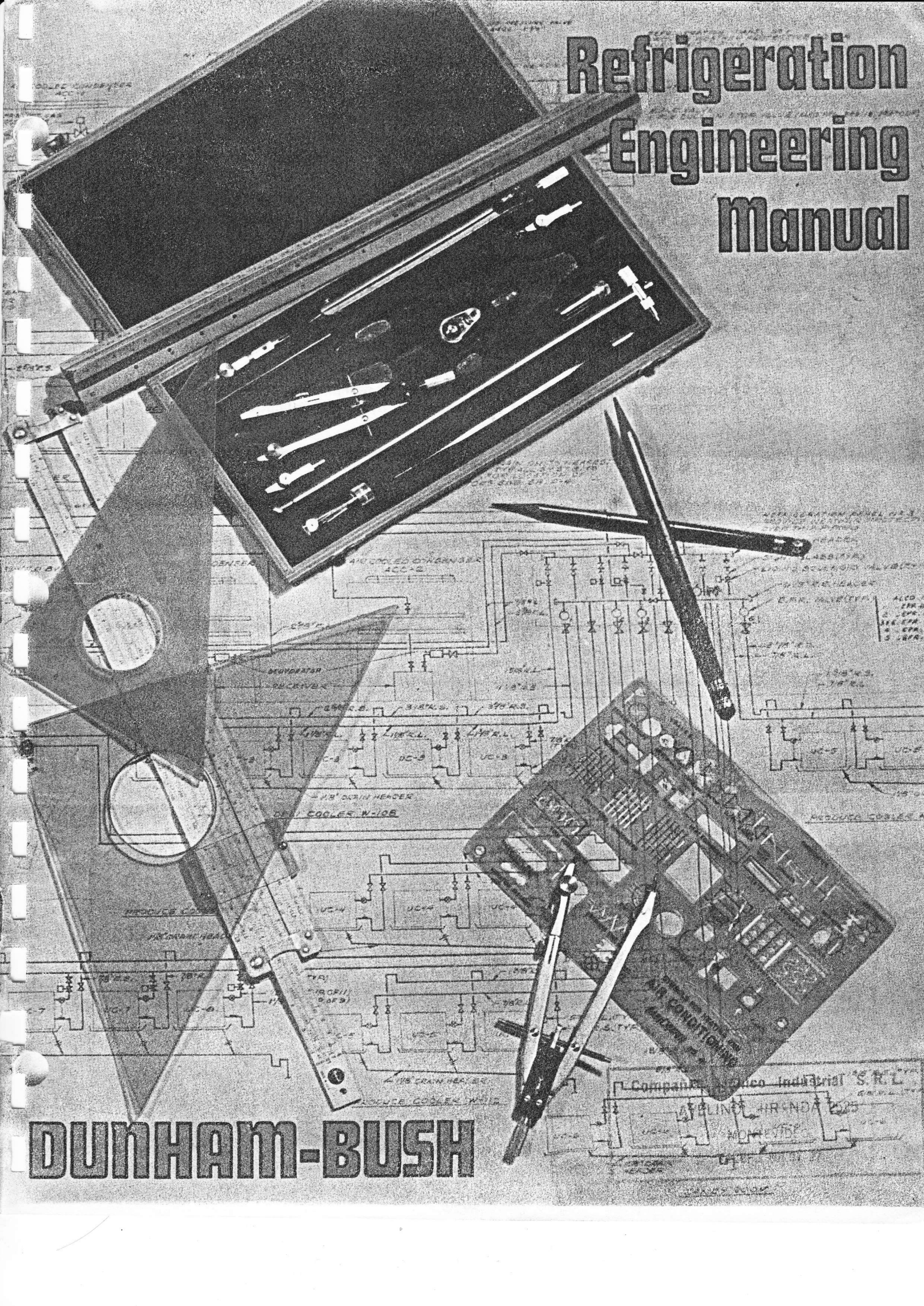


Refrigeration Engineering Manual



DUNHAM-BUSH

INTRODUCTION

The Dunham-Bush Refrigeration Load Engineering Manual is a composite of technical information prepared specifically to permit accurate and simplified load calculation procedures. All facets of estimating are covered in detail, starting with the preliminary job survey through the selection of refrigeration equipment.

The refrigeration load estimate form is designed to enable the user to include a basic facility layout, outline all pertinent load survey and estimating data, complete calculations and select the required equipment. A short form method is included for applications where information is incomplete for product, infiltration or miscellaneous loads.

Certain tabular information has been extracted from ASHRAE Handbooks. All other data has been compiled by Dunham-Bush specifically for this publication.

General information on refrigeration terminology, nomenclature, formula, conversion factors, altitude and temperature effects has been included to support the tables and forms contained in the manual.

If assistance is required for specialized applications or system design, contact your local Dunham-Bush sales representative or the West Hartford Conn. Systems Application Engineering Group.

This manual represents the work of one of Dunham-Bush's most loyal and dedicated employees, Edward Cook B.S., M.S., whose engineering experience and knowledge are well respected throughout our industry. He has brought together a great deal of knowledge relating to the art of refrigeration load estimating.

This work will add to the science of refrigeration by placing at the disposal of engineers, architects and students a workable reference covering refrigeration load estimating.

We are sure that you in the refrigeration industry will join us in expressing appreciation to Edward Cook for his dedicated labor in this work.

INDEX

DESCRIPTION	PAGE
Refrigeration Load Estimate Form	I - IV
Load Estimating Examples	V - VIII
Job Survey	1
Refrigeration Load Calculations	1-4
Wall Heat Load	1
Air Change Load	2
Product Load	2-3
Miscellaneous Loads	3
Safety Factor	3
Summary of Load Calculations	4
Selection and Balancing	4-6
Forced Air Cooling Units	6
Selection of Refrigeration Equipment	6-7
The Short Method	7
Quick Selection Walk-In Coolers & Freezers	7
Proper Sizing of Expansion Valves	8
The Heat Exchanger	8
Warehousing	8
Refrigeration Terminology	35-36
Properties of Water	36
Nomenclature	36
Conversion Factors & Formula	36
Altitude Effects	37
Electrical Formulas	38

TABLE

DESCRIPTION

PAGE

9	Air Changes per 24 Hours for Storage Rooms Above 32°F	.11
10	Air Changes per 24 Hours for Storage Rooms Below 32°F	.11
50	Altitude Effects on Air Cooled Equipment	.37
	Beer	
21	Approximate Time Required to Cool Half Kegs to 40°F in 34°F Room with Forced Air Circulation	.19
24	Back Bar Heat Leakage and Total Load	.19
20	Container Data	.18
23	Heat Load due to Air Infiltration when Storing Containers	.19
22	Quick Selection Beer Storage Walk-In Coolers Based on 4" Corkboard or Equivalent and 50°F TD	.19
25	Beverage Container Data (Soft Drinks - Soda)	.19
	Candy	
39	Expected Storage Life	.26
40	Optimum Design Air Conditions	.27
29	Carcass Average Product Loads	.20
30	Cutting Room Loads	.20
51	English Conversion Factors	.39
54	English/Metric Conversion Factors	.39
4	Evaporator Base Load Multipliers	5
	Fish	
32	Average Water Content, and Specific and Latent Heats of Fishery Products	.25
34	Review of effect of Storage Temperature on Shelf Life of Some Frozen Fishery Products	.25
33	Storage Conditions and Storage Life of Frozen Fish	.25
41	Flowers and Nursery Stock, Storage Conditions for	.27
28	Fruit Temperatures for Banana Ripening	.20
13	Heat Equivalent of Electric Motors	.12
12	Heat Equivalent of Occupancy	.12
15	Heat Gain Usage BTU per 24 Hour for One Cu. Ft. Interior Capacity	.16
11	Heat Removed in Cooling Air to Refrigerator Conditions	.12
42	Heats of Respiration (Approx.)	.28
	Ice Cream	
26	Freezing and Hardening Loads	.19
18	Hardening Loads for Walk-In Freezers BTUH	.18
7	Insulation Thickness, Minimum	.11
52	Multiple & Sub Multiple Prefix Units for Metric & SI - English Conversion Factors	.39
27	Milk Cooling Data	.20
	Outside Area and Internal Volume of Coolers and Freezers	
14A	9 Foot High Outside	.13
14B	12 Foot High Outside	.14
14C	16 Foot High Outside	.15
46	Piling Heights using Pallets without Auxilliary Support	.31
19	Product Freezing Loads for Walk-In Freezers BTUH	.18
16	Product Loading (Average Daily) in Lbs. Per Cu. Ft. for Storage Coolers and Freezers	.16
43	Properties of Liquids	.29
44	Properties of Solids	.29
17	Quick Selection Walk-In Coolers and Freezers	.17
55	SI Metric Conversion Factors	.40
	Space Weight, and Density Data for Commodities Stored in Refrigerated Warehouses	
45A	Apples thru Frozen Fruits, Juices, Vegetables	.30
45B	Grapes thru Veal (Boneless)	.31
	Storage Requirements and Properties of Perishable Products	
31A	Fruits	.21
31C	Meat, Fish and Shellfish	.23
31D	Miscellaneous	.24
31B	Vegetables	.22
1	Storage Temperature and Humidity Conditions	4
8	Sun Effect, Allowance for	.11
	Temperature	
47	Conversion Chart: Fahrenheit - Celsius	.32
5	Design	9
35	Recommendations for Maintaining Quality of Fresh Vegetables in Wholesale Warehouses	.25
37	Recommended in Display Cases	.26
2	Temperature Difference - Coil TD for Four Classes of Foods	4
3	Temperature Difference Guidelines	4
51	Temperature Effects on Air Cooled Evaporators	.38
49	Temperature Loss Pressure Drop Curves	
	R12 Refrigerant	.34
	R22 Refrigerant	.34
	R502 Refrigerant	.34
48	Temperature/Pressure Chart	.33
	Vegetables	
38	Desirable Transit Temperature, Suggested Temperature to Specify and Highest Freezing Points	.26
36	Susceptible to Chilling Injury when at Moderately Low but Non-Freezing Temperatures	.26
6	Wall Heat Gain Table	.10

DUNHAM-BUSH

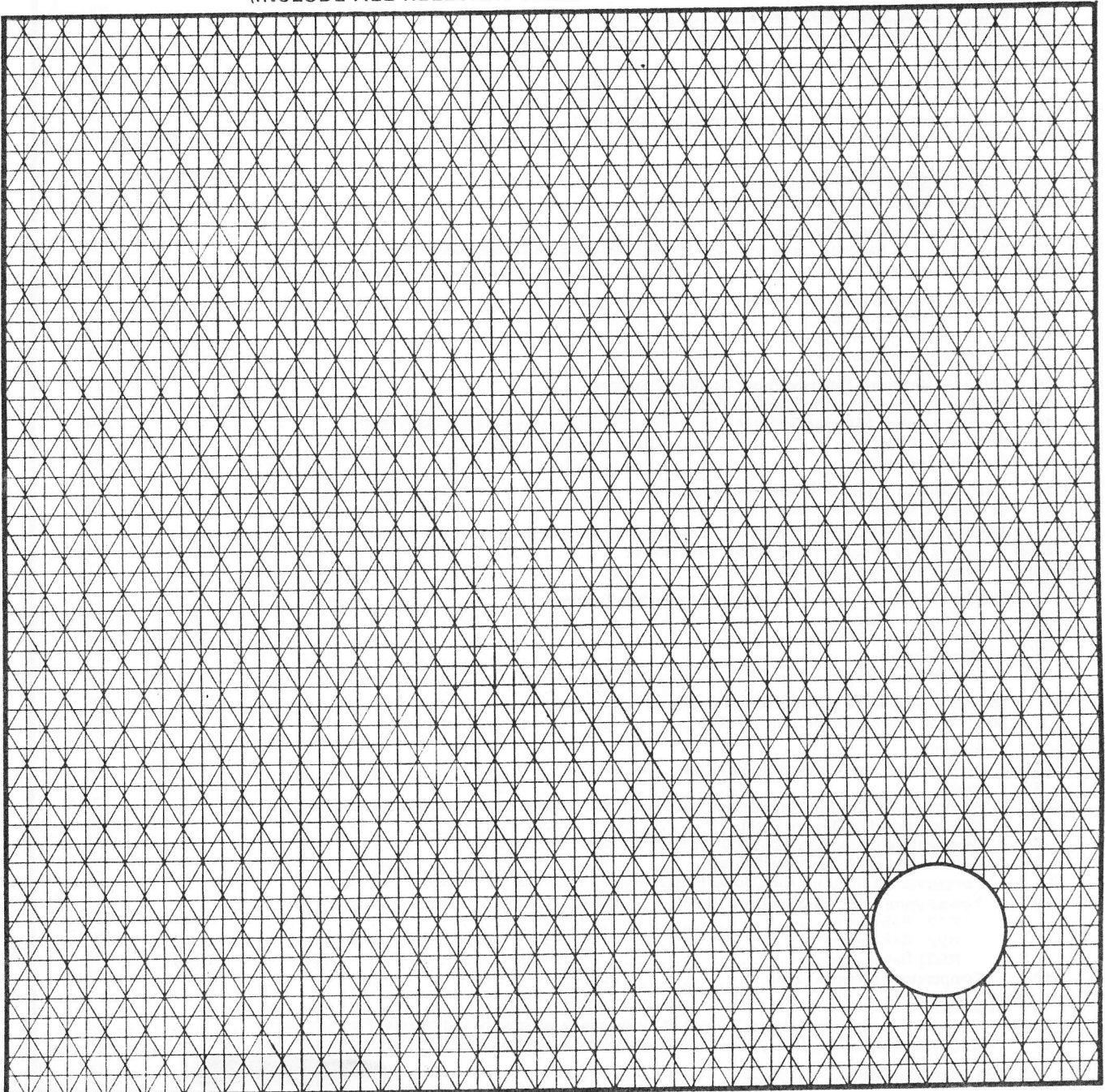
REFRIGERATION LOAD ESTIMATE FORM

FOR ROOMS ABOVE & BELOW FREEZING

SURVEY BY _____ OFFICE _____ DATE _____
CUSTOMER _____ ADDRESS _____
JOB NAME _____ ADDRESS _____
APPLICATION _____

FACILITY LAYOUT

(INCLUDE ALL RELEVANT FACILITY CONSTRUCTION FEATURES)



NOTE: INDICATE DIRECTION OF NORTH WITHIN CIRCLE

REFRIGERATION LOAD ESTIMATE FORM

FOR ROOMS ABOVE AND BELOW FREEZING

- LOAD SURVEY & ESTIMATING DATA -

REF.
TABLE

5, 5A

DESIGN AMBIENT: _____ °FDB, _____ °FWB, _____ %RH, _____ °F SUMMER GROUND TEMP.
(USE 55°F FOR INSULATED FREEZE FLOOR SLAB)

31A, B,
C, D 41

ROOM DESIGN: _____ °FDB, _____ °FWB, _____ %RH _____ °F WINTER DESIGN AMBIENT

ACCESS AREA: _____ °FDB, _____ °FWB, _____ %RH, (ANTE-RM/LOADING DOCK/OTHER)

14A,
B, C

ROOM DIM. OUTSIDE: _____ FT. W _____ FT. L _____ FT. H _____ TOTAL SQ. FT. (OUTSIDE SURFACE)

6
7
8

	Insulation (Table 6)				Wall Thick- ness	Adj. Area °F	Effective Wall TD	°F Sun Effect (Table 8)	Total TD	Overall Wall Heat Gain BTU/24 HRS/Sq. Ft. (Table 6)
	Type	Inches Thick	K Factor	U* Factor						
N. Wall										
S. Wall										
E. Wall										
W. Wall										
Ceiling										
Floor										

* 'U' - Factor = $\frac{K}{\text{Insul. Thickness (in.)}}$

REFRIG. DOOR(S): _____ VENT. FAN(S): _____

ROOM INT. VOL: _____ W x _____ L x _____ H = _____ CU. FT.

(INSIDE ROOM DIMENSION = OUTSIDE DIMENSION - WALL THICKNESSES)

FLOOR AREA _____ W x _____ L = _____ SQ. FT.

ELECTRICAL POWER _____ VOLTS, _____ PH. _____ HERTZ; CONTROL _____ VOLTS

TYPE CONTROL: _____

PRODUCT DATA AND CLASS OF PRODUCT: _____

31A - D
42

Type Product	Amount of Product (Refer to Pg. 2 Item 3)			Product Temp °F		TABLE 31				Table 42 Heat or Respir'n Btu/lb. 24 Hr.	() Pull-Down () Freezing Time Hrs.
	Amount Storage	Daily Turn-Over	Freezing or Cooling	Enter- ing	Final	Specific Heat		Lat. Ht. Freeze Btu/lb.	Highest Product Freeze Temp.		
						Above Freeze	Below Freeze				

EVAP. TD _____, TYPE DEFROST ☐ AIR, ☐ HOT GAS, ☐ ELECTRIC,

CLASS PRODUCT _____

NO. OF DEFROSTS & TOTAL TIME PER 24 HRS. _____ NO., _____ HRS.

COMPRESSOR RUNNING TIME _____ HRS.

BOX USAGE ☐ AVERAGE, ☐ HEAVY, ☐ EXTRA HEAVY

PRODUCT LOAD AND ADDITIONAL INFORMATION: _____

45A & B
46

PACKAGING _____ CONTAINERS _____ WGT. _____ SP. HT. _____ (CONTAINER)

PALLETS: NO. _____ SIZE _____ WGT. EA. _____ SP. HT. _____

PRODUCT RACKS: NO. _____ MAT'L _____ WGT. EA. _____ SP. HT. _____

45A & B

ESTIMATING PRODUCT LOADING CAPACITY OF ROOM

ESTIMATED PRODUCT LOADING = 0.40 x _____ CU. FT. x _____ LBS./CU. FT. = _____ LBS:
(ROOM VOLUME) (LOADING DENSITY)
(TABLE 45A OR B)

MISCELLANEOUS LOADS

PEOPLE NO. _____ HRS. _____

MOTORS (OTHER THAN EVAP. FAN)

USE: _____ HP, _____ HRS.
_____ HP, _____ HRS.

FORK LIFTS NO. _____ HP, _____ HRS./DAY, OTHER _____
(REFER TO PG. 3, ITEM 4)

LIGHTS _____ WATTS/SQ. FT. (REFER TO PG. 3, ITEM 4)

CALCULATIONS

REF. TABLE	I WALL LOSS (TRANSMISSION LOAD)			
6 14A, B, C	SURFACE	TD	AREA OF SURFACE	WALL HEAT GAIN FACTOR TABLE 6 BTU/24 HRS.
	N. Wall		Ft. L x Ft. H = Sq. Ft. x	=
	S. Wall		Ft. L x Ft. H = Sq. Ft. x	=
	E. Wall		Ft. L x Ft. H = Sq. Ft. x	=
	W. Wall		Ft. L x Ft. H = Sq. Ft. x	=
	Ceiling		Ft. L x Ft. W = Sq. Ft. x	=
	Floor		Ft. L x Ft. W = Sq. Ft. x	=
	Box		(TABLE 14A, B, C) Total: Surface = Sq. Ft. x	=
I Total Wall Transmission Load BTU/24 HRS. =				
14A, B, C 15	II_{SF} (SHORT FORM) USAGE HEAT GAIN () AVG. () HVY. () EX. HVY. COOLERS ONLY Refer to II _{LF} (Long Form) if application exceeds data shown in Table 15. (INT. BOX VOLUME) (TABLE 14) CU. FT. x BTU/24 HR./CU. FT. (@ TD) = (USAGE HEAT GAIN) (TABLE 15) NOTE: IF PRODUCT LOADS ARE UNUSUAL USE THE LONG FORM EX. HVY. = 1½ x HVY. USAGE TOTAL I + II_{SF} =			
	IF USAGE HEAT GAIN ABOVE IS USED DO NOT USE (II _{LF} III & IV)			
14A, B, C 9 or 10 11	II_{LF} (LONG FORM) INFILTRATION (AIR CHANGE LOAD) (TABLE 14) CU. FT. x (TABLE 9 OR 10) AIR CHANGES/24 HRS. x (FROM NOTES TABLE 9 OR 10) SRVC. FACTOR x (TABLE 11) BTU/CU. FT. =			
II INFILTRATION LOAD BTU/24 HRS. =				
31A, B, C 32 42 44	III PRODUCT LOAD			
	PRODUCT TEMP. REDUCTION ABOVE FREEZING (SENSIBLE HEAT)			
	* LBS./DAY x °F TEMP. REDUCTION x SP. HT. =			
	PRODUCT FREEZING (LATENT HEAT LOAD)			
	* LBS./DAY x BTU/LB. LATENT HEAT =			
	PRODUCT TEMP. REDUCTION BELOW FREEZING (SENSIBLE HEAT)			
	* LBS./DAY x °F TEMP. REDUCTION x SP. HT. =			
	HEAT OF RESPIRATION			
LBS. PRODUCT (STORAGE) x BTU/LB./24 HRS. =				
MISCELLANEOUS PRODUCT LOADS (1) CONTAINERS (2) PALLETS (3) OTHER				
LBS./DAY x °F TEMP. REDUCTION x SP. HT. =				
LBS./DAY x °F TEMP. REDUCTION x SP. HT. =				
III TOTAL PRODUCT LOAD BTU/24 HRS. =				
12 13	IV MISCELLANEOUS LOADS			
	(a) LIGHTS Ft. ² Floor Area x Watts/Ft. ² x 3.41 Btu/Watt x HRS/24 HRS = (1 TO 1½ WATTS/SQ. FT. IN STORAGE AREAS & 2 TO 3 FOR WORK AREAS)			
	(b) OCCUPANCY NO. OF PEOPLE x BTU/HR. x HRS. =			
	(c) MOTORS BTU/HP/HR. x HP x HRS./24 HRS. = BTU/HP/HR. x HP x HRS./24 HRS. =			
	(d) MATERIAL HANDLING			
	FORK LIFT(S) x EQUIV. HP x 3100 BTU/HR./HP. x HRS. OPERATION = OTHER =			
IV TOTAL MISCEL. LOADS BTU/24 HRS. =				
* IF THE PRODUCT PULL-DOWN IS ACCOMPLISHED IN LESS THAN 24 HRS. THE DAILY PRODUCT WILL BE : LBS. PRODUCT x 24 HRS. / PULLDOWN HRS. =				
TOTAL BTU LOAD I TO IV BTU/24 HRS. =				
ADD 10% SAFETY FACTOR =				
TOTAL BTU/24 HRS. WITH SAFETY FACTOR (NOT INCLUDING EVAP. FAN OR DEFROST HEAT LOADS) 24 HR. BASE REFRIGERATION LOAD =				

REF. TABLE	EQUIPMENT SELECTION FROM LOAD CALCULATION FORM
1, 2	1. DETERMINE EVAP. TD REQUIRED FOR CLASS OF PRODUCT AND ROOM TEMP. _____ °F (TD) (FROM LOAD SURVEY DATA)
43	2. DETERMINE COMPRESSOR RUNNING TIME BASED ON OPERATING TEMPERATURES AND DEFROST REQUIREMENTS _____ HRS. (FROM LOAD SURVEY DATA)
	3. EVAPORATOR TEMP. °F = _____ - _____ = _____ °F (ROOM TEMP) (EVAP. TD**) **FROM LOAD SURVEY DATA
49	4. COMP. SUCT. TEMP. °F = _____ - _____ = _____ °F (EVAP. SUCT. TEMP) (SUCT. LINE LOSS)
13	<p>BTU/24 HR. BASE REFRIGERATION LOAD WITH SAFETY FACTOR = _____ (NOT INCLUDING EVAPORATOR FAN OR DEFROST HEAT)</p> <p>REFER TO PAGES 6 AND 7 "SELECTION OF REFRIGERATION EQUIPMENT TO DETERMINE PROCEDURE FOR EQUIPMENT SELECTION.</p> <p>PRELIMINARY HOURLY LOAD = _____ BTU/24 HR. (BASE LOAD) = _____ BTU/HR. HRS./DAY (COMP' RUNNING TIME)</p> <p>FAN HEAT LOAD ESTIMATE BTU/HR. =</p> <p>_____ QTY. x _____ WATTS EA. x 3.41 BTU/WATT x _____ HRS. = _____ BTU/24 HRS. (MOTORS) (INPUT)</p> <p>OR _____ QTY. x _____ HP EA. x _____ BTU/HP/HR. x _____ HRS. = _____ BTU/24 HRS. (MOTORS) (TABLE 13)</p> <p>DEFROST HEAT LOAD ESTIMATE BTU/HR =</p> <p>_____ QTY. EVAPS. x _____ WATTS EA. x _____ HRS. x 3.41 BTU/WATT x _____ DEFROST LOAD FACTOR* = _____ BTU/24 HRS.</p> <p>*USE 0.50 FOR ELECTRIC DEFROST 0.40 FOR HOT GAS DEFROST</p> <p>BTU/24 HR. TOTAL LOAD = _____ + _____ + _____ = _____ BTU/24 HRS. (BASE LOAD) (FAN HEAT) (DEFROST HEAT)</p> <p>OR _____ x _____ = _____ BTU/24 HRS. (Refer to Pg. 5) (BASE LOAD) (BASE LOAD MULT.)</p> <p>ACTUAL HOURLY LOAD = _____ BTU/24 HRS. (TOTAL LOAD) = _____ BTU/HR. HRS./DAY (COMP. RUNNING TIME)</p>

EQUIPMENT SELECTION

	COMPRESSOR UNITS		CONDENSING UNITS		EVAPORATORS		CONDENSERS	
MODEL NO.								
QUANTITY								
BTU/HR. CAPACITY (EA.)								
CFM AIR VOLUME (EA.)								
	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
°F EVAPORATOR TEMP.								
°F EVAP TD								
°F SUCTION TEMP.								
°F CONDENSING TEMP.								
°F DESIGN AMBIENT TEMP.								
°F MIN. OPER. AMBIENT TEMP.								

LOAD ESTIMATING EXAMPLE NO. 1

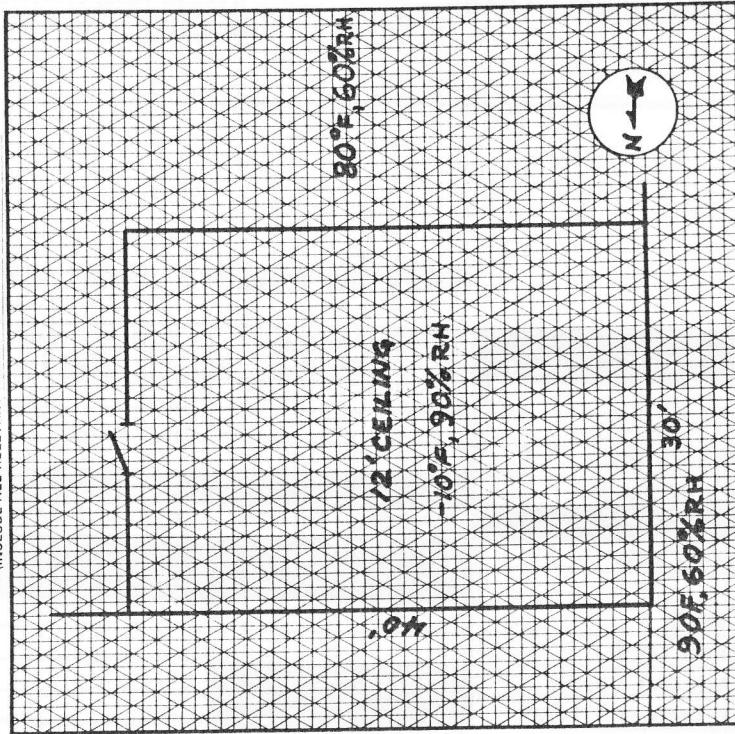
DUNHAM-BUSH

REFRIGERATION LOAD
ESTIMATE FORM
FOR ROOMS ABOVE & BELOW FREEZING

SURVEY BY JIM JONES OFFICE NEW YORK DATE 4-1-79
CUSTOMER REFRIG. SYS. INC. ADDRESS 157 LEXINGTON AVE. N.Y.C.
JOB NAME FREEZE-RITE FOODS ADDRESS 25 PARK RIVER RD. N.Y.C.
APPLICATION Frozen Foods

FACILITY LAYOUT

(INCLUDE ALL RELEVANT FACILITY CONSTRUCTION FEATURES)



NOTE: INDICATE DIRECTION OF NORTH WITHIN CIRCLE

REFRIGERATION LOAD ESTIMATE FORM
FOR ROOMS ABOVE AND BELOW FREEZING

LOAD SURVEY & ESTIMATING DATA

DESIGN AMBIENT: 90 °FDB 77 °FWB 60 °RH 65 °F SUMMER GROUND TEMP
USE 55 °F FOR INSULATED FREEZE FLOOR SLAB
ROOM DESIGN: -10 °FDB °FWB 90 °RH °F WINTER DESIGN AMBIENT
ACCESS AREA: 80 °FDB °FWB 60 °RH (ANTE RM/LOADING DOCK/OTHER)
ROOM DIM. OUTSIDE: 30 FT W 40 FT L 12 FT H 4080 TOTAL SQ. FT. OUTSIDE SURFACE)

Type	Insulation (Table B)	U-Factor	Wall Area	Effective Temp. (Table B)	Adj. Heat Loss (Table B)	Total Heat Loss (Table B)	Overall Wall Heat Gain BTU/24 HRS Sq. Ft.
N Wall	6	0.033	8	90	100	100	80
S Wall	6	0.033	8	80	90	90	72
E Wall	6	0.033	8	80	90	90	72
W Wall	6	0.033	8	80	90	90	72
Ceiling	6	0.033	8	80	90	90	72
Floor	4	0.025	10	90	100	20	72
							72

* U-Factor = Insul. Thickness (in.)

REFRIG. DOOR(S): (1) 7' x 4' VENT (FANIS) —
ROOM INT. VOL. 28 2/3 W x 38 2/3 L x 10 2/3 H = 11823 CU. FT.
(INSIDE ROOM DIMENSION - WALL THICKNESSES)
FLOOR AREA 28 2/3 W x 38 2/3 L = 1108 SQ. FT.
ELECTRICAL POWER 440 VOLTS 3 PH 60 HERTZ CONTROL 115 VOLTS

TYPE CONTROL:

PRODUCT DATA AND CLASS OF PRODUCT: FROZEN FOODS (PACKAGED)

Type Product	Amount of Product (Table B)		Product Temp. °F	Specific Heat		Table 42 Heat of Fusion (Btu/lb)	Table 42 Heat of Respiration (Btu/lb 24 Hrs)
	Tons	Daily Amount		Lat. Heat	Product Temp. °F		
Frozen Foods	50	12	Freezing +5 -10	0.46	—	—	—

EVAP. TD. 10° TYPE DEFROST ☐ AIR ☐ HOT GAS, V.ELECTRIC.

CLASS PRODUCT —

NO. OF DEFROSTS & TOTAL TIME PER 24 HRS. 6 NO. 2 HRS.

COMPRESSOR RUNNING TIME 18 HRS.

BOX USAGE ☐ AVERAGE ☐ HEAVY ☐ EXTRA HEAVY

PRODUCT LOAD AND ADDITIONAL INFORMATION: PRODUCT ARRIVES IN REFRIGERATED TRUCKS. ALLOW 15° F PULLDOWN TO FREEZER TEMPERATURE. PRODUCT PACKAGED & SEALED IN CARTONS.

