WT-ENG-0313A

Refrigeration

Engineering

Manual 110

See Catalog WT-SAX for details

Super-Flo - The Low Profile Unit Cooler

- Efficient Air Pattern
- Longest Air Throw
- Universal Repair Parts
- Air, Electric & Hot Gas Defrost
- Circuited for the New Refrigerants
- 56 Model Sizes from 3600 to 41,000 BTUH

See Catalog WT-WWF for details

Easy-Flo - The Low Velocity Unit Cooler

- Use For . . .
  - Refrigerated Work Rooms
  - Storage of Sensitive Products
- Air, Electric & Hot Gas Defrost
- New Ultra-Quiet Motot Mounting
- Circuited for the New Refrigerants
- 9 Model Sizes from 5000 to 34,000 BTUH

See Catalog WT-WDL for details

WD-Series - Air Cooled Condensing Units

- 3 thru 22 HP Models
- Indoor & Outdoor
- Discus and Semi-Hermetic Compressors
- High, Medium & Low Temperature
- Pre-Wired and Pre-Piped Components
- Factory Pre-Selected Systems

Other Witt Products

- Air-Cooled Condensing Units thru 80HP
- Heavy-Duty Unit Coolers from 11,500 thru 165,00 BTUH
- Reach-In Unit Coolers
- Ripening Room Systems
- Air Cooled Condensers from 1 to 250 Tons
- ARI Certified Air Handlers from 3 to 65 Square Foot Face Area
- Heating & Cooling Coils - Water, Glycol, Steam & Refrigerant

Witt

Refrigeration Manual

Introduction

This is a manual for professionals, people interested in the containment and movement of refrigerated air and products.

We have made every effort to insure the accuracy of the data in this manual. Since it was necessary in some cases to use weighted averages, we cannot be responsible for differences in results, nor for typographical errors or omissions.

Its scope is almost unlimited. With it, you can quickly determine the Net Refrigeration Load Requirements for practically any refrigeration situation. For walk-ins of any size. For almost every product and for adding glass display doors to merchandise direct from walk-in coolers and freezers.

Witt is a leader in providing our customers with quality refrigeration products. With a broad line of heat transfer products that reflect creative approach. The versatility of the Witt product line permits the use of equipment matched and balanced to meet the system load for maximum utilization of energy at minimal cost.

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Quick Reference Chart for Estimating Small Box Loads

Outside Area Quick - Check

COOLER SIZE (ft. sq.)

L-ft.	D-ft.	H - 9 ft.	H - 12 ft.
8	6	343	432
10	6	408	504
12	6	468	576
14	6	528	648
16	6	588	720
18	6	648	792
20	6	708	864
22	6	768	936
24	6	828	1008
8	8	116	512
10	8	484	592
12	8	552	672
14	8	620	752
16	8	688	832
18	8	756	912
20	8	824	992
22	8	892	1072
24	8	960	1152
26	8	1028	1232
28	8	1096	1312
30	8	1164	1392
32	8	1232	1472
10	10	560	680
12	10	636	768
14	10	712	856
16	10	788	944
18	10	864	1032
20	10	940	1120
22	10	1016	1208
24	10	1092	1296
26	10	1168	1384
28	10	1244	1472
30	10	1320	1560
32	10	1396	1648
34	10	1472	1736
36	10	1548	1824
38	10	1624	1912
40	10	1700	2000
12	12	720	864
14	12	804	960
16	12	888	1056
18	12	972	1152
20	12	1056	1248
22	12	1140	1344
24	12	1224	1440
26	12	1308	1536
28	12	1392	1632
30	12	1476	1728
32	12	1560	1824
34	12	1644	1920
36	12	1728	2016
14	14	896	1064
16	14	988	1168
18	14	1080	1272
20	14	1172	1376
22	14	1264	1480
24	14	1356	1584
26	14	1448	1688
28	14	1540	1792

FOR USE WITH QUICK REFERENCE GRAPH ON PAGE 2

COOLER SIZE (ft. sq.)

L-ft.	D-ft.	H - 9 ft.	H - 12 ft.
30	14	1632	1896
32	14	1724	2000
34	14	1816	2104
36	14	1908	2208
38	14	2000	2312
40	14	2092	2416
42	14	2184	2520
16	16	1088	1280
18	16	1188	1392
20	16	1288	1504
22	16	1388	1616
24	16	1488	1728
26	16	1588	1840
28	16	1688	1952
30	16	1788	2064
32	16	1888	2176
18	18	1296	1512
20	18	1404	1632
22	18	1512	1752
24	18	1620	1872
26	18	1728	1992
28	18	1836	2112
30	18	1944	2232
32	18	2052	2352
34	18	2160	2472
36	18	2268	2592
20	20	1520	1760
22	20	1636	1888
24	20	1752	2016
26	20	1868	2144
28	20	1984	2272
30	20	2100	2400
32	20	2216	2528
34	20	2332	2656
36	20	2448	2784
38	20	2564	2912
40	20	2680	3040
24	24	2016	2304
26	24	2148	2448
28	24	2280	2592
30	24	2412	2736
32	24	2544	2880
34	24	2676	3024
36	24	2808	3168
38	24	2940	3312
40	24	3072	3456
42	24	3204	3600
44	24	3336	3744
46	24	3468	3888
48	24	3600	4032
30	30	2880	3240
34	30	3192	3576
38	30	3504	3912
42	30	3816	4248
46	30	4128	4584
50	30	4440	4920
54	30	4752	5256
60	30	5220	5760

Walk-in Coolers– Normal Temperature

Determining BTU/Hour Loads for Walk-in Storage Coolers Normal Temperature (54°)

Steps to Follow in Determining Refrigeration Load

1. Select Cooler size. Determine Ambient Temperature of location. (80° air conditioned location, 90° non-air conditioned location, 100° southern states or outdoor location.) Find BTU wall and infiltration losses per hour.

2. Add on Average Product Load BTU/HR. If specific product is known, use Page 12 only for product load. When Page 12 is used, do not add the Average Product Load.

3. When Glass Display Doors are used, add to total from Page 8.

4. Add BTU/HR load totals for the Net Refrigeration requirements.

Examples

Example No. 1
Normal Cooler with Average Product Load

Size: 24'Lx 10'Dx9'H Page 5 (Design ambient 80°F, air conditioned location)	9130
Average Product Load Page 5	47 50
Total Net Refrigeration Requirements	13,880 BTU/Hour

Example No. 2
Normal Cooler with Specific Product

Size: 24'Lx 10'D x 9'H Page 5 (ambient 80°, air conditioned location)	9130
Product: Beer—Pop Page 12 (100 cases per day 75°to 36" per 24 hours) Adjusted to match 16 hour Time Cycle Factor (used in Page 5) 5900 BTU/Hour x 1.5 (factor to adjust to 1 6 hour cycle)	8850
Total Net Refrigeration Requirements	17,980 BTU/Hour

Example No. 3
Normal Cooler with Glass Display Doors

Size: 24'Lx 10'Dx 9'H Page 5 (Designed ambient 80°F air conditioned location)	9130
Doors: 10 Arco Double Glass Page 8 (10'box depth, 80 "ambient)	7700
Product: Beer—Pop Page 12 (100 cases per day 75"to 36" per 24 hours) Adjusted to match 1 6 hour Time Cycle Factor (used in Page 5) 5900 BTU/Hour x 1.5 (factor to adjust to 1 6 hour cycle)	8850
Total Net Refrigeration Requirements	25,680 BTU/Hour

Walk-in Coolers– BTU Per Hour Wall and Infiltration Losses

Note: Wall and infiltration losses based on Ambient Temperatures listed and Cooler construction incorporating 4" polyurethane or equivalent.

All loads adjusted to 16-18 hours running time.

*Chart usable for 8' and 10' heights also.

BTU Per Hour Wall & Infiltration Losses

Cooler Size L	D	H*	Average Temperature 80°	90°	100°	Average Product Load BTU/Hr
8	6	9	3430	4200	4940	950
10			4140	5030	5950	1190
12			4820	5890	6950	1430
14			5490	6720	7950	1650
16			5640	6800	8100	1900
18			5930	7250	8540	2150
20			6490	7930	9370	2380
22			7070	8650	10210	2620
24			7690	9370	11050	2850
8	8	9	4290	5240	6190	1280
10			5120	6250	7390	1590
12			5210	6340	7560	1900
14			5810	7100	8390	2220
16			6530	7960	9390	2530
18			7240	8840	10430	2870
20			7390	8970	10630	3180
22			7560	9250	10920	3500
24			8180	9980	11780	3820
26			8400	10270	12100	4120
28			9070	11070	13050	4450
30			9580	11690	13780	4750
32			10140	12400	14670	5050
10	10	9	5230	6380	7530	1980
12			6070	7400	8720	2380
14			6880	8390	9920	2790
16			6920	8530	10010	3170
18			7440	9070	10720	3570
20			7770	9510	11240	3960
22			8450	10290	12170	4350
24			9130	11140	13170	4750
26			9790	11980	14130	5150
28			10550	12870	15180	5550
30			10960	12950	15300	5950
32			11000	13000	15500	6350
34			11200	13100	15650	6750
36			11350	13270	15710	7150
38			11520	14040	16590	7550
40			12060	14680	17360	7980
12	12	9	6940	8450	9990	2860
14			7020	8560	10110	3320
16			7740	9430	11160	3800
18			8140	9960	11760	4300
20			8880	10900	12810	4750
22			9690	11810	13950	5250
24			10430	12750	15050	5450
26			11080	13480	15650	6160
28			11850	14000	16300	6650
30			12650	14900	17200	7120
32			13370	15770	17950	7600
34			14250	16450	18750	8070
36			15100	17300	19600	8550
14	14	9	7830	9560	11300	3700
16			8320	10160	12010	4250
18			9170	11230	13260	4750
20			9900	12120	14280	5270
22			10570	13080	15100	5800
24			10700	13250	15300	6340
26			10860	13390	15440	6870
28			11040	13590	15810	7400

BTU Per Hour Wall & Infiltration Losses

Cooler Size L	D	H*	Average Temperature 80°	90°	100°	Average Product Load BTU/Hr
30	14	9	11260	13750	15900	8300
32			11550	14050	16250	8850
34			11830	14380	16500	9425
36			12200	14700	16950	10000
38			12650	15250	17500	10500
40			13100	15800	18100	11100
42			13750	16500	18850	11600
16	16	9	9270	11110	13370	4850
18			9430	11200	13510	5440
20			9580	11490	13670	6050
22			9950	12140	14360	6650
24			10700	13100	15460	7250
26			11420	13960	16500	7850
28			12170	14890	17610	8450
30			12320	15080	17810	9050
32			13010	15950	18850	9650
18	18	9	9250	11290	13340	6100
20			10090	12270	14560	6800
22			10840	13210	15630	7470
24			11690	14240	16850	8150
26			11920	14570	17250	8800
28			12740	15520	18350	9520
30			13490	16450	19470	10200
32			14260	17330	20530	10900
34			15010	18320	21680	11600
36			15770	19220	22750	12300
20	20	9	10950	13300	15810	7550
22			11780	14380	16990	8100
24			12110	14780	17490	9100
26			12940	15780	18680	9850
28			13760	16780	19860	10600
30			14580	17830	21030	11400
32			15350	18780	22210	12100
34			16220	19830	23410	12800
36			17090	20870	24660	13600
38			17920	21920	25830	14400
40			18740	22880	27010	15100
24	24	9	13960	17040	20180	10900
26			15000	18270	21590	11800
28			15950	19400	22950	12700
30			16840	20580	24260	13600
32			17840	21710	25670	13800
34			18730	22830	26980	14700
36			19730	24010	28450	15600
38			20670	25180	29800	16400
40			21630	26370	31120	17300
42			22570	27450	32530	18200
44			23470	28620	33480	19000
46			23790	29080	34270	19800
48			24700	30040	35560	20800
30	30	9	20240	24740	29250	16300
34			22510	27500	32500	18400
38			24070	29380	34700	20500
42			26160	31950	37820	22700
46			28350	34700	40950	24900
50			30640	37350	44060	27000
54			32840	40120	47400	29200
60			36080	44050	52020	32400

Walk-in Freezers

To Determine BTU/Hour Loads
Low Temperature Walk-in Storage Freezer

Steps to Follow

1. Select Freezer size. Determine Design ambient t Temperature of location. (80° air conditioned location, 90° non-air conditioned location, 100° southern states or outdoor location.) Find BTU wall and infiltration losses per hour in appropriate Box Temperature column.

2. Add on Average Product Load BTU/HR. If a specific product is known, use Page 12 only for product load. When Page 12 is used, do not add the Average Product Load.

3. When Glass Display Doors are used, add total from Page 9.

4. Add BTU/HR load totals for the Net Refrigeration requirements.

Note: Wall and infiltration losses based on Ambient Temperatures listed and Freezer construction incorporating 4" polyurethane equivalent. All loads adjusted to 16-18 hours running time • Charts usable for 8' and 10' heights also.

