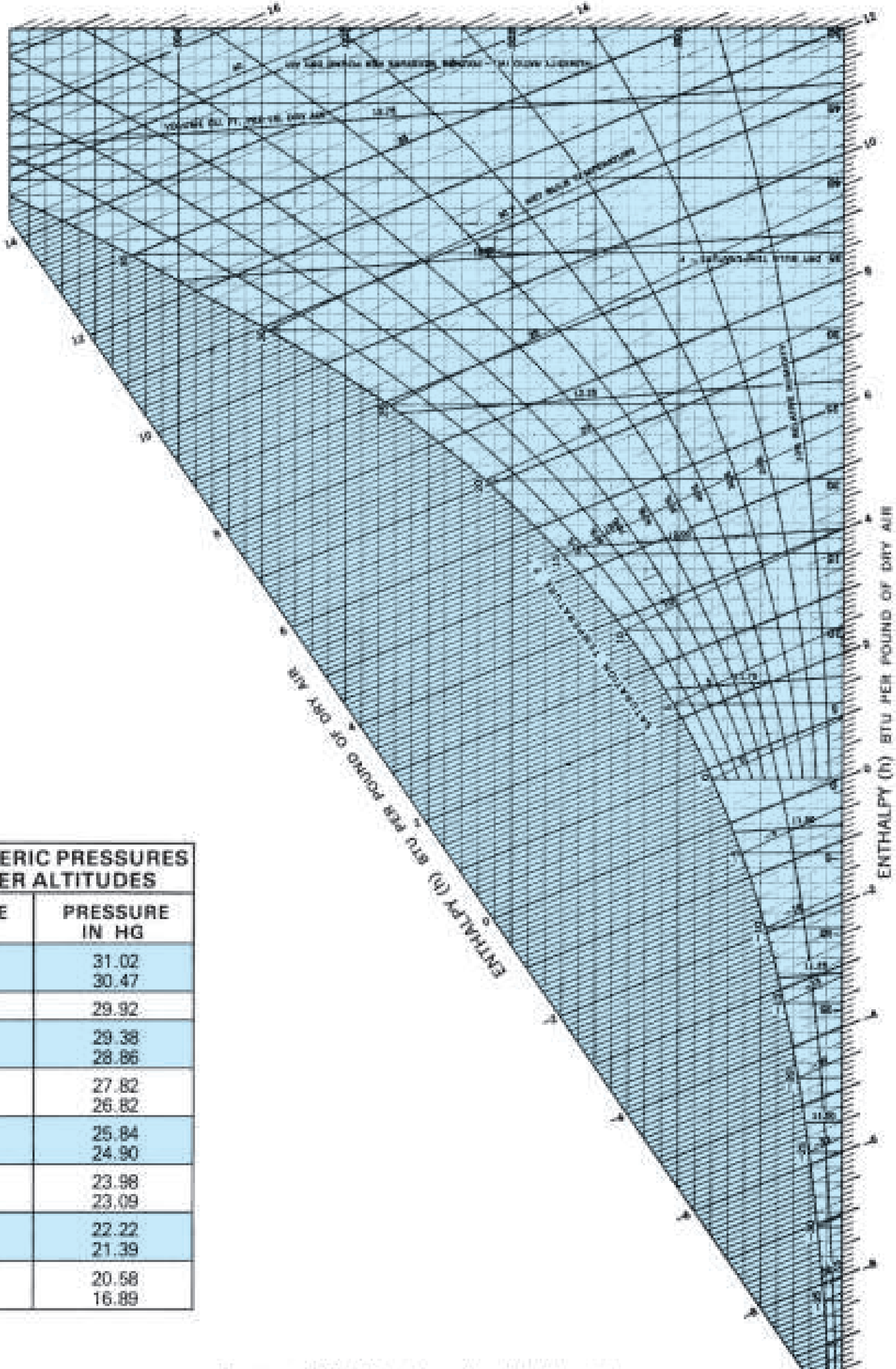
CHART 3 LOW TEMPERATURE PSYCHROMETRIC CHART (– 40 TO 50°F) STANDARD ATMOSPHERIC PRESSURE OF 29.921 IN HG



ATMOSPHERIC PRESSURES AT OTHER ALTITUDES	
ALTITUDE FT	PRESSURE IN HG
– 1000	31.02
– 500	30.47
0	29.92
500	29.38
1000	28.86
2000	27.82
3000	26.82
4000	25.84
5000	24.90
6000	23.98
7000	23.09
8000	22.22
9000	21.39
10000	20.58
15000	16.89

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INDEX OF APPENDIX

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