PACKAGING CARTONS CONTAINERS — WGT 1500 LBS SP. HT. .32 (CONTAINER)

PALLETS: NO 24 SIZE WGT EA. 35 LBS SP. HT. .6 840 LBS TOTAL

PRODUCT RACKS: NO. MAT'L WGT EA. SP. HT.

ESTIMATING PRODUCT LOADING CAPACITY OF ROOM

ESTIMATED PRODUCT LOADING = 0.40 x (ROOM VOLUME) LBS / CU. FT. x (LOADING DENSITY) LBS / CU. FT. = LBS

MISCELLANEOUS LOADS (TABLE 43) MOTORS (OTHER THAN EVAP. FAN) USE HP. HRS.

PEOPLE NO. 4 HRS 10

FORK LIFTS 2 NO. 4 HP 8 HRS / DAY, OTHER

LIGHTS 1/2 WATTS / SQ. FT. (REFER TO PG. 3, ITEM 4)

LOAD ESTIMATING EXAMPLE NO. 1 (CONTINUED)

CALCULATIONS

REF. TABLE	I WALL LOSS (TRANSMISSION LOAD)				WALL HEAT GAIN FACTOR TABLE 6		BTU/24 HRS.
	SURFACE	TD	AREA OF SURFACE	Sq. Ft. x	Sq. Ft. x		
6	N. Wall	100	40 Ft. L x 12 Ft. H =	480	Sq. Ft. x	80	38,400
14A, B, C	S. Wall	90	40 Ft. L x 12 Ft. H =	480	Sq. Ft. x	72	34,560
	E. Wall	90	30 Ft. L x 12 Ft. H =	360	Sq. Ft. x	72	25,920
	W. Wall	106	30 Ft. L x 12 Ft. H =	360	Sq. Ft. x	84.8	30,528
	Ceiling	120	40 Ft. L x 30 Ft. W =	1200	Sq. Ft. x	72	86,400
	Floor	65	40 Ft. L x 30 Ft. W =	1200	Sq. Ft. x	78	93,600
	Box		(Table 14A, B, C) Total Surface =	4080	Sq. Ft. x		309,408
	II SF (SHORT FORM) USAGE HEAT GAIN (AVG. () EX. HVY.) Refer to II, f (Long Form) if application exceeds data shown in Table 15. NOTE: IF PRODUCT LOADS ARE UNUSUAL USE THE LONG FORM. EX. HVY. = 1 1/2 x HVY. USAGE						
14A, B, C	II LF (LONG FORM) INFILTRATION (AIR CHANGE LOAD) 11,823 CU. FT. x 12.5 AIR CHANGES/24 HRS. x 1.5 SVC. FACTOR x 2.8 BTU/CU. FT. (TABLE 14) = 620,707						
31A, B, C	III PRODUCT LOAD PRODUCT TEMP. REDUCTION ABOVE FREEZING (SENSIBLE HEAT) *LBS./DAY x °F TEMP. REDUCTION x BTU/LB. LATENT HEAT *LBS./DAY x °F TEMP. REDUCTION x 0.46 BTU/LB. (24 HRS.) 127005 x 2000 x 15 x 15 = 165,600 MISCELLANEOUS PRODUCT LOADS (1) CONTAINERS (2) PALLETS (3) OTHER 1500 LBS./DAY x 15 = 7,200 PALLETS 840 LBS./DAY x 15 = 7,560 TOTAL PRODUCT LOAD BTU/24 HRS. = 180,360						
12	IV MISCELLANEOUS LOADS (a) LIGHTS 1008 Ft.² Floor Area x 1 1/2 Watts/Ft.² x 12 HRS/24 HRS (1 TO 1 1/2 WATTS/SQ. FT. IN STORAGE AREAS & 2 TO 3 FOR WORK AREAS) (b) OCCUPANCY 4 NO. OF PEOPLE x 1400 BTU/HR. x 12 HRS. = 68,009 (c) MOTORS BTU/HP/HR. x HP x HRS./24 HRS. (d) MATERIAL HANDLING 2 FORK LIFT(S) x 4 EQUIV. HP x 3100 BTU/HP/HR. x 8 HRS. OPERATION = 198,400 OTHER *IF THE PRODUCT PULL DOWN IS ACCOMPLISHED IN LESS THAN 24 HRS. THE ONLY PRODUCT WILL BE LBS. PRODUCT x PULLDOWN HRS. TOTAL BTU/24 HRS. WITH SAFETY FACTOR (NOT INCLUDING DEFROST LOADS) 1,533,105						

REF. TABLE	EQUIPMENT SELECTION FROM LOAD CALCULATION FORM	
1, 2	1. DETERMINE EVAP. TD REQUIRED FOR CLASS OF PRODUCT AND ROOM TEMP. 10 °F (TD) (FROM LOAD SURVEY DATA)	
43	2. DETERMINE COMPRESSOR RUNNING TIME BASED ON OPERATING TEMPERATURES AND DEFROST REQUIREMENTS 1.8 HRS. (FROM LOAD SURVEY DATA)	
	3. EVAPORATOR TEMP. °F = -10 - 10 = -20 °F (ROOM TEMP) (EVAP. TD**) **FROM LOAD SURVEY DATA	
49	4. COMP. SUCT. TEMP. °F = -20 (EVAP. SUCT. TEMP) - 2 (SUCT. LINE LOSS) = -22 °F	
	BTU/24 HR. BASE REFRIGERATION LOAD WITH SAFETY FACTOR = 1,533,105 (NOT INCLUDING EVAPORATOR FAN OR DEFROST HEAT) REFER TO PAGES 6 AND 7 "SELECTION OF REFRIGERATION EQUIPMENT TO DETERMINE PROCEDURE FOR EQUIPMENT SELECTION." PRELIMINARY HOURLY LOAD = 1,533,105 BTU/24 HR. (BASE LOAD) = 85,172 BTU/HR. FAN HEAT LOAD ESTIMATE BTU/HR. = 1.8 HRS./DAY (COMP. RUNNING TIME) QTY. x WATTS EA. x 3.41 BTU/WATT x HRS. = 85,172 BTU/24 HRS. (MOTORS) (INPUT) OR 6 QTY. x 1/3 HP EA. x 3850 BTU/HP/HR. x 20 HRS. = 154,000 BTU/24 HRS. (MOTORS) (TABLE 13) DEFROST HEAT LOAD ESTIMATE BTU/HR. = 3 QTY. EVAPS. x 3600 WATTS EA. x 2 HRS. x 3.41 BTU/WATT x 0.5 DEFROST LOAD FACTOR* = 98,208 BTU/24 HRS. *USE 0.50 FOR ELECTRIC DEFROST 0.40 FOR HOT GAS DEFROST BTU/24 HR. TOTAL LOAD = 1,533,105 + 154,000 + 98,208 = 1,785,313 BTU/24 HRS. FL = 3600/1000 OR 1,533,105 x 1.15 = 1,793,732 BTU/24 HRS. (Refer to Pg. 5) (BASE LOAD) (BASE LOAD MULT.) ACTUAL HOURLY LOAD = 1,785,313 BTU/24 HRS. (TOTAL LOAD) = 99,184 BTU/HR. 1.8 HRS./DAY (COMP. RUNNING TIME)	

EQUIPMENT SELECTION			
MODEL NO.	COMPRESSOR UNITS	CONDENSING UNITS	CONDENSERS
QUANTITY		W353-LFN	ECF360
BTU/HR. CAPACITY (EA.)		109,000	36,000
CFM AIR VOLUME (EA.)			7800 @ 40'
°F EVAPORATOR TEMP.	DESIGN	ACTUAL	DESIGN
°F EVAP. TD			
°F SUCTION TEMP.			
°F CONDENSING TEMP.			
°F DESIGN AMBIENT TEMP.			
°F MIN. OPER. AMBIENT TEMP.			

LOAD ESTIMATING EXAMPLE NO. 2

DUNHAM-BUSH

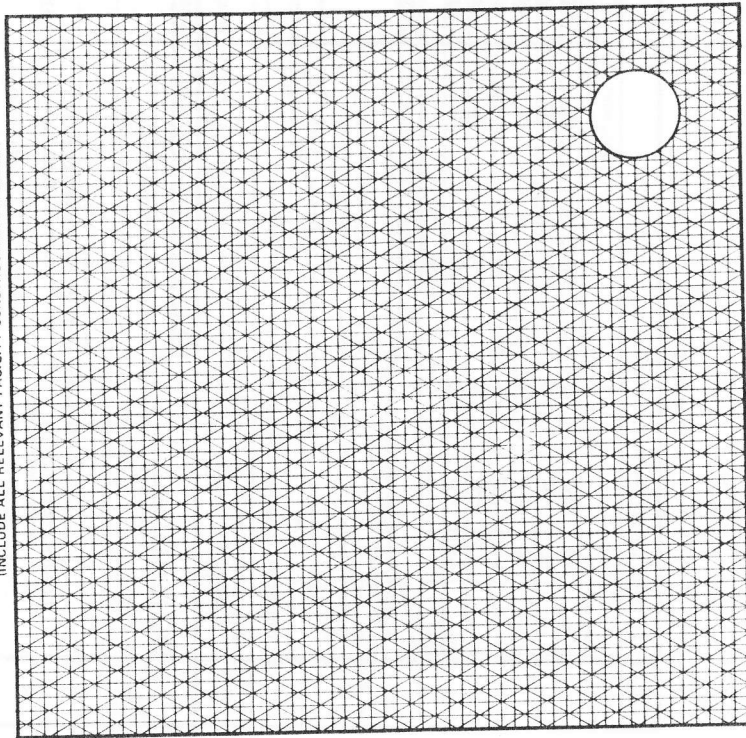
REFRIGERATION LOAD ESTIMATE FORM

FOR ROOMS ABOVE & BELOW FREEZING

SURVEY BY PETE HARRIS OFFICE CHICAGO DATE 4-1-79
CUSTOMER GOLD STORAGE INC. ADDRESS 133 RIVER RD. CHICAGO
JOB NAME LOW'S DELI ADDRESS 75 STEWART ST. CHICAGO
APPLICATION WALK-IN COOLER

FACILITY LAYOUT

(INCLUDE ALL RELEVANT FACILITY CONSTRUCTION FEATURES)



NOTE: INDICATE DIRECTION OF NORTH WITHIN CIRCLE

REFRIGERATION LOAD ESTIMATE FORM FOR ROOMS ABOVE AND BELOW FREEZING

- LOAD SURVEY & ESTIMATING DATA -

DESIGN AMBIENT: 95 °FDB, 50 °RH	F °F	°RH	(USE 55 °F FOR INSULATED FREEZE FLOOR SLAB)
ROOM DESIGN: 35 °FDB, 90 °RH	F °F	°RH	F °F WINTER DESIGN AMBIENT
ACCESS AREA: 85 °FDB, 50 °RH	F °F	°RH	F °F WINTER DESIGN DOCK/OTHER
ROOM DIM. OUTSIDE: 8 FT W, 14 FT L, 9 FT H	620 TOTAL SQ. FT. (OUTSIDE SURFACE)		

Type	Insulation (Table 6)	U-Factor	Area	Effective Wall Area	F Sun Effect (Table B)	Over all Wall Heat Gain (Table A)
N Wall	4" COR-BOARD	0.3	67	95	60	108
S Wall						
E Wall						
W Wall						
Floor						

REFRIG. DOOR(S): (1) 7' x 4' VENT. FAN(S):
ROOM INT. VOL: 7' W x 13' L x 8' H = 728 CU. FT.
INSIDE ROOM DIMENSION - OUTSIDE DIMENSION - WALL THICKNESS
FLOOR AREA 7' W x 13' L = 91 SQ. FT.
ELECTRICAL POWER 208 VOLTS, 3 PH, 60 HERTZ, CONTROL 115 VOLTS

TYPE CONTROL:

PRODUCT DATA AND CLASS OF PRODUCT:

Type of Product	Amount of Product (Refer to Pg. 2 Item 3)	Product Temp. °F	Specific Heat		Table 31	Table 42
			Lat. Hr. Protect (Table 31)	Below Freeze		
Mixed Veg.	3500	2184	45	35	9	2

EVAP. TD 10 ° TYPE DEFROST AIR, HOT GAS, ELECTRIC

CLASS PRODUCT II

NO. OF DEFROSTS & TOTAL TIME PER 24 HRS. NO. HRS.

COMPRESSOR RUNNING TIME 16 HRS.

BOX USAGE AVERAGE, HEAVY, EXTRA HEAVY

PRODUCT LOAD AND ADDITIONAL INFORMATION MIXED VEGETABLE BOX

PACKAGING PAPER CARTONS CONTAINERS WGT. 100 LBS SP. HT. 34 (CONTAINER)

PALLETS: NO. SIZE WGT. EA. SP. HT.

PRODUCT RACKS: NO. MAT'L WGT. EA. SP. HT.

ESTIMATING PRODUCT LOADING CAPACITY OF ROOM

ESTIMATED PRODUCT LOADING 0.40 x 728 CU. FT. x 1/2 LBS/CU. FT. = 3490 LBS.

(LOADING DENSITY) (ROOM VOLUME)

MISCELLANEOUS LOADS

PEOPLE NO. 1 HRS. 2

FOOD LISTS NO. HP HRS./DAY, OTHER

LIGHTS 1 1/2 WATTS/SQ. FT. (REFER TO PG. 3, ITEM 4)

USE: HP HRS.

MOTORS (OTHER THAN EVAP. FAN)

LOAD ESTIMATING EXAMPLE NO. 2 (CONTINUED)

CALCULATIONS

REF. TABLE	I WALL LOSS (TRANSMISSION LOAD)				WALL HEAT GAIN FACTOR TABLE 6	BTU/24 HRS.
6	SURFACE	TD	AREA OF SURFACE	Ft. L x Ft. H =	Sa, Ft. x	
14A, B, C	N. Wall		Ft. L x Ft. H =	Sa, Ft. x		
	E. Wall		Ft. L x Ft. H =	Sa, Ft. x		
	W. Wall		Ft. L x Ft. H =	Sa, Ft. x		
	Ceiling		Ft. L x Ft. W =	Sa, Ft. x		
	Floor		Ft. L x Ft. W =	Sa, Ft. x		
	Box	60	Total Surface = 620		108	66,960
14A, B, C	II SF (SHORT FORM) USAGE HEAT GAIN (I) AVG. (I) HVY. (I) EX. HVY.					66,960
15	COOLERS ONLY (Refer to Table 14 for Long Form) (If applicable, use data shown in Table 15)					
	NOTE: IF PRODUCT LOADS ARE UNUSUAL USE THE LONG FORM					
	EX. HVY. = 1% USAGE					
14A, B, C	IF USAGE HEAT GAIN ABOVE IS USED DO NOT USE (II, (f) III & IV)					
11	II LF (LONG FORM) INFILTRATION (AIR CHANGE LOAD)					28,433
	728 CU. FT. x 2.1 AIR CHANGES/24 HRS. x 1/ SRVC. FACTOR x .186 BTU/CU. FT. (TABLE 11)					
31A, B, C	III PRODUCT LOAD					28,433
32	PRODUCT TEMP. REDUCTION ABOVE FREEZING (SENSIBLE HEAT)					
	2180 LBS./DAY x 10 °F TEMP. REDUCTION x 0.9 SP. HT. =					19,620
	PRODUCT FREEZING (LATENT HEAT LOAD)					
	LBS./DAY x BTU/LB. LATENT HEAT					
	LBS./DAY x °F TEMP. REDUCTION x SP. HT. =					
42	HEAT OF RESPIRATION					
	3500 LBS. PRODUCT (STORAGE) x 2 BTU/LB. /24 HRS. =					7,000
44	MISCELLANEOUS PRODUCT LOADS (1) CONTAINERS (2) PALLETS (3) OTHER					
	LBS./DAY x °F TEMP. REDUCTION x SP. HT. =					
	LBS./DAY x °F TEMP. REDUCTION x SP. HT. =					
	III TOTAL PRODUCT LOAD BTU/24 HRS. =					26,620
12	IV MISCELLANEOUS LOADS					
13	(a) LIGHTS 31 Ft. x Floor Area x 1 Watts/Ft. x 3.41 Btu/Watt x 12 HRS/24 HRS. =					3,723
	(b) OCCUPANCY 1 NO. OF PEOPLE x 500 BTU/HR. x 12 HRS. =					10,800
	(c) MOTORS BTU/HP/HR. x HP x HRS./24 HRS. =					
	(d) MATERIAL HANDLING					
	FORK LIFT(S) x EQUIV. HP x 3100 BTU/HR./HP. x HRS. OPERATION =					
	OTHER					
	*IF THE PRODUCT PULL-DOWN IS ACCOMPLISHED IN LESS THAN 24 HRS. THE DAILY PRODUCT WILL BE:					
	LBS. PRODUCT x PULLDOWN HRS. =					
	TOTAL BTU LOAD I TO IV BTU/24 HRS. =					14,523
	TOTAL BTU LOAD I TO IV BTU/24 HRS. =					136,538
	ADD 10% SAFETY FACTOR					13,650
	TOTAL BTU/24 HRS. WITH SAFETY FACTOR (NOT INCLUDING EVAP. FAN OR DEFROST HEAT LOADS) =					150,188

REF. TABLE	EQUIPMENT SELECTION FROM LOAD CALCULATION FORM			
1, 2	1. DETERMINE EVAP. TD REQUIRED FOR CLASS OF PRODUCT AND ROOM TEMP. 10 °F (TD) (FROM LOAD SURVEY DATA)			
43	2. DETERMINE COMPRESSOR RUNNING TIME BASED ON OPERATING TEMPERATURES AND DEFROST REQUIREMENTS 16 HRS. (FROM LOAD SURVEY DATA)			
	3. EVAPORATOR TEMP. °F = 35 (ROOM TEMP) 10 = 25 °F (FROM LOAD SURVEY DATA)			
49	4. COMP. SUCT. TEMP. °F = 25 (EVAP. SUCT. TEMP) 2 = 23 °F (SUCT. LINE LOSS)			
	BTU/24 HR. BASE REFRIGERATION LOAD WITH SAFETY FACTOR = 150,188 (NOT INCLUDING EVAPORATOR FAN OR DEFROST HEAT) REFER TO PAGES 6 AND 7 "SELECTION OF REFRIGERATION EQUIPMENT TO DETERMINE PROCEDURE FOR EQUIPMENT SELECTION. PRELIMINARY HOURLY LOAD = 150,188 BTU/24 HR. (BASE LOAD) = 9,386 BTU/HR. FAN HEAT LOAD ESTIMATE BTU/HR. = 16 HRS./DAY (COMP. RUNNING TIME) QTY. x WATTS EA. x 3.41 BTU/WATT x HRS. = BTU/24 HRS. OR 1 QTY. x 1/6 HP EA. x 4350 BTU/HP/HR. x 24 HRS. = 17,400 BTU/24 HRS. (MOTORS) DEFROST HEAT LOAD ESTIMATE BTU/HR. = QTY. EVAPS. x WATTS EA. x HRS. x 3.41 BTU/WATT x DEFROST LOAD FACTOR = BTU/24 HRS. *USE 0.50 FOR ELECTRIC DEFROST 0.40 FOR HOT GAS DEFROST			
13	BTU/24 HR. TOTAL LOAD = 150,188 + 17,400 = 167,588 BTU/24 HRS. FL = 1 x 1/6 x 4350 = 150,188 x 1.10 = 165,206 BTU/24 HRS. = 60.4 (Refer to Pg. 5) (BASE LOAD MULT.) ACTUAL HOURLY LOAD = 167,588 BTU/24 HRS. (TOTAL LOAD) = 10,474 BTU/HR. HRS./DAY (COMP. RUNNING TIME)			

EQUIPMENT SELECTION					
MODEL NO.	COMPRESSOR UNITS	CONDENSING UNITS	EVAPORATORS	CONDENSERS	
QUANTITY		4H/5H	WT/20		
BTU/HR. CAPACITY (EA.)		12,500	12,500		
CFM AIR VOLUME (EA.)					
°F EVAPORATOR TEMP.	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN
°F EVAP. TD					
°F SUCTION TEMP.		23			
°F CONDENSING TEMP.					
°F DESIGN AMBIENT TEMP.		95			
°F MIN. OPER. AMBIENT TEMP.		0			

JOB SURVEY

To select refrigeration equipment that will result in a balanced system it is necessary to:

1. Determine all pertinent information by making a job survey.
 - A. Design ambient temperatures.
 - B. Storage area temperature and humidity requirements.
 - C. Room dimensions and type of construction, insulation, exposure etc.
 - D. Type, amount of product, and class of operation.
 1. Holding type cooler or freezer.
 2. Product chilling (meat, fruits, etc.).
 3. Holding fruits and vegetables, which can have high heats of respiration and special atmosphere requirements.
 4. Freezers having freezing or hardening loads in addition to holding (sharp freezing).
 5. Blast freezers or freezing tunnels.
 6. Walk-in service coolers and freezers with average, heavy or extra heavy service.
 - E. Electrical service, water availability, etc.
2. Based on the data obtained in the job survey, calculate the total heat load of the refrigerated space. This total load usually includes the following main sources of heat gain:
 - A. Wall heat load (transmission, solar heat, etc.).
 - B. Air change load (infiltration)
 - C. Product load.
 - D. Miscellaneous loads, including the heat gain from people and all electric energy dissipated by lights, motors, heaters, etc.
 - E. Evaporator fan motors and defrost heat.
 - F. It is recommended that a 10% safety factor be added to the load total.
3. Determine the hourly load and the required temperature difference (TD) between the refrigerated space temperature and the evaporator temperature.
 - A. The hourly operating load will be inversely proportional to the running time of the compressors, which will depend essentially on room and evaporator temperatures and type and number of defrosts per day. Btu/Hr. equals Btu per 24 hours divided by compressor running time in hours.
 - B. The storage area humidity requirements will depend on the type of product, the type of operation, product packaging, etc., and will determine the required operating TD between the room and the evaporator.
 - C. The type of operation and the product will determine the limits of air motion within the room. Higher velocities being required for chill and freezer operation and lower velocities for unpackaged products and others subject to dehydration and weight loss, etc.
4. With the calculated hourly load as a guide, select the compressor(s) and high side components to handle the load. Allowance must be made for temperature penalties incurred by line and control valve pressure drops. Select the required types of evaporator(s) to balance the selected compressor capacity at the required TD.
5. Select all system components to match the actual system capacity and conform with the overall requirements of the installation.

REFRIGERATION LOAD CALCULATIONS

Based on the specified or survey data for the job, the total heat gain load of the refrigerated space will be the sum total of the:

1. Wall, floor and ceiling transmission load
2. Air change load
3. Product load
4. Miscellaneous loads

A 10% safety factor would normally be added before selecting evaporator and compressor.

1. WALL HEAT LOAD

The heat gain through walls, floor and ceiling will vary with the following factors:

- Type and thickness of insulation.
- Type of construction.
- Outside wall area in square feet.
- Temperature difference between refrigerated space and outside ambient adjusted to allow for solar heat load on any surface exposed to the sun.

The overall heat transfer factors based on the actual wall construction can be calculated, or the tabulated heat gain factors (Table 6) at intervals of overall temperature differences, can be used to simplify calculations. With these factors expressed in Btu/square feet/24 hours, it is only necessary to multiply by the outside surfaces of the box to obtain the heat load in Btu/24 hours.

For small walk-in coolers and freezers, when there are no unusual requirements, the wall load may be taken as the total outside surface times the appropriate wall heat gain factor based on the ambient air temperature difference.

For unusual applications and larger coolers, and freezers, it may be necessary to treat each exposed surface separately.

Some coolers for above freezing temperatures have been constructed with only a floor slab (no floor insulation). The heat loss would be subject to too many variables to accurately predict. The factors shown in the wall heat gain (Table 6) are based on concrete floor slab and the TD between the local ground temperature and the storage room temperature.

For freezers it becomes necessary to provide heat in the base slab to avoid freezing of the ground water and heaving of the floor. Minimum slab temperature should be at least 40°F. Normally 55°F should be used for freezer applications.

2. AIR CHANGE LOAD

Every time the door of a refrigerated space is opened some outside air will enter the room. This air must be cooled to the storage room temperature and will therefore increase the load requirements of the room.

Tables 9 and 10 indicate the average number of air changes to be expected per day for various size coolers and freezers. This information is based on experience, since it is impossible to accurately determine, from day to day, and from installation to installation, just how many air changes will occur. (For heavy usage the average infiltration may be doubled or more.)

For ease of calculation the heat removed from a cubic foot of air (Btu/cubic foot) to cool it from outside conditions to storage area temperature has been tabulated (Table 11).

The air change load in Btu/24 hours is arrived at by multiplying the room volume in cubic feet by the number of air changes per 24 hours times the Btu to be removed per cubic foot of air.

The following various means have been employed to reduce the infiltration (air change) load on refrigerated areas, particularly freezers where there is a high temperature difference between the outside and the refrigerated areas:

- Automatic closing refrigerator doors.
- Vestibules with outer cold storage doors and inner two way auto-close doors.
- Refrigerated ante-rooms or vestibules.
- Automatic closing refrigerator doors with air curtains. Under ideal conditions with no draft or wind effects, claims are made for up to 50% reduction in infiltration over an open door, but improper adjustment can greatly increase the air exchange and the infiltration load. If "bat wing" or swinging auto-close doors are installed inside the cold storage doors they will provide an effective control of infiltration and minimize the transfer of moisture across the air curtain. This is evidenced by frost or rime on the apron of the doorway and inside the freezer on walls and ceiling and forced air coil casings.
- Outside loading dock doors are fitted with inflated bumpers to seal against the body of the refrigerated truck.

The initial infiltration rate through an opened door, assuming no wind or difference in pressure, will be due to the difference in air temperature between the inside and outside air and can be approximated by taking the resulting average velocity over 1/2 the height of the door and multiplying by 1/2 the area of the doorway. For estimating purposes

$$\text{CFM of air} = 2.43 \times H \times W \times \sqrt{H \times TD}$$

where H & W are door dimensions in feet and TD is the temperature difference in °F. Then the instantaneous load will be the CFM times the Btu/cubic foot of air.

EXAMPLE:

For a 8' H x 6' W door on a -10°F freezer with 90°F and 60% RH outside ambient:

$$TD \text{ equals } 90^\circ\text{F} + 10^\circ\text{F} = 100^\circ\text{F}$$

$$\begin{aligned} \text{CFM} &= 2.43 \times H \times W \times \sqrt{H \times TD} \\ &= 2.43 \times 8 \times 6 \times \sqrt{8 \times 100} = 3293 \text{ CFM} \end{aligned}$$

$$\text{From Table 11 Cooling air from } 90^\circ\text{F @ 60\% RH to } -10^\circ\text{F} = 3.85 \text{ Btu/cubic ft.}$$

$$\begin{aligned} \text{Initial Load} &= 3.85 \times 3293 = 12,678 \text{ Btu/min.} \\ &= 760,683 \text{ Btu/hr.} \end{aligned}$$

$$\frac{760,683}{12,000} = 63.4 \text{ tons}$$

with a 50°F @ 70% RH ante room the CFM would be reduced to 2554 and the initial load based on 1.73 Btu/cubic foot of air (from Table 11) would be reduced to 22.1 tons.

This will serve to illustrate why it is so necessary to keep the door openings to a minimum. A 10,000 cubic foot freezer at 4.9 air changes per 24 hours figures 49,000 cubic feet of air per 24 hours which would allow an 8 x 6 foot door to be open a total of only 49,000/3293 CFM or 15 minutes during the day with 90°F outside ambient without exceeding the average air change rate.

3. THE PRODUCT LOAD

Products placed in a refrigerated room at a temperature higher than the storage temperature will require the extraction of heat until reduced to storage temperature. The calculation of the actual product load will require information on one or more of the following:

- Product specific heat above freezing
- Product heat of respiration
- Product freezing point
- Product latent heat of fusion
- Product specific heat below freezing

Specific Heat - is the amount of heat removed to lower the temperature of one (1) pound of the product 1°F (specific heat above freezing and specific heat below freezing) Btu/lb./°F.

Heat of Respiration - is the amount of heat given off by products, such as fresh fruits and vegetables, during storage. Since the products are alive, they continually undergo a change in which energy is released in the form of heat, which varies with the type and temperature of the product. Tabulated values are usually in Btu/lb./24 hours, and are applied to the total weight of product being stored and not just the daily turn-over. Do not use the maximum values, as the heat of respiration varies with storage temperature and time in storage. Use a value close to freezing (32°F).

Latent Heat of Fusion - is the amount of heat removal at the freezing temperature to freeze one (1) pound of product. Most products have a freezing point in the range of 26°F to 31°F, and if the exact temperature is unknown, it may be assumed to be 28°F. There is a definite relationship between the latent heat of fusion and the water content of the product. If the water content is known the latent heat of fusion may be approximated by multiplying the water content in % by weight divided by 100 x 144 Btu/lb.

Product load calculations will depend on the type of operation and the amount of product involved along with the entering product temperature, room temperature, etc.

Storage Coolers:

$$\text{Product Sensible Heat Load Btu/24 Hrs.} = \frac{\text{Turnover lbs./24 hrs.} \times TD \times \text{Sp. Ht.}}{1}$$

Where:

- Turnover = Daily product turnover in lbs./24 hrs.
- TD = Temperature reduction (figure at least 20°F)
- Sp. Ht. = Specific heat above freezing (0.8 to 0.9 Btu/°F/lb.)

$$\begin{aligned} \text{Heat of Respiration Load Btu/24 hrs.} &= \\ \text{Total Product Inventory lbs.} \times \text{Heat of Respiration} &= \\ \text{in Btu/lb./24 hrs.} & \end{aligned}$$

REFRIGERATION LOAD CALCULATIONS (CONTINUED)

Storage Holding Freezers (Product already frozen):

$$\text{Product Sensible Heat Load Btu/24 hrs} = \frac{\text{Turnover lbs/24 hrs.} \times \text{TD} \times \text{Sp. Ht.}}{24}$$

Where:

Turnover lbs/24 hrs. = Daily product turnover in lbs/24 hrs.

TD = Temperature reduction
(Figure at least 15°F)

Sp. Ht. = Specific heat below freezing
(0.40 to 0.45 btu/°F/lb)

Any product freezing load should be figured separately and added to the storage load. For any pulldown requirement less than 24 hours the calculated load should be divided by the hours pulldown and multiplied by 24 hours. This will put it on a 24 hour basis and allow for the additional load rate. (Products to be frozen may be located in a special section of the room and subjected to an air blast from auxiliary fans)

Freezers (Sharp, Blast and Tunnel)

The sensible heat above freezing, the latent heat of freezing, and the sensible heat below freezing would be calculated and totaled for the product being frozen. The freezing time for the product will depend on:

- The type of product
- The product shape, thickness weight and method of arranging on racks etc.
- Product packaging
- Air distribution and velocity (spacing of product for air distribution)
- Air temperature
- Type of freezing operation
 - Batch freezing (room held below freezing or allowed to warm up.)
 - Continuous freezing

For continuous freezers or batch freezers, the 24 hour load would be the hourly freezing load x 24 hours or the total freezing load divided by the freezing time in hours and multiplied by 24 hours (to adjust the load to a 24 hour basis).

Freezing times may be calculated (see the ASHRAE Application Data Book) or based on past experience or tests.

In some applications the product goes from the blast freezer into the storage freezer where it is pulled down to final storage temperature. The load on the storage freezer may include not only removal of sensible heat below freezing, but part of the freezing load which was not completed in the blast freezer. This information should come from the customer or the engineer.