Freezer Size	80° Ambient			90° Ambient			100° Ambient			Average Product Load BTU/Hr.
L D H*	Box 0°	-10°	-20°	0°	-10°	-20°	0°	-10°	-20°	
8 x 6 x 9	6,060	6,410	6,750	6,200	6,550	6,890	6,360	6,710	7,050	1210
10	6,610	7,010	7,390	6,820	7,230	7,620	7,050	7,470	7,910	1510
12	7,130	7,580	8,010	7,360	7,820	8,260	7,610	8,080	8,570	1820
14	7,640	8,130	8,610	7,880	8,390	8,870	8,150	8,670	9,210	2110
16	8,130	8,670	9,190	8,360	8,890	9,420	8,640	9,170	9,690	2420
18	8,610	9,190	9,750	8,880	9,480	10,050	9,180	9,800	10,430	2730
20	9,080	9,700	10,310	9,360	10,000	10,620	9,670	10,340	11,020	3020
22	9,540	10,200	10,850	9,840	10,520	11,180	10,170	10,870	11,600	3330
24	9,990	10,700	11,390	10,300	11,010	11,700	10,690	11,400	12,090	3630
8 x 8 x 9	6,740	7,140	7,540	6,900	7,310	7,710	7,100	7,510	7,900	1620
10	7,370	7,840	8,290	7,610	8,080	8,540	7,870	8,350	8,860	2020
12	7,980	8,500	9,000	8,230	8,770	9,280	8,510	9,060	9,630	2420
14	8,570	9,140	9,690	8,840	9,430	9,990	9,140	9,750	10,370	2820
16	9,140	9,760	10,360	9,390	10,010	10,620	9,710	10,330	10,940	3220
18	9,690	10,360	11,020	10,000	10,690	11,350	10,340	11,050	11,780	3640
20	10,240	10,960	11,660	10,560	11,300	12,010	10,910	11,680	12,460	4050
22	10,770	11,540	12,290	11,110	11,900	12,660	11,480	12,300	13,140	4450
24	11,300	12,110	12,900	11,640	12,450	13,250	12,090	12,900	13,690	4800
26	11,820	12,670	13,510	12,190	13,070	13,930	12,600	13,510	14,460	5200
28	12,330	13,230	14,120	12,710	13,650	14,550	13,220	14,130	15,010	5600
30	12,830	13,780	14,710	13,230	14,210	15,160	13,670	14,680	15,730	6000
32	13,330	14,330	15,300	13,770	14,760	15,740	14,330	15,330	16,310	6450
10 x 10 x 9	8,090	8,620	9,130	8,350	8,890	9,410	8,570	9,090	9,610	2520
12	8,780	9,370	9,940	9,020	9,600	10,170	9,320	9,920	10,560	3020
14	9,450	10,090	10,720	9,740	10,410	11,040	10,070	10,760	11,460	3520
16	10,090	10,790	11,470	10,410	11,130	11,820	10,740	11,430	12,120	4020
18	10,720	11,470	12,210	11,020	11,780	12,510	11,390	12,170	12,990	3720
20	11,340	12,140	12,930	11,690	12,520	13,330	12,080	12,940	13,830	4150
22	11,940	12,800	13,640	12,320	13,200	14,060	12,730	13,640	14,590	4550
24	12,540	13,450	14,340	12,930	13,870	14,780	13,410	14,320	15,220	4960
26	13,120	14,090	15,030	13,520	14,490	15,430	13,980	14,970	16,020	5400
28	13,700	14,720	15,720	14,130	15,180	16,190	14,600	15,690	16,800	5800
30	14,280	15,340	16,390	14,720	15,820	16,890	15,330	16,390	17,440	6200
32	14,850	15,960	17,060	15,310	16,460	17,580	15,820	17,010	18,240	6620
34	15,410	16,580	17,720	15,890	17,090	18,260	16,420	17,660	18,950	7050
36	15,970	17,180	18,380	16,460	17,720	18,930	17,190	18,400	19,600	7450
38	16,520	17,790	19,030	17,040	18,340	19,610	17,610	18,950	20,350	7850
40	17,070	18,380	19,680	17,630	18,950	20,240	18,400	19,720	21,010	8300
12 x 12 x 9	9,550	10,200	9,580	9,850	10,520	9,870	10,180	10,870	10,240	3640

BTU Per Hour Wall and Infiltration Losses

Walk-in Freezers (cont'd)

Freezer Size	80° Ambient			90° Ambient			100° Ambient			Average Product Load BTU/Hr.
L D H*	Box 0°	-10°	-20°	0°	-10°	-20°	0°	-10°	-20°	
14 x 12 x 9	10,290	11,000	11,350	10,610	11,340	11,670	10,970	11,720	12,070	4220
16	11,000	11,780	12110	11,350	12,150	12,450	11,730	12,560	12,880	4830
18	11,700	12,540	13,350	12,070	12,930	13,760	12,470	13,360	14,280	5440
20	12,390	13,280	14,160	12,780	13,700	14,590	13,210	14,160	15,140	6040
22	13,060	14,020	14,950	13,470	14,450	15,400	13,920	14,930	15,980	6650
24	13,730	14,740	15,730	14,160	15,200	16,210	14,630	15,710	16,820	7250
14 x 14 x 9	11,100	11,880	12,640	11,440	12,250	13,030	11,820	12,660	13,520	4060
16	11,880	12,730	13,560	12,260	13,130	13,970	12,670	13,570	14,500	4650
18	12,650	13,570	14,460	13,050	13,990	14,900	13,490	14,460	15,460	5250
20	13,410	14,390	15,350	13,830	14,840	15,810	14,290	15,340	16,410	5800
22	14,150	15,190	16,220	14,590	15,670	16,710	15,080	16,190	17,340	6370
24	14,880	15,990	17,070	15,350	16,490	17,590	15,860	17,040	18,250	6950
26	15,600	16,770	17,920	16,090	17,300	18,460	16,630	17,880	19,150	7550
28	16,320	17,550	18,750	16,830	18,090	19,320	17,390	18,690	20,050	8100
16 x 16 x 9	12,740	13,660	14,560	13,140	14,090	15,010	13,580	14,560	15,580	5290
18	13,580	14,570	15,540	14,000	15,030	16,020	14,470	15,530	16,620	5950
20	14,400	15,460	16,500	14,850	15,950	17,010	15,350	16,480	17,650	6630
22	15,210	16,340	17,450	15,690	16,850	17,980	16,210	17,410	18,660	7300
24	16,010	17,210	18,380	16,510	17,740	18,940	17,060	18,330	19,650	7950
26	16,800	18,060	19,300	17,320	18,620	19,890	17,900	19,240	20,640	8600
28	17,570	18,910	20,210	18,120	19,500	20,830	18,720	20,150	21,610	9300
30	18,340	19,740	21,120	18,920	20,360	21,750	19,550	21,040	22,570	9900
32	19,110	20,570	22,010	19,700	21,210	22,670	20,360	21,920	23,520	10600
18 x 18 x 9	14,490	15,550	16,600	14,940	16,040	17,100	15,440	16,580	17,740	6710
20	15,370	16,520	17,640	15,860	17,030	18,170	16,390	17,600	18,850	7450
22	16,250	17,470	18,660	16,760	18,010	19,230	17,320	18,610	19,950	8200
24	19,670	18,400	19,670	20,280	18,980	20,260	20,960	19,610	21,020	8920
26	17,960	19,330	20,660	18,520	19,930	21,290	19,140	20,590	22,090	9650
28	18,810	20,240	21,650	19,390	20,870	22,300	20,040	21,560	23,140	10450
30	19,640	21,140	22,620	20,250	21,800	23,310	20,920	22,530	24,190	11150
32	20,470	22,040	23,590	21,100	22,730	24,300	21,800	23,490	25,210	11600
34	21,290	22,930	24,550	21,950	23,640	25,290	22,680	24,430	26,240	11900
36	22,100	23,810	25,500	22,790	24,550	26,270	23,550	25,370	27,260	12300
20 x 20 x 9	16,330	17,550	18,750	16,840	18,100	19,320	17,400	18,700	20,050	8300
22	17,270	18,570	19,850	17,810	19,150	20,450	18,400	19,790	21,220	8890
24	18,200	19,580	20,930	18,760	20,190	21,560	19,390	20,860	22,370	9950
26	19,110	20,570	22,000	19,710	21,210	22,660	20,370	21,920	23,510	10750
28	20,020	21,550	23,060	20,640	22,220	23,750	21,330	22,960	24,640	11600
30	20,910	22,520	24,100	21,570	23,220	24,830	22,290	23,990	25,760	12420
32	21,800	23,490	25,140	22,480	24,220	25,900	23,230	25,030	26,870	13240
34	22,680	24,440	26,170	23,390	25,200	26,960	24,170	26,040	27,970	14070
36	23,560	25,390	27,200	24,290	26,180	28,020	25,100	27,050	29,070	14900
38	24,430	26,330	28,210	25,190	27,150	29,060	26,030	28,050	30,150	15730
40	25,290	27,270	29,220	26,080	28,120	30,100	26,950	29,050	31,230	16560
24x24 x 9	20,320	21,870	23,400	20,950	22,560	24,110	21,650	23,310	25,020	10900
26	21,360	23,000	24,620	22,030	23,720	25,360	22,760	24,510	26,310	11800
28	22,390	24,120	25,820	23,090	24,870	26,600	23,860	25,700	27,600	12700
30	23,410	25,230	27,010	24,140	26,010	27,830	24,940	26,870	28,870	13600
32	24,420	26,320	28,190	25,190	27,140	29,040	26,030	28,040	30,130	14600
34	25,430	27,410	29,360	26,220	28,260	30,250	27,090	29,200	31,380	15400
36	26,430	28,490	30,530	27,250	29,380	31,450	28,160	30,360	32,630	16350
38	27,420	29,570	31,680	28,270	30,490	32,640	29,210	31,500	33,860	17200
40	28,400	30,640	32,830	29,290	31,590	33,820	30,260	32,640	35,090	18350
42	29,380	31,700	33,980	30,300	32,680	35,000	31,310	33,770	36,310	19150
44	30,360	32,750	35,120	31,300	33,770	36,170	32,340	34,890	37,530	20000
46	31,330	33,810	36,250	32,300	34,860	37,340	33,370	36,020	38,740	20900
48	32,290	34,850	37,370	33,300	35,940	38,500	34,410	37,130	39,940	21800
30 x 30 x 9	27,060	29,180	31,260	27,900	30,080	32,200	28,830	31,080	33,410	17100
34	29,440	31,750	34,030	30,360	32,740	35,060	31,370	33,830	36,370	19350
38	31,790	34,300	36,770	32,780	35,370	37,880	33,870	36,540	39,300	21500
42	34,120	36,820	39,480	35,180	37,960	40,670	36,350	39,220	42,190	23800
46	36,420	39,310	42,160	37,550	40,530	43,430	38,800	41,870	45,060	26100
50	38,700	41,780	44,820	39,900	43,080	46,170	41,220	44,510	47,900	28400
54	40,970	44,230	47,460	42,240	45,610	48,890	43,640	47,120	50,720	30700
60	44,340	47,880	51,390	45,710	49,370	52,930	47,230	51,010	54,910	34000

Glass Display Doors - Coolers

Extra Load to be Added When Glass Display Doors are Included with 34°F Walk-in Coolers:

Standard Door 24” x 55

Steps to Follow in Determining Refrigeration Load

1. Select number of doors for box depth indicated and proper Design Ambient Temperature of location, (80° air conditioned location, 90° non-air conditioned location, 100° southern states or outdoor location.)

2. Add the appropriate BTU losses per hour to the Cooler total from Page 5. Calculations are based on regular double-glazed insulating glass doors.

Note: Calculations are for 6’ minimum box depth and are not suitable for Reach-in Refrigerators. All loads adjusted for 16-18 hours running time.

	34º Refrigerator Temperature & Double Glass Doors			
	Number	Ambient Temperature		
	Doors	80°	90°	100°
Box Depth 6' to 9'	2	1980	2330	2700
	3	3100	3660	4250
	4	4050	4770	5540
	5	5100	6020	6980
	6	5900	6950	8050
	7	6500	7670	8920
	8	7000	8250	9540
	9	75-50	8900	10350
	10	7980	9400	10900
	11	8450	9950	11540
	12	9000	10600	12300
	13	9450	11150	12960
	14	9900	11700	13600
	15	10200	12050	14000
	16	10600	12520	14540
	17	11000	13050	15180
	18	11300	13360	15510
	19	11600	13700	15920
	20	11800	13950	16200
Box Depth 10'to 16'	5	4100	4840	5600
	6	5200	6140	7120
	7	6100	7200	8350
	8	6800	8030	9310
	9	7250	8550	9930
	10	7700	9.080	10550
	11	8000	9460	11010
	12	8400	9920	11520
	13	8700	10300	11950
	14	9000	10640	12380
	15	9300	11000	12810
	16	9700	11480	13300
	17	9900	11710	13600
	18	10200	12080	14020
	19	10400	12320	14300
	20	10650	12600	14610

Glass Display Doors - Freezers

Extra Load to be Added When Glass Display Doors are Made a Part of Walk-in Freezers:

Steps to Follow in Determining Refrigeration Load

1. Determine Box-to-Ambient Temperature Difference.

Temperature Box	*Ambient	Box to Ambient Difference
0°	80° 90° 100°	80° 90° 100°
-10°	80° 90° 100°	90° 100° 110°
-20°	80° 90° 100°	100° 110° 120°

2. Add the appropriate BTU losses per hour to the Freezer total from Pages 6-7. Calculations are based on triple-glazed electric insulating glass doors.

Note: Calculations are for 6' minimum box depth and are not suitable for Reach-in Freezers. All loads adjusted to 16-18 hours running time.

*80° air conditioned location, 90° non-air conditioned location, 100° southern states or outdoor location.

Low Temperature Doors

	Number Doors	Temperature Difference—Box to Ambient				
		80°	90°	100°	110°	120°
Box Depth 6' to 9'	2	4120	4510	5030	5480	5870
	3	5110	5600	6220	6760	7250
	4	6120	6700	7440	8100	8660
	5	7910	8700	9650	10510	11260
	6	9750	10700	11870	12900	13800
	7	11650	12800	14200	15480	16510
	8	12750	14000	15560	16950	18150
	9	14050	15400	17100	18650	19970
	10	15300	16800	16650	20300	21710
	11	16480	16100	20100	22920	24520
	12	17560	19300	21400	23360	25000
	13	18750	20600	22850	24910	26600
	14	19650	21600	24000	26200	28000
	15	20500	22500	25050	27320	29200
	16	21550	23600	26200	28620	30610
	17	22100	24300	27000	29410	31550
	18	22900	25100	28000	30500	32620
	19	23400	25600	28500	31150	33380
	20	23800	26100	29050	31790	34000
Box Depth 10' to 16'	5	6830	7500	8320	9070	9750
	6	8110	8900	9870	10760	11510
	7	9750	10700	11890	12920	13820
	8	11300	12400	13780	15000	16100
	9	12740	14000	15550	16920	18110
	10	14200	16600	17300	18860	20200
	11	15550	17000	1(3890	20590	22000
	12	16750	18400	20400	22210	23800
	13	17950	19700	21900	23920	25600
	14	18800	20700	23000	25150	26910
	15	19700	21600	24010	26220	2S100
	16	20690	22700	25200	27420	29400
	17	21500	23600	26250	28610	30620
	18	22350	24500	27200	29690	31810
	19	22910	25100	27900	30400	32600
	20	23450	25700	28500	31150	33300

Refrigerator - Wall Heat Loss

To Find BTU Per Hour Wall Heat Loss Load for Any Size Refrigerator (See Page 34)

Steps to Follow

1. Determine total square feet of wall, ceiling and floor areas (Example A).
2. Subtract desired refrigerator temperature from ambient temperature of location (Example B). Select wall insulation thickness. Find factor in chart.
3. Multiply total square feet by chart factor for total BTU/HR wall heat loss load. Now refer to Page 11 for Interior

Examples

A. 20'W x 16'D x 9'H

1. 20' x 16' x 2 = 640 sq. ft.
2. 20' x 9' x 2 = 360 sq. ft.
3. 16' x 9' x 2 = 288 sq. ft.

Total 1288 sq. ft.

B. Ambient Temp. 100°F
Refrigerator Temp. -10°F
Temp. Reduction Factor 110
Wall insulation — 5" Fiberglass

C. 5" Wall—110 Temp. Reduction Factor = 5.5 Chart Factor 1288 sq ft. x5.5 = 7,084 BTU/HR load required over a 24 hour time cycle for wall heat loss for 20' x 16' x 9' size refrigerator.

Note: BTU/HR loads are based on 24 hour time cycle with all equipment running at full capacity. Use Time Cycle Factor Chart to convert to other than a 24 hour time cycle Example-7,084 x 1.2 (20 hr. run) = 8,500 BTU/HR.

BTU Per Hour Wall Heat Gain Load

Insulation		Temperature Difference — Ambient to Box -°F											
Thick-ness Inches	K Factor *	1°	20°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°
1	.25	.250	5.00	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5
	.16	.160	3.20	6.40	8.00	9.60	11.2	12.8	14.4	16.0	17.6	19.2	20.8
2	.25	.125	2.50	5.00	6.25	7.50	8.75	10.0	11.25	12.5	13.75	15.0	16.25
	.16	.080	1.60	3.20	4.00	4.80	5.60	6.4	7.20	8.0	8.80	9.60	10.4
3	.25	.083	1.67	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8
	.16	.053	1.07	2.13	2.67	3.20	3.73	4.27	4.80	5.33	5.87	6.40	6.93
4	.25	.063	1.25	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13
	.16	.040	.800	1.60	2.00	2.40	2.80	3.20	3.60	4.00	4.40	4.80	5.20
5	.25	.050	1.00	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50
	.16	.032	.640	1.28	1.60	1.92	2.24	2.56	2.88	3.20	3.52	3.84	4.16
6	.25	.042	.833	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42
	.16	.027	.533	1.07	1.33	1.60	1.87	2.13	2.40	2.67	2.93	3.20	3.47
7	.25	.036	.714	1.43	1.79	2.14	2.50	2.86	3.21	3.57	3.93	4.29	4.64
	.16	.023	.457	.914	1.14	1.37	1.60	1.83	2.06	2.29	2.51	2.74	2.97
8	.25	.031	.625	1.25	1.56	1.88	2.19	2.50	2.81	3.13	3.44	3.75	4.06
	.16	.020	.400	.800	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60
9	.25	.028	.555	1.11	1.39	1.67	1.94	2.22	2.50	2.78	3.06	3.33	3.61
	.16	.018	.355	.711	.889	1.07	1.24	1.42	1.60	1.78	1.96	2.13	2.31
10	.25	.025	.500	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25
	.16	.016	.320	.640	.80	.960	1.12	1.28	1.44	1.60	1.76	1.92	2.08
Single Glass		1.125	22.5	45.0	56.3	67.5	78.8	90.0	102.0	113.0	124.0	135.0	146.0
Double Glass		.458	9.17	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6
Triple Glass		.292	5.83	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9

*K = .25 Fiberglass or Expanded Polystyrene
K = .16 Polyurethane

Note: For corkboard or mineral wool, multiply .25 values in. table by 1 2, for Polystyrene Board, multiply .25 values by 8

Note: Increase insulated wall loss values by 10% for stud walls

Multiply By Factors Under Running Time Selected				
22 hrs.	20 hrs.	18 hrs.	16 hrs.	14 hrs.
1.1	1.2	1.3	1.5	1.7

Cooler Load Additions for Walk-in Refrigerated Enclosure

	Fractional HP Motors	Integral HP Motors	Lights	BTU Per Sq. Ft.	People Working
	Per Horsepower	Per Horsepower	Per Watt Input	Floor Surface	Per Person
Nominal BTU/Hr.	3500	2900	3.5	3.5	900

Allowance for sun effect

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

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

Concrete Slab U Factor

	1°	20°	40°	50°	60°	70°	80°
6 inch concrete floor slab on ground. Under 400 sq. ft., see note at right	0. 25	5	10	12.5	15	17.5	20

NOTE: Determine TD as difference between ground temp (Assume 30° below summer amb.) and box temp For floor area greater than 400 sq. ft., multiply factors shown by 65.

Refrigerator - Wall Heat Loss

To Find BTU Per Hour Infiltration and Door Loss Load for Any Size Refrigerator:

Steps to Follow

1. Determine total cubic volume of refrigerator, outside air conditions (temperature and humidity).
2. Find BTU infiltration and door loss load per hour for desired refrigerator temperature.
3. Add this load figure to the BTU/HR wall heat loss load from Page 10 cooler load additions from Page 10. Refer to Page 12 for a specific product BTU/HR load.

Note: BTU/HR loads are based on 24 hour time cycle with all equipment running at full capacity. Use Time Cycle Factor Chart to convert to other than a 24 hour time cycle, Example-4,650 x 1.2 (20 hr. run) = 5,580 BTU/HR.

Example: 20'W x16'D x 9'H = 2,880cu.ft. 2,880 cu. ft. @100°F/50%RH for -10°F = 4,650 BTU/HR infiltration and door loss load for interior volume of 20' x 16'x 9' size refrigerator.

Interior Refrigerator Volume Total Cubic feet	Outside Air Temp °F.	% Relative Humidity	BTU Per Hour Loads Refrigerator Temperature (°F) 45°	34°	0°	-10°	-20°
400 to 1000	34	85			630	775	920
	45	60		125	755	900	1040
		85		195	825	970	1120
	70	50	470	685	1260	1390	1530
		60	550	770	1340	1480	1620
	80	50	750	960	1525	1660	1790
		60	865	1075	1640	1770	1900
	90	50	1070	1270	1810	1940	2080
		60	1240	1440	1975	2110	2240
	100	50	1440	1640	2170	2290	2430
		60	1660	1860	2390	2510	2640
1000 to 6000	34	85			1270	1560	1850
	45	60		245	1520	1810	2100
		85		390	1660	1950	2250
	70	50	940	1375	2520	2790	3050
		60	1110	1540	2680	2960	3240
	80	50	1500	1920	3050	3320	3580
		60	1730	2150	3280	3540	3800
	90	50	2160	2570	3660	3910	4200
		60	2500	2910	4000	4250	4530
	100	50	2920	3310	4380	4650	4900
		60	3350	3750	4830	5060	5340

Interior Refrigerator Volume Total Cubic feet	BTU Per Hour Loads Refrigerator Temperature (°F) 45°	34°	0°	-10°	-20°
6000 to 20000			2260	2780	3300
		440	2700	3230	3750
		690	2960	3480	4000
	1680	2440	4480	4960	5460
	1980	2750	4800	5270	5760
	2670	3420	5400	5900	6400
	3080	3820	5830	6300	6800
	3830	4550	6500	6950	7450
	4450	5160	7100	7550	8050
	5160	5860	7750	8200	8660
	5940	6650	8520	8950	9450
20000 to 80000			5300	6500	7750
		1140	6350	7550	8800
		1620	6950	8150	9350
	3900	5700	10500	11600	12800
	4650	6400	11200	12300	13500
	6220	7950	12600	13800	14900
	7200	8900	13600	14700	15800
	9020	10750	15250	16350	17500
	10450	12150	16700	17800	18900
	12050	13650	18100	19150	20200
	13850	15500	19900	20900	22000

Refrigerating Specific Products

To Find BTU Per Hour Loads to Refrigerate Specific Products:

Steps to Follow

1. Determine product, quantity and initial temperature of product. Find BTU/HR required for final product temperature desired.

2. Add total Specific Product load to Wall and Infiltration losses Page 5—Coolers, or Page 6—Freezers. Do not use the Average Product Load of Page 5 or 6 if Page 12 is used.

3. The total BTU per hour loads of Charts from Page 10, 11 and 12 will give the Net Refrigeration Load for any application.

Example: 5,000 lbs. Pork
Initial temperature of 34°
Final temperature desired -20°

4430 BTU/HR x 5 (thousand pounds) = 22,150 BTU/HR required over a 24 hour time cycle

Note: BTU/HR loads are based on a 24 hour time cycle with all equipment running at full capacity and depending on packaging, spacing and thickness Use Time Cycle Factor Chart to convert to other than a 24 hour time cycle. Example—22,150 x 1.2 (20 hr. run) = 26,580 BTU/HR

BTU/HR *

Product	Specific Example	Quantity of Product per 24 Hr. Load Cycle	Initial Temp. °F	Final Product Temperature						
				+40'	+36°	32°	0°	-10°	-20°	-30°
Beef	Carcass and	Per 1,000 Lbs	100°	1930	2060	2190				
	Carcass Parts		50°	320	450	580				
			30°			130	4880	5050	5210	
			32°				4750	4920	5080	
Pork—Lamb—Veal	Carcass and	Per 1,000 Lbs.	100°	1750	1850	1960				
	Carcass Parts		34"			60	4130	4270	4430	
Sea Food	Fish—Shrimp—Lobster	Per 100 Lbs.	32°				490	510	530	
	Oysters—Scallops									
Ice Cream	Soft Mix from Batch Freezer	Per 100 Gals.	28"				2320	2500	2670	2840
Bakery Goods	Bread—Cake	Per 100 Lbs.	80°	120	130	140	410	430	440	
			50°	30	40	50	330	340	350	
			36°			10	280	300	320	
Pizza	Pizza—TV Dinners	Per 100	80°	100	110	120	360	370	380	
TV Dinners	Meat Pies—Chicken Pies	14 Oz. Units	34°			10	240	250	260	
Poultry	Chickens—Turkeys	Per 1,000 Lbs.	55°	500	630	760	5540	5700	5850	
			33°			30	4780	4940	5090	
Frozen Food	Cartoned Products all types	Per 1,000 Lbs,	**0°**					210	420	
Beer—Pop	Cases of 12 oz. bottles	Per 100 Cases	75°	5300	5900	6500				
Milk	Bottles in wire or plastic cases	Per 100 Gals. (33 cases)	45°	250	350	650				
Vegetables	Artichokes—Asparagus-	Per 1,000 Lbs.	90°	1880	2030	2180	8100	8280	8440	
	Beans—Beets—Broccoli—Brussels Sprouts-Cabbage—Carrots-Cauliflower—Corn—Eggplant—Peas-White Potatoes—Spinach-Squash—Turnips		75°	1310	1460	1620	7610	7800	7990	
			45°	190	340	490	5990	6180	6370	

Coil Placement

General Arrangements for Placement of Forced Air Evaporators (Propeller Fan Type) in Refrigerated Enclosures

LEFT
Cooler or Freezer
With Glass Display Doors

RIGHT
Elevation View of Glass Display Door Cooler or Freezer Be sure Air Discharge Blows Above, not Directly at Doors. Provide Baffle if Door Extends Above Blower Level.

LEFT
Small Cooler or Freezer

RIGHT
Large Cooler or Freezer

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

Note: Always avoid placement of Unit Coolers directly above doors and door openings where low temperature is being maintained and wherever possible for normal temperature. Allow sufficient space between rear of Unit Cooler and wall to permit free return of air. Refer to Unit manufacturers' catalog for proper space. Always trap drain lines individually to prevent vapor migration. Traps on low temperature units must be outside of refrigerated enclosures.

Cutting Rooms and Preparation Rooms

To Find BTU Per Hour Loads

Find length and width of room and temperature desired to determine total BTU/HR load.

Note: Room loads are adjusted lo compensate for personnel, lights, packaging machinery, pass-thru doors, connected horsepower of process machinery, glass wall panels, etc. temperature conditions calculated at 60% to 70% Relative humidity. Evaporator should be selected at 20° minimum and 25° maximum below room temperature selected. Compressor should be selected to match evaporator capacity at suction temperature equivalent to room temperature less 20° or 25° as case may be, but not below 30° suction temperature.

BTU Per Hour Load

Room Length	Room Depth					
	15 Ft.		20 Ft.		25 Ft.	
Ft.	50°	55°	50°	55°	50°	55°
10'	16000	14500	20700	18500	25300	22500
15'	25400	22600	29700	26500	38000	34000
20'	29700	26500	38000	34000	46000	41000
25'	38000	34000	46000	41000	55500	49500
30'	42000	37500	52500	47000	61000	54500
35'	49500	44000	59000	52500	71000	63500
40'	52500	47000	66000	59000	77000	69000
45'	58500	52500	71500	64000	84000	75000
50'	61000	54500	77000	69000	89500	80000

Banana Rooms

Refrigeration Requirements

Note: Evaporator blowers to deliver air volume against 5/8″ external water gauge static pressure. Evaporators should be designed to operate in the range of 55°F. Condensing units should develop capacity to match evaporator at approximately 40° suction temperature.

Room Size	Number Boxes Prod.	Evaporator BTU per 10° TD	Approx. CFM Air Volume	Elec. Heat input	Humidification If Required Water G.P.H.
$^1/_2$ Car	432	36000	6000	6 KW	1.5 GPH
1 Car	864	72000	12000	12 KW	3.0 GPH
2 Car	1728	144000	24000	24 KW	6.0 GPH

Beer Data

CONTAINER SIZE& TYPE	BOTTLE & CAN DATA			FULL CARTONS- BOTTLES OR CANS					
	DIMEN. (IN.) Dia. x Ht.	WEIGHT EMPTY	WEIGHT FULL	NUMBER IN CARTON	WEIGHT CARTON ONLY	CARTON MATERIAL	CARTON DIMEN. Ht.xDept.xLgt.	WEIGHT FULL CARTON Lbs.	BTU TO COOL THRU 1°F.
12 oz. Glass Bottles	$2^1/_2$ X $7^5/_8$	7.625 oz.	20.12 oz.	24	15 oz.	Cardboard	$8^1/_4$ X $11^3/_8$ X 17	31.12	20.63
12 oz Alum Cans	$2^1/_2$ X $4^3/_4$	0 706 oz.	13.2 oz.	24	4½ oz.	Cardboard	$4^1/_8$ X 11 X $16^1/_4$	20.08	18.63
12 oz. Alum, Cans	$2^1/_2$ X $4^3/_4$	0.706 oz.	13.2 oz.	12	3½ oz.	Cardboard	$4^1/_8$ X $7^7/_8$ X $10^1/_2$	10.12	11.37
16 oz. Alum Cans	$2^1/_2$ X $6^1/_4$	0.81 oz.	1 7 37 oz.	24	4½ oz.	Cardboard	$6^1/_4$ X 11 X $16^1/_4$	26.49	25.76
32 oz. Glass Bottles	$3^1/_2$ X $10^5/_8$	17.0 oz.	50 32 oz.	12	17 oz.	Cardboard	$10^1/_2$ X $11^1/_2$ X $15^1/_2$	38.80	27.00
ALUM. KEGS.	**DIMEN. INCHES**	**WEIGHT EMPTY**	**WEIGHT FULL**	**BTU TO COOL THRU 1°F.**	FOR FAST ESTIMATION OF BEER LOADS, ASSUME BEER TO BE SAME AS WATER:				
7 ¾ Gal.	19-5/16x15-7/32	18 Lbs.	82 Lbs.	68	Cp=1.0 BTU/LB-°F SP. GR =1.0				
15 ½ Gal.	15 ½ x 23 ¼	31 ½ Lbs.	159 Lbs.	135	OTHER SPEC. HEATS: Cardboard = 0.40 Glass = 0 20 Aluminum = 0214				