Chill Coolers – in a meat carcass chill cooler it is essential that the pulldown be as rapid as possible without actually freezing the surface of the product. During product chilling there is a high rate of moisture transfer from meat products which results in a loss of product weight in addition to surface moisture. After pull-down meat products would normally be moved to a holding room with reduced air motion and close control of temperature and humidity. Fruits and vegetables have a high heat of respiration, which will be reduced as the product is brought down to storage temperature.

Ice Cream Hardening Rooms – the amount of heat to be removed in the hardening room depends on the % overrun of the ice cream leaving the ice cream freezer. The ice cream may go direct to a storage freezer for hardening, or may be hardened in a freezing tunnel before going to the storage freezer.

The cooling load imposed by packaging, boxing and crating and palletizing plus the heat introduced by conveyors, etc., must be included in the product load.

Actual product loads should be used when available, but make certain that they are accurate and are based on the maximum utilization of the facility.

4. MISCELLANEOUS LOADS

All electrical energy dissipated by lights, motors, heaters, etc., located in the refrigerated area must be included in the heat load.

Lights – The light load equals the total lighting wattage times the number of hours times 3.41 Btu/Watt for incandescent or 4.2 for fluorescent lights.

Coolers and freezers are generally figured at 1 to 1½ Watts per square foot of floor area. Allow up to double this amount for work areas.

Motors – The heat input from motors will vary with the motor size, BHP output, efficiency and whether it is located within, or outside of, the refrigerated space.

The heat equivalent of 1 BHP is 2545 Btu/hr. Motor efficiencies vary from 40% and less for small fan motors to 80% or more for integral horsepower motors. The motor output will be its BHP x 2545 Btu/hr. x hours of operation.

If the motor is located in the refrigerated area, divide its output by its efficiency. If the motor is located outside the refrigerated area, its inefficiency will be dissipated outside, then only its output will figure in the room load. If the motor is located in the room and the load is outside, only the inefficiency will be added to the room load. Multiply the output by (1 – efficiency).

For motors rated in Watts output divide by 746 to obtain the heat equivalent HP rating.

See Table 13 heat equivalent of electric motors.

Material Handling Equipment – If powered material handling equipment is used, such as fork lift trucks, this must be included under Motor Heat Loads. Generally only battery operated lift trucks are used in refrigerated rooms, which represent a heat gain of 8,000 to 12,000 Btu/hr. or more over the period of operation plus losses due to heat and moisture picked up outside of the storage room. (Lift truck may be assumed as equivalent to a 4 HP motor at about 3100 Btu/hr./HP if actual information is not available.)

Occupancy Load – People working in a refrigerated storage area dissipate heat at a rate depending on the room temperature. The heat load added to the room will be equal to the number of people, the hours of occupancy and heat equivalent per person. For multiple occupancies of short duration they will carry additional heat into the room. See Table 12 Heat Equivalent of Occupancy.

The summation of the above, Items #1 through #4 represents the Total Basic Refrigeration Load.

5. SAFETY FACTOR

A minimum 10% safety factor is normally added to the total refrigeration load to allow for minor omissions and inaccuracies, but it should not be assumed this is adequate to take care of the evaporator fan load. (Additional safety or reserve capacity may be available from the compressor running time and average loading.)

The Total Basic Calculated 24 hour Refrigeration Load including Safety Factor does not include the evaporator fan or defrost loads, which must be evaluated and added to the Basic Load to arrive at the Total Load for the final selection of the Refrigerating Equipment. Tables and data required for calculating loads are tabulated for quick reference.

SUMMARY OF LOAD CALCULATIONS

1. Wall Losses	Btu/24 Hrs.	6. Safety Factor	Btu/24 Hrs.
2. Infiltration	Btu/24 Hrs.	(10% of Refrigeration Load)	
3. Product Load	Btu/24 Hrs.	7. Basic Refrigeration Load	
4. Miscellaneous Loads	Btu/24 Hrs.	with Safety Factor (5)	Btu/24 Hrs.
• Lights	Btu/24 Hrs.	8. Hourly refrigeration load (Btu/Hr.) = basic daily re-	
• Motors	Btu/24 Hrs.	frigeration load (Btu/24 Hrs.) divided by the compres-	
• Material Handling	Btu/24 Hrs.	sor operating time in hours per day.	
• Occupancy	Btu/24 Hrs.	9. Daily and hourly loads must be adjusted for evapora-	
5. Basic Refrigeration Load (1 thru 4)	Btu/24 Hrs.	tor fan and defrost heat loads.	

SELECTION AND BALANCING

The selection of equipment depends on the following factors:

1. Daily Load
2. Running Time of Compressors (Hrs./day)
3. Hourly Load (Btu/Hr.)
4. Room Temperature (°F)
5. Room Relative Humidity (% RH)
6. Coil Operating TD (Room temp-Refrigerant temp.)
7. Coil Evaporator Temp. (Saturated suction temp.)
8. Suction Line Temperature Penalty Due to Pressure Drop From Coil to Compressor
9. Design Condensing Temperature for Compressor Including Correction For any Discharge Line Pressure Drops to Remote Condenser
10. Available Compressor Sizes, with or without Capacity Control.

The following will serve as a guide for determining the required compressor and evaporator operation: (Refer also to tables of Storage Temperature and Humidity Conditions and Coil Temperature Differences for four classes of foods.)

TABLE 1

STORAGE TEMPERATURE AND HUMIDITY CONDITIONS

Product	Short-Time Storage		24 - 72 Hr. Storage	
	°F	Moisture	°F	Moisture
Vegetables	36 - 42	Class 2	32 - 36	Class 1
Fruits	36 - 42	Class 2	32 - 36	Class 2
Meats (cut)	34 - 38	Class 2	32 - 36	Class 2
Meats (carcass)	34 - 38	Class 3	32 - 36	Class 3
Poultry	32 - 36	Class 2	30 - 35	Class 1 - 2‡
Fish	35 - 40	Class 1	35 - 40	Class 1
Eggs	36 - 42	Class 2	31 - 35	Class 1
Butter, Cheese	38 - 45	Class 1*	35 - 40	Class 2 - 3†
Bottled beverages	35 - 45	Class 4	40 - 45	Class 4
Frozen Foods			0	Class 2

ASRE 1959 Data Book and ASHRAE 1962 Guide and Data book
- Reprinted by permission

Temperatures and moisture conditions shown above give customary restaurant practice. Some variations may be expected due to different varieties of fruits or vegetables and the growing conditions in different geographical locations. For complete and detailed information, including approximate long-time storage life, on all types of foods, refer to Table 1, Chapter 23. The USDA Handbook No. 66 is another authoritative source for conditions for the long-time preservation of fruits and vegetables.

* If not packaged.

† If packaged

‡ Freeze and hold at 0°F or below if held for more than 72 hours.

CLASSES OF FOOD

Class 1. Such products as eggs, unpackaged butter and cheese and most vegetables held for comparatively long periods of time. These products require very high relative humidity because it is necessary to effect a minimum of moisture evaporation during storage.

Class 2. Such foods as cut meats, fruits and similar products. These require high relative humidities but not as high as Class 1.

Class 3. Carcass meats and fruit such as melons which have tough skins. These products require only moderate relative humidities because they have surfaces whose rate of moisture evaporation is moderate.

Class 4. Canned goods, bottled goods, and other products which have a protective covering. These are products which need only low relative humidities or which are unaffected by humidity. Products from whose surfaces there is a very low rate of moisture evaporation or none at all, fall into this class.

TABLE 2

**TEMPERATURE DIFFERENCES*
COIL TD FOR FOUR CLASSES OF FOODS**

Type Coils	Class 1	Class 2	Class 3	Class 4
Forced Air Coils	6 - 9°F	9 - 12°F	12 - 20°F	Above 20°F
Gravity Coils	14 - 18°F	18 - 22°F	21 - 28°F	27 - 37°F

*Temperature difference is defined as average fixture temperature minus average refrigerant temperature.

The choice of the correct differential between storage room temperature and the evaporating refrigerant in the cooling unit, to provide the proper balance in the system is the simplest, least expensive and most practical method for approximating the desired conditions of temperature and humidity.

In the proper application of the evaporator it is most important to insure that there is a balance between the condensing unit and the lowside. (The evaporators should be selected to match the capacity of the selected compressor and not necessarily the original calculated load.) The temperature difference between the air to be passed through the evaporator and the refrigerant temperature in the coil will determine the conditions which will be maintained in a given cooler.

TABLE 3

TEMPERATURE DIFFERENCE GUIDELINES

Room Temp. °F	Evap. Temp. °F	Defrosting		Compressor Running Time Hrs.	Rel. Hum. %	Evap. °F TD
		Type	No./24 Hrs.			
Over 35	Over 30	None	-	18 - 20 & up	90	8 - 10
35 & up		Ambient	4	16	85	10 - 12
35 to 25	Below 30	Elec. or Hot Gas	4	18 - (20*)	80	12 - 15
10 & less			6	(18*) - 20	75	16 - 20
					-	8 - 10

*Preferred compressor running time.

TABLE 4
EVAPORATOR BASE LOAD MULTIPLIERS
 (USE FOR WALK-IN COOLERS & FREEZERS,
 DO NOT USE FOR BLAST FREEZERS OR SPECIAL PURPOSE ROOMS)

	"FL" Fan Heat* Btu/1000 Btu /Hr. @ 10° TD	Type of Defrost	MULTIPLIERS						
			Evaporator TD °F (Room Temp. - Evap. Temp.)						
			8	10	12	14	16	18	20
The 24 hour Total Calculated Basic Refrigeration Loads include a 10% safety factor but do not include evaporator fan motor, or defrost heat loads. This additional capacity requirement must be met by the condensing unit and the evaporator must be selected to balance within the required operating TD limits. A rough estimate can be way off and trial and error estimates and revisions can be tedious.	40	A	1.081	1.065	1.053	1.045	1.039	1.034	1.031
		4E	1.093	1.072	1.059	1.051	1.044	1.038	1.034
		6E	1.132	1.103	1.084	1.071	1.062	1.055	1.049
The purpose of the Base Load multiplier is to permit a close approximation of the total 24 hour load, including fan and defrost heat loads, by applying a multiplier to the Total Calculated Base Load. These multipliers are tabulated for various classes of evaporators, based on a fan heat per 1000 Btu/Hr. (MBH) of evaporator capacity at 10° TD, for 3 basic defrosts and a range of evaporator TD's. The base load x multiplier ÷ compressor running time gives the Btu/hr. load for selection of compressors and evaporator(s) (See Table No. 4).	50	A	1.103	1.081	1.067	1.056	1.049	1.043	1.039
		4E	1.107	1.074	1.069	1.058	1.05	1.044	1.040
		6E	1.152	1.118	1.096	1.081	1.07	1.062	1.056
	60	A	1.127	1.10	1.081	1.069	1.060	1.053	1.047
		4E	1.125	1.096	1.08	1.068	1.058	1.051	1.046
		6E	1.172	1.133	1.109	1.092	1.079	1.07	1.062
	70	A	1.15	1.117	1.097	1.082	1.07	1.062	1.055
		4E	1.14	1.11	1.091	1.077	1.066	1.058	1.052
		6E	1.192	1.146	1.12	1.102	1.088	1.077	1.069
	80	A	1.177	1.136	1.11	1.094	1.081	1.072	1.063
		4E	1.16	1.125	1.103	1.086	1.074	1.066	1.058
		6E	1.216	1.165	1.134	1.113	1.097	1.086	1.076
	90	A	1.20	1.155	1.127	1.107	1.092	1.08	1.072
		4E	1.185	1.142	1.116	1.098	1.09	1.074	1.066
		6E	1.24	1.18	1.148	1.122	1.106	1.094	1.083
	100	A	1.23	1.176	1.143	1.120	1.103	1.092	1.081
		4E	1.20	1.155	1.125	1.105	1.108	1.080	1.072
		6E	1.263	1.20	1.16	1.135	1.116	1.102	1.091
	125	A	1.305	1.23	1.185	1.155	1.133	1.115	1.103
		4E	1.245	1.19	1.152	1.127	1.127	1.096	1.086
		6E	1.33	1.243	1.197	1.165	1.14	1.123	1.108
	150	A	1.39	1.29	1.23	1.190	1.163	1.044	1.127
		4E	1.315	1.242	1.192	1.16	1.136	1.12	1.106
		6E	1.397	1.295	1.234	1.194	1.166	1.145	1.128
	175	A	1.475	1.35	1.28	1.23	1.192	1.17	1.15
		4E	1.375	1.285	1.22	1.185	1.157	1.136	1.122
		6E	1.475	1.35	1.275	1.225	1.194	1.166	1.148
	200	A	1.60	1.43	1.33	1.274	1.231	1.20	1.176
		4E	1.45	1.33	1.26	1.215	1.182	1.16	1.140
		6E	1.564	1.406	1.317	1.26	1.220	1.191	1.169
	250	A	1.873	1.60	1.453	1.364	1.303	1.262	1.231
		4E	1.6	1.43	1.34	1.275	1.232	1.20	1.178
		6E	1.777	1.538	1.411	1.333	1.28	1.24	1.21

A	Ambient defrost, 16 hr. compressor operation and continuous fan operation.
4E	Electric Defrost, 20 hr. compressor operation and 4 - 15 min. defrosts.
6E	Electric Defrost, 18 hr. compressor operation and 6 - 20 min. defrosts.

*The "FL" Fan Heat Evaporator Index must first be determined for an evaporator, typical of the evaporator(s) to be used, before entering the tables, to determine the load multiplier for the type of defrost and the evaporator TD. i.e. electric defrost evaporator with (3) 1/3 HP fans, rated at 48,000 Btu/hr. at 10°TD with 10,910 total defrost Watts. Heat equivalent of 1/3 HP fan motor = 3850 Btu/HP/HR each (Table 13).

$$\text{FL FOR EVAP.} = \frac{3 \times 1/3 \times 3850}{48,000/1000} = 80.2 \text{ BTU/1000 BTU/HR.}$$

Enter Table 4 at 'FL' = 80

For a 6E defrost ([6] - 20 minute defrosts and 18 hour compressor running time) the base load multiplier for a 10°F operating TD would be estimated at 1.165 (1.216 at an 8° TD or 1.134 for a 12° TD).

$$\text{TOTAL 24 HR. LOAD} = \text{BASE 24 HR. LOAD} \times 1.165 = \text{BTU/24 HRS.}$$

$$\text{TOTAL HOURLY LOAD} = \text{TOTAL 24 HR. LOAD} / 24 \text{ HR. COMPRESSOR RUNNING TIME} = \text{BTU/HR.}$$

NOTE:

The Ambient Defrost Base Load Multipliers can be used for standard evaporators at other than 16 hr. compressor operation by multiplying the evaporator "FL" by 16 and dividing by hrs. compressor running time before entering the Base Load Multiplier Table. i.e. for "FL" of 60, and 20 hr. compressor running time, the adjusted "FL" would be 60 x 16/20 or 48 and entering the table at a "FL" of 48 the multiplier for 10°F TD would be about 1.078. (1.10 multiplier for ('FL' of 60)

SELECTION AND BALANCING (CONTINUED)

For the general purpose refrigerator, involving meats, vegetables, and dairy products, it is common procedure to balance the lowside to the condensing unit at a 10°F to 12°F temperature difference; that is, they are balanced to maintain a temperature difference between the refrigerant in the coil and the air temperature of 10°F to 12°F. It has been learned by experience that, if this is done, one may expect to maintain in a cooler 80% to 85% relative humidity, which is a good range for general storage.

A coil which is selected for a wide temperature difference will maintain a lower relative humidity in service, whereas one which is selected for too close temperature difference will produce relative humidities which are higher than required for practical operation and surface sliming may result on stored meat products during winter periods when loads are reduced and compressor running time falls off. Heat may have to be added to room for about 6 hrs./day compressor operation. On straight vegetable coolers where higher humidities are desired, the coil should be selected to balance the compressor at a 8°F to 10°F temperature difference, as

such will produce an average relative humidity of 90% within the refrigerated space. The same recommendation applies to florists' display boxes, and in both cases, the maintenance of a high relative humidity in long term storage is beneficial whereas some exception with reference to meat products is noted above.

On low temperature units, if one stops to consider that the amount of dehumidification is in proportion to the temperature difference, it is obvious that the closer the temperature difference, the less frost accumulation. We strongly recommend that coils for low temperature work be selected to balance the condensing unit at a 10°F temperature difference or less.

With the hourly load established by the compressor running time and evaporators and compressor(s) selected to balance at the required evaporator TD, plus allowance for suction line temperature penalty, run a check on the estimated evaporator fan motor heat rejection to make sure it is covered in the load estimate.

FORCED AIR COOLING UNIT LOADS

• Fan Motor Input Load in Btu/Hr. times the Hours of Operation

The motors will nearly always be located in the refrigerated area, except for some freezing tunnel applications, so the total heat of the motor will apply.

• Coil Defrost Heat Input

A portion of defrost heat goes to melt the frost off the coil. Of the balance, some is dissipated to the room air during defrost and the balance goes to heating up the drain pan and coil, which are cooled back down when the cooling unit goes back on refrigeration.

For electric defrost coils, figure 50% of the defrost heat goes into the room load. The amount of heat input will depend on the coil wattage x 3.41 Btu/Watt, the number of defrosts per day and the length of defrost in fractions of an hour (if actual wattage evaporator rating is not available figure 2.8 kW per ton at 10° TD or 795 Btu per 1000 Btu/Hr. evaporator rating at 10° TD).

For hot gas coils, figure 40% of the heat input of the corresponding electric defrost coil.

Defrost heat load in Btu/24 hrs. = 0.5 or 0.4 x defrost Watts x 3.41 Btu/Watt x number of defrosts per day x defrost time in hours. For 28°F to 35°F rooms figure four (4) defrosts per day, and for freezers, at least six (6) defrosts a day. Total of 1 and 2 hours defrost time per 24 hours.

Fan motor and defrost loads will vary considerably with the type of evaporator and the application, with 6% to 25% or more of the coil basic rating being added to the heat load of the room. The propeller fan type unit coolers generally run less than 100 Btu fan heat per 1000 Btu/Hr. rating at 10° coil TD but a heavy duty product cooler with deep coils can run 200 or more Btu fan heat per 1000 Btu/Hr. coil rating at 10° TD which can represent up to 35% or more of the room load.

SELECTION OF THE REFRIGERATION EQUIPMENT

For quick estimate of total load, including evaporator fan and defrost heats, refer to Base Load Multiplier Table (Table 4), or the following conventional method may be used to select equipment.

The calculated 24 hour total load with 10% safety factor does not include the evaporator fan motor(s) or defrost heat gain; these should be added to arrive at the load which must be balanced by the equipment selection.

The additional capacity requirement will depend on the type of evaporator, the TD needed to meet storage requirements of the product, and the defrost requirement of the evaporator.

AMBIENT OR OFF-CYCLE DEFROST

For rooms over 35°F, with evaporator temperatures below 30°F, the evaporator fans operate all the time and the compressor selected for 16 hours operation out of 24, cycles on time clock for the defrost periods. At a 12°F TD the fan motor heat can amount to 8% to 10% of the 24 hour base load for a propeller fan type evaporator and up to 15% or

more for a centrifugal type blower fan. This percentage would be less at higher and greater at lower TD's.

POSITIVE DEFROST SYSTEMS, ELECTRIC OR HOT GAS

For medium temperature rooms 28°F to 34°F with moderate defrost requirements (4) - 15 minute defrosts a day (total of 1 hour defrost time) are usually adequate. The compressor running time is usually figured at up to 20 hours and the fan operating time will be 24 hours less defrost and the delay following defrost to pull the coil back down to room temperature and freeze the free water before the fans come on. Fan motor and defrost heat loads can add 10% or more to the 24 hour base load for a propeller fan unit at a 12°F TD and considerably higher for centrifugal fan units.

For freezers, 0°F and below defrost requirements of (6) 20 minute defrosts a day (total of 2 hour defrost time) would not be unusual. The compressor is usually selected on the basis of 18 hours running time and the fan operating time

SELECTION OF THE REFRIGERATION EQUIPMENT (CONTINUED)

would be 24 hours less defrost and fan delay time following defrost. The evaporator TD is figured at 10°F or less to minimize frosting of the coil and dehydration of the product. Evaporator fan motor and defrost heat can add 15% or more to the 24 hour base load for the propeller fan units and considerably higher for centrifugal fan type.

As previously stated the evaporator should be selected to balance the compressor capacity at the TD required to meet room conditions. Refer to **tables #1, 2, 3 and 31** for Product Classifications and Requirements and **table #13** for Heat Equivalent of Electric Motors.

To select the required evaporator(s) and condensing unit(s) it is first necessary to determine:

1. Room temperature and required relative humidity.
2. Evaporator TD to meet product requirements
3. Allowance for suction line pressure drop penalty in degrees F, **Table 49**
4. Compressor suction = room temperature - (Evap. TD + Suction line loss)
5. Condensing temperature
6. Compressor operating time in hours
7. Fan operating time (24 hours less time off during defrost)

Knowing that the operating load will have to include fan motor and defrost heat loads:

1. Select a condensing unit having some excess capacity over the 24 hour base load divided by the compressor running time in hours.
2. Select an evaporator to match the compressor capacity. Do not select evaporator at above the required oper-

ating TD (apply any capacity correction factors to evaporator ratings).

3. Multiply the fan motor heat in Btu/hr. by the number of hours the fans operate, and add to the 24 hour base load.
 4. Multiply the evaporator total defrost Watts, in the case of an electric defrost unit, by 3.41 Btu/Hr./Watt and by the hours of defrost time; adding 50% of this figure to the 24 hour base load. (For hot gas defrost figure about 80% of the electric defrost load)
- NOTE: 50% of the defrost heat is assumed assimilated in melting the ice which collects in the pan and goes to the drain. The other 50% is residual and is added to the room load.
5. Divide the adjusted 24 hour load by the compressor running time and check this figure against the capacity balance point of the equipment selected.
 6. If the capacity of the equipment selected is not equal to or greater than the adjusted hourly load then it may be necessary to select another evaporator or select a larger condensing unit with matching evaporator. In which case the load balance must be re-checked.

NOTE: For freezer applications the fan motors can pull well in excess of their rated HP at the reduced room temperature. The fans will handle the same CFM of air regardless of air density and the BHP required will increase directly with the air density. The motor BHP capacity increases at a faster rate than the BHP requirement. Blast freezers may require a 30% increase in fan rated HP when the motors are located outside of the refrigerated space.

THE SHORT METHOD

There are many short forms or "rule of thumb" methods of estimating loads for retail and wholesale service refrigerators, large wholesale refrigerators and long storage warehouse refrigerators.

Experience has shown that such loads must be based on the internal volume as well as the exterior surface of the room. Those based on exterior surface alone are basically incorrect since the usage load will depend upon the volume, and the volume of a box is not proportional to the external surface.

The total heat load is made up of (1) wall heat load and (2) usage heat load. The wall heat loads are estimated in the usual manner, based on the outside surface of the box and the type of construction.

The usage heat load, combining the air change, product and miscellaneous loads can be determined by multiplying the interior volume by the applicable heat gain factor. The values are based on experience and, judgement must be used in their application.

To find the hourly load the total 24 hour load is divided by the compressor running time, 16 hours for ambient defrost and 20 hours for a positive defrost for rooms 30°F to 36°F.

For average and heavy service the product load is based on product entering at 10°F above refrigerator temperature and on only one door being used for loading and unloading. For higher than normal infiltration or product load the total load must be adjusted or the load calculated by the long method, with all of the factors evaluated.

REFER TO:

Table No. 5 - Summer Design Conditions

Table No. 6 - Wall Heat Gain Factors

Table No. 8 - Allowance for Sun Effect

Table No. 14A, B or C - Outside Area and Internal Volume of Coolers

Table No. 15 - Usage Heat Gain

QUICK SELECTION WALK-IN COOLERS AND FREEZERS

Quick approximation of walk-in cooler and freezer loads may be made using **Table No. 17**. 35°F cooler loads are based on ambient defrost with 16 hour compressor operation for normal, heavy and extra heavy service. The room loads may be used for 30°F coolers with positive defrost and 20 hour compressor operation. For 28°F meat storage rooms use extra heavy 35°F room loads and positive defrost.

Freezer loads, based on 18 hour compressor operation, are for storage only and do not include any product loads. Pre-

calculated product load **Tables 18 and 19** may be used to arrive at total load or load may be calculated based on the specific product. Note that a 20% safety factor has been allowed to cover service loads etc.

Table 16 may be used for approximating daily product loading for storage freezers when specific daily product loading is not available.

PROPER SIZING OF EXPANSION VALVES

The selection and installation of thermal expansion valves is of utmost importance for best coil performance. Valve capacity must be at least equal to the coil load rating, but not oversized for the conditions. Any valve which is sub-

stantially oversized will tend to be erratic in operation and this will penalize both coil performance and rated capacity output. Liquid line strainers should always be installed ahead of all thermal expansion valves.

THE HEAT EXCHANGER

Although sometimes a subject of controversy in high temperature applications, it is generally agreed that in medium and low temperature refrigeration systems, heat exchangers when properly applied, perform the following functions of utmost importance to over-all system performance:

1. Subcooling the liquid refrigerant entering the thermal expansion valve reduces the flash gas load of the evaporator inlet. It likewise increases the enthalpy difference of the refrigerant during its evaporating phase which produces more useful work in the evaporator.
2. In process of heat exchanger subcooling, the heat extracted from the liquid refrigerant is transferred to the suction gas, thereby insuring a dry suction return to the compressor at an entering superheat level which will produce the best possible volumetric efficiencies for the refrigerant used.
3. The increase in suction line temperature will likewise reduce possibility of sweating.

4. The use of a heat exchanger will permit more open adjustment of the thermal expansion valve without risk of serious flood-back of liquid to the compressor under light or variable load conditions, at the same time assuring the maximum utilization of evaporator surface.

In all low temperature applications, it is most important to correctly size and properly apply heat exchangers. Selections must be based on accurate performance ratings checked out against the calculated design loads involved for each evaporator or otherwise for the entire system. Care must likewise be taken to insure that both liquid and suction connections are properly sized in order to reduce entrance and exit losses to a minimum. Recommended allowable suction line pressure drops due to the heat exchanger vary from 0.50 psi maximum for +20°F evaporator applications to 0.25 psi maximum for -40°F evaporator temperatures.

WAREHOUSING

Types

- Long Storage
- Short Storage
- Distribution Storage

Inventory

- Palletized stacking may be carried to a height of 15' to 18' with minimum of 20 ft. clear height.
- Product loading of 8 to 10 lbs. per gross cubic ft. of internal volume, with 40% allowance for head room and aisles. (See ASHRAE '74 Application Guide)
- A 12' - 6" high fresh meat cooler can run 5 to 8 lbs./cubic ft.
- A 10' high banana box 5 to 6 lbs./cubic ft.

Ice Cream Handling

- Stacked loose 10 gal./sq. ft. floor space
- Pallet stacking 25 gal./sq. ft. floor space

Daily Turn Over

- Storage freezers 1/2 to 1 lb./cubic ft. for up to 10% or more of inventory.
- Storage coolers 2 to 3 lbs./cubic ft. for up to 20% or more of inventory.

- Incoming refrigerated products may require a 10°F to 20°F reduction in temperature due to heat picked up in transit.
- As the product load can vary greatly with the amount of inventory and daily turn over, accurate information should be obtained to establish those factors.

Material Handling

- Storage Rooms
- Loose Handling of Product 3 to 4 man hours/1000 lbs.
- Palletized Handling w/lift truck .5 to 1 man hr./1000 lbs. Figure 2 pallets per ton of product and 30 to 40 lbs. per pallet.
- Heat Rejection of Electric Fork Truck Figure 4 to 5 HP, and about 12,000 to 15,000 Btu/Hr.

Ice Cream Hardening Rooms

- Manual Stacking 4.5 man hours/1000 gal.
- Palletized w/fork Truck 1-1/2 man hours/1000 gal.

The above information should not be used in establishing loads or size of storage. Accurate information should be obtained from your customer. (Refer to tables for space, weight and density data for commodities stored in refrigerated warehouses.

TABLE 5

DESIGN TEMPERATURES - UNITED STATES

State	City	Summer		Winter	Elev. Ft.
		Dry Bulb °F	Wet Bulb °F	Dry Bulb °F	
Alabama	Birmingham	97	79	19	610
Alaska	Mobile	96	80	26	211
	Fairbanks	82	64	-53	436
	Juneau	75	66	-7	17
Arizona	Phoenix	108	77	31	1117
Arkansas	Tucson	105	74	29	2584
	Fort Smith	101	79	15	449
	Little Rock	99	80	19	257
California	Bakersfield	103	72	31	495
	Fresno	101	73	28	326
	Los Angeles	94	72	42	312
	Oakland	85	65	35	3
	San Francisco	80	64	32	8
Colorado	Denver	92	65	-2	5283
Connecticut	Hartford	90	77	1	15
	New Haven	88	77	5	6
Delaware	Dover	93	79	13	38
District of Columbia	Wilmington	93	79	12	78
	Washington	94	78	15	14
Florida	Jacksonville	96	80	29	24
	Key West	90	80	55	6
	Miami	92	80	44	9
	Tampa	92	81	36	19
Georgia	Atlanta	95	78	15	1005
	Savannah	95	81	24	42
Hawaii	Honolulu	87	75	60	7
Idaho	Boise	96	68	4	2842
Illinois	Chicago	94	78	-3	594
	Peoria	94	78	-2	652
	Springfield	95	79	-5	587
Indiana	Evansville	96	79	6	381
	Fort Wayne	93	77	0	791
	Indianapolis	93	78	0	793
	Terre Haute	95	79	3	601
Iowa	Des Moines	95	79	-7	948
Kansas	Sioux City	96	79	-10	1095
	Dodge City	99	74	3	2594
	Topeka	99	79	3	877
	Wichita	102	77	5	1321
Kentucky	Louisville	96	79	8	474
Louisiana	New Orleans	93	81	32	3
	Shreveport	99	81	22	252
Maine	Bangor	88	75	-8	162
	Portland	88	75	-5	61
Maryland	Baltimore	94	79	16	14
	Boston	91	76	6	15
	Springfield	86	74	-3	247
Massachusetts	Detroit	92	76	4	633
	Grand Rapids	91	76	2	601
	Lansing	89	76	2	652
Minnesota	Duluth	85	73	-19	1426
Mississippi	Minneapolis	92	77	-14	822
	Vicksburg	97	80	23	234
Missouri	Kansas City	100	79	4	742
Montana	St. Louis	96	79	7	465
	Billings	94	68	-10	3367
	Helena	90	65	-17	3893
Nebraska	Lincoln	100	78	-4	1150
Nevada	Oman	97	79	-5	978
	Reno	95	64	12	4490
New Hampshire	Concord	91	75	-11	339

State	City	Summer		Winter	Elev. Ft.
		Dry Bulb °F	Wet Bulb °F	Dry Bulb °F	
New Jersey	Atlantic City	91	78	14	11
New Mexico	Newark	94	77	11	11
	Trenton	92	78	12	144
	Albuquerque	96	66	14	5310
New York	Sante Fe	90	65	7	7045
	Albany	91	76	1	19
	Buffalo	88	75	3	705
North Carolina	New York	93	77	11	132
	Asheville	91	75	13	2770
	Charlotte	96	78	18	735
	Raleigh	95	79	16	433
North Dakota	Wilmington	93	52	23	30
	Bismarck	95	74	-24	1647
	Cincinnati	94	78	8	761
	Cleveland	91	76	2	777
	Columbus	92	77	2	212
Ohio	Dayton	92	77	0	997
	Toledo	92	72	0	900
Oklahoma	Oklahoma City	102	78	11	1280
	Tulsa	102	79	12	650
Oregon	Portland	91	69	26	57
	Erie	88	76	7	732
	Philadelphia	93	78	11	7
	Pittsburgh	90	75	7	749
	Scranton	89	75	2	940
Rhode Island	Providence	89	76	6	55
South Carolina	Charleston	95	81	26	9
	Greenville	95	77	19	957
	Huron	97	77	-16	1282
South Dakota	Rapid City	96	72	-9	3165
	Sioux Falls	95	77	-14	1430
Tennessee	Chattanooga	97	78	75	670
	Knoxville	95	77	13	980
	Memphis	98	80	17	263
	Nashville	97	79	12	577
Texas	Amarillo	98	72	8	3607
	Corpus Christi	95	32	32	43
	Dallas	101	79	19	481
	El Paso	100	70	21	3918
	Galveston	91	32	32	5
	Houston	96	80	29	158
	San Antonio	99	77	25	792
	Salt Lake City	97	67	5	4220
Utah	Burlington	88	74	-12	331
	Norfolk	94	79	20	26
	Richmond	96	79	14	152
	Roanoke	94	76	15	1174
Virginia	Seattle	81	69	28	14
	Spokane	93	66	-2	2357
	Charleston	92	76	9	939
Washington	Parkersburg	93	77	8	615
	Green Bay	88	75	-12	683
Wisconsin	Madison	92	77	-9	858
	Milwaukee	90	77	-5	672
	Cheyenne	89	63	-6	6128
Wyoming	Death Valley - 280' Elev.				