Standard Milk Data

CASE DATA				SEPARATE WEIGHTS			
CASE MATERIAL	CONTENTS	NO. PER CASE	CASE DIMENSION INCHES H x W x L	CASE ONLY	CONTAINER ONLY	MILK ONLY	BTU TO COOL THRU 1°F FULL CASE
Plastic	1 Gal. Plastic Bottles	6	$10^5/_8$X$13^1/_8$X$16^5/_8$	6 Lbs.	70 Grams	8.6 Lbs.	52.0
Plastic	$^1/_2$ Gal. Paper Cartons or Plastic Bottles	12	$10^5/_8$X$13^1/_8$X$16^5/_8$	6 Lbs.	65 Grams	4.3 Lbs.	52.0
Plastic	1 Qt. Paper Cartons or Plastic Bottles	24	$10^5/_8$X$13^1/_8$X$16^5/_8$	6 Lbs.	32 Grams	2.15 Lbs.	52.0
Plastic	1 Pt. Paper Cartons	48	$10^5/_8$X$13^1/_8$X$16^5/_8$	6 Lbs.	25 Grams	1.075 Lbs.	52.0
Plastic	1/3 Qt. Paper Cartons	60	$10^5/_8$X$13^1/_8$X$16^5/_8$	6 Lbs.	16 Grams	0.717 Lbs	44.0
Plastic	½ Pt. Paper Cartons	60	$10^5/_8$X$13^1/_8$X$16^5/_8$	6 Lbs.	14 Grams	0.5375 Lbs.	34.0

Standard Milk Density = 8.6 Lbs./Gal.
8.6 Lbs./Gal. x 0.93 Cp x 1 °F. = 8 Btu/Gal. to cool Std. Milk thru 1 °F.
For Plastic, use Cp = 0.50

Spec. Heat above freezing = 0.93

For Cardboard, use Cp = 0.40

Specific Heats of Milk and Milk Derivatives

	32 F	59.0 F	104.0 F	140.0 F		32 F	59.0 F	104.0 F	140.0 F
Whey Skim	0.978	0.976	0 974	0.972	30% Cream	0.673	0.983	0.852	0.860
Milk Whole	0.940	0.943	0.952	0.963	45% Cream	0.606	1.016	0.787	0.793
Milk	0.920	0.938	0.930	0.918	60% Cream	0.560	1.053	0.721	0.737
15% Cream	0.750	0.923	0.899	0.900	Milk fat	(0.512)[a]	(0.527)[a]	0.556	0.580
20% Cream	0.723	0.940	0.880	0.886	Butter	(0.445)[a]	(0.467)[a]	0.500	0.530

(a) For butter and milk fat, values in parenthesis were obtained by interpolation under assumption that the specific heat is about the same in the Solid and liquid States.

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Candy Storage

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
Hand dippers	62	45
Moulded goods cooling	40 - 45	84 - 70
Chocolate packing room	65	50
Chocolate finished stock storage	65	50
Centers tempering room	72 - 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 - 10
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		
Nonpareil pan supply air	75 - 80	35 - 30
Hard candy cooling tunnel supply air	100 - 120	20
Hard candy packing	60 - 70	55 - 40
Hard candy storage	70 - 75	40 - 35
Caramel rooms	50 - 70	40
	70 - 80	40

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Department or Process	Dry- 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 syrup	90 - 100	
Liquid sugar	75 - 80	40 - 30
Comfort air conditions	75 - 80	60 - 50

a Temperature and humidity ranges are given in respective order, i e., first temperature corresponds to first humidity
b Conditions given in this table are intended as a guide and represent values which have been found to be satisfactory for many
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
will change the temperature humidity or both to some degree
c Optimum conditions.
d Depends on removal system. With higher temperatures, coloration and fluidity are greater.

Fish Products Data

Average Water Content and Specific and Latent Heats of Various Fishery Products

Fish	Water Content %	Average Freezing Point, °F	Specific Heat[3] Above Freezing, Btu/(Lb) (F deg)	Specific Heat" 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

(a) Calculated by Siebel's formula, for values above S = 0.008a + 0.20: for values below freezing S = 0.20 where a = water content is percent, 0.20 = specific heat of solid constituents of the substance
(b) Values for latent heat (latent heal of fusion) in Btu per Ib. calculated by multiplying the percentage of water content by the latent heat of fusion of water. 143.4 Btu.

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
Buffalo fish, flounders, halibut, ocean perch, rockfish, sable-fish, red, sockeye, silver or Coho, salmon, shrimp	Packaging	7 - 12
Blue Pike, haddock, cod, hake, lingcod	Packaging	Over 12

(a) All packaging should be with moisture resistant films.

Space Requirements for Frozen Fishery Products

Commodity	Product Package	Container or Storage	Space Required Lb. per Cu Ft
Fish sticks, breaded shrimp, breaded scallops	8 or 10 oz. consumer pkg.	Cardboard master cartons	25—30
	1, 5 or 10 Ib. packages	In cardboard master cartons	50—60
Fish fillets, fish steaks, small dressed fish	2'/2 and 5 Ib. cartons	In cardboard master cartons	35
Shrimp	None	Wooden box	35
Panned, frozen fish (mackerel chubs)	None	Wooden box	30-35
		Stacked loose	38
Round ground fish	None	Stacked loose	32
Round salmon	None	Stacked loose	33—35

Shell Egg Storage

Typical conditions affecting the refrigeration load are:

Storage Temperature		F	30
Relative Humidity		%	30 to 90
Average Weight of Egg Crate		lb.	50
Standard Case Size	width	in.	12
	height	in.	13
	length	in.	26
Insulation Losses			Normal
Air Infiltration Losses			Normal
Lighting per sq ft floor		watts	1
Occupant per 400 sq ft floor			1
Max. Allowable Air Velocity across Eggs (forced circulation)		fpm	40

Heat Control of Egg Products[a]

Item	Percent solids	Freezing point, F	Specific heat[b]		Latent heat of freezing, Btu/lb.[c]
			Above freezing	Below freezing	
Water	0	32	1.00	0.5	144
Whole eggs	25	31	0.88	0.5	108
Whites	12	31	0.94	0.5	127
Yolks	44	31	0.78	0.5	81
Sugared yolks	50	25	0.75	0.5	72
Salted yolks	50	1	0.75	0.5	64

(a) From USDA Egg Pasteurization Manual. ARS 74-48, Feb. 1969.
(b) Btu/lb./FL or calories/gm./C.
(c) To convert to calories/gm. multiply values by 0 555. These data together with the specific heat values can be used to calculate the Btu required to lower (or raise) the temperature of eggs including the freezing step. For example, the Btu that must be removed to lower the temperature of 30 lb. of whole eggs from 40 F to 0 are obtained as follows: 30 x 0.88 x (40-31) + (30 x 108) + (30 x 0.5) x (31 -0) = 3,943 Btu.

Liquid Egg Storage

Liquid egg products are extremely perishable and should be kept at 34°F or lower at all times after production until used. Storage temperatures of 0°F or below will guarantee quality in frozen eggs for long periods of time. In fact products tested after ten years storage at 0°F have been found to be entirely satisfactory.

Densities of Commercial Egg Products[a]

Type	Density Ratio	Lb./cu ft.	Lb./gal
Water	1.00	62.4	8.34
Whites, yolks, whole eggs	1.035	64.6	8.63
Blend 32-33% solids	1.05	65.5	8.76
10% sugared yolks or eggs	1.07	67.0	8.92
10% salted yolks or eggs	1.10	68.6	9.17

(a) From USDA Egg Pasteurization Manual, ARS 74-78. February 1969.

Flour and Bread Dough

1. Specific heat of flour = 0.42 Btu per (lb.) (F deg.)
2. Specific heat of dough = 0.60 Btu per (lb.) (F deg.)
3. Average specific heat of other ingredients = 0.40 Btu per(lb.) (F deg.)
4. Specific heat of liquid sponges
   10% flour content = 0.85 Btu per (lb.) (F deg.)
   30% flour content = 0.79 Btu per (lb.) (F deg.)
   50% flour content = 0.70 Btu per (lb.) (F deg.)

Range of Condensing Units Commonly Specified for Various Mixer Sizes

Dough Capacity, Lb.	Condensing Unit Hp.
800	5
1000	$7^1/_2$-10
1300	10-15
1600	15-20
2000	20

5. Average heat of hydration=6.5 Btu per lb.
6. Heat generated by mixer motor=42.4 Btu per (min) (hp).

Bread

Specific heat of bread (above freezing)=0.74 Btu per (lb) (F deg).
Specific heat of bread (below freezing)=0.34 Btu per (lb) (F deg)
Latent heat of bread=47.0 Btu per lb.
Bread freezes at 16—20 F

Display Case

Recommended Temperatures

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

(a)These temperatures are air temperatures, with thermometer in the re-frigerated air stream and not in contact with the product.
(b) Minimum temperatures for frozen food and ice cream are not critical; maximum temperature is the important factor for proper preservation of product quality

General Product Information

Commodity	Storage Temp, F	Relative Humidity, %	Approximate Storage Life	Water Content, %	Highest Freez-ing Point, F	Specific Heat Above Freezing Btu/lb/F	Specific Heat Below Freezing Btu/lb/F	Latent Heat {Calcu-lated) Btu/lb
Alfalfa meal	0 or below	70-75	1 year, plus		-	_	-	—
Apples	30-40	90	3-8 months	84.1	29.3	0.87	0.45	121
Apricots	31-32	90	1-2 weeks	85.4	30.1	0.88	0.46	122
Artichokes (Globe)	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	32-36	95	2-3 weeks	93.0	30.9	0.94	0.48	134
Avocados	45-55	85-90	2-4 weeks	65.4	31.5	0.72	0.40	94
Bananas	—	85-95	—	74.8	30.6	0.80	0.42	108
Beans (Green or snap)	40-45	90-95	7-10 days	88.9	30.7	0.91	0.47	128
Lima	32-40	90	1 week	66.5	31.0	0.73	0.40	94
Beer, keg	35-40	—	3-8 weeks	90.2	28.0	0.92	—	129
bottles, cans	35-40	65 or below	3-6 months	90.2	—	—	—	—
Beets								
Bunch	32	95	10-14 days	—	31.3	—	—	—
Topped	32	95-100	4-6 months	87.6	30.1	0.90	0.46	126
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
Bread	0	—	3 weeks to 3 months	32-37	—	0.70	0.34	46-53
Broccoli, sprouting	32	95	10-14 days	89. 9	30.9	0.92	0.47	130
Brussels sprouts	32	95	3-5 weeks	84.9	30.5	0.88	0.46	122
Cabbage, late	32	95-100	3-4 months	92.4	30.4	0.94	0.47	132
Candy	0-34	40-65	—	—	—	—	—	—
Canned foods	32-60	70 or lower	1 year	—	—	—	—	—
Carrots, Topped, immature	32	98-100	4-6 weeks	88.2	29.5	0.90	0.46	126
Topped, mature	32	98-100	5-9 months	88.2	29.5	0.90	0.46	126
Cauliflower	32	95	2-4 weeks	91.7	30.6	0.93	0.47	132
Celery	32	95	1-2 months	93.7	31.1	0.95	0.48	135
Cherries, sour	31-32	90-95	3-7 days	83.7	29.0	0.87		120
Frozen	0to-10	—	1 year	—	—	—	0.45	—
Sweet	30-31	90-95	2-3 weeks	80.4	28.8	0.84	—.	—
Cocoa	32-40	50-70	1 year, plus	—	—	—	—	—
Coconuts	32-35	80-85	1-2 months	46.9	30.4	0.58	0.34	67
Coffee (green)	35-37	80-85	2-4 months	10-15	—	0.30	0.24	14-21
Collards	32	95	10-14 days	86.9	30.6	0.90		—
Corn, sweet	32	95	4-8 days	73.9	30.9	0.79	0.42	106
Cranberries	36-40	90-95	2-4 months	87.4	30.4	0.90	0.46	124
Cucumbers	50-55	90-95	10-14 days	96.1	31.1	0.97	0.49	137
Currants	31-32	90-95	10-14 days	84.7	30.2	0.88	0.45	120
Cheese, Cheddar	30-34	65-70	18 months	37.5	8.0	0.50	0.31	53
Cheddar	40	65-70	6 months	37.5	8.0	0.50	0.31	53
Processed	40	65-70	12 months	39.0	19.0	0.50	0.31	56
Grated	40	60-70	12 months	31.0	—	0.45	0.29	44
Butter	40	75-85	1 month	16.0	-4 to 31	0.50	—	23
Butter	-10	70-85	12 months	16.0	-4 to 31	—	0.25	23
Cream	-10 to-20	—	6-12 months	55-75	31.0	0.66-0.80	0.36-0.42	79-107
Ice cream	-20 to-15	—	3-12 months	58-63	21.0	0.66-0.70	0.37-0.39	86
Milk, fluid whole								
Pasteurized, Grade A	32-34	—	2-4 months	87.0	31.0	0.93	—	125
Pasteurized, Grade A	-15	—	3-4 months	87.0	31.0	—	0.46	125
Condensed, sweetened	40	—	15 months	28.0	**5.0**	0.42	0.28	40
Evaporated	70	—	12 months	74.0	29.5	0.79	0.42	106
Evaporated	40	—	24 months	74.0	29.5	0.79	0.42	106
Milk, dried Whole	70	low	6-9 months	2-3	—	—	—	4
Non-fat	45-70	low	16 months	2-4.5	—	0.36	—	4
Whey, dried	70	low	12 months	3-4	—	0.36	—	4
Dates	0or32	75 or less	6-12 months	20.0	3.7	0.36	0.26	29
Dewberries	31-32	90-95	3 days	84.5	29.7	0.88	—	—
Dried foods	32-70	low	6 months to 1 year, plus	—	—	—	—	—
Dried fruits	32	50-60	9-12 months	14.0-26.0	—	0.31-0.41	0.26	20-37
Eggplant	45-50	90-95	7-10 days	92 7	30.6	0.94	0.48	132
Eggs, Shell	29-31	80-85	5-6 months	66.0	28 **0**	0.73	0.40	96
Shell, farm cooler	50-55	70-75	2-3 weeks	66.0	28.0	0.73	0.40	96

General Product Information (cont'd)