Summer design DB & WB temperatures equal to or exceeded 1% of 4 summer months. (about 30 hours), and winter DB temperatures 99% of 3 winter months (about 22 hours).

Ground temperatures (GT) for cold storage room calculations may be approximated for range -30° to +30°F. Winter design Dry Bulb (WDB) by GT, °F = 65 + WDB/2.

DESIGN TEMPERATURES - CANADA

Province	Sta. City	Summer		Winter	Elev. Ft.
		Dry Bulb °F	Wet Bulb °F	Dry Bulb °F	
Alberta	Calgary	87	66	-29	3540
British Columbia	Vancouver	80	68	15	60
Manitoba	Winnipeg	90	78	-28	786
Newfoundland	Gander	85	69	-5	482
Northwest Territories	Fort Smith	85	67	-49	665
Nova Scotia	Halifax	83	69	0	136
Ontario	Toronto	90	77	-3	578

Province	Sta. City	Summer		Winter	Elev. Ft.
		Dry Bulb °F	Wet Bulb °F	Dry Bulb °F	
Prince Edward Island	Charlottetown	84	71	-6	186
Quebec	Montreal	88	75	-16	98
	Quebec	86	75	-19	245
Saskatchewan	Regina	92	73	-34	1884
Yukon	White Horse	78	62	-45	2289

ASHRAE 1972 Fundamentals - Reprinted by permission

TABLE 6

WALL HEAT GAIN TABLE

(BTU/24 Hr./Sq. Ft. of Outside Surface)

INSULATION		TEMPERATURE DIFFERENCE IN °F (AMBIENT TEMPERATURE - STORAGE TEMPERATURE)																						
Thick- ness Inches	k Factor	1	10	20	30	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	
1	.30	7.2	72	144	216	288	324																	
	.25	6.0	60	120	180	240	270	300	330															
	.20	4.8	48	96	144	192	216	240	264	288	312													
	.16	3.84	38	77	115	154	173	192	211	230	250	269	288	307										
	.14	3.36	34	67	101	134	151	168	185	202	218	235	252	269	286	302								
2	.30	3.6	36	72	108	144	162	180	198	216	234	252	270	288	306									
	.25	3.0	30	60	90	120	135	150	165	180	195	210	225	240	255	270	285	300						
	.20	2.4	24	48	72	96	108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	
	.16	1.92	19	38	58	77	86	96	106	115	125	134	144	154	163	173	182	192	202	211	221	230	240	
	.14	1.68	17	34	50	67	76	84	92	101	109	118	126	134	143	151	160	168	176	185	193	202	210	
3	.30	2.4	24	48	72	96	108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	
	.25	2.0	20	40	60	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	
	.20	1.6	16	32	48	64	72	80	88	96	104	112	120	128	136	144	152	160	168	176	184	192	200	
	.16	1.28	13	26	38	51	58	64	70	77	83	90	96	102	109	115	122	128	134	141	147	154	160	
	.14	1.13	11	23	34	45	50	56	62	67	73	78	84	90	95	101	106	112	118	123	129	134	140	
4	.30	1.8	18	36	54	72	81	90	99	108	117	126	135	144	153	162	171	180	189	198	207	216	225	
	.25	1.5	15	30	45	60	68	75	83	90	98	105	113	120	128	135	143	150	158	165	173	180	188	
	.20	1.2	12	24	36	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	
	.16	0.96	10	19	29	38	43	48	53	58	62	68	72	77	82	87	91	96	101	106	111	115	120	
	.14	0.84	9	17	25	34	38	42	46	50	55	59	63	68	71	75	80	84	88	92	97	101	105	
5	.30	1.44	14	29	42	58	65	72	79	87	94	101	108	115	122	130	137	144	151	159	166	173	180	
	.25	1.2	12	24	36	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	
	.20	0.96	10	19	29	38	43	48	53	58	62	67	72	77	82	87	91	96	101	106	110	115	120	
	.16	0.76	8	15	23	31	35	38	42	46	50	54	58	61	65	69	73	77	81	84	88	92	96	
	.14	0.67	7	13	20*	27	30	34	37	40	44	47	50	54	57	60	64	67	71	74	77	81	84	
6	.30	1.2	12	24	36	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	
	.25	1.0	10	20	30	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	
	.20	0.8	8	16	24	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	
	.16	0.64	6	13	19	26	29	32	35	38	42	45	48	51	54	58	61	64	67	70	74	77	80	
	.14	0.56	6	11	17	22	25	28	31	34	36	39	42	45	48	50	53	56	59	62	64	67	70	
7	.30	1.02	10	20	30	41	46	52	57	62	67	72	77	82	88	93	98	103	108	113	118	124	129	
	.25	0.85	9	17	26	34	39	43	47	51	56	60	64	68	73	77	81	86	90	94	99	103	107	
	.20	0.68	7	14	21	27	31	34	38	41	45	48	51	55	58	62	65	69	72	75	79	82	86	
8	.30	0.90	9	18	27	36	41	45	50	54	59	63	68	72	77	81	86	90	95	99	104	108	113	
	.25	0.75	8	15	23	30	34	38	41	45	49	53	56	60	64	68	71	75	79	83	86	90	94	
	.20	0.60	6	12	18	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	
9	.30	0.80	8	16	24	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	
	.25	0.67	7	13	20	27	30	34	37	40	44	47	50	54	57	60	64	67	70	74	77	80	84	
10	.30	0.72	7	14	21	29	32	36	40	43	47	50	54	58	61	65	68	72	76	79	83	86	90	
	.25	0.60	6	12	18	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	
11	.30	0.65	6.5	13	19.5	26	30	33	36	40	43	46	50	53	56	60	63	66	69	73	76	79	82	
	.25	0.55	5.5	11	17	22	25	28	30	33	36	39	41	44	47	50	52	55	58	61	63	66	69	
12	.30	0.60	6	12	18	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	
	.25	0.50	5	10	15	20	23	25	28	30	33	35	38	40	43	45	48	50	53	55	58	60	63	
Single Glass		27	270	540	810	1080	1220	1350	1490	1620														
Double Glass		11	110	220	330	440	500	550	610	660	715	770	825	880	936	990	1050	1100	1160	1210	1270	1320	1375	
Triple Glass		7	70	140	210	280	320	350	390	420	454	490	525	560	595	630	665	700	740	770	810	840	875	
Concrete Floor Slab on the ground (See Note)		For 6 or 8 inch concrete floor on the ground, not insulated use the TD between the average summer ground temp. and box temp. (Note: Not for freezers or for coolers operated close to freezing. Insulated floors recommended for all coolers and freezers (use insul. thickness and TD room to slab temperature).																						
Floor under 144 sq. ft.		6	60	120	180	240	270																	
Floor over 144 sq. ft.		4.5	45	90	135	180	203																	

Insulation * k = 0.30 Corkboard, Mineral Wool
 0.25 Fiberglass Styrofoam, Expanded Polystyrene
 .20 Moulded Polystyrene
 .16 Sprayed Urethane, Foam Urethane Sheets, Slabs and Panels
 .14 Urethane Panels (Foamed in Place).

*Check with supplier for applicable k factor

k Factor in Btu/Hr./Sq. Ft./Deg. F/Inch

ASHRAE 1977 Fundamentals - Reprinted by permission

TABLE 8

ALLOWANCE FOR SUN EFFECT
(Fahrenheit degrees to be added to the normal temperature difference for heat leakage calculations to compensate for sun effect - not to be used for air conditioning design)

TABLE 7

MINIMUM INSULATION THICKNESS

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

ASHRAE 1972 - Reprinted by permission

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

ASHRAE 1972 Fundamentals - Reprinted by permission

TABLE 9

AVERAGE AIR CHANGES PER 24 HOURS FOR STORAGE ROOMS ABOVE 32°F
Due to Door Opening and Infiltration

Volume Cu. Ft.	Air Changes Per 24 Hrs.	Volume Cu. Ft.	Air Changes Per 24 Hrs.	Volume Cu. Ft.	Air Changes Per 24 Hrs.	Volume Cu. Ft.	Air Changes Per 24 Hrs.
200	44.0	800	20.0	5000	7.2	25,000	3.0
250	38.0	1000	17.5	6000	6.5	30,000	2.7
300	34.5	1500	14.0	8000	5.5	40,000	2.3
400	29.5	2000	12.0	10,000	4.9	50,000	2.0
500	26.0	3000	9.5	15,000	3.9	75,000	1.6
600	23.0	4000	8.2	20,000	3.5	100,000	1.4
						350,000	1.13*
						700,000	0.97*

NOTE: For heavy usage multiply the above values by a service factor of 2.
For long storage multiply the above values by 0.6.

* = Extrapolated

ASHRAE 1967 Fundamentals - Reprinted by permission

TABLE 10

AVERAGE AIR CHANGES PER 24 HOURS FOR STORAGE ROOMS BELOW 32°F
Due to Door Opening and Infiltration

Volume Cu. Ft.	Air Changes Per 24 Hrs.	Volume Cu. Ft.	Air Changes Per 24 Hrs.	Volume Cu. Ft.	Air Changes Per 24 Hrs.	Volume Cu. Ft.	Air Changes Per 24 Hrs.
200	33.5	800	15.3	5000	5.6	25,000	2.3
250	29.0	1000	13.5	6000	5.0	30,000	2.1
300	26.2	1500	11.0	8000	4.3	40,000	1.8
400	22.5	2000	9.3	10,000	3.8	50,000	1.6
500	20.0	3000	7.4	15,000	3.0	75,000	1.3
600	18.0	4000	6.3	20,000	2.6	100,000	1.1
						150,000	0.88*
						200,000	.77

NOTE: ● For heavy usage multiply the above values by a service factor of 2.
For long storage multiply the above values by 0.6.
● For 2 doors in same wall multiply by 1.25.
● For 2 doors in opposite walls multiply by 2.5, but two open doors on adjacent or opposite walls should not be tolerated.

* = Extrapolated

ASHRAE 1967 Fundamentals - Reprinted by permission

TABLE 11

**HEAT REMOVED IN COOLING AIR TO
REFRIGERATOR CONDITIONS
BTU per cu. ft.**

Storage Room Temp. F	Temperature of Outside Air, F								Storage Room Temp. F	Temperature of Outside Air, F							
	85		90		95		100			40		50		90		100	
	Relative Humidity, %									Relative Humidity, %							
	50	60	50	60	50	60	50	60		70	80	70	80	50	60	50	60
65	0.65	0.85	0.93	1.17	1.24	1.54	1.58	1.95	30	0.24	0.29	0.58	0.66	2.26	2.53	2.95	3.35
60	0.85	1.03	1.13	1.37	1.44	1.74	1.78	2.15	25	0.41	0.45	0.75	0.83	2.44	2.71	3.14	3.54
55	1.12	1.34	1.41	1.66	1.72	2.01	2.06	2.44	20	0.56	0.61	0.91	0.99	2.62	2.90	3.33	3.73
50	1.32	1.54	1.62	1.87	1.93	2.22	2.28	2.65	15	0.71	0.75	1.06	1.14	2.80	3.07	3.51	3.92
45	1.50	1.73	1.80	2.06	2.12	2.42	2.47	2.85	10	0.85	0.89	1.19	1.27	2.93	3.20	3.64	4.04
40	1.69	1.92	2.00	2.26	2.31	2.62	2.67	3.06	5	0.98	1.03	1.34	1.42	3.12	3.40	3.84	4.27
35	1.86	2.09	2.17	2.43	2.49	2.79	2.85	3.24	0	1.12	1.17	1.48	1.56	3.28	3.56	4.01	4.43
30	2.00	2.24	2.26	2.53	2.64	2.94	2.95	3.35	-5	1.23	1.28	1.59	1.67	3.41	3.69	4.15	4.57
From Chapter 27 "ASHRAE Guide and Data Book, 1961". Used by permission.									-10	1.35	1.41	1.73	1.81	3.56	3.85	4.31	4.74
									-15	1.50	1.53	1.85	1.92	3.67	3.96	4.42	4.86
									-20	1.63	1.68	2.01	2.09	3.88	4.18	4.66	5.10
									-25	1.77	1.80	2.12	2.21	4.00	4.30	4.78	5.21
									-30	1.90	1.95	2.29	2.38	4.21	4.51	4.90	5.44

TABLE 12

HEAT EQUIVALENT OF OCCUPANCY

Cooler Temperature, F	Heat Equivalent Per Person, Btuh	When people enter a refrigerated space for short durations, they carry with them a considerable amount of heat over and above that listed in Table 12. Some allowance must be made if traffic load of this type is heavy. ASHRAE 1977 Fundamentals - Reprinted by permission
50	720	
40	840	
30	950	
20	1050	
10	1200	
0	1300	
-10	1400	

TABLE 13

HEAT EQUIVALENT OF ELECTRIC MOTORS

Evaporator Fan Motor HP	Connected Load In Refrigerated Space	Motor Losses Outside Refrig. Space	Connected Load Outside Refrig. Space
	Btu/HP/Hr.	Btu/HP/Hr.	Btu/HP/Hr.
1/20 HP	6400	2545	
1/15 HP	5700	2545	
1/12 HP	5300	2545	
1/10 HP	4950	2545	
1/8 HP	4650	2545	
1/6 HP	4350	2545	
1/4 HP	4000	2545	1455
1/3 HP	3850	2545	1305
1/2 HP	3700	2545	1155
3/4 HP	3600	2545	1055
1 HP	3500	2545	955
2 HP	3300	2545	755
3 HP	3200	2545	655
5 HP	3100	2545	555
7 1/2 HP	3050	2545	505
10 to 20	3000	2545	455

*For motors rated in Watts (input) multiply Watts by 3.41 Btu/W/Hr.

At a given fan speed the fan will deliver approximately the same air quantity through a given coil at any air temperature.

The lower the air temperature the greater the weight of air handled by the fan at a given fan speed. The fan horsepower will vary directly with the air density or inversely with the absolute temperature of the air ($^{\circ}\text{F} + 460^{\circ}$ or $^{\circ}\text{C} + 273^{\circ}$)

The increased heat dissipation of the motor at the lower temperatures offsets the greater HP requirement and increased amp draw.

For altitudes above and below sea level, the weight of air handled by the fan and the fan HP will vary directly with the change in air density.

ASHRAE 1977 Fundamentals - Reprinted by permission

TABLE 14A

**OUTSIDE AREA AND INTERNAL VOLUME
OF COOLERS AND FREEZERS**
(Volume Based on Insulated Floor)

ROOM OUTSIDE DIM. - FT.		9 FT. HIGH OUTSIDE					
		OUTSIDE AREA SQ. FT.	VOLUME - CU. FT.				
			TOTAL WALL THICKNESS - INCHES				
W	L		3"	4"	6"	8"	10"
5	4	202	134	120	96	75	57
	5	270	172	156	128	103	82
	6	258	210	192	160	131	106
	7	286	249	228	192	159	131
	8	314	287	264	224	187	155
6	6	288	257	237	200	167	138
	7	318	304	281	240	203	170
	8	348	351	325	280	238	202
	9	378	397	370	320	274	233
	10	408	444	414	360	310	265
7	7	350	359	334	288	246	209
	8	382	414	386	336	289	248
	9	414	470	439	384	333	287
	10	446	525	492	432	376	326
	12	510	635	597	528	464	404
8	8	416	478	448	392	340	294
	9	450	542	509	448	392	341
	10	484	606	570	504	444	396
	12	552	733	692	616	545	479
	14	620	861	814	728	647	572
9	9	486	614	578	512	450	394
	10	522	686	647	576	509	448
	12	594	831	786	704	627	556
	14	666	975	925	832	745	663
	16	738	1120	1064	960	863	771
10	10	560	767	725	648	575	509
	12	636	929	881	792	709	631
	14	712	1090	1036	936	840	754
	16	788	1252	1191	1080	976	876
	18	864	1413	1347	1224	1107	998
12	12	720	1124	1069	968	872	785
	14	804	1320	1258	1144	1036	935
	16	888	1515	1447	1320	1200	1086
	18	972	1711	1635	1496	1363	1238
	20	1056	1906	1824	1672	1527	1390
14	14	896	1549	1480	1352	1229	1115
	16	988	1779	1721	1560	1424	1296
	18	1080	2008	1924	1768	1618	1477
	20	1172	2238	2146	1976	1813	1656
	25	1402	2811	2702	2496	2298	2110
16	16	1088	2042	1957	1800	1649	1506
	18	1188	2306	2213	2040	1874	1716
	20	1288	2569	2468	2280	2095	1925
	25	1538	3228	3106	2880	2660	2452
18	18	1296	2603	2502	2312	2129	1956
	20	1404	2901	2790	2584	2385	2196
	25	1674	3644	3512	3264	3024	2795
20	20	1520	3232	3112	2888	2670	2464
	25	1810	4061	3918	3648	3387	3137
25	25	2150	5102	4931	4608	4299	3992
	30	2490	6143	5944	5568	5200	4548
30	30	2880	7397	7166	6728	6300	5887
	40	3660	9905	9509	9048	8498	7964

1. Internal Volume based on Floor Insulation
2. For corkboard and similar insulation, wall thickness figured at Insulation + 2 inches.
3. Subtract 2 x Wall Thickness for inside dimension.

TABLE 14B

**OUTSIDE AREA AND INTERNAL VOLUME
OF COOLERS AND FREEZERS**
(Volume Based on Insulated Floor)

ROOM OUTSIDE DIM.-FT.		OUTSIDE AREA SQ. FT.	12 FT. HIGH OUTSIDE				
			VOLUME - CU. FT.				
			TOTAL WALL THICKNESS - INCHES				
W	L		3"	4"	6"	8"	10"
5	4	256	181	163	132	104	80
	5	298	233	212	176	143	115
	6	324	285	261	220	182	149
	7	356	336	310	264	221	182
	8	392	388	360	308	260	218
6	6	360	348	322	275	232	194
	7	396	411	382	330	282	238
	8	432	474	443	385	332	284
	9	468	538	503	440	382	328
	10	504	601	563	495	431	373
7	7	444	486	454	396	342	293
	8	472	561	526	462	403	349
	9	510	635	597	528	463	404
	10	548	710	669	594	524	459
	12	624	860	813	726	645	569
8	8	512	647	609	539	473	414
	9	552	733	692	616	545	480
	10	592	819	775	693	628	544
	12	672	992	941	847	758	675
	14	752	1164	1107	1001	900	806
9	9	594	831	786	704	626	555
	10	636	929	880	792	708	631
	12	720	1124	1085	968	872	783
	14	804	1319	1274	1144	1036	934
	16	888	1515	1447	1320	1199	1086
10	10	680	1038	986	891	800	727
	12	768	1256	1198	1089	986	889
	14	856	1475	1409	1287	1168	1062
	16	944	1693	1620	1485	1357	1234
	18	1032	1912	1832	1683	1540	1406
12	12	864	1521	1454	1331	1213	1103
	14	960	1785	1711	1573	1441	1317
	16	1056	2050	1968	1825	1669	1530
	18	1152	2314	2225	2057	1896	1744
	20	1248	2579	2481	2299	2123	1959
14	14	1064	2096	2013	1859	1710	1571
	16	1168	2406	2315	2145	1981	1826
	18	1272	2717	2617	2431	2281	2081
	20	1376	3027	2919	2717	2522	2336
	25	1636	3804	3675	3432	3197	2973
16	16	1280	2763	2663	2640	2294	2122
	18	1392	3119	3010	2992	2607	2418
	20	1504	3476	3357	3344	2920	2715
	25	1784	4367	4226	4224	3700	3465
18	18	1512	3521	3402	3179	2962	2756
	20	1682	3924	3795	3553	3311	3094
	25	1932	4930	4777	4488	4207	3938
20	20	1760	4372	4233	3971	3714	3472
	25	2080	5494	5328	5016	4712	4420
25	25	2450	6903	8707	6336	5974	5625
	30	2820	8312	8085	7656	7234	6831
30	30	3240	10007	9746	9251	7234	8295
	40	4080	13400	13069	12441	11823	11222

1. Internal Volume based on Floor Insulation
2. For Corkboard and similar insulation wall thickness figured at Insulation + 2 inches.
3. Subtract 2 x Wall Thickness for inside dimension.

TABLE 14C

**OUTSIDE AREA AND INTERNAL VOLUME
OF COOLERS AND FREEZERS**
(Volume Based on Insulated Floor)

ROOM OUTSIDE DIM.-FT.		16 FT. HIGH OUTSIDE					
		OUTSIDE AREA SQ. FT.	VOLUME - CU. FT.				
			TOTAL WALL THICKNESS - INCHES				
W	L		3"	4"	6"	8"	10"
7	7	546	665	614	540	471	408
	8	592	767	711	630	554	484
	9	638	870	808	720	537	561
	10	684	972	905	810	720	637
	12	776	1176	1099	990	886	790
8	8	640	872	823	735	652	575
	9	688	988	936	840	750	666
	10	736	1104	1048	945	848	756
	12	832	1337	1273	1159	1043	938
	14	928	1569	1498	1365	1239	1119
9	9	738	1120	1064	960	862	771
	10	788	1252	1191	1080	974	876
	12	888	1515	1447	1320	1200	1086
	14	988	1779	1702	1560	1424	1296
	16	1088	2042	1958	1800	1649	1505
10	10	840	1399	1334	1215	1100	995
	12	944	1693	1620	1485	1356	1233
	14	1048	1988	1907	1755	1606	1475
	16	1152	2282	2193	2025	1867	1712
	18	1256	2577	2479	2295	2117	1950
12	12	1056	2050	1968	1825	1668	1534
	14	1168	2406	2315	2145	1982	1827
	16	1280	2763	2662	2475	2295	2122
	18	1392	3119	3010	2805	2607	2420
	20	1504	3476	3357	3135	2921	2717
14	14	1288	2825	2724	2535	2351	2179
	16	1408	3243	3133	2925	2724	2533
	18	1528	3662	3541	3315	3095	2887
	20	1648	4080	3950	3705	3468	3240
	25	1948	5127	4972	4680	4396	4124
16	16	1536	3724	3602	3375	3154	2944
	18	1664	4204	4073	3825	3585	3354
	20	1792	4685	4543	4275	4015	3767
	25	2112	5886	5718	5400	5088	4793
18	18	1800	4746	4604	4335	4072	3823
	20	1936	5289	5135	4845	4562	4292
	25	2276	6646	6464	6120	5784	5463
20	20	2080	5894	5728	5415	5107	4816
	25	2440	7405	7210	6840	6479	6132
25	25	2850	9304	9074	8640	8214	7802
	30	3470	11203	10939	10440	9947	9475
30	30	3720	13488	13187	12615	12052	11507
	40	4640	18061	17684	16965	16256	15566

1. Internal Volume based on Floor Insulation
2. For Corkboard and similar insulation wall thickness figured at Insulation + 2 inches.
3. Subtract 2 x Wall Thickness for inside dimension.

TABLE 14B

**OUTSIDE AREA AND INTERNAL VOLUME
OF COOLERS AND FREEZERS**
(Volume Based on Insulated Floor)

ROOM OUTSIDE DIM.-FT.		12 FT. HIGH OUTSIDE					
		OUTSIDE AREA SQ. FT.	VOLUME - CU. FT.				
			TOTAL WALL THICKNESS - INCHES				
W	L		3"	4"	6"	8"	10"
5	4	256	181	163	132	104	80
	5	298	233	212	176	143	115
	6	324	285	261	220	182	149
	7	356	336	310	264	221	182
	8	392	388	360	308	260	218
6	6	360	348	322	275	232	194
	7	396	411	382	330	282	238
	8	432	474	443	385	332	284
	9	468	538	503	440	382	328
	10	504	601	563	495	431	373
7	7	444	486	454	396	342	293
	8	472	561	526	462	403	349
	9	510	635	597	528	463	404
	10	548	710	669	594	524	459
	12	624	860	813	726	645	569
8	8	512	647	609	539	473	414
	9	552	733	692	616	545	480
	10	592	819	775	693	628	544
	12	672	992	941	847	758	675
	14	752	1164	1107	1001	900	806
9	9	594	831	786	704	626	555
	10	636	929	880	792	708	631
	12	720	1124	1085	968	872	783
	14	804	1319	1274	1144	1036	934
	16	888	1515	1447	1320	1199	1086
10	10	680	1038	986	891	800	727
	12	768	1256	1198	1089	986	889
	14	856	1475	1409	1287	1168	1062
	16	944	1693	1620	1485	1357	1234
	18	1032	1912	1832	1683	1540	1406
12	12	864	1521	1454	1331	1213	1103
	14	960	1785	1711	1573	1441	1317
	16	1056	2050	1968	1825	1669	1530
	18	1152	2314	2225	2057	1896	1744
	20	1248	2579	2481	2299	2123	1959
14	14	1064	2096	2013	1859	1710	1571
	16	1168	2406	2315	2145	1981	1826
	18	1272	2717	2617	2431	2281	2081
	20	1376	3027	2919	2717	2522	2336
	25	1636	3804	3675	3432	3197	2973
16	16	1280	2763	2663	2640	2294	2122
	18	1392	3119	3010	2992	2607	2418
	20	1504	3476	3357	3344	2920	2715
	25	1784	4367	4226	4224	3700	3465
18	18	1512	3521	3402	3179	2962	2756
	20	1682	3924	3795	3553	3311	3094
	25	1932	4930	4777	4488	4207	3938
20	20	1760	4372	4233	3971	3714	3472
	25	2080	5494	5328	5016	4712	4420
25	25	2450	6903	8707	6336	5974	5625
	30	2820	8312	8085	7656	7234	6831
30	30	3240	10007	9746	9251	7234	8295
	40	4080	13400	13069	12441	11823	11222

1. Internal Volume based on Floor Insulation
2. For Corkboard and similar insulation wall thickness figured at Insulation + 2 inches.
3. Subtract 2 x Wall Thickness for inside dimension.

TABLE 14C

**OUTSIDE AREA AND INTERNAL VOLUME
OF COOLERS AND FREEZERS
(Volume Based on Insulated Floor)**

ROOM OUTSIDE DIM.-FT.		OUTSIDE AREA SQ. FT.	16 FT. HIGH OUTSIDE				
			VOLUME - CU. FT.				
			TOTAL WALL THICKNESS - INCHES				
W	L		3"	4"	6"	8"	10"
7	7	546	665	614	540	471	408
	8	592	767	711	630	554	484
	9	638	870	808	720	537	561
	10	684	972	905	810	720	637
	12	776	1176	1099	990	886	790
8	8	640	872	823	735	652	575
	9	688	988	936	840	750	666
	10	736	1104	1048	945	848	756
	12	832	1337	1273	1159	1043	938
	14	928	1569	1498	1365	1239	1119
9	9	738	1120	1064	960	862	771
	10	788	1252	1191	1080	974	876
	12	888	1515	1447	1320	1200	1086
	14	988	1779	1702	1560	1424	1296
	16	1088	2042	1958	1800	1649	1505
10	10	840	1399	1334	1215	1100	995
	12	944	1693	1620	1485	1356	1233
	14	1048	1988	1907	1755	1606	1475
	16	1152	2282	2193	2025	1867	1712
	18	1256	2577	2479	2295	2117	1950
12	12	1056	2050	1968	1825	1668	1534
	14	1168	2406	2315	2145	1982	1827
	16	1280	2763	2662	2475	2295	2122
	18	1392	3119	3010	2805	2607	2420
	20	1504	3476	3357	3135	2921	2717
14	14	1288	2825	2724	2535	2351	2179
	16	1408	3243	3133	2925	2724	2533
	18	1528	3662	3541	3315	3095	2887
	20	1648	4080	3950	3705	3468	3240
	25	1948	5127	4972	4680	4396	4124
16	16	1536	3724	3602	3375	3154	2944
	18	1664	4204	4073	3825	3585	3354
	20	1792	4685	4543	4275	4015	3767
	25	2112	5886	5718	5400	5088	4793
18	18	1800	4746	4604	4335	4072	3823
	20	1936	5289	5135	4845	4562	4292
	25	2276	6646	6464	6120	5784	5463
20	20	2080	5894	5728	5415	5107	4816
	25	2440	7405	7210	6840	6479	6132
25	25	2850	9304	9074	8640	8214	7802
	30	3470	11203	10939	10440	9947	9475
30	30	3720	13488	13187	12615	12052	11507
	40	4640	18061	17684	16965	16256	15566

1. Internal Volume based on Floor Insulation
2. For Corkboard and similar insulation wall thickness figured at Insulation + 2 inches.
3. Subtract 2 x Wall Thickness for inside dimension.

TABLE 15

USE FOR COOLERS ONLY
USAGE HEAT GAIN BTU PER 24 HR. FOR ONE CU. FT. INTERIOR CAPACITY

Volume cu ft	Service*	Temperature difference (ambient temp minus storage room temp), F deg										
		1	40	50	55	60	65	70	75	80	90	100
20	Average	4.68	187	234	258	281	305	328	351	374	421	468
	Heavy	5.51	220	276	303	331	358	386	413	441	496	551
30	Average	3.30	132	165	182	198	215	231	248	264	297	330
	Heavy	4.56	182	228	251	274	297	319	342	365	410	456
50	Average	2.28	91	114	126	137	148	160	171	182	205	228
	Heavy	3.55	142	177	196	213	231	249	267	284	320	355
75	Average	1.85	74	93	102	111	120	130	139	148	167	185
	Heavy	2.88	115	144	158	173	188	202	216	230	259	288
100	Average	1.61	64	81	84	97	105	113	121	129	145	161
	Heavy	2.52	101	126	139	151	164	176	189	202	227	252
200	Average	1.38	55	69	76	83	90	97	103	110	124	138
	Heavy	2.22	90	111	122	133	144	155	166	178	200	222
300	Average	1.30	52.0	65	71.5	78	84.5	91	97.5	104	117	130
	Heavy	2.08	83.2	104	114	125	135	146	156	166	187	208
400	Average	1.24	49.6	62	68.2	74.4	80.6	86.8	93	99.2	112	124
	Heavy	1.90	78.4	98	108	118	128	137	147	157	176	196
500	Average	1.21	48.4	60.5	66.6	72.6	78.7	84.7	90.7	96.8	109	121
	Heavy	1.87	74.8	93.5	103	112	122	131	140	150	168	187
600	Average	1.17	46.8	58.5	64	70	76	82	88	94	105	117
	Heavy	1.85	74.0	92.5	102	111	120	130	139	148	167	185
800	Average	1.11	44.4	55.5	61.1	66.6	72.2	77.7	83.3	88.8	100	111
	Heavy	1.76	70.4	88.0	96.8	106	115	123	132	141	158	176
1,000	Average	1.10	44.0	55.0	60.5	66	71.5	77	82.5	88	99	110
	Heavy	1.67	66.8	83.5	91.9	100	108	117	125	134	150	167
1,200	Average	.995	39.8	49.8	54.7	59.7	64.7	69.7	74.7	79.6	89.6	99.5
	Heavy	1.58	63.2	79.0	86.9	94.8	103	111	119	126	142	158
1,500	Average	.920	36.8	46.0	50.6	55.2	59.8	64.4	69	73.6	82.8	92
	Heavy	1.50	60.0	75.0	82.5	90.0	97.5	105	113	120	135	150
2,000	Average	.835	33.4	41.8	45.9	50.1	54.3	58.5	62.7	66.8	75.2	83.5
	Long storage	.775	31.0	38.8	42.6	46.5	50.4	54.3	58.1	62	69.8	77.5
3,000	Average	.750	30.0	37.5	41.3	45.0	48.8	52.5	56.2	60.0	67.5	75.0
	Long storage	.576	23.0	28.8	31.7	34.6	37.3	40.3	43.2	46.1	51.8	57.6
5,000	Long storage	.403	16.1	20.2	22.2	24.2	26.2	28.2	30.2	32.2	36.3	40.3
7,500	Long storage	.305	12.2	15.3	16.8	18.3	19.8	21.4	22.9	24.4	27.5	30.5
10,000	Long storage	.240	9.6	12.0	13.2	14.4	15.6	16.8	18.0	19.2	21.6	24.0
20,000	Long storage	.187	7.48	9.35	10.3	11.2	12.2	13.1	14.0	15.0	16.8	18.7
50,000	Long storage	.178	7.12	8.90	9.79	10.7	11.6	12.5	13.4	14.2	16.0	17.8
75,000	Long storage	.176	7.04	8.80	9.68	10.6	11.5	12.3	13.2	14.1	15.8	17.6
100,000	Long storage	.173	6.92	8.65	9.52	10.4	11.2	12.1	13.0	13.8	15.6	17.3

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

ASHRAE 1972 Fundamentals - Reprinted by permission

TABLE 16

AVERAGE DAILY PRODUCT LOADING IN LBS. PER CU. FT.
FOR STORAGE COOLERS AND FREEZERS

Cu. Ft. Room Volume	Daily Product Loading Lbs./Cu. Ft. of Int. Vol.		Cu. Ft. Room Volume	Daily Product Loading Lbs./Cu. Ft. of Int. Vol.	
	Cooler	Freezer		Cooler	Freezer
500	3.6	1.45	5,000	2.42	0.69
750	3.2	1.20	7,500	2.32	0.64
1,000	3.0	1.08	10,000	2.27	0.61
1,250	2.9	0.99	15,000	2.20	0.57
1,500	2.8	0.93	20,000	2.13	0.54
2,000	2.7	0.86	30,000	2.07	0.52
3,000	2.6	0.78	50,000	2.0	0.48
4,000	2.5	0.72	100,000	1.9	0.44

NOTES:

1. This table is for estimating purposes only, when specific product loading data is not available. Do not use when loads are unusual or for process cooling or freezing.
2. Product Loading represents daily product turn-over and not storage capacity of room.
3. To cover heat-up of incoming product, due to transportation and handling, figure minimum pull-down of 15 to 20°F for coolers and 10 to 15°F for freezers, to allow for bringing product back down to storage temperature.

TABLE 17

QUICK SELECTION WALK-IN COOLERS AND FREEZERS
(Based on Box Located within 95°F Ambient Area)

		Walk-In Coolers. Ambient Defrost - 16 Hr. Compressor Operation				Walk-In Freezers Storage Only - No Product Load 18 Hr. Compressor Operation					
Outside Dimensions L x W x H	Outside Surface Sq. Ft.	35°F Based on 4" Cork Insulation				6" Cork Insulation		8" Cork Insulation			
		Volume Cu. Ft.	Normal Load Btu/Hr.	Heavy Load Btu/Hr.	Extra Heavy Load Btu/Hr.	Volume Cu. Ft.	0°F Btu/h	-10°F Btu/h	Volume Cu. Ft.	-10°F Btu/h	-20°F Btu/h
5 x 4 x 9	202	96	2200	2530	2910	75	2860	3300	57	2710	2750
5 x 5 x 9	230	128	2530	3080	3560	103	3410	3850	82	3160	3300
5 x 6 x 9	258	160	2970	3520	4130	131	3850	4290	106	3530	3740
5 x 7 x 9	286	192	3410	3960	4680	159	4230	4730	131	3920	4180
5 x 8 x 9	314	224	3740	4510	5236	187	4620	5060	155	4280	4620
6 x 6 x 9	288	200	3410	4070	4790	167	4310	4840	138	4000	4290
6 x 7 x 9	318	240	3850	4620	5500	203	4730	5280	170	4430	4840
6 x 8 x 9	348	280	4290	5170	6060	238	5060	5610	202	4800	5280
6 x 9 x 9	378	320	4620	5720	6580	274	5390	6050	233	5260	5720
6 x 10 x 9	408	360	4950	6160	6990	310	5720	6380	265	5540	6050
7 x 7 x 9	350	288	4400	5390	6270	246	5170	5720	208	4980	5390
7 x 8 x 9	382	336	4730	5940	6990	289	5610	6160	248	5360	5830
7 x 9 x 9	414	384	5170	6490	7700	333	5940	6600	287	5740	6270
7 x 10 x 9	446	432	5610	7040	8360	376	6380	7040	326	6120	6710
7 x 12 x 9	510	528	6380	8030	9735	464	7040	7810	404	6790	7480
8 x 8 x 9	416	382	5280	6600	7600	340	6050	6710	294	5860	6380
8 x 9 x 9	450	448	5720	7150	8640	392	6490	7150	341	6280	6820
8 x 10 x 9	484	504	6270	7700	9270	444	6930	7590	396	6790	7260
8 x 12 x 9	552	616	7150	8910	10870	545	7700	8360	476	7620	8030
8 x 14 x 9	620	728	8030	10010	12220	647	8360	9240	572	8430	8800
9 x 9 x 9	486	512	6270	7920	9740	450	6930	7700	394	7010	7370
9 x 10 x 9	522	576	6820	8470	10420	509	7480	8140	448	7410	7810
9 x 12 x 9	594	704	7920	9790	11940	627	8250	9020	556	8210	8690
9 x 14 x 9	666	832	8910	11000	12300	745	9020	9900	663	9010	9570
9 x 16 x 9	738	960	9790	12100	14960	863	9790	10780	771	9810	10340
10 x 10 x 9	560	648	7370	9240	11210	575	7810	8690	509	7850	8250
10 x 12 x 9	636	792	8470	10670	12960	709	8800	9680	631	8760	9350
10 x 14 x 9	712	936	9570	11990	14670	840	9680	10560	754	9690	10230
10 x 16 x 9	788	1080	10570	13200	16190	976	10450	11440	876	10620	11000
10 x 18 x 9	864	1224	11660	14410	17800	1107	11220	12320	998	11350	11770
12 x 12 x 9	720	968	9900	12100	14670	872	9790	10780	785	9860	10340
12 x 14 x 9	804	1144	11110	13750	16770	1036	10890	11880	935	10890	11330
12 x 16 x 9	888	1320	12210	15290	18770	1200	11880	12980	1086	11800	12320
12 x 18 x 9	972	1496	13310	16720	20630	1363	12650	13860	1238	12770	13200
12 x 20 x 9	1056	1672	14410	18040	22500	1527	13420	14850	1390	13720	14080
14 x 14 x 9	896	1352	12430	15510	18990	1229	11990	13090	1115	12030	12540
14 x 16 x 9	988	1560	13640	17160	21190	1424	12980	14190	1296	13060	13530
14 x 18 x 9	1080	1768	14850	18590	23320	1618	13860	15290	1477	14080	14520
14 x 20 x 9	1172	1976	15950	20020	25590	1813	14850	16280	1656	15080	15400
14 x 25 x 9	1402	2496	18280	22910	28590	2298	16830	18590	2110	17210	17270
16 x 16 x 9	1088	1800	14960	18920	23600	1649	14080	15510	1506	14250	14630
16 x 18 x 9	1188	2040	16170	20460	25880	1874	15180	16610	1716	15250	15620
16 x 20 x 9	1288	2280	17380	21890	28010	2099	16170	17600	1927	16400	16500
16 x 25 x 9	1538	2880	21000	26530	33530	2660	18150	20020	2452	18520	18370
18 x 18 x 9	1296	2312	17600	22110	28690	2129	16280	17710	1956	16530	16610
18 x 20 x 9	1404	2584	18810	23650	30745	2385	17160	18810	2196	17550	17600
18 x 25 x 9	1674	3264	22100	27780	36080	3024	19360	21450	2795	20010	20070
20 x 20 x 9	1520	2888	20020	2530	34060	2670	18260	20130	2464	18470	18650
20 x 25 x 9	1810	3648	23740	29900	38550	3387	20680	22990	3137	20710	20950
25 x 25 x 9	2150	4608	28720	36160	46620	4299	23870	26620	3992	23360	23490

NOTES:

- Capacities listed for 35°F rooms include average usage and product loads.
- For a 30°F room, use the capacities listed for a 35°F room but with positive defrost and 20 hour compressor operation.
- Freezer loads are storage only. Product freezing and service loads must be added to arrive at total box load.
- Refer to Tables No. 18 and 19 for precalculated Product Loads for freezers.

TABLE 18

ICE CREAM HARDENING LOADS FOR WALK-IN FREEZERS BTUH
(24 Hour Pulldown - 18 Hour Compressor Operation)
20% Safety Factor Added to Allow for Service Loads Etc.

Percent Overrun	Btu Per Gal.	Wgt. Lbs./Gal. (9.2 Lb./Gal. Mix)	Gals. Ice Cream Per Day			
			100	250	500	1000
120	386	4.18	2237	5593	11188	22376
100	425	4.6	2833	7083	14169	28333
80	470	5.11	3134	7833	15666	31333
60	532	5.75	3547	8866	17733	35467

Ice cream assumed at 25°F, and 30% frozen, entering hardening room. To retain a smooth texture in hardened ice cream it is necessary to freeze the remaining water content rapidly. With forced air circulation in the hardening room and containers spaced to allow air circulation, time to harden will be about 10 hours with room maintained at -20°F. Hardening rooms are usually sized to allow for a minimum of 3 times the daily peak production and for a stock of all flavors with the sizing based on 10 gallons per sq. ft. of floor area, which includes aisles.

Storage rooms are held at about -10°F and space in storage rooms can be estimated at 25 gallons per sq. ft. stacked solid 6 ft. high, including space for aisles.

Adjust the hardening room load in Btu/hr. for the required pull-down time by multiplying by 24 and dividing by the pull-down time in hours. (i.e. for 10 hr. pull-down multiply the above loads by 24 hrs/10 hrs. for the adjusted Btuh)

TABLE 19

PRODUCT FREEZING LOADS FOR WALK-IN FREEZERS
(24 Hour Pulldown - 18 Hour Compressor Operation)
20% Safety Factor Added to Loads to Allow for Service

Product	Specific Heat Btu/Lb./°F		Latent Heat Btu/lb.	Freezing Temp. °F	-10°F Freezer Temperature BTUH for Indicated Lbs. Product/Day					
	Above Freezing	Below Freezing			100	300	750	1000	1500	3000
Beef	.72	.40	95	29	790	2370	5925	7900	11850	23700
Pork	.53	.32	60	28	523.5	1571	3926	5235	7853	15710
Veal & Lamb	.76	.45	100	28	841.4	2524	6311	8414	12621	25240
Poultry	.79	.42	106	27	878.7	2636	6590	8787	13181	26360
Sea Food	.80	.43	110	28	906.3	2719	6797	9063	13595	27190
Vegetables	.92	.47	130	30	1053	3159	7898	10530	15795	31590
Bakery Foods	.74	.34	53	20	520	1560	3900	5200	7800	15600
Frozen Foods for 10°F Pulldown to Storage Temp.	-	.45	-	-	30	90	225	300	450	900

Freezing loads based on product entering at 40°F maximum.

For a specific pull-down time, the product load Btu/Hr. may be adjusted by multiplying the above loads by 24 and dividing by the specified pull-down time in hours.

To adjust for 0°F freezer temperature, multiply above loads by 0.97 and for -20°F freezer multiply by 1.04.

TABLE 20

BEER CONTAINER DATA

BOTTLE AND CAN DATA									
Size & Type of Container	Dimensions in Inches Dia. H	Wgt. Full Oz.	Wgt. Empty Oz.	Btu to Cool Full Container 1°F	Full Case of Bottles or Cans				
					No. in Case	Wgt. Empty Lbs.	Material	Wgt. Full Lbs.	Btu to Cool Full Case 1°F
12 oz. Glass Bottle Tall	2 1/2 x 9 1/2	24	12	0.90	24	3.19	Fibre	39.2	22.9
12 oz. Glass Bottle Squat	2 5/8 x 5 3/4	18.4	6.4	0.83	24	1.38	Carton	29.0	20.4
32 oz. Glass Bottle Quart	3 5/8 x 11 1/4	48.5	16.5	2.21	12	1.81	Carton	38.2	27.1
12 oz. Steel Container	2 5/8 x 4 5/8	13.8	1.8	.77	24	0.27	Carton	20.7	18.43
12 oz. Alum Container	2 9/16 x 4 5/8	13	1	.78	24	0.27	Carton	19.5	18.43
16 oz. Steel Container, Pint	2 5/8 x 6 1/4	18.1	2.1	1.02	24	0.27	Carton	27.15	24.5
Wood Kegs					Wt. x Sp. Ht. of beer assumed same as water for estimating. Sp. Ht. Glass Bottles 0.2 Sp. Ht. Steel 0.12 Sp. Ht. Aluminum 0.214 Sp. Ht. Fibre Carton 0.4 Sp. Ht. Corrugated Carton 0.34 Sp. Ht. Wood Keg 0.60				
31 Gal. One Keg	24 x 31	365	105	300					
15 Gal. Half Kegs	20 x 24	195	65	155					
8 Gal. Quarter Keg	17 x 21	105	35	80					
4 Gal. Eighth Keg	13 1/2 x 16	55	22	41					
Insulated Steel Kegs									
16 Gal. Half Keg	19 x 23 1/2	184	60	120					
8 Gal. Quarter Keg	16 x 17 1/4	95	33	60					
Aluminum Kegs									
16 Gal. Half Keg	19 1/4 x 23 1/2	194	70	130					
8 Gal. Quarter Keg	16 x 17 1/4	94	32	64					
4 Gal. Eighth Keg	13 x 15	53	22	35					

ASRE 1940 Refrigeration and Application Data - Reprinted by permission

TABLE 21

APPROXIMATE TIME REQUIRED TO COOL HALF KEGS
OF BEER TO 40°F IN 34°F ROOM
WITH FORCED AIR CIRCULATION

Initial Beer Temp. °F	Time to Cool to 40°F, Hrs.		
	Wood Keg	Insulated Steel Keg	Cast Aluminum Keg
72	65	46	11
68	63	43	9
64	60	39	7
60	56	35	6
56	51	30	
52	46	25	3
46	27	13	2
44	18	9	1
43	13	7	
42	9	5	
41	4	2	
40	0	0	0

TABLE 22

QUICK SELECTION
BEER STORAGE WALK-IN
COOLERS BASED ON
4" CORKBOARD OR EQUIVALENT
AND 50° TD

Walk-In Cooler Size	Capacity Half Kegs Beer	Btu/Hr. Load Based on 16 Hr. Compressor Operation
6 x 6	9	3400
6 x 8	12	4000
6 x 10	16	4670
6 x 12	18	5300
8 x 8	18	4900
8 x 10	20	5600
8 x 12	24	6400
10 x 10	25	6500
10 x 12	30	7500

ASRE 1940 Refrigeration Engineering
Application Data -- Reprinted by permission.

TABLE 23

Table HEAT LOAD DUE TO AIR INFILTRATION
WHEN STORING CONTAINERS

Containers in storage refrig.	Temperature difference, °F*					
	60	55	50	45	40	35
	Heat load for each container, Btu.					
Full keg	3200	2600	2100	1700	1400	1100
Half keg	2600	2100	1700	1400	1100	900
Quarter keg	2200	1900	1600	1300	1000	800
Case 24 - 12 oz. bottles	2100	1800	1500	1200	900	700
Case 24 - 12 oz. bottles in service refrig.	2000	1600	1300	1000	750	600

*Temperature difference of inside and outside refrigerator.

TABLE 24

BACK BAR HEAT LEAKAGE AND TOTAL LOAD

Height	Width	Insulation	Back bar Temp., °F	Btu per hr. per ft. of length			
				Leakage load		Total load	
				85°F	100°F	85°F	100°F
36	20	2 in. cork	45	75	100	100	135
42	20	2 in. cork	45	80	105	105	140

*Based on 25 per cent of full storage capacity being replaced daily.

TABLE 25

BEVERAGE CONTAINER DATA (SOFT DRINKS - SODA)

Bottles and Can Data						Full Case of Bottles or Cans				
Size Oz.	Type Container	Dimensions in Inches Dia. H	Wgt. Full Oz.	Wgt. Empty Oz.	Btu to Cool Full Bottle 1°F	No. in Case	Wgt. Empty Lbs.	Material	Wgt. Full Lbs.	Btu to Cool Full Case 1°F
6	Glass Bottle	2 1/2 x 7 3/4	20	14	.55	24	5	Wood	35	16.2
7	Glass Bottle	2 3/8 x 7 7/8	21	14	.62	24	5	Wood	36.5	17.9
8	Glass Bottle	2 1/2 x 7 1/4	22	14	.68	24	5	Wood	38	19.32
9	Glass Bottle	2 1/4 x 9 1/8	23	14	.74	24	5	Wood	39.5	20.8
12	Glass Bottle	2 5/8 x 9 3/4	28	16	.95	24	5	Wood	47	25.8
32	Glass Bottle	3 5/8 x 11 1/2	64	32	2.40	12	5	Wood	53	31.8
12	Alum. Can	2 1/2 x 4 3/4	13	1	0.76	24	0.5	Carton	20	18.7

Sp. Ht. of beverage 1.0, glass 0.2, wood 0.6, cardboard 0.34, aluminum 0.214.

TABLE 26

ICE CREAM FREEZING & HARDENING LOADS

Percent of Overrun	BTU/GAL In Freezer	BTU/GAL In Hardening Room	Total BTU/GAL	LBS/ GAL
120	396	386	782	4.18
110	407	405	812	4.38
100	420	425	845	4.60
90	433	447	880	4.84
80	449	470	919	5.11
70	466	500	966	5.41
60	485	532	1017	5.75

500 BTU/GAL is frequently used in figuring freezing and hardening loads. Leaving freezer @ 25% with 30% water frozen.

% overrun = $100 \times \frac{\text{Wt. per gal. mix} - \text{Wt. per gal ice cream}}{\text{Wt. per gal. ice cream}}$

Product load would be based on about 10 hrs. hardening time with forced air circulation.

Hardening rooms figured at 10 gal./sq. ft. including aisles for minimum of 3 times the daily peak production.

Storage rooms figured at 25 gal./sq. ft., stacked solid 6 ft. high, including space for aisles.

ASHRAE 1974 Applications - Reprinted by permission

TABLE 27
MILK COOLING DATA

CONTAINER		WEIGHTS IN LBS.			BTU TO COOL 1°F		
Type and Contents	Dimensions in Inches L W H	Case Only	Bottles or Cartons	Milk Only	Milk Only	Case and or Containers Only	Full Containers
Cases, Wood (0.60 Sp. Ht.)							
4 - 1 Gal. Glass Bottles	15 1/4" x 14" x 12 5/8"	14	14	34.4	32.34	11.2	43.5
12 - 1 Qt. Glass Bottles	18 1/2" x 14 1/2" x 10 1/2"	16	24	25.8	24.25	14.4	38.6
20 - 1 Pt. Glass Bottles	18 1/2" x 14 1/2" x 8 1/2"	14	15	21.6	20.3	11.6	31.9
30 - 1/2 Pts. Glass Bottles	18 1/2" x 14 1/2" x 6 3/4"	11	15	16.2	15.23	9.6	24.8
Cases, Steel (0.12 Sp. Ht.)							
4 - 1 Gal. Cartons	13" x 13" x 10 1/2"	9	1	34.4	32.34	1.58	33.9
9 - 1/2 Gal. Cartons	13" x 13" x 10 1/2"	9	1.35	38.7	36.38	1.72	38.1
16 - 1 Qt. Cartons	13" x 13" x 10 1/2"	9	1.2	34.4	32.34	1.68	34.0
28 - 1 Pt. Cartons	13" x 13" x 10 1/2"	9	1.3	30.24	28.27	1.74	30.0
44 - 1/2 Pt. Cartons	13" x 13" x 10 1/2"	9	1.4	23.76	22.3	1.76	24.1
Case, Plastic (0.5 Sp. Ht.)							
2 - 10 Qt. Bags	13" x 13" x 11"	3.5	0.5	43	40.42	1.8	42.2
Cor., Steel (0.12 Sp. Ht.)							
5 Gal.	10 1/2" Dia. x 19 1/2"		15	43	40.42	1.8	42.2
10 Gal.	13" Dia. x 25"		26	86	80.84	3.12	84.0

Whole Milk, 8.60 Lbs./Gal. and 0.94 Sp. Ht. above freezing
8.084 Btu/Gal. to cool, milk only, 1°F.

TABLE 28

FRUIT TEMPERATURES FOR BANANA RIPENING

Ripening Schedule	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
4 Days	64	62	60					
5 Days	62	62	62	62	60			
6 Days	62	62	60	60	60	58		
7 Days	60	60	60	60	60	58	58	
8 Days	58	58	58	58	58	58	58	58

Air temperatures used during processing, 45°F to 65°F
ASHRAE 1974 Applications - Reprinted by permission

TABLE 29

CARCASS AVERAGE PRODUCT LOADS

Product	Avg. Sp. Ht.	Avg. Carcass Weight Lbs.	Carcass Temperature °F		Number of Carcasses Per 12,000 btu/hr.
			Entering	Final	
Beef	.77	550	106	35	9.5
Calves	.76	150	104	35	35
Hogs	.54	180	106	35	41
Sheep	.76	45	101	33	125

BANANA RIPENING ROOMS

Banana hands or clusters shipped green in fiberboard cartons, 10" x 16" x 22", holding 42 lb. net (47 lbs. gross weight) with 864 boxes 32,288 lbs. net in a carload lot. Temperature held 56 to 58°F.

Ripening facility consists of 5 or more air tight rooms to permit a complete weekly turn-over (1/2 carload room, measuring 30' x 6' x 22' H outside, holds 432 boxes packed 24 boxes each on 18 pallets stacked 3 high by 6 long). Ripening process started with ethylene gas and ripening schedules maintained by control of room temperatures.

Heating is provided to bring the load up to temperature before ripening process is initiated. 20 to 12 kW per carload. (Electric heater sheath temperature not over 600°F in dead still air.

Humidification is not required with tropical boxing of fruit.

Evaporators are selected at a TD of 15°F, or less, with evaporator temperature controlled at not less than 40°F. Approximately 12.5 cfm at 2/3" to 3/4" static per 41 lb. box of bananas.

Pulldown load for 1°F/hr. pulldown rate based on maximum heat of respiration of 0.50 btu/hr./lb. and 0.8 sp. ht. for bananas and 0.4 for fiberboard boxing, plus minimal wall losses etc., 80 to 85 btu/hr./box of bananas. Holding load approximately 44 btu/hr./box.

Extracted from ASHRAE 1974A, 32.5-8.

Loading 5.3 lbs./cu. ft. of box
 11.28 lbs. net per pallet

TABLE 30

CUTTING ROOM LOADS
(Btu/Hr./Sq. Ft. of Floor Area)

Floor Area Sq. Ft.	Approx. 65% R. H. Room Temp.	
	55°F	50°F
	BTU/HR/SQ. FT.	
100	98	110
200	93	104
300	89	100
400	85	95
500	82	92
600	79	89
700	76	85
800	73	82
900	70.5	79
1000	68.5	77
1200	65	73

Room loads based on continuous operation and includes allowance for average number of personnel, processing equipment etc., with glass panel in one wall and walls and ceilings insulated with two (2) inches of cork or equivalent, with box located within air conditioned area.

Evaporator should be low outlet velocity type to avoid drafts and should be selected for continuous operation and not less than 30°F evaporator temperature.

ASHRAE 1974 Applications - Reprinted by permission

TABLE 31A

STORAGE REQUIREMENTS AND PROPERTIES OF PERISHABLE PRODUCTS

Commodity	Retail Storage °F % RH		Storage Temp. °F	Relative Humidity %	Approximate Storage Life	Water Content %	Highest Freezing Point °F	Specific Heat Above Freezing Btu/lb/F	Specific Heat Below Freezing Btu/lb/F	Latent Heat (Calculated) Btu/lb
FRUITS										
Apples*	35	85 - 88	30 - 40	90	3 - 8 months	84.1	29.3	0.87	0.45	121
Apricots	35	80 - 85	31 - 32	90	1 - 2 weeks	85.4	30.1	0.88	0.46	122
Avocados	50	85 - 90	45 - 55	85 - 90	2 - 4 weeks	65.4	31.5	0.72	0.40	94
Bananas*	56	90 - 95	56	85 - 95	8 days	74.8	30.6	0.80	0.42	108
Blackberries			31 - 32	95	3 days	84.8	30.5	0.88	0.46	122
Blueberries			31 - 32	90 - 95	2 weeks	82.3	29.7	0.86	0.45	118
Cherries	35	80 - 85	31 - 32	90	10 - 14 days	83.0	28.8	0.87	0.45	120
Coconuts	35	80 - 85	32 - 35	80 - 85	1 - 2 months	46.9	30.4	0.58	0.34	67
Cranberries	40	85 - 90	36 - 40	90 - 95	2 - 4 months	87.4	30.4	0.90	0.46	124
Currants	36	85 - 90	31 - 32	90 - 95	10 - 14 days	84.7	30.2	0.88	0.45	120
Dates (fresh)			0 - 10			78	27.1	.82	.43	112
Dewberries			31 - 32	90 - 95	3 days	84.5	29.7	.88		112
Dried fruits*	35	50 - 60	32	50 - 60	9 to 12 months	14.0 - 26.0		0.31 - 0.41	0.26	20 - 37
Figs, fresh	40	65 - 75	31 - 32	85 - 90	7 - 10 days	78.0	27.6	0.82	0.43	112
Frozen-pack fruits			-10 - 0		6 - 12 months					
Gooseberries			31 - 32	90 - 95	2 - 4 weeks	88.9	30.0	0.90	0.46	126
Grapefruit *	45	85 - 90	50 - 60	85 - 90	4 - 6 weeks	88.8	30.0	0.91	0.46	126
Grapes (Chapter 29)										
American type	35	80 - 90	31 - 32	85 - 90	2 - 8 weeks	81.9	29.7	0.86	0.44	116
European type			30 - 31	90 - 95	3 - 6 months	81.6	28.1	0.86	0.44	116
Lemons*	55	85 - 90	32 or 50 - 58	85 - 90	1 - 6 months	89.3	29.4	0.91	0.46	127
Limes	45	85 - 90	48 - 50	85 - 90	6 - 8 weeks	86.0	29.1	0.80	0.46	122
Logan blackberries			31 - 32	85 - 90	5 - 7 days	8.29	29.7	0.86	0.45	118
Mangoes			55	85 - 90	2 - 3 weeks	81.4	30.3	0.85	0.44	117
Melons, Cantaloupe	45	85 - 90	36 - 40	90 - 95	5 - 15 days	92.0	29.9	0.93	0.48	132
Persian			45 - 50	90 - 95	2 weeks	92.7	30.5	0.94	0.48	132
Honeydew and Honey Ball			45 - 50	90 - 95	3 - 4 weeks	92.6	30.3	0.94	0.48	132
Casaba			45 - 50	85 - 90	4 - 6 weeks	92.7	30.1	0.94	0.48	132
Watermelons			40 - 50	80 - 90	2 - 3 weeks	92.1	31.3	0.97	0.48	132
Oranges*	40	85 - 90	32 - 48	85 - 90	3 - 12 weeks	87.2	30.6	0.90	0.46	124
Orange juice, chilled			30 - 35		3 - 6 weeks	89.0		0.91	0.47	128
Papayas			45	85 - 90	1 - 3 weeks	90.8	30.4	0.82	0.47	130
Peaches and nectarines	35	80 - 85	31 - 32	90	2 - 4 weeks	89.1	30.3	0.90	0.46	124
Pears	35	90 - 95	29 - 31	90 - 95	2 - 7 months	82.7	29.2	0.86	0.45	118
Pears, green			32	90 - 95	1 - 2 weeks	74.3	30.9	0.79	0.42	106
Persimmons			30	90	3 - 4 months	78.2	28.1	0.84	0.43	112
Pineapples										
Mature green	50	85 - 90	50 - 55	85 - 90	3 - 4 weeks		30.2			
Ripe	40	85 - 90	45	85 - 90	2 - 4 weeks	85.3	30.0	0.88	0.45	122
Plums, including fresh prunes	40	80 - 85	31 - 32	90 - 95	2 - 4 weeks	82.3	30.5	0.88	0.45	122
Pomegranates			32	90	2 - 4 weeks		26.6			
Quinces	35	80 - 85	31 - 32	90	2 - 3 months	85.3	28.4	0.88	0.45	122
Raspberries	31	85 - 90								
Black			31 - 32	90 - 95	2 - 3 days	80.6	30.0	0.84	0.44	122
Red			31 - 32	90 - 95	2 - 3 days	84.1	30.9	0.87	0.45	121
Frozen (red or black)			-10 - 0		1 year					
Strawberries										
Fresh	31	85 - 90	31 - 32	90 - 95	5 - 7 days	89.9	30.6	0.92		129
Frozen*			-10 - 0		1 year	72.0			0.42	103
Tangerines	40	85 - 90	32 - 38	85 - 90	2 - 4 weeks	87.3	30.1	0.90	0.46	125

Estimating Specific and Latent Heats:

Sp. Ht. above freezing = $0.20 + 0.008 \times \% \text{ water}$.Sp. Ht. below freezing = $0.20 + 0.003 \times \% \text{ water}$.Latent Heat = $143.4 \times \% \text{ water}$.