Commodity	Storage Temp, F	Relative Humidity, %	Approximate Storage Life	Water Content, %	Highest Freez-ing Point, F	Specific Heat Above Freezing Btu/lb/F	Specific Heat Below Freezing Btu/lb/F	Latent Heat {Calcu-lated) Btu/lb
Frozen, whole	0 or below	—	1 year, plus	74.0	—	—	0.42	106
Frozen, yoke	0 or below	—	1 year, plus	55.0	—	—	0.36	79
Frozen, white	0 or below	—	1 year, plus	88.0	—	—	0.46	126
Whole egg solids	35-40	low	6-12 months	2-4	—	0.22	0.21	4
Yolk solids	35-40	low	6-12 months	3-5	—	0.23	0.21	6
Flake albumen solids	Room Temp	low	1 year, plus	12-16	—	0.31	0.24	20
Figs, Dried	32-40	50-60	9-12 months	24.0	—	0.39	0.27	34
Fresh	31-32	85-90	7-10 days	78.0	27.6	0.82	0.43	112
Fish, Fresh	33-35	90-95	5-15 days	62-85	28.0	0.70-0.86	—	89-122
Frozen	-20- 0	90-95	6-12 months	62-85	—	—	0.38-0.45	89-122
Smoked	40-50	50-60	6-8 months	—	—	0.70	0.39	92
Brine salted	40-50	90-95	10-12 months	—	—	0.76	0.41	100
Mild cured	28-35	75-90	4-8 months	—	—	0.76	0.41	100
Shellfish, Fresh	30-33	85-95	3-7 days	80-87	28.0	0.83-0.90	—	113-125
Frozen	-20- 0	90-95	3-8 months	—	—	—	0.44-0.46	113-125
Frozen-pack fruits	-10- 0	—	6-12 months	—	—	—	—	—
Frozen-pack vegetables	-10- 0	—	6-12 months	—	—	—	—	—
Furs and Fabrics	34-40	45-55	several years	—	—	—	—	—
Garlic, dry	32	65-70	6-7 months	61.3	30.5	0.69	0.40	89
Gooseberries	31-32	90-95	2-4 weeks	88.9	30.0	0 90	0.46	126
Grapefruit	50-60	85-90	4-6 weeks	88.8	30.0	0,91	0.46	126
Grapes, American type	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
Greens, leafy	32	95	10-14 days	—	—	—	—	—
Guavas	45-50	90	2-3 weeks	83.0	—	0.86	—	—
Honey	—	—	1 year, plus	18.0	—	0.35	0.26	26
Hops	29-32	50-60	several months	—	—	—	—	—
Horseradish	30-32	95-100	10-12 months	73.4	28.7	0.78	0.42	104
Kale	32	95	3-4 months	86.6	31.1	0.89	0.46	124
Lard (without antioxidant)	45	90-95	4-8 months	0	—	—	—	—
Lard (without antioxidant)	0	90-95	12-14 months	0	—	—	—	—
Lemons	32 or 50-58	85-90	1-6 months	89.3	29.4	0.91	0.46	127
Lettuce, head	32-34	95-100	2-3 weeks	94.8	31.7	0.96	0.48	136
Limes	48-50	85-90	6-8 weeks	86.0	29.1	0.89	0.46	122
Mangoes	55	85-90	2-3 weeks	B1.4	30.3	0.85	0.44	117
Maple syrup	—	—	—	35.5	—	0.48	0.31	51
Meat								
Bacon, frozen	-10- 0	90-95	4-6 months	—	—	—	—	—
cured (Farm style)	60-65	85	4-6 months	13-29		0.30-0.43	0.24-0.29	18-41
cured (Packer style)	34-40	85	2-6 weeks	—	—	—	—	—
Beef, fresh	32-34	88-92	1-6 weeks	62-77	28-29	0.70-0.84	—	89-110
frozen	-10- 0	90-95	9-12 months	—	—	—	0-38-0.43	—
Fat backs	34-36	85-90	0-3 months	6-12	—	0-25-0.30	0.22-0.24	9-17
Hams and shoulders, Fresh	32-34	85-90	7-12 days	47-54	28-29	0.58-0.63	—	67-77
Frozen	-10- 0	90-95	6-8 months	—	—	—	0.34-0.36	—
Cured	60-65	50-60	0-3 years	40-45	—	0,52-0.56	0.32-0.33	57-64
Lamb, Fresh	32-34	85-90	5-12 days	60-70	28-29	0.68-0.76	—	86-100
Frozen	-10- 0	90-95	8-10 months	—	—	—	0.38-0.51	—
Livers, Frozen	-10- 0	90-95	3-4 months	70.0	—	—	0.41	100
Pork, Fresh	32-34	85-90	3-7 days	32-44	28-29	0.46-0.55	—	46-63
Frozen	-10- 0	90-95	4-6 months	—	—	—	0.30-0.33	—
Smoked Sausage	40-45	85-90	6 months	60.0	—	0.68	0.38	86
Sausage Casings	40-45	90-95	—	—	—	—	—	—
Veal, Fresh	32-34	90-95	5-10 days	64-70	28-29	0.71-0.76	—	92-100
Frozen	-10- 0	90-95	8-10 months	—	—	—	0.39-0.41	—
Melons, Cantaloupe	36-40	90-95	5-15 days	92.0	29.9	0.93	0.48	132
Casaba	45-50	85-95	4-6 weeks	92.7	30.1	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
Persian	45-50	90-95	2 weeks	92.7	30.5	0.94	0.48	132
Watermelons	40-50	80-90	2-3 weeks	92.1	31.3	0.97	0.48	132
Mushrooms	32	90	3-4 days	91.1	30.4	0.93	0.47	130
Mushroom, Manure spawn	34	75-80	8 months	—	—	—	—	—
Grain spawn	32-40	75-80	2 weeks	—	—	—	—	—
Nectarines	31-32	90	2-4 weeks	81.8	30.4	—	—	—

General Product Information (cont'd)

Commodity	Storage Temp, F	Relative Humidity, %	Approximate Storage Life	Water Content, %	Highest Freez-ing Point, F	Specific Heat Above Freezing Btu/lb/F	Specific Heat Below Freezing Btu/lb/F	Latent Heat {Calcu-lated) Btu/lb
Nursery stock	32-35	85-90	3-6 months	—	—	—	—	—
Nuts	32-50	65-75	8-12 months	3-6	—	0.22-0.25	0.21-0.22	4-8
Oil (vegetable salad)	70	—	1 year, plus	0	—	—	—	—
Okra	45-50	90-95	7-10 days	89.8	28.7	0.92	0.46	128
Oleomargarine	35	60-70	1 year, plus	15.5	—	0.32	0.25	22
Olives, fresh	45-50	85-90	4-6 weeks	75.2	29.4	0.80	0.42	108
Onions (dry) and onion sets	32	65-70	1-8 months	87.5	30.6	0.90	0.46	124
green	32	95	3-4 weeks	89.4	30.4	0.91	—	—
Oranges	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
Parsley	32	95	1-2 months	85.1	30.0	0.88	0.45	122
Parsnips	32	98-100	4-6 months	78.6	30.4	0.84	0.44	112
Peaches and nectarines	31-32	90	2-4 weeks	89.1	30.3	0.90	0.46	124
Pears	29-31	90-95	2-7 months	82.7	29.2	0.86	0.45	118
Peas, green	32	95	1-3 weeks	74.3	30.9	0.79	0.42	106
Peppers, Sweet	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
Persimmons	30	90	3-4 months	78.2	28.1	0.84	0.43	112
Pineapples, Mature green	50-55	85-90	3-4 weeks	—	30.2	—	—	—
Ripe	45	85-90	2-4 weeks	85.3	30.0	0.88	0.45	122
Plums, including fresh prunes	31-32	90-95	2-4 weeks	82.3	30.5	0.88	0.45	118
Pomegranates	32	90	2-4 weeks	—	26.6	—	—	—
Popcorn, un-popped	32-40	85	4-6 months	13.5	—	0.31	0.24	19
Potatoes, 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
Poultry, Fresh	32	85-90	1 week	74.0	27.0	0.79	—	106
Frozen, eviscerated	0 or below	90-95	8-12 months	—	—	—	0.42	—
Pumpkins	50-55	70-75	2-3 months	90.5	30.5	0.92	0.47	130
Quinces	31-32	90	2-3 months	85.3	28.4	0.88	0.45	122
Radishes—Spring prepackaged	32	95		93 6	30.7	0.95	0.48	134
Winter	32	95-100	2-4 months	93.6	—	0.95	0.48	134
Rabbits, Fresh	32-34	90-95	1-5 days	68.0	—	0.74	0.40	98
Frozen	-10- 0	90-95	0-6 months	—	—	—	—	—
Raspberries, 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	—	—	—	—	—
Rhubarb	32	95	2-4 weeks	94.9	30.3	0.96	0.48	134
Rutabagas	32	98-100	4-6 months	89.1	30.1	0.91	0.47	127
Seed, vegetable	32-50	50-65		7.0-15.0	—	0.29	0.23	16
Spinach	32	95	10-14 days	92.7	31.5	0.94	0.48	132
Squash, Acorn	45-50	70-75	5-8 weeks	—	30.5	—	—	—
Summer	32-50	85-95	5-14 days	94.0	31.1	0.95	—	135
Winter	50-55	70-75	4-6 months	88.6	30.3	0.91	—.	127
Strawberries, Fresh	31-32	90-95	5-7 days	89.9	30.6	0.92	—	129
Frozen	-10- 0	—	1 year	72.0	—	—	0.42	103
Sweet Potatoes	55-60	85-90	4-7 months	68.5	29.7	0.75	0.40	97
Tangerines	32-38	85-90	2-4 weeks	87.3	30.1	0.90	0.46	125
Tobacco, hogsheads	50-65	50-55	1 year	—	—	—	—	—
Bales	35-40	70-85	1-2 years	—	—	—	—	—
Cigarettes	35-46	50-55	6 months	—	—	—	—	—
Cigars	35-50	60-65	2 months	—	—	—	—	—
Tomatoes, Mature green	55-70	85-90	1-3 weeks	93.0	31.0	0.95	0.48	4
Firm ripe	45-50	85-90	4-7 days	94.1	31.1	0.94	0.48	134
Turnips, roots	32	95	4-5 months	91.5	30.1	0.93	0.47	130
Vegetable seed	32-50	50-65	—	7.0-15.0	—	0.29	0.23	16
Yams	60	85-90	3-6 months	73.5	—	0.79	—	105
Yeast, compressed baker's	31-32	—	—	70.9	—	0.77	0.41	102

*Not based on maintaining nutritional value.

Commodity Package Information

Commodity	Type of Package	Outside Dimensions of Package, Inches	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	$19\frac{1}{2}$x11x$12\frac{3}{16}$	50	42	33.1	27.8
	Fiber Tray Carton	$20\frac{1}{2}$x$12\frac{1}{2}$x$13\frac{1}{4}$	$46\frac{3}{4}$	43	23.8	21.9
	Fiber Master Carton	$22\frac{1}{2}$X$12\frac{1}{2}$X13	$44\frac{3}{4}$	41	21.2	19.4
	Fiber Bulk Carton	19x$12\frac{1}{2}$x13	$44\frac{3}{4}$	41	25.0	22.9
	Pallet Box	47x47x30	1030	900	26.9	23.5
Beef						
Boneless	Fiber Carton	28x18x6	146	140	83.4	80.0
Fores	Loose	—	—	—	—	22.2
Hinds	Loose		—	—	—	22.2
Celery	Wire-bound Crates	$20\frac{1}{2}$x16x$9\frac{3}{4}$	60	55	32.8	30.0
	Fiber Carton	16x11x10	36	32	35.4	31.4
Cheese	Hoops	16x16x13	84	78	43.6	50.5
	Wood, Export	17x17x14	87	76	37.1	32.5
Cheese, Swiss	Wheels	$32\frac{1}{2}$x$32\frac{1}{2}$x7	—	171	—	40.0
Chili Peppers	Bags	45x21x26	234	229	16.5	16.1
Citrus Fruits						
Oranges	Box	$12\frac{1}{8}$x$13\frac{1}{4}$X$26\frac{1}{4}$	77	69	31.5	28.3
	Bruce Box	13x11x$26\frac{1}{4}$	88	83	40.5	38.3
	Pallet, 40 Cartons	40x48x$58\frac{1}{2}$	1690	1480	26.0	22.8
California Oranges	Fiber Carton	$16\frac{3}{8}$x$10\frac{1}{16}$X$10\frac{1}{2}$	40	37	38.0	35.2
Florida Oranges	Fiber Carton	$19\frac{1}{4}$X$12\frac{1}{4}$X8	45	37	41.3	33.9
Lemons	Fiber Carton	$16\frac{3}{8}$x$10\frac{1}{16}$X$10\frac{1}{2}$	40	37	40.0	37.0
Grapefruit	Fiber Carton	$19\frac{1}{4}$X$12\frac{1}{4}$X8	40	38	36.7	34.9
Coconut, Shredded	Bags	38x$18\frac{1}{2}$x8	101	100	31.0	30.7
Cranberries	Fiber Carton	$15\frac{3}{4}$x$11\frac{1}{4}$X$10\frac{1}{2}$	26	24	24.1	22.2
Cream	Tins	12x12x14	$52\frac{3}{4}$	50	45.2	42.9
Dried Fruit	Wood Box	$15\frac{1}{2}$X10x$6\frac{1}{2}$	$26\frac{1}{2}$	25	45.4	42.9
Dates	Fiber Carton	14x14x11	32	30	25.7	24.0
Raisins, prunes, figs, peaches	Fiber Carton	15x11x7	32	30	47.9	44.9
Eggs, Shell	Wood Cases	26x12x13	55	45	23.4	19.1
Eggs, Frozen	Cans	10x10x$12\frac{1}{2}$	32	30	44.2	41.5
Frozen Fishery Products						
Blocks	4/13 $\frac{1}{2}$ lb. Carton	$20\frac{3}{4}$x$12\frac{1}{8}$x$6\frac{3}{4}$	56	54	57.0	55.0
	4/16 $\frac{1}{2}$ lb. Carton	$19\frac{3}{4}$X$10\frac{3}{4}$X$11\frac{1}{4}$	68	66	49.2	47.8
Fillets	12/16 oz. Carton	$12\frac{3}{4}$x$8\frac{5}{8}$ x $3\frac{13}{16}$	13.5	12	55.8	49.6
	10/5 lb. Carton	$14\frac{1}{2}$x10x14	52.25	50	44.6	42.7
	5/10 lb. Carton	$14\frac{1}{2}$x10x14	52.2	50	44.5	42.7
Fish Sticks	12/8 oz. Carton	11x$8\frac{3}{8}$x$3\frac{7}{8}$	6.9	6	33.6	29.3
	24/8 oz. Carton	$16\frac{7}{16}$x$8\frac{5}{16}$x$4\frac{5}{8}$	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,	—	—	—	30-35
		Stacked Loose	—	—	—	38.0
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	24/12 oz. Carton	$13\frac{1}{2}$x$11\frac{3}{4}$x$8\frac{1}{4}$	21	18	27.7	23.8
Beans, Green	36/10 oz. Carton	$12\frac{1}{2}$x11x8	$25\frac{3}{4}$	$22\frac{3}{4}$	40.1	35.5
Blueberries	24/12 oz. Carton	12x$11\frac{1}{2}$x8	20	18	31.3	28.2
Broccoli	24/10 oz. Carton	$12\frac{1}{2}$x$11\frac{1}{2}$X$8\frac{1}{2}$	$18\frac{3}{4}$	15	26.2	21.2
Citrus Concentrates	Fiber Carton 48/6 oz.	13x$8\frac{3}{4}$x$7\frac{1}{2}$	27	26	54.7	52.7
Peaches	24/1 lb. Carton	$13\frac{1}{2}$x$11\frac{1}{4}$x$7\frac{1}{2}$	27	24	41.0	36.4
Peas	6/5 lb. Carton	17x11x$9\frac{1}{2}$	32	30	31.1	28.2
	48/12 oz. Carton	$21\frac{1}{2}$X$8\frac{1}{2}$X$12\frac{1}{2}$	38	36	28.7	27.2
Potatoes, French Fries	12/16 oz. Carton	—	—	—	—	28.6
	24/9 oz. Carton	—	—	—	—	24.0
Spinach	24/14 oz. Carton	$12\frac{1}{2}$X11X$8\frac{1}{2}$	24	21	35.5	31.0
Strawberries	30 lb. Can	$12\frac{1}{2}$x10x10	32	30	44.2	41.5
	24/1 lb. Carton	13x11x8	28	24	42.3	36.2
	450 lb. Barrel	35x25x25	—	450	—	35.5