ASHRAE 1974 and 1972 Fundamentals - Reprinted by permission

TABLE 31B

STORAGE REQUIREMENTS AND PROPERTIES OF PERISHABLE PRODUCTS (CONTINUED)

Commodity	Retail Storage °F % RH	Storage Temp. °F	Relative Humidity %	Approximate Storage Life	Water Content %	Highest Freezing Point °F	Specific Heat Above Freezing Btu/lb/F	Specific Heat Below Freezing Btu/lb/F	Latent Heat (Calculated) Btu/lb
VEGETABLES									
Artichokes (Globe)	40 90 - 95	31 - 32	95	2 weeks	83.7	29.9	0.87	0.45	120
Jerusalem		31 - 32	90 - 95	5 months	79.5	27.5	0.83	0.44	114
Asparagus	40 85 - 90	32 - 36	90 - 95	2 - 3 weeks	93.0	30.9	0.94	0.48	134
Beans (Green or snap)	45 85 - 90	45	90 - 95	7 - 10 days	88.9	30.7	0.91	0.47	128
Lima	40 85 - 90	32 - 40	90	7 days	66.5	31.0	0.73	0.40	94
Beets	40 85 - 90								
Bunch		32	95	10 - 14 days		31.3			
Topped		32	95 - 100	4 - 6 months	87.6	30.1	0.90	0.46	126
Broccoli, sprouting	40 90 - 95	32	95	10 - 14 days	89.9	30.9	0.92	0.47	130
Brussels sprouts	40 90 - 95	32	90 - 95	3 - 4 weeks	84.9	30.5	0.88	0.46	122
Cabbage, late	35 90 - 95	32	95 - 100	3 - 4 months	92.4	30.4	0.94	0.47	132
Carrots	40 85 - 90								
Prepackaged		32	80 - 90	3 - 4 weeks	88.2	29.5	0.90	0.46	126
Topped		32	90 - 95	4 - 5 months	88.2	29.5	0.90	0.46	126
Cauliflower	35 85 - 90	32	95	2 - 4 weeks	91.7	30.6	0.93	0.47	132
Celeriac		32	95 - 100	3 - 4 months	88.3	30.3	0.91	0.46	126
Celery	35 85 - 90	32	95	1 - 2 months	93.7	31.1	0.95	0.48	135
Collards		32	95	10 - 14 days	86.9	30.6	0.90		
Corn, sweet	35 85 - 90	32	95	4 - 8 days	73.9	30.9	0.79	0.42	106
dried							0.28	0.23	15
Cucumbers	50 85 - 95	50 - 55	90 - 95	10 - 14 days	96.1	31.1	0.97	0.49	137
Eggplant	50 85 - 95	45 - 50	90 - 95	7 - 10 days	92.7	30.6	0.94	0.48	132
Endive (escarole)	35 90 - 95	32	95	2 - 3 weeks	93.3	31.9	0.94	0.48	132
Frozen-pack vegetables		-10 - 0		6 - 12 months					
Garlic, dry	35 85 - 90	32	65 - 70	6 - 7 months	61.3	30.5	0.69	0.40	89
Horseradish	45	30 - 32	95 - 100	10 - 12 months	73.4	28.7	0.78	0.42	104
Kale		32	95	3 - 4 weeks	86.6	31.1	0.89	0.46	124
Kohlrabi		32	95	2 - 4 weeks	90.1	30.2	0.92	0.47	128
Locks, green	35 90 - 95	32	95	1 - 3 months	85.4	30.7	0.88	0.46	126
Lettuce, head	35 90 - 95	32 - 34	95 - 100	2 - 3 weeks	94.8	31.7	0.96	0.48	136
Mushrooms	40 75 - 80	32	90	3 - 4 days	91.1	30.4	0.93	0.47	130
Olives, fresh		45 - 50	85 - 90	4 - 6 weeks	75.2	29.4	0.80	0.42	108
Onions and onion sets	50 70 - 75	32	65 - 70	1 - 8 months	87.5	30.6	0.90	0.46	124
Parsley		32	95	1 - 2 months	85.1	30.0	0.88	0.45	122
Parsnips	35 90 - 95	32	98 - 100	4 - 6 months	78.6	30.4	0.84	0.44	112
Peas, green	35 85 - 90	32	95	1 - 3 weeks	74.3	30.9	0.79	0.42	106
dried					9.5		0.28	0.22	14
Peppers, sweet	50 90 - 95	45 - 50	90 - 95	2 - 3 weeks	92.4	30.7	0.94	0.47	132
Peppers, chili (dry)		32 - 50	60 - 70	6 months	12.0		0.30	0.24	17
Popcorn, unpopped	40 85	32 - 40	85	4 - 6 months	13.5		0.31	0.24	19
Potatoes	50 85 - 90								
Early crop		50 - 55	90		81.2	30.9	0.85	0.44	116
Late crop		38 - 50	90		77.8	30.9	0.82	0.43	111
Sweet potatoes	55 85 - 90	55 - 60	85 - 90	4 - 7 months	68.5	29.7	0.75	0.40	97
Pumpkins	55 70 - 75	50 - 55	70 - 75	2 - 3 months	90.5	30.5	0.92	0.47	130
Radishes-spring, prepackaged	35 90 - 95	32	95	3 - 4 weeks	93.6	30.7	0.95	0.48	134
winter		32	95 - 100	2 - 4 months	93.6		0.95	0.48	134
Rhubarb	35 95	32	95	2 - 4 weeks	94.9	30.3	0.96	0.48	134
Rutabagas	35 95	32	98 - 100	4 - 6 months	89.1	30.1	0.91	0.47	127
Salsify		32	98 - 100	2 - 4 months	79.1	30.0	0.83	0.44	113
Sauerkraut	45 75 - 80				8.9	2.6	0.92	0.47	129
Spinach	35 90 - 95	32	95	10 - 14 days	92.7	31.5	0.94	0.48	132
Squash	50 70 - 75								
acorn	50 85 - 95	45 - 50	70 - 75	5 - 8 weeks		30.5			
summer	50 85 - 95	32 - 50	85 - 95	5 - 14 days	94.0	31.1	0.95		135
winter	55 85 - 95	50 - 55	70 - 75	4 - 6 months	88.6	30.3	0.91		127
Tomatoes	55 85 - 90								
Mature green	50 85 - 90	57 - 70	85 - 90	1 - 3 weeks	93.0	31.0	0.95	0.48	134
Firm ripe		45 - 50	85 - 90	4 - 7 days	94.1	31.1	0.94	0.48	134
Turnips, roots	35 90 - 95	32	95	4 - 5 months	91.5	30.1	0.93	0.47	130
Vegetables, mixed		32 - 40	90 - 95	1 - 4 weeks	90.0		0.90	0.45	130
Yams		60	85 - 90	3 - 6 months	73.5	28.5	0.79	0.40	130

Estimating Specific and Latent Heats:

Sp. Ht. above freezing = $0.20 + 0.008 \times \% \text{ water}$.Sp. Ht. below freezing = $0.20 + 0.003 \times \% \text{ water}$.Latent Heat = $143.4 \times \% \text{ water}$.

ASHRAE 1974 and 1972 Fundamentals - Reprinted by permission

TABLE 31C
STORAGE REQUIREMENTS AND PROPERTIES OF PERISHABLE PRODUCTS (CONTINUED)

Commodity	Retail Storage °F % RH		Storage Temp. °F	Relative Humidity %	Approximate Storage Life	Water Content %	Highest Freezing Point °F	Specific Heat Above Freezing Btu/lb/F	Specific Heat Below Freezing Btu/lb/F	Latent Heat (Calculated) Btu/lb
MEATS - FISH - SHELLFISH										
Bacon Cured, Farm Style Packer Style Frozen	55	55 - 65	60 - 65 34 - 40 -10 - 0	85 85 90 - 95	4 - 6 months 2 - 6 weeks 4 - 6 months	20 13 - 29		0.50 .3 - .43	0.30 .24 - .29	29 18 - 41
Fat Backs Hams & Shoulders Fresh Cured Frozen	34 55	85 - 88 55 - 65	34 - 36 32 - 34 60 - 65 -10 - 0	85 - 90 85 - 90 50 - 60 90 - 95	0 - 3 months 7 - 12 days 0 - 3 years 6 - 8 months	6 - 12 47 - 54 40 - 45	28 - 29	.25 - .30 .58 - .63 .52 - .56	.22 - .24 .34 - .36 .32 - .33 .34 - .36	9 - 17 67 - 77 57 - 64
Pork Fresh Fresh Frozen Smoked	34 55	85 - 90 55 - 65	32 - 34 -10 - 0	85 - 90 90 - 95	3 - 7 days 4 - 6 months	32 - 44 60 57	28 - 29 28	.46 - .55 .68 .60	.38 .3 - .33 .32	46 - 63 86.5
Sausage Casings Drying Franks Fresh Smoked	35 35 40	80 - 90 85 - 90 80 - 85	40 - 45 40 - 45	85 - 90 85 - 90	6 months	65.5 60 65 60	26 29 26 25	0.6 0.89 .86 .89 .68	.56 .56 .56 .38	93 86 93 86
Beef, Dried Fresh-Lean Fresh-Fat Brined Frozen Veal Cut Meats	34 40 34 34	85 - 90 80 - 85 85 - 90 85 - 90	32 - 34 -10 - 0 32 - 34 30 - 34	88 - 92 90 - 95 90 - 95 88 - 92	1 - 6 weeks 9 - 12 months 5 - 10 days	5 - 15 62 - 67 64 - 70 65	28 - 29 28 28 - 29 29	.22 - .34 .70 - .84 .6 .75 .71 - .76 .72	.19 - .26 .40 .35 .38 - .43 .30 .40	7 - 22 89 - 110 79 92 - 100 95
Lamb, Fresh Frozen	34	85 - 90	32 - 34 -10 - 0	85 - 90 90 - 95	5 - 12 days 8 - 10 months	60 - 70	28 - 29	.68 - .76	.38 - .51 .38 - .51	86 - 100
Rabbits, Fresh Frozen	34	85 - 90	32 - 34 -10 - 0	90 - 95 90 - 95	1 - 5 days 0 - 6 months	68.0		.74	.40	98
Livers, Fresh Frozen	34	85 - 90	32 - 34 -10 - 0	80 - 85 90 - 95	1 - 6 weeks 3 - 4 months	65.5 70	29	.72	.40 .41	93.3 100
Poultry, Fresh *Frozen (eviscerated)	28	85 - 90	32 0 or below	85 - 90 90 - 95	1 week 8 - 12 months	74	27	.79	.42	106
Fish, Fresh (Red) Dried Frozen Smoked Brine Salted Mild Cured	30	80 - 95	33 - 35 40 - 50 -20 - 0 40 - 50 40 - 50 28 - 35	90 - 95 50 - 60 90 - 95 50 - 60 90 - 95 75 - 90	5 - 15 days 6 - 8 months 6 - 12 months 6 - 8 months 10 - 12 months 4 - 8 months	62 - 85 62 - 85	28	.70 - .86 .56 .70 .76 .76	.34 .38 - .45 .39 .41 .41	89 - 122 65 89 - 122 92 100 100
Shellfish, Fresh Frozen Oysters & Clams, Shell Shucked	32 32	70 - 75 70 - 75	30 - 33 -20 - 0 33 33	85 - 95 90 - 95 90 - 95 90 - 95	3 - 7 days 3 - 8 months	80 - 87 80.4 87	28 27 27	.83 - .90 .83 .90	.44 - .46 .44 .46	113 - 125 113 - 125 116 125
Scallops Shrimp	32 32	70 - 75 70 - 75	33 33	90 - 95 90 - 95		80.3 70.8	28 28	.89 .83	.48 .45	116 119
Lobsters, Crabs, Boiled	32	80 - 90	25	89 - 90	10 days	79		.85	.44	113

Estimating Specific and Latent Heats:

Sp. Ht. above freezing = $0.20 + 0.008 \times \% \text{ water}$.

Sp. Ht. below freezing = $0.20 + 0.003 \times \% \text{ water}$.

Latent Heat = $143.4 \times \% \text{ water}$.

ASHRAE 1974 and 1972 Fundamentals - Reprinted by permission

TABLE 31D
STORAGE REQUIREMENTS AND PROPERTIES OF PERISHABLE PRODUCTS (CONTINUED)

Commodity	Retail Storage °F % RH	Storage Temp. °F	Relative Humidity %	Approximate Storage Life	Water Content %	Highest Freezing Point °F	Specific Heat Above Freezing Btu/lb/F	Specific Heat Below Freezing Btu/lb/F	Latent Heat (Calculated) Btu/lb
MISCELLANEOUS									
Beer (Barrels, metal keg wood keg)	40 40 85 - 90	35 - 40 35 - 40	85 - 90	3 - 9 weeks 3 - 9 weeks	90.2 90.2	28 28	.92 .92		129 129
Bread Bread Dough	0 35 85 - 90	0 35 - 40	85 - 90	3 wks - 3 mos. 1 - 3 days	32 - 37 46 - 58	20	.7 .6 - .75	.34 .34 - .37	46 - 53 66 - 83
Butter Candy Cavier (Tub)	40 75 - 80 34 40 - 50	40 0 - 34	75 - 85 40 - 65 85 - 90	1 month	16 55	31 20	.5 .93	.34	23
Cheese, American Camembert Limberger Roquefort Swiss	40 75 - 80 40 80 - 85 40 80 - 85 45 75 - 80 40 75 - 80	40 - 45 30 - 34 30 - 34 30 - 34 30 - 34	65 - 70		60 60 55 55 55	17 18 19 3 15	.64 .70 .70 .65 .64	.36 .40 .40 .32 36	79 86 86 79 79
Chocolate (Coating) Cream 40% Cream (sweetened)	65 40 - 50 35	60 33 -15	40 - 50	6 months 7 weeks sev. months	55 73 72.5	95 - 85 28	.55 .85 .78	.30 .4 .42	40 90 104
Coffee, green Eggs, shell frozen, whole frozen, yolk frozen, white	37 80 - 85 40 80 - 85	35 - 37 29 - 31 0 - less 0 - less 0 - less	80 - 85 80 - 85	2 - 4 months 5 - 6 months 1 year + 1 year + 1 year +	10 - 15 66 74 55 88	28	.30 .73	.24 .40 .42 .36 .46	14 - 21 96 106 79 126
Whole Egg Solids Yolk Solids Flake Albumen Dried Spray Albumen	40	35 - 40 35 - 40 room room	low low low low	6 - 12 months 6 - 12 months 1 year + 1 year +	2 - 4 3 - 5 12 - 16 5 - 8		.22 .23 .31 .26	.21 .21 .24 .22	4 6 20 11
Flour Flowers, cut (see table) Furs-Woolens Furs-to-shock	82 60 - 65 40 45 - 55	78 32 34 - 40 15	60 - 65 45 - 55	sev. years	13.5		.38 .40	.28	
Honey Hops Ice Cream Ice	40 65 - 70 32 50 - 60 -15	29 - 32 -20 - 15 25 - 28	50 - 60	1 year + sev. months 3 - 12 months	18 58 - 63 100	21	.35 .66 - .7 1.00	.26 .37 - .39 0.5	26 86 144
Lard Malt Maple Sugar Maple Syrup	45 75 - 80 45 65 - 70 45 65 - 70	45 0 31 31	90 - 95 90 - 95 65 - 70 65 - 70	4 - 8 months 12 - 14 months 1 year + 1 year +	0 5 35.5		.52 .24 .48	.21 .31	7 51
Milk Nuts (Dried) Oleomargarine	35 65 - 75 40 65 - 75 45 75 - 80	33 32 - 50 35	65 - 75 60 - 70	6 - 10 months 1 year +	87.5 3 - 10 15.5	31	.93 .21 - .29 .32	.49 .19 - .24 .25	124 4.3 - 14 22
Tobacco Hogsheads Bales Cigarettes Cigars		50 - 65 35 - 40 35 - 46 35 - 50	50 - 55 70 - 85 50 - 55 60 - 65	1 year 1 - 2 years 6 months 2 months					
Veg. Seed Yeast	50 55 - 65 35 80 - 85	32 - 50 31 - 32	50 - 65		7.0 - 15.0 70.9		.29 .77	.23 .41	16 102

Estimating Specific and Latent Heats:

Sp. Ht. above freezing = $0.20 + 0.008 \times \% \text{ water}$.

Sp. Ht. below freezing = $0.20 + 0.003 \times \% \text{ water}$.

Latent Heat = $143.4 \times \% \text{ water}$.

ASHRAE 1974 and 1972 Fundamentals - Reprinted by permission

TABLE 32

AVERAGE WATER CONTENT AND SPECIFIC AND LATENT HEATS OF VARIOUS FISHERY PRODUCTS

Fish	Water Content %	Average Freezing Point, F	Specific Heat ^a Above Freezing, Btu/(Lb) (F deg)	Specific Heat ^b Below Freezing, Btu/(Lb) (F deg)	Latent Heat ^b Btu/Lb
WHOLE FISH					
Haddock, Cod	78	28	0.82	0.43	112
Halibut	75	28	0.80	0.43	108
Tuna	70	28	0.76	0.41	100
Herring (kippered)	70	28	0.76	0.41	100
Herring (smoked)	64	28	0.71	0.39	92
Salmon	64	28	0.71	0.39	92
Menhaden	62	28	0.70	0.38	89
FISH FILLETS OR STEAKS					
Haddock, Cod, Ocean perch	80	28	0.84	0.44	115
Hake, Whiting	82	28	0.86	0.45	118
Pollock	79	28	0.83	0.44	113
Mackerel	57	28	0.66	0.37	82
SHELL FISH					
Scallop meat	80	28	0.84	0.44	115
Shrimp	83	28	0.86	0.45	119
American lobster	79	28	0.83	0.44	113
Oysters and Clams (meat and liquor)	87	28	0.90	0.46	125

^aCalculated by Siebel's formula, for values above freezing $S = 0.008a + 0.20$; for values below freezing $S = 0.003a + 0.20$ where a = water content in percent; 0.20 = specific heat of solid constituents of the substance.

^bValues for latent heat (latent heat of fusion) in Btu per lb, calculated by multiplying the percentage of water content by the latent heat of fusion of water 143.4 Btu.

ASHRAE 1974 Applications - Reprinted by permission

TABLE 33

STORAGE CONDITIONS AND STORAGE LIFE FOR FROZEN FISH

Fish	Recommended Protection ^a	Storage Life, 0 F, Months
Chub, pink salmon	Ice glazing and packaging	4-6
Mackerel, sea herring, pollock, chub, smelts	Ice glazing and packaging	5-9
Pacific sardines, tuna	Packaging	4-6
Buffalofish flounders, halibut, ocean perch, rockfish, sablefish, red, sockeye, silver or coho salmon, whiting, shrimp	Packaging	7-12
Blue pike, haddock, cod, hake, lingcod	Packaging	Over 12

^aAll packaging should be with moisture resistant films.

ASHRAE 1974 Applications - Reprinted by permission

TABLE 34

REVIEW OF EFFECT OF STORAGE TEMPERATURE ON SHELF LIFE OF SOME FROZEN FISHERY PRODUCTS

Product	Temperature, F	Shelf Life, Months	Product	Temperature, F	Shelf Life, Months
Packaged Haddock	10	4 to 5	Glazed Whole Halibut	10	3
	0	11 to 12		0	6
Filletts	-20	Longer than 12		-10	9
				-20	12
Packaged Cod Fillets	10	5	Whole Blue Fin Tuna	10	4
	0	6		0 to -5	8
	-10	10 to 11		-20	12
Packaged* Pollock	20	1	Glazed Whole Herring	0	6
	10	2		-17	9
	0	8			
Filletts	-10	11			
	-20	24			
Packaged Ocean Perch Fillets	15	1½ to 2	Packaged Mackerel Fillets	15	2
	10	3½ to 4		0	3
	0	6 to 8		-10	3 to 5
	-10	9 to 10			
Packaged Striped Bass Fillets	15	4	Glazed Blocks of Whale Meat	14	3
	0	9		5	6
				-4	12

*Prepared from 1-day old iced fish.

ASHRAE 1974 Applications - Reprinted by permission

TABLE 35

TEMPERATURE RECOMMENDATIONS FOR MAINTAINING QUALITY OF FRESH VEGETABLES IN WHOLESALE WAREHOUSES

Store at 32 F and 90 % Relative Humidity		Store at 50 F and 80 to 85 % Rel. Hum.
Artichokes	Horseradish	Beans, green
Asparagus	Kohlrabi	Cucumbers
Beans, Lima	Lettuce	Eggplants
Beets	Mushrooms	Garlic, dry
Broccoli	Onions, green	Melons
Brussels sprouts	Parsnips	Okra
Cabbage	Peas, green	Onions, dry
Carrots	Radishes	Peppers
Cauliflower	Rhubarb	Potatoes
Celery	Rutabagas	Pumpkins
Corn, sweet	Spinach	Squash, hard shell
Endive	Squash, summer	Sweet potatoes
Escarole	Turnips	Tomatoes, ripe

ASHRAE 1974 Applications - Reprinted by permission

TABLE 36

VEGETABLES SUSCEPTIBLE TO CHILLING INJURY
WHEN AT MODERATELY LOW BUT NON-
FREEZING TEMPERATURES

Commodity	Approximate Lowest Safe Temp F	Character of Injury when Stored Between 32 F and Safe Temp.
Beans (snap)	45	Pitting and russetting
Cucumbers	45	Pitting, water-soaked spots, decay
Eggplants	45	Surface scald, <i>Alternaria</i> rot
Melons: Cantaloupes Honeydew Casaba Crenshaw and Persian Watermelons	^a 45 to 50 45 to 50 45 to 50 40	Pitting, surface decay Pitting, failure to ripen Pitting, surface decay Pitting, surface decay Pitting, objectionable flavor
Okra	45	Discoloration, water-soaked areas, pitting, decay
Peppers, sweet	45	Sheet pitting, <i>Alternaria</i> rot on pods and calyxes
Potatoes	38	Mahogany browning (Chippewa and Sebago), sweetening ^b
Pumpkins and Hard-Shell Squash	50	Decay, especially <i>Alternaria</i> rot
Sweet potatoes	55	Decay, pitting, internal discoloration
Tomatoes: Ripe Mature-green	45-50 ^a 55	Water-soaking and softening decay Poor color when ripe; <i>Alternaria</i> rot

^aSee text.

^bOften these symptoms are apparent only after removal to warm temperatures as in marketing.

ASHRAE 1974 Applications - Reprinted by permission

TABLE 38

DESIRABLE TRANSIT TEMPERATURE,
SUGGESTED TEMPERATURE TO SPECIFY,
AND HIGHEST FREEZING POINTS FOR
VARIOUS VEGETABLES

Vegetable	Desirable Transit Temp, °F	Suggested Temperature to Specify ^b for Thermostat	Highest Freezing Point ^c
Artichokes	32	33	29.9
Asparagus	32-36	35	30.9
Beans, snap	45	45	30.7
Beets, topped	32	34	30.3
Broccoli	32	34	30.9
Brussels sprouts	32	34	30.5
Cabbage	32	34	30.4
Cantaloupes	35-40	36	29.9
Carrots, topped	32	33	29.5
Cauliflower	32	34	30.6
Celery	32	34	31.1
Corn, sweet	32	34	30.9
Cucumbers	45-50	45	31.1
Eggplant	45-50	46	30.6
Endive and Escarole	32	34	31.9
Honeydew melon	45-50	45	30.3
Lettuce	32	34	31.7
Onions, dry	32-40	35	30.6
Peas, green	32	34	30.9
Peppers, sweet	45-50	46	30.7
Potatoes: Early crop Late crop For chipping: Early crop Late crop	50-60 40-50 65-70 50-60	50 40 65-70 50-60	30.9 30.9 30.9 30.9
Radishes	32	34	30.7
Spinach	32	34	31.5
Sweet potatoes	55-60	55	29.7
Tomatoes: Mature green Pink	55-65 45-50	55 45-50	31.0 31.0

^aData from USDA Agriculture Handbook No. 195 by Redit and USDA Marketing Research Report No. 196 by Whiteman.

^bFor shipments of vegetables in mechanically refrigerated cars under Rule 710 and in trailers under Rule 800 of the Perishable Protective Tariff.

^cHighest temperature at which freezing occurs.

ASHRAE 1974 Applications - Reprinted by permission

TABLE 37

RECOMMENDED TEMPERATURES
IN DISPLAY CASES

Type Fixture	Temperature—F	
	Min ^a	Max ^a
Meat, unwrapped display area storage compartment	35 34	38 37
Meat, wrapped display area storage compartment	28 28	36 35
Produce, display area	35	45
Produce, storage compartment	35	45
Dairy	35	42
Frozen Food	— ^b	0
Ice Cream	— ^b	—12

^aThese temperatures are air temperatures, with thermometer in the refrigerated air stream and not in contact with the product.

^bMinimum temperatures for frozen food and ice cream are not critical; maximum temperature is the important factor for proper preservation of product quality.

ASHRAE 1962 Application - Reprinted by permission

TABLE 39

EXPECTED STORAGE LIFE FOR CANDY

Candy	Moisture Content %	Relative Humidity %	Storage Life—Months			
			Storage Temperature—F			
			68	48	32	0
Sweet chocolate	0.36	40	3	6	9	12
Milk chocolate	0.52	40	2	2	4	8
Lemon drops	0.76	40	2	4	9	12
Chocolate covered peanuts	0.91	40-45	2	4	6	8
Peanut brittle	1.58	40	1	1½	3	6
Coated nut roll	5.16	45-50	1½	3	6	9
Uncoated peanut roll	5.89	45-50	1	2	3	6
Nougat bar	6.14	50	1½	3	6	9
Hard creams	6.56	50	3	6	12	12
Sugar bonbons	7.53	50	3	6	12	12
Coconut squares	7.70	50	2	3	6	9
Peanut butter taffy kisses	8.20	40	2	3	5	10
Chocolate covered creams	8.09	50	1	3	6	9
Chocolate covered soft creams	8.22	50	1½	3	5	9
Plain caramels	9.04	50	3	6	9	12
Fudge	10.21	65	2½	5	12	12
Gum drops	15.11	65	3	6	12	12
Marshmallows	16.00	65	2	3	6	9

ASHRAE 1974 Applications - Reprinted by permission

OPTIMUM DESIGN AIR CONDITIONS

TABLE 40

Department or Process	Dry-Bulb Temp, F	RH %
Chocolate pan supply air	55-62	55-45
Enrober room	80-85	30-25
Chocolate cooling tunnel supply air	40-45	85-70 ^c
Hand dippers	62	45
Moulded goods cooling	40-45	85-70
Chocolate packing room	65	50
Chocolate finished stock storage	65	50
Centers tempering room	75-80	35-30
Marshmallow setting room	75-78	45-40
Grained marshmallow (deposited in starch) drying	110	40
Gum (deposited in starch) drying	125-150	25-15
Sanded gum drying	100	25-40
Gum finished stock storage	50-65	65
Sugar pan supply air (engrossing)	85-105	30-20
Polishing pan supply air	70-80	50-40
Pan rooms	75-80	35-30
Nonpareil pan supply air	100-120	20
Hard candy cooling tunnel supply air	60-70	55-40
Hard candy packing	70-75	40-35
Hard candy storage	50-70	40
Caramel rooms	70-80	40

Department or Process	Dry-Bulb Temp, F	RH %
RAW MATERIAL STORAGE		
Nuts (insect)	45	60-65
Nuts (rancidity)	34-38	85-80
Eggs	30	85-90
Chocolate (flats)	65	50
Butter	20	
Dates, figs, etc.	40-45	75-65
Corn sirup ^d	90-100	
Liquid sugar	75-80	40-30
Comfort air conditions	75-80	60-50

^aTemperature and humidity ranges are given in respective order, i.e., first temperature corresponds to first humidity.

^bConditions given in this table are intended as a guide and represent values which have been found to be satisfactory for many installations. However, specific cases may vary widely from these values due to such factors as type of product, formulas, cooking process, method of handling, and time. Acceleration or deceleration of any of the foregoing will change the temperature, humidity, or both to some degree.

^cOptimum conditions.

^dDepends on removal system. With higher temperatures, coloration and fluidity are greater.

ASHRAE 1974 Applications - Reprinted by permission

TABLE 41

STORAGE CONDITIONS FOR CUT FLOWERS AND NURSERY STOCK*

Commodity	Storage Temperature F	Relative Humidity, %	Approximate Storage Life	Method of Holding	Highest Freezing 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	31-32	90-95	2-4 weeks	Dry pack	30.8
Chrysanthemum	31-32	90-95	2-4 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 weeks	Dry pack	31.0
Gladiolus	40-42	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	55	90-95	1-2 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	40-42	90-95	1-2 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	2-3 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
Magnoli	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
Caladium	70	70-75	2-4 months	-	29.7
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	-	-

*Data from USDA Handbook No. 66 and bulletin by Post and Fischer.

†For details for various trees, shrubs, and perennials, see bulletin by Mahistede and Fletcher.

ASHRAE 1974 Fundamentals - Reprinted by permission.

TABLE 42

HEATS OF RESPIRATION (APPROX.)

BTU/LB./24 HRS.				
Product	STORAGE TEMPERATURE DEGREES F.			
	32°F	40°F	60°F	°F Other
FRUITS				
Apples	.25 - .450	.55 - .80	1.5 - 3.4	@ 68° 4.2 - 4.6
Apricots	0.55 - .63	.70 - 1.0	2.33 - 3.74	
Avacados	-	-	6.6 - 15.35	
Bananas	-	-	2.3 - 2.75	
Blackberries	1.70 - 2.52	5.91 - 5.00	7.71 - 15.97	@ 70° 5.7 - 7.5
Blueberries	0.65 - 1.10	1.0 - 1.35	3.75 - 6.5	
Cherries	0.65 - 0.90	1.4 - 1.45	5.5 - 6.6	
Cherries, Sour	0.63 - 1.44	1.41 - 1.45	3.0 - 5.49	
Cranberries	0.30 - 0.35	0.45 - 0.50	-	
Figs, Mission	-	1.18 - 1.45	2.37 - 3.52	
Gooseberries	0.74 - 0.96	1.33 - 1.48	2.37 - 3.52	
Grapefruit	0.20 - 0.50	0.35 - 0.65	1.1 - 2	
Grapes - American	0.30	0.60	1.75	
Grapes - European	0.15 - 0.20	0.35 - 0.65	1.10 - 1.30	
Lemons	0.25 - 0.45	0.30 - 0.95	1.15 - 2.50	
Limes	-	0.405	1.485	
Melons - Cantaloupes	0.55 - 0.63	0.96 - 1.11	3.70 - 4.22	
Melons - Honey Dew	-	0.45 - 0.55	1.2 - 1.65	
Oranges	0.20 - 0.50	0.65 - 0.8	1.85 - 2.6	
Peaches	0.45 - 0.70	0.70 - 1.0	3.65 - 4.65	
Pears	0.35 - 0.45	-	4.40 - 6.60	
Plums	0.20 - 0.35	0.45 - 0.75	1.20 - 1.40	
Raspberries	1.95 - 2.75	3.40 - 4.25	9.05 - 11.15	
Strawberries	1.35 - 1.90	1.80 - 3.40	7.80 - 10.15	
Tangerines	1.63	2.93	-	
VEGETABLES				
Artichokes (Globe)	2.48 - 4.93	3.48 - 6.56	8.49 - 15.90	
Asparagus	2.95 - 6.60	5.85 - 11.55	11.0 - 25.75	
Beans, Green or Snap	-	4.60 - 5.7	16.05 - 22.05	
Beans, Lima	1.15 - 1.6	2.15 - 3.05	11.0 - 13.7	
Beets, Topped	1.35	2.05	3.60	
Broccoli	3.75	5.50 - 8.80	16.9 - 25.0	
Brussels Sprouts	1.65 - 4.15	3.30 - 5.50	6.60 - 13.75	
Cabbage	0.60	0.85	2.05	
Carrots, Topped	1.05	1.75	4.05	
Cauliflower	1.80 - 2.10	2.10 - 2.40	4.70 - 5.40	
Celery	0.80	1.20	4.10	
Corn, Sweet	3.60 - 5.65	5.30 - 6.60	19.20	
Cucumbers	-	-	1.65 - 3.65	
Garlic	0.33 - 1.19	0.63 - 1.08	1.18 - 3.0	
Horseradish	0.89	1.19	3.59	
Kohlrabi	1.11	1.78	5.37	
Leeks	1.04 - 1.78	2.15 - 3.19	9.08 - 12.82	@ 50° 11.0
Lettuce, Head	1.15	1.35	3.95	
Lettuce, Leaf	2.25	3.20	7.20	
Mushrooms	3.10 - 4.80	7.80	-	
Okra	-	6.05	15.8	
Olives	-	-	2.37 - 4.26	
Onions, Dry	0.35 - 0.55	0.90	1.20	
Onions, Green	1.15 - 2.45	1.90 - 7.50	7.25 - 10.70	
Peas, Green	4.10 - 4.20	6.60 - 8.0	19.65 - 22.25	
Peppers, Sweet	1.35	2.35	4.25	
Potatoes, Immature	-	1.30	1.45 - 3.4	
Potatoes, Mature	-	0.65 - 0.90	0.75 - 1.30	
Potatoes, Sweet	-	0.85	2.15 - 3.15	
Radishes with Tops	1.59 - 1.89	2.11 - 2.30	7.67 - 8.5	
Radishes, Topped	0.59 - 0.63	0.85 - 0.89	3.04 - 3.59	
Rhubarb, Topped	0.89 - 1.44	1.19 - 2.0	3.41 - 4.97	
Spinach	2.10 - 2.45	3.95 - 5.60	18.45 - 19.0	
Squash, Yellow	1.3 - 1.41	1.55 - 2.04	8.23 - 9.97	
Tomatoes, Mature Green	-	0.55	3.10	
Tomatoes, Ripe	0.50	0.65	2.8	
Turnips	0.95	1.10	2.65	
Vegetables, Mixed	2.0	-	-	
MISCELLANEOUS				
Caviar, Tub	-	-	1.91	@ 45° 2.0
Cheese, American	-	-	2.34	
Camembert	-	-	2.46	
Limburger	-	-	2.46	
Roquefort	-	-	-	
Swiss	-	-	2.33	
Flowers, Cut	0.24 BTU/24 Hrs./Sq. Ft. Floor Area			
Honey	-	0.71	-	@ 35° 0.75
Hops	-	-	-	@ 50° 0.75
Malt	-	-	-	@ 45° 0.71
Maple Sugar	-	-	-	
Maple Syrup	-	-	-	
Nuts	0.074	0.185	0.37	
Nuts, Dried	-	-	-	@ 35° 0.50

Notes: All fruits and vegetables are living and give off heat in storage: If heat of respiration not given, an approximate value or average value should be used.