Commodity Package Information (cont'd)

Commodity	Type of Package	Outside Dimensions of Package, Inches	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	6 1/2x15x18	31	28	32.4	29.2
Lamb, Boneless	Fiber Box	20x15x5	57	53	65.7	61.0
Lard (2/28 lb.)	Wood Export Box	18x13 1/4x7 3/4	64	56	59.8	52.5
Lettuce, head	Fiber Carton	20 1/2Xi3 1/2x9 1/2	37 1/2	35	24 **7**	—
	Fiber Carton	21 1/2X14 1/4X10 1/2	45-55	42-52	26.9	25.2
	Pallet, 30 Cartons	42x50x66	1350	1170	16.8	14.6
Milk, Condensed	Barrels	35x25 1/2x25 1/2	670	600	50.9	45.6
Nuts						
Almonds, in Shell	Sacks	24 x15 x 33	91 1/2	90	13.3	13.1
Almonds, Shelled	Cases	6 3/4x 23 1/2X 11	32	28	31.7	27.7
English Walnuts, in Shell	Sacks	25 x 11 x 31	103	100	20.9	20.3
English Walnuts, Shelled	Fiber Carton	14 x 14 x 10	27	25	23.8	22.0
Peanuts, Shelled	Burlap Bag	35 x 10 x 15	127	125	39.2	38.6
Pecans, in Shell	Burlap Bag	35 x 22 x 12	126 1/2	125	23.7	23.4
Pecans, Shelled	Fiber Carton	13 x 13 x11	32	30	29.8	27.9
Peaches	3/4 Bushel Baskets	16 7/8 top dia.	41	38	43.9	40.7
	1/2 Bushel Baskets	14 1/2 top dia.	28	25	45.0	40.2
	Wire bound Crate	19 x 11 3/4 x 11 1/8	42	38	29.2	26.4
	Wood Lug Box	18 1/8 X 11 1/2 X 5 3/4	26	23	38.0	33.1
Pears	Wood Box	8 1/2 X 11 1/2X18	52	48	51.0	47.1
Pears, place pack	Fiber Carton	18 1/2x 12 x 10	52	46	40.5	35.6
Pork						
Bundle Bellies	Bundles	23 1/2x 10 1/2x 7	57	57	57.0	57.0
Loins (Regular)	Wood Box	28 x 0 x10	60	54	37.0	33.3
Loins (Boneless)	Fiber Box	20 x 15 x 5	57	52	65.7	59.9
Potatoes	Sack	33 x 17 1/2 x1 1	101	100	27.5	27.2
Poultry, Fresh (Eviscerated)						
Fryers, Whole, 24-30 to Pkg.	Wire bound Crate	24 x10 x 7	65	60	27.5	25.4
Fryer Parts	Wire bound Crate	17 3/4 x 10 x 12 1/2	54	50	42.1	38.9
Ducks, 6 to Pkg.	Fiber Carton	22 x 16 x 4	32 1/2	31	39.9	38.0
Fowl, 6 to Pkg.	Fiber Carton	20 3/4 x 18 x 5 1/2	33 1/2	31	28.2	26.1
Fryers, cut up, 12 to Pkg.	Fiber Carton	17 1/4X 15 3/4 x 4 1/4	30 1/2	28	45.4	41.7
Roasters, 8 to Pkg.	Fiber Carton	20 3/4x18 x 5 1/2	32 1/2	30	27 **3**	25,2
Turkeys,						
3-6 lb. 6 to Pkg.	Fiber Carton	21 x 17 x 6 1/2	30	27	22.5	20.1
6-10 lb. 6 to Pkg.	Fiber Carton	26 x 21 1/2X 7	52 1/2	48	23.3	21.2
10-13 lb. 4 to Pkg.	Fiber Carton	26 1/2x 16 x 7 1/2	50	46	27.2	25.0
13-16 lb. 4 to Pkg.	Fiber Carton	29 x 18 1/2x 9	67 1/22	62	24.2	22.2
16-20 lb. 2 to Pkg.	Fiber Carton	17 x16 x 9	39	36	27.7	25.4
20-24 lb. 2 to Pkg.	Fiber Carton	19 x16 1/2x 9 1/2	47 1/2	44	27.6	25.5
Tomatoes						
Florida	Fiber Carton	19 x 10 7/8x 10 3/4	43	40	33.3	31.0
	Wire bound Crate	18 3/4X 11 15/16X 11 15/16	64	60	41.3	38.7
California	Wood Lug Box	17 1/2X 14 x 7 3/4	34	30	30.9	27.3
Texas	Wood Lug Box	17 1/2x14 x 6 5/8	34	30	36.2	31.9
Veal (Boneless)	Fiber Carton	20 x 15 x 5	57	53	65.7	61.0

Relative Humidity and Recommended Temperature Difference for Various Foods

Storage requirement	Desirable RH %	Approximate TD
Minimum moisture evaporation during storage	90%	7° to 9°F
General Storage - Packaged foods. Meat, vegetables, fruit and similar items.	80 - 85%	10° to 12°F
Moderate R.H. requirements. Beer, Wine, tough skinned fruits and vegetables such as melons, potatoes and onions.	65 - 80%	12° to 15°F
Prep rooms, beer warehouses, loading docks, film storage, candy storage.	50 - 65%	16° to 25°F

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

Estimating Specific and Latent Heats: Sp. Ht.
Above Freezing = 0.20 + 0.008 x % water. Sp. Ht.
Below Freezing = 0.20 + 0.003 x % water
Latent Heat = 143.4 x % water

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Heat of Respiration

Approximate rates of evolution of heat by certain fresh fruits, vegetables and cut flowers when stored at the temperatures indicated.

COMMODITY	BTU PER TON PER 24 HRS		
	32 F	40 F	60 F
Apples	500 - 900	1,100 - 1,600	3,000 - 6,800
Asparagus	5,900-13,200	11,700 - 23,100	22,000 – 55, 500
Avocados	—	—	13,200 - 30,700
Bananas			4,600 – 5,500
Beans, green or snap	—	9,200 -1 1,400	32,100 - 44,100
Beans, lima	2,300- 3,200	4,300 – 6,100	22,000 - 27,400
Beets, topped	2,700	4,100	7,200
Blueberries	1, 300 – 2,200	2,000 - 2,700	7,500 - 13,000
Broccoli, sprouting	7,500	11, 000 - 1 7,600	33,800 - 50,000
Brussels sprouts	3,300 – 8,300	6,600 -1 1,000	13,200 - 27 500
Cabbage	1, 200	1,700	4,100
Carrots, topped	2,100	3,500	8,100
Cauliflower	3,600 – 4, 200	4,200 – 4,800	9,400-10,800
Celery	1, 600	2,400	8,200
Cherries	1,300 - 1,800	2,800 – 2,900	11,000-13,200
Corn, sweet	7,200 – 11,300	10,600 -13,200	38,400
Cranberries	600 - 700	900 - 1 000	
Cucumbers	–	–	3,300- 7,300
Flowers, cut	480/Sq Ft of Floor Area		
Grapefruit	400 – 1,000	700 - 1,300	2,200 - 4,000
Grapes, American	600	1,200	3,500
Grapes, European	300 - 400	700 – 1,300	2,200 - 2,600
Lemons	500 - 900	600 - 1,900	2,300 – 5,000
Lettuce, head	2,300	2,700	7,900
Lettuce, leaf	4, 500	6.400	14,400
Melons, cantaloupes	1.300	2,000	8,500
Melons, honeydews	–	900 – 1,100	2,400 – 3,300
Mushrooms	6,200 - 9,600	15,600	22,000 (50°F)
Okra	–	12,100	31,600
Onions	700 - 1,100	800	2,400
Onions, green	2,300 - 4,900	3,800-15,000	14,500-21,400
Oranges	400 - 1,000	1,300 - 1,600	3,700 - 5,200
Peaches	900 - 1,400	1,400 - 2,000	7,300 - 9,300
Pears	700 - 900	–	8,800-13,200
Peas, green	8,200 - 8.400	13 200-16,000	39,300-44,500
Peppers, sweet	2.700	4.700	8,500
Plums	400 - 700	900 - 1.500	2,400 - 2,800
Potatoes, immature	–	2,600	2,900 - 6,800
Potatoes, mature	–	1 .300 - 1 800	1,500 - 2.600
Raspberries	3,900 - 5,500	6 800 - 8,500	18,100 - 22,300
Spinach	4,200 - 4,900	7,900 - 11.200	36,900 - 38.000
Strawberries	2,700 - 3.800	3,600 - 6,800	15,600 - 20,300
Sweet Potatoes	–	–	4,300 - 6,300
Tomatoes, mature green	–	1,100	6,200
Tomatoes, ripe	1,000	1,300	5,600
Turnips	1 ,900	2,200	5,300

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Cut Flowers and Nursery Stock

The optimum temperature for storage of many cut flowers is 31°- 33°F. Most nursery stock can be stored satisfactorily at 35°F, 90-95% RH. Following storage, flowers conditioned at about 50°F will regain full turgidity most rapidly. Stem ends should be cut or crushed under water and then be placed in water or a food solution at approximately 80°F for 6 to 8 hours. Temperatures and approximate storage life given above are conservative. However, storage life of all cut flowers and greens can be lengthened dramatically through use of “Ethylene Scrubbers” positioned in the refrigerated area, thusly keeping any ethylene gas concentrations to a minimum.

Cut Flowers and Nursery Stock (cont'd)

Commodity	Storage Temperature °F	Relative Humidity, %	Approximate Storage Life	Method of Holding	Highest Freezing Point, °F
Cut Flowers:					
Calla lily	40	90 to 95	1 week	Dry pack	
Camellia	45	90 to 95	3 to 6 days	Dry pack	30.6
Carnation	31-32	90 to 95	2 to 4 weeks	Dry pack	30.8
Chrysanthemum	31-32	90 to 95	2 to 4 weeks	Dry pack	30.5
Daffodil (Narcissus)	32-33	90 to 95	1 to 3 weeks	Dry pack	31.8
Dahlia	40	90 to 95	3 to 5 days	Dry pack	
Gardenia	32-33	90 to 95	2 weeks	Dry pack	31.0
Gladiolus	40-42	90 to 95	1 week	Dry pack	31.4
Iris, tight buds	31-32	90 to 95	2 weeks	Dry pack	30.6
Lily, Easter	32-35	90 to 95	2 to 3 weeks	Dry pack	31.1
Lily-of-the-Valley	31-32	90 to 95	2 to 3 weeks	Dry pack	—
Orchid	55	90 to 95	1 to 2 weeks	Water	31.4
Peony, tight buds	32-35	90 to 95	4 to 6 weeks	Dry pack	30.1
Rose, tight buds	32	90 to 95	1 to 2 weeks	Dry pack	31.2
Snapdragon	40-42	90 to 95	1 to 2 weeks	Dry pack	30.4
Sweet peas	31-32	90 to 95	2 weeks	Dry pack	30.4
Tulips	31-32	90 to 95	4 to 8 weeks	Dry pack	
Greens:					
Asparagus (plumosus)	32-40	90 to 95	4 to 5 months	Poly lined cases	26.0
Fern, dagger and wood	30-32	90 to 95	2 to 3 months	Dry pack	28.9
Holly	32	90 to 95	4 to 5 weeks	Dry pack	27.0
Huckleberry	32	90 to 95	1 to 4 weeks	Dry pack	26.7
Laurel	32	90 to 95	1 to 4 weeks	Dry pack	27.6
Magnolia	35-40	90 to 95	1 to 4 weeks	Dry pack	27.0
Rhododendron	32	90 to 95	1 to 4 weeks	Dry pack	27.6
Salal	32	90 to 95	1 to 4 weeks	Dry pack	26.8
Bulbs:					
Amaryllis	38-45	70 to 75	5 months	Dry	30.8
Caladium	70	70 to 75	2 to 4 months	—	29.7
Crocus	48-63		2 to 3 months	—	
Dahlia	40-45	70 to 75	5 months	Dry	28.7
Gladiolus	38-50	70 to 75	8 months	Dry	28.2
Hyacinth	55-70		2 to 5 months	—	29.3
Iris, Dutch, Spanish	80-85	70 to 75	4 months	Dry	—
Gloriosa	63	70 to 75	3 to 4 months	Poly liner	—
Candidum	31-33	70 to 75	1 to 6 months	Poly liner & peat	—
Croft	31-33	70 to 75	1 to 6 months	Poly liner & peat	
Longiflorum	31-33	70 to 75	1 to 10 months	Poly liner & peat	28.9
Speciosum	31-33	70 to 75	1 to 6 months	Poly liner & peat	—
Peony	33-35	70 to 75	5 months	Dry	—
Tuberose	40-45	70 to 75	4 months	Dry	—
Tulip	31-32	70 to 75	5 to 6 months	Dry	27.6
Nursery Stock:					
Trees and Shrubs	32-36	80 to 85	4 to 5 months	[b]	
Rose Bushes	32	85 to 95	4 to 5 months	Bare rooted with poly liner	—
Strawberry Plants	30-32	80 to 85	8 to 10 months	Bare rooted with poly liner	29.9
Rooted Cuttings	33-40	85 to 95	—	Polywrap	
Herbaceous Perennials	27-28 or 33-35*	80 to 85		[b]	—
Christmas trees	22-32	80 to 85	6 to 7 weeks	—	—

(a) Data from USDA Handbook No. 66 and bulletin by Post and Fischer.
(b) For details for various trees, shrubs, and perennials, see bulletin by Mahlstede and Fletcher.

Refrigerant Line Sizes

1. Suction Line Sizes are based on 100 ft. run with average number of fittings
2. Liquid lines based on 4 psi. maximum drop per 100 ft. equivalent length.
3. Drop one size and trap the line to insure oil return on risers.

Refrigerant 404A – Capacity MBH

Suction Lines (Δt = 2°F)					
	Saturated Suction Temperature °F				
Line Size	-40	-20	0	20	40
Type L Copper	Corresponding Δp, psi/100 ft.				
Tubing	0.97	1.41	1.96	2.62	3.44
OD	Capacity - MBH				
1/2"	1.1	1.8	2.9	4.4	6.4
5/8"	2.0	3.4	5.3	8.2	12.0
3/4"	3.4	5.7	9.2	13.8	20.4
7/8"	5.2	8.8	14.1	21.4	31.6
1 1/8"	10.6	17.9	28.5	43.4	63.8
1 3/8"	18.5	31.1	49.6	75.4	110.8
1 5/8"	29.3	49.2	78.4	119.1	169.8
2-1/8"	60.9	102.3	162.4	246.4	360.8

Refrigerant 22 – Capacity MBH

Suction Lines (Dt = 2°F)					
	Saturated Suction Temperature °F				
Line Size	-40	-20	0	20	40
Type L Copper	Corresponding Dp, psi/100 ft.				
Tubing	0.79	1.15	1.6	2.22	2.91
OD	Capacity - MBH				
1/2"	—	—	—	4.8	7.2
5/8"	—	3.9	6.2	9.2	13.2
7/8"	6.3	10.4	15.6	24.0	34.8
1 1/8"	13.2	20.4	32.4	48.0	69.6
1 3/8"	22.8	37.2	56.4	84.0	121.2
1 5/8"	36.0	57.6	90.0	133.2	192.0
2 1/8"	74.4	120.0	187.2	277.2	397.2

Refrigerant 407C - Capacity MBH

Suction Lines (Dt = 2°F)					
	Saturated Suction Temperature °F				
Line Size	-40	-20	0	20	40
Type L Copper	Corresponding Dp, psi/100 ft.				
Tubing	0.79	1.15	1.6	2.22	2.91
OD	Capacity - MBH				
1/2"	1.0	1.7	2.8	4.4	6.5
5/8"	1.8	3.2	5.2	8.2	12.3
3/4"	3.2	5.4	8.9	14.0	20.9
7/8"	4.8	8.4	13.8	21.5	32.2
1 1/8"	9.9	17.1	28.0	43.6	65.1
1 3/8"	17.2	29.8	48.9	76.0	113.4
1 5/8"	27.3	47.2	77.3	120.0	179.2
2 1/8"	56.9	98.2	160.5	248.7	370.8

Discharge Lines

Discharge Line Sizing									
Line Size (O.D.) Type L Tubing	R22			R404A R507			R407C		
	Saturated Suction Temperature °F								
	-40	0	40	-40	0	40	-40	0	40
1/2”	9	10	10	7	8	9	9	10	11
5/8”	17	18	19	14	16	18	17	18	20
7/8”	44	47	50	36	41	47	44	49	53
1 1/8”	90	96	102	72	84	94	89	98	106
1 3/8”	157	168	178	126	145	164	155	171	185
1 5/8”	248	265	281	198	229	258	245	270	292
2 1/8”	514	548	582	408	473	532	506	557	603

Discharge Lines

Condensing Temp (°F)	Discharge Line Sizing Correction Factors			
	R22	R404A	R407C	R507
80	0.790	0.870	0.787	0.873
90	0.880	0.922	0.782	0.924
100	0.950	0.974	0.957	0.975
110	1.040	1.009	1.036	1.005
120	1.100	1.026	1.109	1.014
130	1.180	1.043	1.182	1.024

Liquid Line

Net Refrigerating Effect (MBH)						
Line Size (O.D.) Type L Tubing	Condenser to Receiver Piping*			Receiver to TXV Piping†		
	R22	R404A R507	R407A R407C	R22	R404A R507	R407C
1/2”	28	16	25	43	31	55
5/8”	44	25	41	80	58	103
7/8”	94	52	83	218	152	271
1 1/8”	158	88	142	444	307	550
1 3/8”	242	135	216	776	535	956
1 5/8”	342	190	306	1230	846	1511
2 1/8”	595	331	533	2556	1752	3128

Weight of Refrigerant in Copper Lines

Pounds per 100 feet of Type L Tubing

Line Size (O.D.) Type L Tubing	I.D. Line Size	Weight of Refrigerant, Pounds											
		Liquid Line				Suction Line				Discharge Line			
		110°F				40°F				115°F			
		R22	R404A	R407A R407C	R507	R22	R404A	R407A R407C	R507	R22	R404A	R407A R407C	R507
5/8	.545	11.3	9.7	10.6	9.6	0.2	0.3	0.2	0.4	0.8	1.2	0.9	1.3
7/8	.785	23.4	20.1	22.0	19.8	0.5	0.6	0.4	0.8	1.6	2.4	2.0	2.7
1 1/8	1.025	39.8	34.3	37.6	33.8	0.9	1.1	0.7	1.3	2.8	4.1	3.3	4.6
1 3/8	1.265	60.7	52.3	57.2	51.5	1.3	1.6	1.1	2.0	4.2	6.2	5.1	7.0
1 5/8	1.505	85.9	74.0	81.0	72.9	1.9	2.3	1.6	2.9	6.0	8.8	7.2	10.0
2 1/8	1.985	149.4	128.7	140.9	126.8	3.3	4.0	2.8	5.0	10.4	15.4	12.5	17.4
2 5/8	2.465	230.4	194.8	217.3	195.5	5.0	6.2	4.3	7.7	16.1	23.7	19.3	26.8
3 1/8	2.945	328.9	283.3	310.2	279.0	7.2	8.8	6.1	11.0	22.9	33.8	27.5	38.2
3 5/8	3.425	444.8	383.3	419.6	377.4	9.7	11.9	8.2	14.8	31.0	45.8	37.2	51.7

To obtain 100° weights at other than 100 ft.; Lineal Ft ÷ 100 X weight under proper heading.

Example: 60′, $\frac{5}{8}$″ O.D. Liquid Line, 100° R-22

$\frac{60}{100}$ X 11.3 = 6.78 Lbs.

Equivalent Feet of Pipe Caused By Friction

Type L Copper Tube, O.D.	1/2"	5/8"	7/8"	1 1/8"	1 5/8"	2 1/8	2 5/8
90° turn through Tee	3	4	5	6	8	9	12
Long radius 90° elbow	1	1.3	1.6	2.0	2.6	3.4	4.2
Short radius 90° elbow	1.2	1.5	1.8	2.4	3.8	5.2	6.5
90° Angle valve (open)	7.0	9.1	12.2	15.5	21.4	28.3	28.0
Ball Valve (open)							

Selected Winter Dry Bulb and Summer Dry Bulb and Wet Bulb Design Temperature

STATE	CITY	Winter Design °F	Summer	Design °F
		Dry Bulb	Dry Bulb	Wet Bulb
Alabama	Birmingham	19	97	79
	Mobile	28	95	80
Alaska	Fairbanks	-53	82	64
Arizona	Phoenix	31	108	77
	Tucson	29	105	74
	Yuma	37	111	79
Arkansas	Little Rock	19	99	80
California	Bakersfield	31	103	72
	Fresno	28	101	73
	Los Angeles	42	94	72
	San Francisco	35	83	65
Colorado	Denver	-2	92	65
Connecticut	Hartford	15	90	77
	New Haven		88	77
Delaware	Wilmington	12	93	79
Dist. of Columbia	Washington	16	94	79
Florida	Jacksonville	29	96	80
	Miami	44	92	80
	Tampa	36	92	81
Georgia	Atlanta	18	95	78
	Augusta	20	98	80
	Savannah	24	96	81
Hawaii	Honolulu	60	87	75
Idaho	Boise	4	96	68
Illinois	Chicago	- 4	92	78
	Peoria	- 2	94	78
Indiana	Fort Wayne	0	93	77
	Indianapolis	0	93	78
Iowa	Des Moines	- 7	95	79
	Sioux City	- 1 0	96	79
Kansas	Topeka	35	99	79
	Wichita		102	77
Kentucky	Louisville	8	96	79
Louisiana	New Orleans	32	93	81
	Shreveport	22	99	81
Maine	Portland	-5	88	75
Maryland	Baltimore	12	94	79
	Cumberland	5	94	76
Massachusetts	Boston	6	91	76
	Springfield	- 3	91	76
Michigan	Detroit	4	92	76
	Grand Rapids	2	91	76
	Saginaw	-1	88	76
Minnesota	Duluth	- 1 9	85	73
	Minneapolis	- 1 4	92	77
Mississippi	Vicksburg	23	97	80
Missouri	Kansas City	4	100	79
	St. Louis	4	98	79
Montana	Helena	-17	90	65
Nebraska	Omaha	-5	97	79

STATE	CITY	Winter Design °F	Summer	Design °F
		Dry Bulb	Dry Bulb	Wet Bulb
Nevada	Reno	2	95	64
New .Hampshire	Concord	-11	91	75
New Jersey	Atlantic City	14	91	78
	Newark	11	94	77
	Trenton	12	92	78
New Mexico	Santa Fe	7	90	65
New York	Albany	- 5	91	76
	Buffalo New	3	88	75
	York	11	94	77
North Carolina	Asheville	13	91	75
	Charlotte	18	96	78
	Raleigh	16	95	79
North Dakota	Bismarck	-24	95	74
Ohio	Cincinnati	8	94	78
	Cleveland	2	91	76
	Columbus	2	92	77
	Toledo	1	92	77
Oklahoma	Oklahoma City	11	100	78
	Tulsa	12	102	79
Oregon	Portland	21	91	69
Pennsylvania	Erie	7	88	76
	Philadelphia	11	93	78
	Pittsburgh	5	90	75
	Scranton	2	89	75
Rhode Island	Providence	6	89	76
South Carolina	Charleston	23	95	81
	Greenville	19	95	77
South Dakota	Sioux Falls	-14	95	77
Tennessee	Chattanooga	15	97	78
	Knoxville	13	95	77
	Memphis	7	98	80
	Nashville	12	97	79
Texas	Amarillo	8	98	72
	Dallas	19	101	79
	El Paso	21	100	70
	Galveston	32	91	82
	Houston	28	96	80
	San Antonio	25	99	77
Utah	Salt Lake City	5	97	67
Vermont	Burlington	-12	88	74
Virginia	Norfolk	20	94	79
	Richmond	14	96	79
	Roanoke	15	94	76
Washington	Seattle	28	81	67
	Spokane	- 2	93	66
West Virginia	Charleston	9	92	76
	Wheeling	5	91	76
Wisconsin	Green Bay	- 1 2	88	75
	Milwaukee	- 6	90	77
Wyoming	Cheyenne	-6	89	63

Conversion Factors

Length
1 cm = 0.39379 in.
1 m = 3.2808 ft.
1mm = 1000 microns
1 in. = 25.4 mm

Area
1 sq cm = .155 sq. in.
1 sq m = 10.76 sq.ft.
1 sq ft = 144 sq. in.

Volume
1 cu cm = 0.06 cu. in.
1 cu m = 35.3 cu. ft.
1 cu ft = 1728 cu. in.

Capacity
1 liter = 61.0250 cu. in.
1 liter = 0.03532 cu. ft.
1 liter = 1000 cc
1 liter = 1.057 qts.
1 liter = 0.2642 gal.
1 gal (U.S.) = 231 cu. in.

Weight
1 lb = 7,000 grains
1 kg = 2.2046 lbs.
1 lb = 453.6 grams
1 oz = 28.35 grams

Pressure
1 kg/sq cm = 14.223 lbs/sq. in.
1 kg/sq m = 0.2048 lbs/sq. in.
1 atm = 14.696 lbs/sq. in.
1 atm = 1.0332 kgs/sq. cm.
1 lb/sq in. = 2.3125 ft. water at 70°F
1 in. water at 70°F = 5.20 lbs/sq. ft.

Force
1 dyne X10° = 1.020 kqs.
1 kg = 2.205 lbs.

Mass
1 slug = 32.17 lbs.
1 kg = 0.0685 lbs.

Gravity
1 ft/sec = 12.96 X 10 ft/hr
32.17 ft/sec = 4.17 X 10 ft/hr
1 ft/sec = 30.48 cm/sec
32.17 ft/sec = 980.7 cm/sec

Work, Energy, Heat
1 erg or dyne-cm = 10 watt-sec
1 joule = 1 watt-sec
1 g cal = 4.186 watt-sec
1 ft-lb = 1.356 watt-sec
1 Btu = 778.3 ft-lb.
1 Btu = 1054.8 watt-sec.
1 watt = 3.413 Btu/hr
1 kcal = 3.968 Btu

Heat Capacity
1 joule/(g)(°C) = 0.23895 Btu/(lb)(°F)
1 g cal/(g)(°C) = 1 Btu/(lb)(°F)
1 Btu/(lb)(°F) = 1,900 watt-sec
1 cal/gr. = 1.8 Btu/lb.
1 kg/metric ton = 3.6 Btu/ton/24 hrs.

Thermal Conductivity
1 cal/(sec)(cm)(°C) = 241.9 Btu/(hr)(sq ft)
1 kcal/(hr)(m)(°C) = 0.672 Btu/(hr)(sq ft)
1 watt/(cm)(°C) = 57.79 Btu/ hr)(sq ft)

Surface Conductance, Over-all Coefficient
1 cal/(sec)(sq cm)(°C) = 7373 Btu/(hr)(sq ft)
1 kcal/(hr)(sq m)(°C) = 0.2048 Btu/(hr)(sq ft)

Viscosity
1 lb-hr/sq ft = 12.96 X 10 slug/(ft)(hr)
1 slug/(ft)(hr) = 32.17 lb/(ft)(hr)
1 centipoise = 0.41 lb/(ft)(hr)

Air Pressure—Density Relationship Above Sea-Level

FEET ABOVE SEA LEVEL	LBS/SQ. IN. (ABSOLUTE)	INCHES OF MERCURY (HG)	DENSITY RATIO	CU.FT. EQUAL TO 1 LB. AT SEA LEVEL	ALTITUDE FACTOR
0	(1) 14.696	(2) 29.92	1.0000	13.071	1.000
1000	14.176	28.86	.9711	13.460	1.030
2000	13.665	27.82	.9428	13.864	1.061
3000	13.174	26.82	.9151	14.284	1.093
4000	12.693	25.84	.8888	14.718	1.126
5000	12.231	24.90	.8617	15.164	1.160
6000	11.779	23.98	.8359	15.637	1.196
7000	11.342	23.09	.8106	16.125	1.234
8000	10.914	22.22	.7860	16.630	1.272
9000	10.507	21.39	.7620	17.153	1.312
10000	10.109	20.58	.7385	17.699	1.354
20000	6.754	13.75	.5328	24.533	1.877

(1) Commonly used as 14.7
(2) Commonly used as 30.0

Useful Formula

Air

(1) $\frac{\text{60 Min./Hr.}}{\text{Cu.Ft./Lb.@ °F}}$ = Factor [Relates CFM to Lbs./Hr.]