For Btu/24 hrs./Ton/°F multiply by 2000.

ASHRAE 1972, 1974 and 1978 - Reprinted by permission

TABLE 43
PROPERTIES OF LIQUIDS

Name or Description	Normal Boiling Point F at 1 atm	Enthalpy of Vaporization Btu/lb	Specific Heat, c_p		Enthalpy of Fusion Btu/lb	Specific Gravity or Density (ρ)		Thermal Conductivity** Btuh/(ft ²)(Deg F/ft)		Freezing Point F
			Btu/lb (deg F)	Temp. F		lb/ft ³	Temp. F	k	Temp. F	
Acetic Acid	245.3	174.1	0.522	79-203	84.0	65.49	68	0.099	68	61.9
Acetone	133.2	228.9	0.514	37-73	42.1	49.4	68	0.102	86	-139.6
Alcohol-ethyl	173.3	367.5	0.680	32-208	46.4	49.27	68	0.105	68	-179.1
Alcohol-methyl	148.9	473.0	0.601	59-68	42.7	49.40	68	0.124	68	-144.0
Benzene	176.2	169.4	0.412	68	54.2	54.9	68	0.085	68	42
Carbon Tetrachloride	170.2	83.7	0.201	68	12.8	99.5	68	0.062	68	- 9
Ethyl Chloride	54.2	165.9(68)	0.368	32	29.68	56.05	68	0.179	33.6	-213.5
Ethylene Glycol	388.4	344.0(651)			77.86	69.22	68	0.100	68	12.7
Glycerine (glycerol)	359 (20mm)					78.72	68	0.113	68	68
Kerosine	400-560		0.50	68		51.2	68	0.086	68	
Naphthalene	411.4	136	0.402	m.p.	64.9	60.9	m.p.			176.4
Petroleum		98-165	0.4-0.6	68		40-66	68			
Sulfuric Acid and Water										
100% by wt.	550.0		0.335	68		114.4	68			50.9
95% by wt.	550.0		0.35	68		114.6	68			- 18
90% by wt.	500.0		0.39	68		113.4	68	0.22	68	15.0
Toluene (C ₆ H ₅ CH ₃)	231	156	0.404	68	30.9	54.1	68	0.090	68	-139
Turpentine	303	123	0.42	68		53.9	68	0.073	68	
Water	212	970.3	0.999	68	143.5	62.32	68	0.348	68	32.018

**Thermal Conductivity units are Btuh/(Ft.²)(deg F/ft.) Multiply by 12 for Btuh/(Ft.²)(deg.F/in.)
ASHRAE 1972 Applications - Reprinted by permission

TABLE 44
PROPERTIES OF SOLIDS

(Values are for room temperature unless otherwise noted in brackets)
Superscript letters indicate data source from References

Material Description	Specific Heat Btu/(lb) (F)	Density lb/ft. ³	Thermal Conductivity Btuh/(ft ²) (F/ft.)
Aluminum (alloy 1100)	0.214	171	128
Aluminum Bronze (76% Cu, 22% Zn, 2% Al)	0.09	517	58
Asbestos: fiber	0.25	150	0.097
insulation	0.20	36	0.092
Asphalt	0.22	132	0.43
Bakelite	0.35	81	9.7
Brick, building	0.2	123	0.4
Brass: red (85% Cu, 15% Zn)	0.09	548	87
yellow (65% Cu, 35% Zn)	0.09	519	69
Bronze	0.104	530	17(32)
Cellulose	0.32	3.4	0.033
Cement (Portland clinker)	0.16	120	0.017
Clay	0.22	63	
Coal	0.3	90	0.098(32)
Concrete (stone)	0.156(392)	144	0.54
Copper (electrolytic)	0.092	556	227
Earth (dry and packed)		95	0.037
Fireclay Brick	0.198(212)	112	0.58(392)
Glass: crown(soda-lime)	0.18	154	0.59(200)
flint (lead)	0.117	267	0.79
pyrex	0.20	139	0.59(200)
Gypsum	0.259	78	0.25

Material Description	Specific Heat Btu/(lb) (F)	Density lb/ft. ³	Thermal Conductivity Btuh/(ft ²) (F/ft.)
Ice: (32F)	0.487	57.5	1.3
(-4F)	0.465		1.41*
Iron: cast	0.12(212)	450	27.6(129)
wrought		485	34.9
Lead	0.0309	707	20.1
Limestone	0.217	105	0.54
Marble	0.21	162	1.5
Paper	0.32	58	0.075
Paraffin	0.69	56	0.14(32)
Plaster		132	0.43(167)
Porcelain	0.18	162	1.3
Rock Salt	0.219	136	
Rubber: vulcanized (soft)	0.48	68.6	0.08
(hard)		74.3	0.092
Sand	0.191	94.6	0.19
Snow (freshly fallen)		7	0.34
(at 32F)		31	1.3
Steel (mild)	0.12	489	26.2
Stone (quarried)	0.2	95	
Tar: pitch	0.59	67	0.51
bituminous		75	0.41
Woods: hardwoods	0.45/0.65	23/70	0.065/0.148
maple, oak, etc.			
Softwoods	0.065/0.67	23/46	0.061/0.093
fir, pine, etc.			

*For Thermal Conductivity k in Btuh/(ft²) (F/in.) Multiply Tabular Values by 12.
ASHRAE 1972 Applications - Reprinted by permission

TABLE 45A

SPACE, WEIGHT, AND DENSITY DATA FOR COMMODITIES STORED IN REFRIGERATED WAREHOUSES

Commodity	Type of Package	Outside Dimensions of Package, In.	Avg Gross Wt of Pkg, Lb	Avg Net Wt of Mdse, Lb	Avg Gross Wt Density, Lb per Cu Ft	Avg Net Wt Density, Lb per Cu Ft
Apples	Wood Box					
	Northwestern	$19\frac{1}{2} \times 11 \times 12\frac{3}{16}$	50	42	33.1	27.8
	Fiber Tray Carton	$20\frac{1}{2} \times 12\frac{1}{2} \times 13\frac{1}{4}$	46 $\frac{3}{4}$	43	23.8	21.9
	Fiber Master Carton	$22\frac{1}{2} \times 12\frac{1}{2} \times 13$	44 $\frac{3}{4}$	41	21.2	19.4
	Fiber Bulk Carton	$19 \times 12\frac{1}{2} \times 13$	44 $\frac{3}{4}$	41	25.0	22.9
	Pallet Box	$47 \times 47 \times 30$	1030	900	26.9	23.5
Beef Boneless Fores Hinds	Fiber Carton	$28 \times 18 \times 6$	146	140	83.4	80.0
	Loose	—	—	—	—	22.2
	Loose	—	—	—	—	22.2
Celery	Wirebound Crates	$20\frac{1}{4} \times 16 \times 9\frac{3}{4}$	60	55	32.8	30.0
	Fiber Carton	$16 \times 11 \times 10$	36	32	35.4	31.4
Cheese	Hoops	$16 \times 16 \times 13$	84	78	43.6	40.5
	Wood, Export	$17 \times 17 \times 14$	87	76	37.1	32.5
Cheese, Swiss	Wheels	$32\frac{1}{2} \times 32\frac{1}{2} \times 7$	—	171	—	40.0
Chili Peppers	Bags	$45 \times 21 \times 26$	234	229	16.5	16.1
Citrus Fruits Oranges California Oranges Florida Oranges Lemons Grapefruit	Box	$12\frac{3}{8} \times 13\frac{1}{4} \times 26\frac{1}{4}$	77	69	31.5	28.3
	Bruce Box	$13 \times 11 \times 26\frac{1}{4}$	88	83	40.5	38.2
	Pallet, 40 Cartons	$40 \times 48 \times 58\frac{1}{2}$	1690	1480	26.0	22.8
	Fiber Carton	$16\frac{3}{8} \times 10\frac{1}{16} \times 10\frac{1}{2}$	40	37	38.0	35.2
	Fiber Carton	$19\frac{1}{4} \times 12\frac{1}{4} \times 8$	45	37	41.3	33.9
	Fiber Carton	$16\frac{3}{8} \times 10\frac{1}{16} \times 10\frac{1}{2}$	40	37	40.0	37.0
	Fiber Carton	$19\frac{1}{4} \times 12\frac{1}{4} \times 8$	40	38	36.7	34.9
	Fiber Carton	$19\frac{1}{4} \times 12\frac{1}{4} \times 8$	40	38	36.7	34.9
Coconut, Shredded	Bags	$38 \times 18\frac{1}{2} \times 8$	101	100	31.0	30.7
Cranberries	Fiber Carton	$15\frac{3}{4} \times 11\frac{1}{4} \times 10\frac{1}{2}$	26	24	24.1	22.2
Cream	Tins	$12 \times 12 \times 14$	52 $\frac{1}{4}$	50	45.2	42.9
Dried Fruit Dates Raisins, prunes, figs, peaches	Wood Box	$15\frac{1}{2} \times 10 \times 6\frac{1}{2}$	26 $\frac{1}{2}$	25	45.4	42.9
	Fiber Carton	$14 \times 14 \times 11$	32	30	25.7	24.0
	Fiber Carton	$15 \times 11 \times 7$	32	30	47.9	44.9
Eggs, Shell	Wood Cases	$26 \times 12 \times 13$	55	45	23.4	19.1
Eggs, Frozen	Cans	$10 \times 10 \times 12\frac{1}{2}$	32	30	44.2	41.5
Frozen Fishery Products Blocks	4/13 $\frac{1}{2}$ lb Carton	$20\frac{3}{4} \times 12\frac{1}{8} \times 6\frac{3}{4}$	56	54	57.0	55.0
	4/16 $\frac{1}{2}$ lb Carton	$19\frac{3}{4} \times 10\frac{3}{4} \times 11\frac{1}{4}$	68	66	49.2	47.8
Fillets	12/16 oz Carton	$12\frac{3}{4} \times 8\frac{5}{8} \times 3\frac{13}{16}$	13.5	12	55.8	49.6
	10/5 lb Carton	$14\frac{1}{2} \times 10 \times 14$	52.25	50	44.6	42.7
	5/10 lb Carton	$14\frac{1}{2} \times 10 \times 14$	52.2	50	44.5	42.7
Fish Sticks	12/8 oz Carton	$11 \times 8\frac{3}{8} \times 3\frac{7}{8}$	6.9	6	33.6	29.3
	24/8 oz Carton	$16\frac{7}{16} \times 8\frac{5}{16} \times 4\frac{5}{8}$	13.8	12	37.8	32.9
Panned Fish	None, Glazed	Wooden Boxes	—	—	—	35.0
Portions	2, 3, 5, and 6 lb Carton	Custom Packing	—	—	—	29–33
Round Ground Fish	None, Glazed	Stacked Loose	—	—	—	33–35
Round Halibut	None, Glazed	Wooden Box, Loose	—	—	—	30–35
Round Salmon	None, Glazed	Stacked Loose	—	—	—	33–35
Shrimp	2 $\frac{1}{2}$ and 5 lb Cartons	Custom Packing	—	—	—	35.0
Steaks	1, 5, or 10 lb Packages	Custom Packing	—	—	—	50–60
Frozen Fruits, Juices and Vegetables Asparagus Beans, Green Blueberries Broccoli Citrus Concentrates Peaches Peas Potatoes, French Fries Spinach Strawberries	24/12 oz Carton	$13\frac{1}{2} \times 11\frac{3}{4} \times 82$	21	18	27.	23.8
	36/10 oz Carton	$12\frac{1}{2} \times 11 \times 8$	25 $\frac{1}{2}$	22 $\frac{1}{2}$	40.1	35.3
	24/12 oz Carton	$12 \times 11\frac{1}{2} \times 8$	20	18	31.3	28.2
	24/10 oz Carton	$12\frac{1}{2} \times 11\frac{1}{2} \times 8\frac{1}{2}$	18 $\frac{1}{2}$	15	26.2	21.2
	Fiber Carton 48/6 oz	$13 \times 8\frac{3}{4} \times 7\frac{1}{2}$	27	26	54.7	52.7
	24/1 lb Carton	$13\frac{1}{2} \times 11\frac{1}{4} \times 7\frac{1}{2}$	27	24	41.0	36.4
	6/5 lb Carton	$17 \times 11 \times 9\frac{1}{2}$	32	30	31.1	28.2
	48/12 oz Carton	$21\frac{1}{2} \times 8\frac{1}{2} \times 12\frac{1}{2}$	38	36	28.7	27.2
	12/16 oz Carton	—	—	—	—	28.6
	24/9 oz Carton	—	—	—	—	24.0
	24/14 oz Carton	$12\frac{1}{2} \times 11 \times 8\frac{1}{2}$	24	21	35.5	31.0
	30 lb Can	$12\frac{1}{2} \times 10 \times 10$	32	30	44.2	41.5
	24/1 lb Carton	$13 \times 11 \times 8$	28	24	42.3	36.2
	450 lb Barrel	$35 \times 25 \times 25$	—	450	—	35.5

ASHRAE 1974 Applications – Reprinted by permission

TABLE 45B

SPACE, WEIGHT, AND DENSITY DATA FOR COMMODITIES STORED IN REFRIGERATED WAREHOUSES

Commodity	Type of Package	Outside Dimensions of Package, In.	Avg Gross Wt of Pkg, Lb	Avg Net Wt of Mdse, Lb	Avg. Gross Wt Density, Lb per Cu Ft	Avg. Net Wt Density, Lb per Cu Ft
Grapes, California	Wood Lug Box	6½ × 15 × 18	31	28	32.4	29.2
Lamb, Boneless	Fiber Box	20 × 15 × 5	57	53	65.7	61.0
Lard (2/28 lb)	Wood Export Box	18 × 13¼ × 7¾	64	56	59.8	52.5
Lettuce, head	Fiber Carton	20½ × 13½ × 9½	37½	35	24.7	—
	Fiber Carton	20½ × 14¼ × 10½	45-55	42-52	26.9	25.2
	Pallet, 30 Cartons	42 × 50 × 66	1350	1170	16.8	14.6
Milk, Condensed	Barrels	35 × 25½ × 25½	670	600	50.9	45.6
Nuts						
Almonds, in Shell	Sacks	24 × 15 × 33	91½	90	13.3	13.1
Almonds, Shelled	Cases	6¾ × 23½ × 11	32	28	31.7	27.7
English Walnuts, in Shell	Sacks	25 × 11 × 31	103	100	20.9	20.3
English Walnuts, Shelled	Fiber Carton	14 × 14 × 10	27	25	23.8	22.0
Peanuts, Shelled	Burlap Bag	35 × 10 × 15	127	125	39.2	38.6
Pecans, in Shell	Burlap Bag	35 × 22 × 12	126½	125	23.7	23.4
Pecans, Shelled	Fiber Carton	13 × 13 × 11	32	30	29.8	27.9
Peaches	¾ Bushel Baskets	16⅞ top dia.	41	38	43.9	40.7
	½ Bushel Baskets	14½ top dia.	28	25	45.0	40.2
	Wirebound Crate	19 × 11¼ × 11⅞	42	38	29.2	26.4
	Wood Lug Box	18⅞ × 11½ × 5¾	26	23	38.0	33.1
Pears	Wood Box	8½ × 11½ × 18	52	48	51.0	47.1
Pears, place pack	Fiber Carton	18½ × 12 × 10	52	46	40.5	35.6
Pork						
Bundle Bellies	Bundles	23½ × 10½ × 7	57	57	57.0	57.0
Loins (Regular)	Wood Box	28 × 10 × 10	60	54	37.0	33.3
Loins (Boneless)	Fiber Box	20 × 15 × 5	57	52	65.7	59.9
Potatoes	Sack	33 × 17½ × 11	101	100	27.5	27.2
Poultry, Fresh (Eviscerated)						
Fryers, Whole, 24-30 to Pkg.	Wirebound Crate	24 × 10 × 7	65	60	27.5	25.4
Fryer Parts	Wirebound Crate	17¾ × 10 × 12½	54	50	42.1	38.9
Poultry, Frozen (Eviscerated)						
Ducks, 6 to Pkg.	Fiber Carton	22 × 16 × 4	32½	31	39.9	38.0
Fowl, 6 to Pkg.	Fiber Carton	20¾ × 18 × 5½	33½	31	28.2	26.1
Fryers, cut up, 12 to Pkg.	Fiber Carton	17¼ × 15¾ × 4¼	30½	28	45.4	41.7
Roasters, 8 to Pkg.	Fiber Carton	20¾ × 18 × 5½	32½	30	27.3	25.2
Turkeys,						
3-6 lb., 6 to Pkg.	Fiber Carton	21 × 17 × 6½	30	27	22.5	20.1
6-10 lb, 6 to Pkg.	Fiber Carton	26 × 21½ × 7	52½	48	23.3	21.2
10-13 lb, 4 to Pkg.	Fiber Carton	26½ × 16 × 7½	50	46	27.2	25.0
13-16 lb, 4 to Pkg.	Fiber Carton	29 × 18½ × 9	67½	62	24.2	22.2
16-20 lb, 2 to Pkg.	Fiber Carton	17 × 16 × 9	39	36	27.7	25.4
20-24 lb, 2 to Pkg.	Fiber Carton	19 × 16½ × 9½	47½	44	27.6	25.5
Tomatoes						
Florida	Fiber Carton	19 × 10⅞ × 10¾	43	40	33.3	31.0
	Wirebound Crate	18¾ × 11½ ₁₆ × 11½ ₁₆	64	60	41.3	38.7
California	Wood Lug Box	17½ × 14 × 7¾	34	30	30.9	27.3
Texas	Wood Lug Box	17½ × 14 × 6⅝	34	30	36.2	31.9
Veal (Boneless)	Fiber Carton	20 × 15 × 5	57	53	65.7	61.0

ASHRAE 1974 - Reprinted by permission

TABLE 46

PILING HEIGHTS USING PALLETS WITHOUT AUXILIARY SUPPORT

Commodity	Units High in Pile	Pallets in Pile	Overall Height Ft
Eggs, wood cases	12	3	14½
Apples, boxes	12	3	13⅓
Grapes, lugs	21	3	14¼
Canned goods, cartons		3-4	15-18
Tierces, on end	4	3-4	13
Cans, 30 lb	12	3	14¼
Butter, 68 lb cubes	12	3	14¼

Commodity	Units High in Pile	Pallets in Pile	Overall Height Ft.
Butter, 68 lb cubes	12	6	15
Frozen fruits & vegetables, cartons		2-4	10-20
Frozen juice concentrate, cartons		4-5	18
Turkeys, boxes approx. 80 lb	21	3	18
Boned meat, fiber cartons, if flat		3-4	13-15

ASHRAE 1974 Applications - Reprinted by permission

TABLE 47

FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION CHART

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.

Temperature			Temperature			Temperature			Temperature		
Celsius	C or F	Fahr	Celsius	C or F	Fahr	Celsius	C or F	Fahr	Celsius	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	+298.4
-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	+363.3
-15.0	+5	+41.0	+18.3	+65	+149.0	+51.9	+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

TABLE 4B
SATURATION TEMPERATURE/PRESSURE CHART

VACUUM — Inches of Mercury — *Italic Figures.*

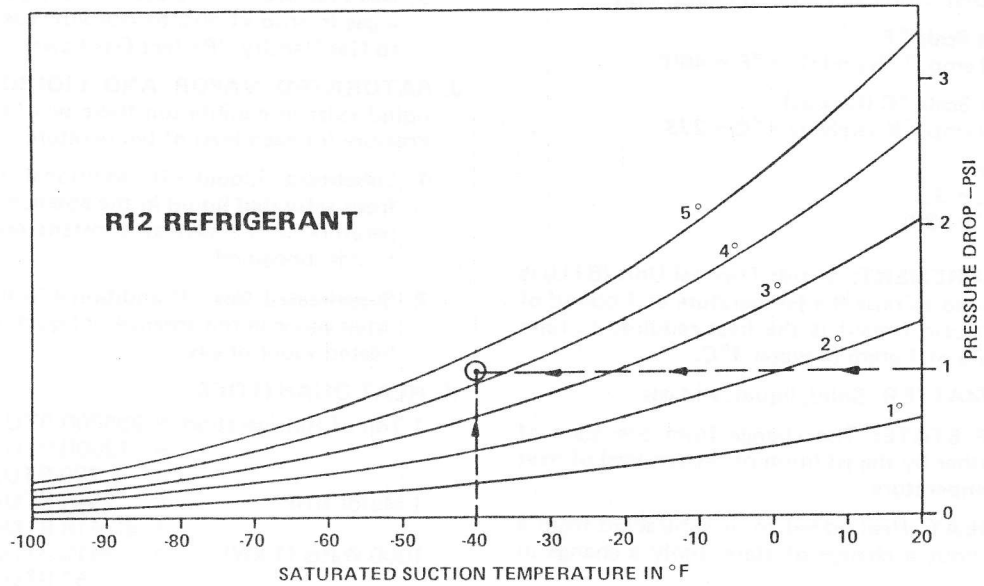
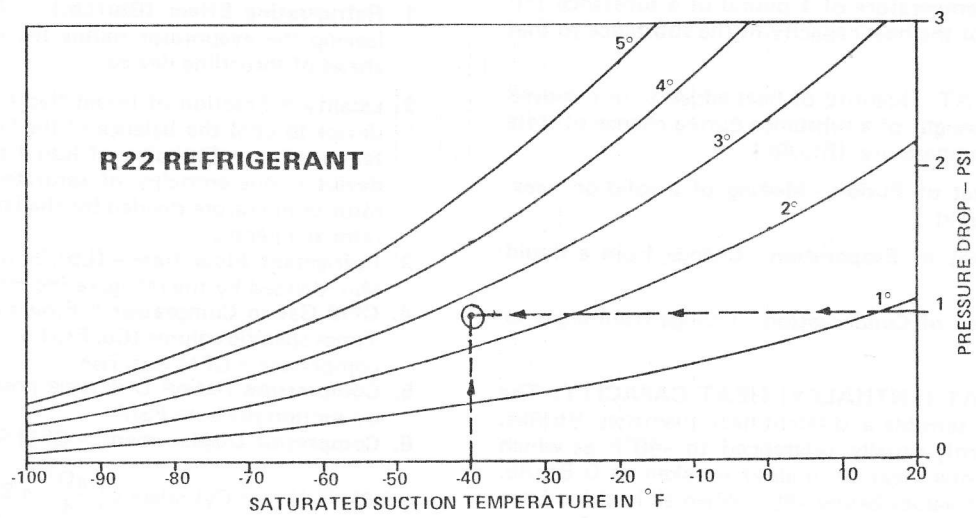
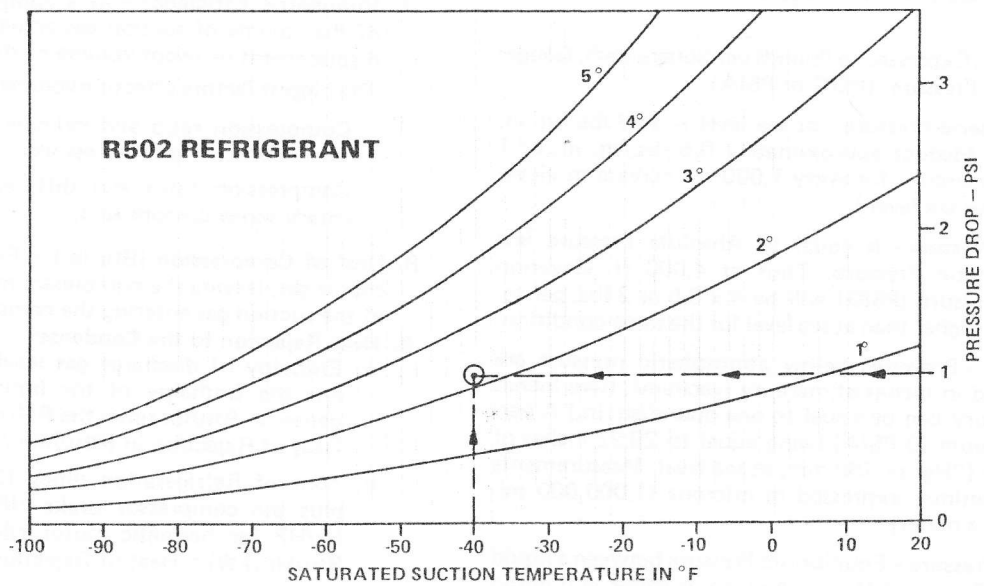
PRESSURE — Pounds per square inch gauge — **BOLD FIGURES**

TEMP. °F	REFRIGERANT				
	12	22	502	500	717
- 60	19.0	12.0	7.0		18.6
- 55	17.3	9.2	3.6		16.6
- 50	15.4	6.2	0.0		14.3
- 45	13.3	2.7	2.1		11.7
- 40	11.0	0.5	4.3	7.8	8.7
- 38	10.0	1.3	5.2	6.6	7.4
- 36	8.9	2.2	6.2	5.4	6.1
- 34	7.8	3.0	7.2	4.1	4.7
- 32	6.7	3.9	8.3	2.8	3.2
- 30	5.5	4.9	9.4	1.4	1.6
- 28	4.3	5.8	10.5	0.0	0.0
- 26	3.0	6.9	11.7	0.7	0.8
- 24	1.6	7.9	13.0	1.5	1.7
- 22	0.3	9.0	14.2	2.3	2.6
- 20	0.6	10.1	15.5	3.1	3.6
- 18	1.3	11.3	16.9	4.0	4.6
- 16	2.0	12.5	18.3	4.8	5.6
- 14	2.8	13.8	19.7	5.8	6.7
- 12	3.6	15.1	21.2	6.7	7.9
- 10	4.5	16.5	22.8	7.7	9.0
- 8	5.4	17.9	24.4	8.7	10.3
- 6	6.3	19.3	26.0	9.8	11.6
- 4	7.2	20.8	27.7	10.9	12.9
- 2	8.2	22.4	29.4	12.1	14.3
0	9.2	24.0	31.2	13.3	15.7
1	9.7	24.8	32.2	13.8	16.5
2	10.2	25.6	33.1	14.5	17.2
3	10.7	26.4	34.1	15.1	18.0
4	11.2	27.3	35.0	15.7	18.8
5	11.8	28.2	36.0	16.3	19.6
6	12.3	29.1	37.0	17.0	20.4
7	12.9	30.0	38.0	17.7	21.2
8	13.5	30.9	39.0	18.3	22.1
9	14.0	31.8	40.0	19.0	22.9
10	14.6	32.8	41.1	19.7	23.8
11	15.2	33.7	42.2	20.4	24.7
12	15.8	34.7	43.2	21.1	25.6
13	16.4	35.7	44.3	21.9	26.5
14	17.1	36.7	45.4	22.6	27.5
15	17.7	37.7	46.6	23.4	28.4
16	18.4	38.7	47.7	24.1	29.4
17	19.0	39.8	48.9	24.9	30.4
18	19.7	40.8	50.1	25.7	31.4
19	20.4	41.9	51.2	26.5	32.5
20	21.0	43.0	52.4	27.3	33.5
21	21.7	44.1	53.7	28.1	34.6
22	22.4	45.3	54.9	28.9	35.7
23	23.2	46.4	56.2	29.8	36.8
24	23.9	47.6	57.4	30.7	37.9
25	24.6	48.8	58.7	31.5	39.0
26	25.4	49.9	60.0	32.4	40.2
27	26.1	51.2	61.4	33.3	41.4
28	26.9	52.4	62.7	34.2	42.6
29	27.7	53.6	64.1	35.1	43.8
30	28.4	54.9	65.4	36.1	45.0
31	29.2	56.2	66.8	37.0	46.3
32	30.1	57.5	68.2	38.0	47.6
33	30.9	58.8	69.7	39.0	48.9
34	31.7	60.1	71.1	40.0	50.2
35	32.6	61.5	72.6	41.0	51.6

TEMP. °F	REFRIGERANT				
	12	22	502	500	717
36	33.4	62.8	74.1	42.0	52.9
37	34.3	64.2	75.6	43.0	54.3
38	35.2	65.6	77.1	44.1	55.7
39	36.1	67.1	78.6	45.1	57.2
40	37.0	68.5	80.2	46.2	58.6
41	37.9	70.0	81.8	47.3	60.1
42	38.8	71.4	83.4	48.4	61.6
43	39.8	73.0	85.0	49.5	63.1
44	40.7	74.5	86.6	50.6	64.7
45	41.7	76.0	88.3	51.8	66.3
46	42.6	77.6	90.0	53.0	67.9
47	43.6	79.2	91.7	54.2	69.5
48	44.6	80.8	93.4	55.3	71.1
49	45.7	82.4	95.2	56.6	72.8
50	46.7	84.0	96.9	57.8	74.5
52	48.8	87.4	100.5	60.3	78.0
54	51.0	90.8	104.1	62.8	81.5
56	53.2	94.3	107.9	65.5	85.2
58	55.4	97.9	111.7	68.2	89.0
60	57.7	101.6	115.6	70.9	92.9
62	60.1	105.4	119.6	73.7	96.9
64	62.5	109.3	123.7	76.6	101.0
66	65.0	113.2	127.9	79.6	105.3
68	67.6	117.3	132.2	82.7	109.6
70	70.2	121.4	136.6	83.8	114.1
72	72.9	125.7	141.1	89.0	118.7
74	75.6	130.0	145.6	92.2	123.4
76	78.4	134.4	150.3	95.5	128.3
78	81.2	139.0	155.1	99.0	133.2
80	84.2	143.6	159.9	102.5	138.3
82	87.2	148.4	164.9	106.1	143.6
84	90.2	153.2	170.0	109.7	149.0
86	93.3	158.2	175.1	113.4	154.5
88	96.5	163.2	180.4	117.3	160.1
90	99.8	168.4	185.8	121.2	165.9
92	103.1	173.7	191.3	125.1	171.9
94	106.5	179.1	196.9	129.2	178.0
96	110.0	184.6	202.6	133.3	184.2
98	113.5	190.2	208.4	137.6	190.6
100	117.2	195.9	214.4	141.9	197.2
102	120.9	201.8	220.4	146.3	203.9
104	124.6	207.7	226.6	150.9	210.7
106	128.5	213.8	232.9	155.4	217.8
108	132.4	220.0	239.3	160.1	225.0
110	136.4	226.4	245.8	164.9	232.3
112	140.5	232.8	252.4	169.8	239.8
114	144.7	239.4	259.2	174.8	247.5
116	148.9	246.1	266.1	179.9	255.4
118	153.2	252.9	273.1	185.0	263.5
120	157.6	259.9	280.3	190.3	271.7
125	169.1	277.9	298.7	204.0	293.1
130	181.0	296.8	318.0	218.2	315.0
135	193.5	316.6	338.1	233.2	335.0
140	206.6	337.2	359.1	248.8	365.
145	220.3	358.9	381.1	265.2	390.0
150	234.6	381.5	403.9	282.3	420.0
155	249.5	405.1	427.8	300.1	450.0

For elevations above sea level deduct approximately 0.5 lbs./sq. in. or 1" of mercury per 1000 ft. of elevation.

TABLE 49
TEMPERATURE LOSS
DUE TO PRESSURE DROP IN SUCTION LINES



REFRIGERATION TERMINOLOGY

A. TEMPERATURE : Indicates level of heat energy

1. **Fahrenheit Scale °F**
Absolute Temp. ° (Rankin) = °F + 460°
2. **Centigrade Scale °C (Celsius)**
Absolute Temp. °K (Kelvin) = °C + 273°
3. **Conversion**
°F = 1.8°C + 32
°C = 5/9 (°F - 32)

B. HEAT MEASUREMENT: British Thermal Unit (BTU) is the heat required to raise the temperature of 1 pound of water 1°F. Calorie (small) is the heat required to raise the temperature of 1 gram of water 1°C.

C. STATES OF MATTER: Solid, liquid, and gas.

D. CHANGE OF STATE: The change from one state of matter to another by the addition or the removal of heat at constant temperature.

E. SENSIBLE HEAT: Heat added to or subtracted from a substance without a change of state. (only a change in temperature.

F. SPECIFIC HEAT: The amount of sensible heat required to raise the temperature of 1 pound of a substance 1°F or the ratio of the heat capacity of the substance to that of water.

G. LATENT HEAT: Quantity of heat added to or removed from a unit weight of a substance during change of state at constant temperature. (Btu/lb.)

1. **Latent Heat of Fusion** - Melting of a solid or freezing of a liquid.
2. **Latent Heat of Evaporation** - Change from a liquid to a gas.
3. **Latent Heat of Condensation** - Change from a gas to a liquid.

H. TOTAL HEAT (ENTHALPY) HEAT CAPACITY: The sum total of sensible and latent heat quantities. Btu/lbs. (Calories/gram), usually referenced to -40°F at which point the Total Heat (Enthalpy) is taken as 0 Btu/lb. with negative values below -40°. When all heat has been extracted from a substance, it is said to be at Absolute Zero 0°R (Rankin), or correspondingly 0°K (Kelvin):

NOTE: Enthalpy referenced to 0°F for air.

I. PRESSURE: Expressed in Pounds per Square Inch, Gauge; or Absolute Pressure. (PSIG or PSIA)

1. **Atmospheric Pressure** - at sea level is 14.7 lbs./sq. in. absolute (deduct approximately 0.5 lbs./sq. in. or 1 inch of mercury for every 1,000 ft. increase in elevation above sea level.)
2. **Gauge Pressure** - is equal to Absolute Pressure less Atmospheric Pressure. Thus at 4,000 ft. elevation gauge pressure (PSIG) will be 4 x 0.5 or 2 lbs. per sq. in. (PSI) higher than at sea level for the same condition.
3. **Vacuum** - Pressures below atmospheric pressure are measured in inches of mercury (vacuum). (two inches of mercury can be equal to one pound/sq. in.) A perfect vacuum (0 PSIA) being equal to 29.92 inches of mercury ("Hg) or 760 mm, at sea level. Measurements are sometimes expressed in microns (1,000,000 microns in a meter).
4. **Vapor Pressure** - Equilibrium Pressure between a liquid and its Saturated Vapor. As long as vapor and liquid are both present there will be only one vapor pressure for each level of temperature.

5. **Gas Pressure** - In the absence of liquid the pressure of a gas is proportional to Absolute gas temperature and to Gas Density. (Perfect Gas Laws)

J. SATURATED VAPOR AND LIQUID: When gas and liquid exist in equilibrium there will be only one Vapor Pressure for each level of temperature.

1. **Subcooled Liquid** - If additional heat is removed from saturated liquid in the absence of vapor, its temperature is reduced at constant pressure and it becomes subcooled.
2. **Superheated Gas** - If additional heat is added to saturated vapor in the absence of liquid, it becomes superheated vapor or gas.

K. HEAT QUANTITIES

- 1 Ton of Refrigeration = 288000.BTU/DAY
= 12000.BTU/HR.
= 200.BTU/MIN.
- 1 Motor BHP = 2545.BTU/HR.
= 42.418 BTU/MIN.
- 1000 Watts (1 kW) = 3415.BTU/HR.
57.BTU/MIN.

L. REFRIGERATION CYCLE CALCULATIONS*

1. **Refrigerating Effect (Btu/Lb.)** = Enthalpy of vapor leaving the evaporator minus the enthalpy of liquid ahead of throttling device.
2. **Quality** = Fraction of liquid flashed at the throttling device to cool the balance of the liquid to evaporator temperature = Enthalpy of liquid ahead of throttling device minus enthalpy of saturated liquid at evaporator temperature divided by the latent heat at evaporator temperature.
3. **Refrigerant Flow Rate** - (Lbs./Min./Ton = 200 Btu/Min. divided by the refrigerating effect.
4. **CFM Gas to Compressor** = Flow rate (Lbs/Min./Ton) Times specific volume (Cu. Ft./Lb.) of gas entering the compressor = CFM Gas/Ton
5. **Compression Ratio** = Discharge pressure PSIA divided by suction pressure PSIA
6. **Compressor Displacement** = CFM Swept Volume
= RPM % No. of Cylinders x $\left(\frac{\pi D^2}{4} \times S\right) \times \frac{1}{1728}$ for Recips.

where: D = Cylinder Bore in inches
S = Piston Stroke in inches

7. **Volumetric Efficiency** - of a compressor is the ratio of the volume of suction gas actually pumped to the displacement or swept volume of the compressor.

The biggest factors affecting volumetric efficiency are:

Compression ratio and cylinder clearance volume for reciprocating compressors.

Compression ratio and differential pressure for rotary screw compressors.

8. **Heat of Compression (Btu/lb.)** = Enthalpy of the discharge gas, leaving the compressor minus the Enthalpy of the suction gas entering the compressor.

9. **Heat Rejection to the Condenser**

- a. Enthalpy of discharge gas leaving the compressor less the Enthalpy of the liquid leaving the condenser in Btu/lb. times the Refrigerant Flow Rate = Heat of Rejection in (Btu/Min./Ton).
- b. Tons of Refrigeration times 12,000 Btu/Hr./Ton plus the compressor brake HP times 2545 Btu/Hr/HP (or hermetic motor kilowatts times 3415 Btu/Hr./kW) = Heat of Rejection in Btu/Hr.

* Refer to Refrigerant Tables or Mollier Charts, for thermodynamic properties of the refrigerant.

REFRIGERATION TERMINOLOGY (CONTINUED)

M. EQUIPMENT EFFICIENCIES: (Including compressors, condensing units, packaged chillers and air conditioning units)

All efficiencies are measured by the Ratio of Energy Output to Energy Input. $\frac{\text{Energy Output}}{\text{Energy Input}}$

a. COP, Coefficient of Performance = $\frac{\text{kW Output}}{\text{kW Input}}$

b. EER, Energy Efficiency Ratio = $\frac{\text{BTUH Output}}{\text{w Input}}$

N. FORMULAS FOR HEAT TRANSFER EQUIPMENT

Based on Standard Air at sea level*

Properties of Standard Dry Air at 70°F and 1 Atmosphere Pressure (29.92" Hg)

Specific Volume	=	13.35 Cubic Feet/Pound
Density	=	0.075 Pounds/Cubic Feet
Specific Heat	=	0.241 Btu/Lb./°F
One CFM Standard Air	=	4.5 Lbs/Hr.

*Standard Air for any Altitude is at 70°F

PROPERTIES OF WATER AT 39.2°F

Density of water	=	62.4 Lbs/Cubic Ft.
Specific Heat of Water	=	1 Btu/Lb./°F
Latent Heat of Vaporization	=	970 Btu/lb. at 212°F & 1 Atm.
	=	1054.3 Btu/lb. at 70°F
Specific Heat of Ice	=	0.5 Btu/Lb./°F
Latent Heat of Fusion	=	144 Btu/lb.
1 Gallon of Water	=	8.33 lbs.
1 Pound of Water	=	7000 Grains

NOMENCLATURE

Q	=	Heat Flow in Btu/Hr.
T	=	Temperature in °F (ΔT = temp. Difference)
C	=	Specific Heat Btu/Lb./°F
A	=	Area in Sq. Ft.
U	=	Coef. of Heat Transfer in Btu/hr./sq.ft./°F
H	=	Total Heat of Air at Wet Bulb Temp. Btu/lb. (ΔH = Enthalpy difference between entering and leaving air.)
D	=	Density in Lbs/Cu. Ft.
SH	=	Specific humidity in grains of moisture/lb. dry air (ΔSH = Specific Humidity difference for entering leaving air)
CFM	=	Cu. Ft./Min.
GPM	=	Gal/Min.

CONVERSION FACTORS (CONSTANTS)

USED IN STANDARD CALCULATIONS

(Must be Corrected for Other than Standard Properties)

Water

500 = 8.33 lbs./gal. x 60 min. - (Converts GPM to lbs./hr.)

Air

4.5 = $\frac{60 \text{ min.}}{13.35 \text{ cu. ft./lb.}}$ - (Converts from CFM to lbs./hr.)

1.08 = 4.5 x 0.241 Btu/lb./°F - (Pounds per Hour x Sp. Ht. of Air)

0.68 = $\frac{4.5 \times 1054.3 \text{ Btu/lb.}}{7000 \text{ gr./lb.}}$ - (4.5 combined with heat of vaporization of water at 70°F and grains per pound of water)

Water Heating, Cooling & Heat Reclaim Coils, Water Chillers, Condensers, Etc.

Q = 500 x GPM x ΔT = Btu/hr.

ΔT = $\frac{Q}{500 \times \text{GPM}}$

For brines, Q = 500 x GPM x ΔT x (Sp. Ht. x Sp. Gr. of Brine) = Btu/hr.

Air Coils

Q Sensible = 1.08 x CFM x ΔT = Btu/hr.

Q Latent = 0.68 x CFM x ΔSH = Btu/hr.

Q Total = 4.5 x CFM x ΔH = Btu/hr.

Lb./Hr. Condensate = $\frac{4.5 \times \text{CFM} \times \Delta\text{SH Grains}}{7000 \text{ grains/lb.}}$

SHR Sensible Heat Ratio = $\frac{Q \text{ Sensible}}{Q \text{ Total}}$

Heat Transmission

Q Total = U x A Surface x ΔT = Btu/hr.

Product

Sensible Heat in Btu/hr. = Lbs/hr. x Sp. Ht. x ΔT

Latent Heat in Btu/hr. = Lbs./hr. x Latent Heat in Btu/lb.

Heat of Respiration in Btu/hr. = Lbs. x Heat of Respiration in Btu/lb./hr.

ALTITUDE EFFECTS

Effect of altitude and temperature on the performance of Air Handling Equipment rated at sea level conditions.

1. A fan will deliver approximately the same air quantity (CFM) through a given coil under any air condition. Like a pump, a fan will deliver a constant volume of fluid against a fixed head regardless of change in fluid density. The motor BHP requirements, however, would be almost directly proportional to the fluid density.
2. Effect of Altitude: The air density will decrease with increase in altitude and increase with decrease in altitude. Standard air at any altitude is taken at 70°F, the same as at sea level. The ratio of standard air density at elevation to standard air density at sea level is called the "Density Ratio". (See Table 50).

The fan motor BHP and the Mass Flow Rate will vary directly with the Density Ratio.

With Direct Drive Fan Evaporators the sensible heat capacity will be approximately proportional to the Density Ratio.

With adjustable speed fans the Mass Flow Ratio and the performance of a coil in air cooled condensers can be adjusted for altitude, but as the motor capacity decreases approximately with the Density Ratio, due to loss of cooling at lower air densities, it may be necessary to increase the size of the motor.

3. Effect of Temperature: With a change in temperature the air density will vary inversely with the absolute temperature (pressure remaining constant) in accordance with the perfect gas laws. Air density ratio would be the air density at temperature divided by the air density for standard 70°F air.

With the fan handling the same CFM of air the Mass Flow Rate and the fan BHP will vary with the air temperature density ratio. Due to the increased motor cooling at the lower temperatures the motor HP capacity will increase at a faster rate than the required BHP. See Table 51.

Selection of Refrigeration Equipment

De-rate the evaporator by multiplying by the density ratio of the evaporator capacity multiplier table 50. for altitude. The fan motor capacity and its BHP requirement will decrease approximately with the density ratio. Small high slip motors will speed up with reduced slip and operate at a higher temperature rise.

The direct drive fan, air cooled condensing unit capacity at elevation may be approximated from Table 50.

For all other capacity corrections refer to the factory.

Characteristics of Fans used with Refrigeration Evaporators

Propeller Fans: These fans generally require a greater power input as the air volume is restricted as by frost build up on coils prior to defrost. This can result in motor overload and trip-outs. Excessive frost build-up should be avoided by properly scheduling defrost cycles.

Centrifugal fans: are used both for free air delivery and for ducted systems. They are capable of handling greater static air pressures and are available with various horsepower motors to handle the total static required by the coil etc. As the volume of air is restricted as by a frosted coil the horsepower requirement (Forward Curved Fans) is reduced and motor overload is not a problem. To maintain coil refrigerating capacity frost build up must be controlled by properly scheduled defrosts.

TABLE 50

EFFECTS OF ALTITUDE ON AIR COOLED EQUIPMENT

Altitude Feet Above Sea Level	Absolute Pressure		Standard Air Density At 70°F Lbs./Cu. Ft.	Air Density Ratio	Capacity Multipliers*	
	In. Hg.	PSIA			Direct Drive Fans	
					Refrig. Evaporator	Air Cooled Cond. Unit
- 1,000	31.02	15.27	0.0778	1.04	1.03	1.005
- 500	30.47	14.97	.0763	1.02	1.02	1.002
0	29.92	14.7	.0749	1.00	1.00	1.00
500	29.38	14.43	.0735	0.98	0.98	0.995
1,000	28.86	14.28	.0719	0.96	0.97	0.998
2,000	27.82	13.67	.0697	0.93	0.94	0.985
3,000	26.81	13.27	.0671	0.90	0.91	0.98
4,000	25.84	12.7	.0647	0.86	0.875	0.975
5,000	24.89	12.23	.0623	0.83	0.85	0.969
6,000	23.98	11.78	.0600	0.80	0.82	0.960
7,000	23.09	11.34	.0578	0.77	0.79	0.955
8,000	22.22	10.92	.0556	0.74	0.76	0.946
9,000	21.38	10.50	.0535	0.71	0.73	0.939
10,000	20.58	10.11	.0515	0.69	0.71	0.93
12,000	19.03	9.35	.0477	0.64	0.66	0.91
14,000	17.57	8.63	.0439	0.59	0.61	0.88

1. Fan BHP and the Mass Flow Rate through the coil will vary directly with the air density. To correct for altitude multiply by the Air Density Ratio. The same correction can be applied to the Sensible Heat Capacity of a Refrigeration Evaporator, or use the multipliers to the right of the Air Density Ratio Table.
2. Capacity multipliers for Air Cooled Condensing Units with direct drive condenser fans are based on the decrease in air cooled condenser capacity with the reduction in mass air flow rate through the condenser.
3. The effect of altitude and reduced air density on motors, is to reduce the motor capacity nearly proportional to the Air Density Ratio. Since the Mass Flow Rate and HP requirements also decrease in proportion to the Air Density Ratio, the fan motor is capable of maintaining CFM air flow except for small high slip motors on fan coil units which will speed up and operate at a higher temperature rise than at sea level.
4. To maintain sea level design Mass Air Flows and capacities at higher elevations will require an increase in fan speeds and motor HP. Refer to the factory for recommendations.

$$\text{Standard Air Densities Lbs./Cu. Ft.} = \frac{\text{PSIA} \times 144}{R \times \text{Abs. Temp. (70°F + 460)}} \quad \text{Where } R = 53.3$$

TABLE 51

EFFECT OF TEMPERATURE ON AIR COOLED EVAPORATORS

AIR DENSITY RATIOS FOR CHANGE IN TEMPERATURE												
Air Temp. °F	70	60	50	40	30	20	10	0	-10	-20	-30	-40
Air Density Ratio	1.00	1.02	1.04	1.06	1.08	1.105	1.13	1.15	1.175	1.20	1.23	1.26
Density °F Dry Air Lbs./Cu. Ft. At Sea Level	.075	.0764	.078	.0795	.0811	.0828	.0846	.0864	.0883	.0903	.0924	.0946

Density of Standard 70°F Air at Sea Level (29.92" Hg.) = 0.75 Lbs./Cu. Ft. Dry Air.
Air Density varies inversely with the Absolute Temp. (°F + 460°) or (°C + 273°)

1. Fan motor BHP and Mass Flow Rate at constant fan speed will vary directly with the Air Density.
2. To adjust the motor BHP at 70°F to storage room temperatures multiply by the Air Density Ratio.
3. Due to the increased dissipation of heat at lower temperatures the equivalent motor HP increase is greater than the increase in the required BHP.
4. Overloads must be selected for the increased motor BHP and amperage after pulldown to temperature.
5. Evaporator ratings at low temperatures require correction for the increased refrigerant pressure drop through the coil at low suction pressures.

ELECTRICAL FORMULAS

E = Volts
I = Current flow in Amps
R = Resistance in ohms
P = Power in Watts

RESISTANCE LOADS	
SINGLE PHASE LOADS	THREE PHASE DELTA LOADS
$E = I \times R$ $P = I \times E = I^2 \times R = \frac{E^2}{R}$ $R = \frac{E}{I} = \frac{E^2}{P}$ $I = \frac{E}{R} = \frac{P}{E}$ $= \frac{\text{Watts}}{\text{Volts}} = \frac{\text{kW} \times 1000}{\text{Volts}}$	<p>BALANCED ($P = P_1 = P_2 = P_3$)</p> $I_{\text{Line}} = \frac{3P}{E \times \sqrt{3}} = \frac{\text{Watts Total}}{\text{Volts} \times 1.73}$ $\frac{\text{kW} \times 1000}{\text{Volts} \times 1.73}$ <p>UNBALANCED</p> <p>(Phase Amps) $I_1 = \frac{P_1}{E}$ $I_2 = \frac{P_2}{E}$ $I_3 = \frac{P_3}{E}$</p> <p>(Line Amps) $I_{\text{Line 1}} = \sqrt{I_1^2 + I_2^2 + I_1(I_2)}$ (Line Amps) $I_{\text{Line 2}} = \sqrt{I_2^2 + I_3^2 + I_2(I_3)}$ (Line Amps) $I_{\text{Line 3}} = \sqrt{I_3^2 + I_1^2 + I_3(I_1)}$</p>

A/C MOTORS

	SINGLE PHASE	THREE PHASE
MOTOR BHP (Output)	$= \frac{\text{Volts} \times \text{Amps} \times \text{Eff.} \times \text{P.F.}}{746 \times 100}$	$= \frac{1.73 \times \text{Volts} \times \text{Amps} \times \text{Eff.} \times \text{P.F.}}{746 \times 100}$
MOTOR kW (Input)	$= \frac{\text{Volts} \times \text{Amps} \times \text{P.F.}}{1000}$	$= \frac{1.73 \times \text{Volts} \times \text{Amps} \times \text{P.F.}}{1000}$

$$\text{Motor Sync. RPM} = \frac{120 \times \text{Hertz}}{\text{No. of Poles}}$$

NOTE: Motor Efficiency (Eff.) expressed in percent
Power Factor expressed as a decimal.

TABLE 52

**MULTIPLE & SUB MULTIPLE PREFIX UNITS FOR
METRIC & SI - ENGLISH CONVERSION FACTORS**

Prefix	Symbol	Multiplication Factors
Mega	M	one million 1,000,000 or 10^6
Kilo	k	one thousand 1,000 or 10^3
Hecto	h	one hundred 100 or 10^2
Deka	da	ten 10 or 10^1
Deci	d	one tenth 0.1 or 10^{-1}
Centi	c	one hundredth 0.01 or 10^{-2}
Milli	m	one thousandth 0.001 or 10^{-3}
Micro	μ	one millionth 0.000001 or 10^{-6}

TABLE 53

ENGLISH CONVERSION FACTORS

	Mult. By	Equals
Acres	43560	Sq. Ft. (Ft. ²)
Atmosphere	14.7	Lbs./Sq. In.
Atmosphere	29.92	ins. of Hg. @ 32°F
Atmosphere	33.9	Ft. of water @ 40°F
Barrels (US Liq)	31.5	Gallons (Gals)
Bushel	1.245	Cu. Ft.
Bushel	32	Quarts (Qtys) Dry
Cubic Feet (Ft ³)	1728	Cu. Ins.
Cubic Feet (Ft ³)	7.481	Gal. (US Liq)
Cubic Feet (Ft ³)	62.43	Lbs. Water
Gallon, US	231	Cu. Ins.
Gallon, Imp.	1.2009	US Gal.
Horsepower	33000	Ft. Lbs./Min.
Horsepower	745.7	Watts
Horsepower	2545	Btu/Hr.
Kilowatts	1.34	Horsepower
Kilowatts	3413	Btu/Hr.
Liter (1000 cc)	1.057	Quarts
Pounds (Avoir)	16	Ounces
Pounds (Avoir)	7000	Grains
Pounds/Sq. In.	2.307	Ft. of water
Miles	5280	Feet
Miles/Hour	.8684	Knots
Ton (Short)	2000	Lbs.
Ton (Long)	2240	Lbs.
Ton Refrig.	288000	Btu/Day
Ton Refrig.	12000	Btu/Hr.
Ton Refrig.	200	Btu/Min.
Tons British Com'l	1.1045	Tons US
Watts	3.41	Btu/Hr.

TABLE 54

METRIC/ENGLISH CONVERSION FACTORS

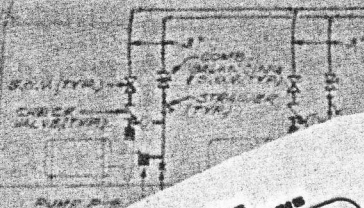
	Mult. By	Equals
Meter (m)	39.37	Inches (Ins.)
Meter (m)	3.28	Feet (Ft.)
Kilometer (km)	0.62137	Miles (Mi.)
Centimeter (cm)	0.3937	Inches (Ins.)
Square Meter (m ²)	10.76	Square Feet (Ft. ²)
Cubic Meter (m ³)	35.3145	Cubic Feet (Ft. ³)
Cubic Meter	264.2	Gallons (Gal.)
Cubic Centimeters (cc ³)	0.06102	Cubic Inches (Ins. ³)
Liter (1000 cc) (l)	61.02	Cubic Inches (Ins. ³)
Liter (1000 cc) (l)	0.2642	Gallons (Gal.)
Liter (1000 cc) (l)	1.057	Quarts, US (Qt.)
Liter (1000 cc) (l)	0.03531	Cubic Feet (Cu. Ft.)
Liters per Second	15.853	Gals./Min. (GPM)
Liters per Second	2.119	Cu. Ft./Min. (CFM)
Kilograms (kg)	2.2046	Pounds (Lbs.)
Kilograms/Sq. cm. (kg/cm ²)	14.22	Lbs./Sq. In. (Lbs./In. ²)
Millimeters (mm)	0.03937	Inches (In.)
Kilograms/Cu. Meter (kg/m ³)	0.0624	Lbs./Cu. Ft. (Lbs./Ft. ³)
Horsepower Metric	0.9862	Horsepower (English)
Kilocalories (kcal)	3.968	Btu
Kilocalories/Hour kcal/h	3.968	Btu/Hr.
Tons (Metric)	1.102	Tons (Short)
Millimeter	1000	Microns

SI METRIC CONVERSION FACTORS

TABLE 55

	MULT. BY	EQUALS	RECIP- ROCAL
HEAT DENSITY			
Joule per metre ² (J/m ²)	8.805 x 10 ⁻⁵	Btu/ft. ²	1.136 x 10 ⁴
Calorie per centimeter ² (cal/cm ²)	3.686	Btu/ft. ²	0.2713
HEAT FLUX DENSITY			
Watt per metre ² (W/m ²)	0.3170	Btu/ft ² · h	3.154
Calorie per centimeter ² · sec	1.327 x 10 ⁴	Btu/ft ² · h	7.536 x 10 ⁻⁵
HEAT TRANSFER COEF(U)			
Watt per metre ² · Kelvin W/(m ² · K)	0.1761	Btu/h · ft ² · °F	5.678
Kilogram calorie per hr · meter ² · °C k/cal/h · m ² · C	0.2048	Btu/h · ft ² · °F	4.8828
SPECIFIC ENTHALPY LATENT			
Joule per kilogram (J/kg)	4.299 x 10 ⁻⁴	Btu/lb.	2326 x 10 ³
Kilo Joule per kilogram (kJ/kg)	0.4299	Btu/lb.	2.326
Calorie/gram (cal/g)	1.8	Btu/lb.	0.555
SPECIFIC HEAT (c)			
Joule per kilogram · Kelvin J/(kg · K)	2.388 x 10 ⁻⁴	Btu/(lb. · °F)	4187.6
Kilojoule per kilogram · Kelvin kJ/(kg · K)	0.2388	Btu/(lb. · °F)	4.187
Calorie/(gram · °C) cal/(g · °C)	1.0	Btu/(lb. · °F)	1
HEAT OF RESPIRATION			
Kilogram calorie/ metric ton per 24 hrs. (kcal/metric ton per 24 hrs.)	3.6	Btu/ton (short) per 24 hrs.	0.278
Watts per megagram per 24 hrs.	74.129	Btu/ton (short) per 24 hrs.	0.0135
Btu/ton per 24 hrs.	5 x 10 ⁻⁴	Btu/lb. per 24 hrs.	2000
THERMAL CONDUCTIVITY(k)			
Watts per metre · Kelvin w/m · K	0.5777	$\frac{(\text{Btu} \cdot \text{ft})}{(\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F})}$	1.731
Watts per meter · Kelvin w/m · K	6.933	$\frac{(\text{Btu} \cdot \text{in.})}{(\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F})}$	0.144
Calorie per sec · cm · K	241.88	$\frac{(\text{Btu} \cdot \text{ft})}{(\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F})}$	4.134 x 10 ⁻³
THERMAL DIFFUSIVITY			
Meter ² per second (m ² /s)	3.875 x 10 ⁴	ft ² /h	2.580 x 10 ⁻³
THERMAL RESISTANCE			
Kelvin · metre ² /Watt (K · m ²)/W	5.678	(°F · h · ft ²)Btu	0.1761
ENERGY Joule (J)			
Joule (J)	1.000	Watt · Sec (W · S)	1.000
Joule (J)	9.484 x 10 ⁻⁴	Btu	1054.4
Joule (J)	0.239	Calorie (cal)	4.184
POWER (HEAT)			
Watt (W)	3.415	Btu/h	0.2928
Watt (W)	0.860	kcal/h	1.163
PRESSURE			
Pascal (Pa)	9.869 x 10 ⁻⁶	Atmosphere	1.013 x 10 ⁵
Pascal (Pa)	2.953 x 10 ⁻⁴	ins. of hg	3.386 x 10 ³
Pascal (Pa)	7.50 x 10 ⁻³	mm of hg	1.333 x 10 ²
Pascal (Pa)	0.010	Millibor	100
Kilo Pascals (kPa)	0.145	psi	6.895
Kilo Pascals (kPa)	0.010	Bars (bar)	100
Kilo Pascals (kPa)	4.021	ins. of water	0.2487

TELEPHONE

[illegible]

Model	A	B	C	D
EL-K2010	17%	20 1/2%	9	27
EL-K2015	17%	20 1/2%	6	27

... Consult factory for ...

Symbol	Δ	%
01.039810	23.76	107.7%
01.039812	25	108.1%
01.039814	27.1	109.2%

NOTES

- * Minimum clearance required
- ** Dimensions may vary due to motor run
- † Minimum required clearance for mechanical clearance

ITEM NO.	DESCRIPTION	UNIT	QTY	PRICE
AL32019	43 1/2"	10 1/2"	1	10 1/2"
AL32019	43 1/2"	10 1/2"	1	10 1/2"
AL32019	43 1/2"	10 1/2"	1	10 1/2"

All dimensions are approximate. Consult factory for certified drawings.

NOTE: Components with an asterisk with options mounted, consult factory for dimensional data. Refer to page 52 for options table and pump down capacities.

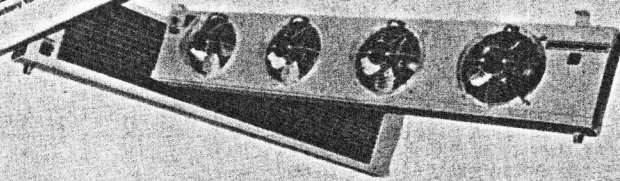
OUT OF ORDER - C-8 177

178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

[illegible]

STANDARD CONDENSING SERIES	
MODEL	SIZE
2000	20 x 700

NOTES:
 * Minimum clearance
 ** Dimensions may vary due to
 † Measurement requires clearance for
 ‡ Consult factory for dimensions of
 Consult factory for specific dimensions



FORM NO. 5045

DUNHAM-BUSH

**'HCLS' LOW SILHOUETTE
HOT GAS DEFROST
UNIT COOLERS & SYSTEMS
4,500 BTUH THRU 54,000 BTUH**

DUNHAM-BUSH, INC. • West Hartford, Connecticut 06110, U.S.A.

5100B-15M-1071A-579B COMPUTER ROOM CONDITIONING UNIT

one of The Signal Companies 