Example: $\frac{\text{1 CFM x 60 Min./Hr.}}{\text{13.32 Cu.Ft./Lb.(69°)}}$ = 4.5 $\frac{\text{1 CFM x 60 Min./Hr.}}{\text{12.46 Cu.Ft./Lb.(35°)}}$ = 4.82

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(2) $\frac{\text{60 Min./Hr.x24 [Air Spec.Ht.}}{\text{Cu.Ft./Lb. DryAir @ °F}}$ = Factor [Relates CFM to Btuh Sens.Ht.]

Example: $\frac{\text{60 Min./Hr.x0.24}}{\text{13.32 Cu.Ft./Lb.(69°)}}$ = 1.08 $\frac{\text{60 Min./Hr.x0.24}}{\text{12.46 Cu.Ft./Lb.(35°)}}$ = 1.15

---

(3) $\frac{\text{Lbs./Hr.x Ht.Vaporization H2O @°F}}{\text{7000 Grains/Lb.H2O}}$ = Factor [Relates CFM to Btuh Latent (Grains/lb.)]

Example - Determine latent ht. in reducing 80° DB, 67° WB to 60° DB, 57° WB.
80° DB, 67° WB Air =0.0112 Lbs. Moisture/Lb. Dry Air, x 7000 Gr./Lb. H2O = 78.4
Grains 60° DB, 57° WB Air =0.0092 Lbs. Moisture/Lb. Dry Air, x 7000 Gr./Lb.H2O = 64.4 Grains
Grains/Lbs. Difference = 14.0

Heat of evaporization H20 @ 67° WB = 1055.4 Btu/Lb. [Consult a H20 Psych. Table]
Heat of evaporization H20 @ 57° WB = 1061.04 Btu/Lb.
2116.44 x .5 = Average Heat Vapor = 1058.22 Btu/Lb.

4.5 Lbs./Hr. x 1058.22 = 068 Factor
7000 Gr./Lb.

1 CFM x 0.68 x 14 Gr./Lb. Dif. =9.52 Btuh Latent/CFM

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(4) $\frac{\text{Btuh Sens.Heat}}{\text{Btuh Total Heat}}$ = Sensible Heat Ratio

---

Water

1 Gal. = 8.33 Lbs. [62.3 Lbs./Cu. Ft.]
8 33 Lbs/Min [1 GPM] x 60 min. = 500 Lbs./Hr./Gal.

Electrical - (Resistance Loads)

SINGLE PHASE LOADS
OHM'S LAW FOR DIRECT CURRENT

W = WATTS
I = CURRENT (Amperes)
E = ELECTROMOTIVE FORCE (Volts)
R = RESISTANCE (Ohms)
To obtain any value in the center circle, for Direct or Alternating Current, perform the operation indicated in one segment of the adjacent outer circle.

3 PHASE DELTA LOADS

3 phase Balanced Loads = P1 + P2 + P3
Total Line Current = Total Power (Balanced Load)

If the phases are unbalanced, each of the phases will differ from the others:

FORMULAE:

$$IL1 = \sqrt{I\frac{2}{2} + I\frac{2}{1}\ (I1 \times I2)}$$

$$IL2 = \sqrt{I\frac{2}{2} + I\frac{2}{3}\ (I2 \times I3)}$$

$$IL3 = \sqrt{I\frac{2}{3} + I\frac{2}{1}\ (I1 \times I3)}$$

Condensing Unit

To Find Condensing Unit Horsepower

Net Refrigeration Requirement		Air Cooled					Water Cooled Suction Temperature				
Tons	BTU/Hr	+ 30°	+ 20°	-10°	-20°	-30°	+ 35°	+ 20°	-10°	-20°	-30°
1/2	6000	1/2 hp	3/4 hp	1 1/2	1 1/2 hp	2 hp	1/2 hp	3/4 hp	1 hp	1 1/2 hp	3 hp
3/4	9000	3/4	1 1/4	1 1/2	2	3	3/4	1	1 1/2	2	3
1	12000	1	1 1/2	2	3	5	1	1 1/2	2	3	5
1 1/4	15000	1 1/2	2	3	3	5	1 1/2	1 1/2	2	3	5
1 1/2	18000	1 1/2	3	3	3	7 1/2	1 1/2	2	3	5	7 1/2
1 3/4	21000	2 1/2	3	3	4	7 1/2	2	2	5	5	7 1/2
2	24000	3	3	4	5	7 1/2	2	2	5	5	10
2 1/4	27000	3	4	4	7 1/2	10	2	3	5	7 1/2	10
2 1/2	30000	3	4	5	7 1/2	10	3	3	5	7 1/2	10
2 3/4	33000	3	4	5	10	10	3	3	7 1/2	7 1/2	10
3	36000	3	5	7 1/2	10	15	3	3	7 1/2	10	15
3 1/4	39000	4	5	7 1/2	10	15	5	5	7 1/2	10	15
3 1/2	42000	4	5	10	10	15	5	5	7 1/2	10	15
3 2/4	45000	4	7 1/2	10	10	15	5	5	10	10	15
4	48000	5	7 1/2	10	10	15	5	5	10	15	20
4 1/2	54000	5	7 1/2	10	15	15	5	5	10	15	20
5	60000	7 1/2	7 1/2	10	15	20	5	7 1/2	10	15	20
5 1/2	66000	7 1/2	7 1/2	10	15	20	7 1/2	7 1/2	10	20	20
6	72000	7 1/2	10	15	20	20	7 1/2	7 1/2	15	20	20
6 1/2	78000	7 1/2	10	15	20	30	7 1/2	10	15	20	20
7	84000	7 1/2	10	20	20	30	7 1/2	10	20	20	30
7 1/2	90000	10	15	20	20	30	10	10	20	20	30
8	96000	10	15	20	20	30	10	15	20	20	30
8 1/2	102000	10	15	25	30	40	10	15	20	30	40
9	108000	10	15	25	30	40	10	15	25	30	40
9 1/2	114000	15	15	25	30	50	10	15	25	30	40
10	120000	15	15	25	40	60	10	15	25	30	50

Pressure-Temperature Chart

	PSIG			
DEG F.	R404A	R22	R407C Vapor	R407C Liquid
-50	0.1	6.2*	11.0*	2.7*
-45	2.0	2.8*	9.2*	0.6
-40	4.3	0.5	4.6*	2.7
-35	9.5	2.6	0.9*	5.1
-30	9.8	4.9	1.6	7.7
-25	12.7	7.4	3.9	10.6
-20	16.0	10.2	6.5	13.7
-15	19.7	13.2	9.3	17.2
-10	23.6	16.5	12.3	20.9
-5	27.9	20.1	15.7	25.1
0	32.6	24.0	19.4	29.5
+5	37.2	28.2	23.5	34.3
10	43.1	32.8	27.9	39.5
15	49.0	37.7	32.7	45.2
20	55.3	43.0	40.1	51.2
25	64.9	48.8	43.5	57.8
30	69.3	54.9	49.6	64.7
35	77.1	61.5	56.2	72.3
40	85.4	68.5	63.2	80.2
45	94.2	76.0	70.8	88.8
50	103.6	84.0	78.8	97.9

*Inches of HG = Vacuum

	PSIG			
DEG F.	R404A	R22	R407C Vapor	R407C Liquid
55	113.7	92.6	92.6	107.6
60	124.2	101.6	96.8	117.9
65	135.5	111.3	106.4	128.9
70	147.4	121.4	117.3	140.5
75	160.1	133.2	118.7	125 8
80	173.4	143.6	140.5	152.9
85	187.5	155.7	153.3	179.6
90	202.4	168.4	166.7	194.1
95	218.1	181.8	181.1	209.4
100	234.6	195.9	196.1	225.5
105	252.1	210.8	212.4	242.5
110	270.4	226.4	229.0	260.3
115	289.7	242.8	247.0	278.9
120	309.9	259.9	265.8	298.6
125	331.2	277.9	285.7	319.2
130	353.5	296.0	306.6	340.7
135	377.1	316.6	328.8	363.5
140	401.7	337.3	352.1	387.0
145	438.5	356.9	376.7	411.5
150	455.1	381.5	402.5	437.5

Cooler / Freezer Air Change Guidelines

Recommended Air Change Rate per hour	Minimum	Maximum
Vegetable and Fruit Storage	30	60
Meat storage	30	50
Meat Chill Room	75	125
Holding Cooler	40	80
Holding Freezer	40	80
Prep / Cutting room	25	30
Blast Freezer	150	250
Banana Ripening	150	200

Fahrenheit-Celsius Temperature Conversion Chart

The numbers in bold-face 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	+ 62.9	**+ 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**	+ 228.8	+ 74.4	**+ 166**	+ 330.8
-25.0	**-13**	+ 8.6	+ 8.3	**+ 47**	+ 116.6	+ 41.7	**+107**	+ 224.6	+ 75.0	**+ 167**	+ 332.6
-24.4	**-12**	+10.4	+ 8.9	**+ 48**	+ 118.4	+ 42.2	**+108**	+ 226.4	+ 75.6	**+ 168**	+ 334.4
-23.9	**-11**	+12.2	+ 9.4	**+ 49**	+ 120.2	+ 42.8	**+109**	+ 228.2	+ 76.1	**+ 169**	+ 336.2
-23.3	**-10**	+14.0	+ 10.0	**+ 50**	+ 122.0	+ 43.3	**+110**	+ 230.0	+ 76.7	**+ 170**	+ 338.0
-22.8	**-9**	+15.8	+ 10.6	**+ 51**	+ 123.8	+ 43.9	**+111**	+ 231.8	+ 77.2	**+ 171**	+ 339.8
-22.2	**-8**	+17.6	+ 11.1	**+ 52**	+ 125.6	+ 44.4	**+112**	+ 233.6	+ 77.8	**+ 172**	+ 341.6
-21.7	**-7**	+19.4	+ 11.7	**+ 53**	+ 127.4	+ 45.0	**+113**	+ 235.4	+ 78.3	**+ 173**	+ 343.4
-21.1	**-6**	+21.2	+ 12.2	**+ 54**	+ 129.2	+ 45.6	**+114**	+ 237.2	+ 78.9	**+ 174**	+ 345.2
-20.6	**-5**	+23.0	+ 12.8	**+ 55**	+ 131.0	+ 46.1	**+115**	+ 239.0	+ 79.4	**+ 175**	+ 347.0
-20.0	**-4**	+24.8	+ 13.3	**+ 56**	+ 132.8	+ 46.7	**+116**	+ 240.8	+ 80.0	**+ 176**	+ 348.8
-19.4	**-3**	+26.6	+ 13.9	**+ 57**	+ 134.6	+ 47.2	**+117**	+ 242.6	+ 80.6	**+ 177**	+ 350.6
-18.9	**-2**	+ 28.4	+ 14.4	**+ 58**	+ 136.4	+ 47.8	**+118**	+ 244.4	+ 81.1	**+ 178**	+ 352.4
-18.3	**-1**	+30.2	+ 15.0	**+ 59**	+ 138.2	+ 48.3	**+119**	+ 246.2	+ 81.7	**+ 179**	+ 354.2
-17.8	**0**	+32.0	+ 15.6	**+ 60**	+ 140.0	+ 48.9	**+120**	+ 248.0	+ 82.2	**+ 180**	+ 356.0
-17.2	**+1**	+33.8	+ 16.1	**+ 61**	+ 141.8	+ 49.4	**+121**	+ 249.8	+ 82.8	**+ 181**	+ 357.8
-16.7	**+ 2**	+35.6	+ 16.7	**+ 62**	+ 143.6	+ 50.0	**+122**	+ 251.6	+ 83.3	**+ 182**	+ 359.6
-16.1	**+ 3**	+37.4	+ 17.2	**+ 63**	+ 145.4	+ 50.6	**+123**	+ 253.4	+ 83.9	**+ 183**	+ 361.4
-15.6	**+ 4**	+39.2	+ 17.8	**+ 64**	+ 147.2	+ 51.1	**+124**	+ 255.2	+ 84.4	**+ 184**	+ 363.2
-15.0	**+ 5**	+41.0	+ 18.3	**+ 65**	+ 149.0	+ 51.7	**+125**	+ 257.0	+ 85.0	**+ 185**	+ 365.0
-14.4	**+ 6**	+42.8	+ 18.9	**+ 66**	+ 150.8	+ 52.2	**+126**	+ 258.8	+ 85.6	**+ 186**	+ 366.8
-13.9	**+ 7**	+44.6	+ 19.4	**+ 67**	+ 152.6	+ 52.8	**+127**	+ 260.6	+ 86.1	**+ 187**	+ 368.6
-13.3	**+ 8**	+46.4	+ 20.0	**+ 68**	+ 154.4	+ 53.3	**+128**	+ 262.4	+ 86.7	**+ 188**	+ 370.4
-12.8	**+ 9**	+48.2	+ 20.6	**+ 69**	+ 156.2	+ 53.9	**+129**	+ 264.2	+ 87.2	**+ 189**	+ 372.2
-12.2	**+ 10**	+50.0	+21.1	**+ 70**	+ 158.0	+ 54.4	**+130**	+ 266.0	+ 87.8	**+ 190**	+ 374.0
-11.7	**+ 11**	+51.8	+ 21.7	**+ 71**	+ 159.8	+ 55.0	**+131**	+ 267.8	+ 88.3	**+ 191**	+ 375.8
-11.1	**+ 12**	+53.6	+ 22.2	**+ 72**	+ 161.6	+ 55.6	**+132**	+ 269.6	+ 88.9	**+ 192**	+ 377.6
-10.6	**+ 13**	+55.4	+ 22.8	**+ 73**	+ 163.4	+ 56.1	**+133**	+ 271.4	+ 89.4	**+ 193**	+ 379.4
-10.0	**+ 14**	+57.2	+ 23.3	**+ 74**	+ 165.2	+ 56.7	**+134**	+ 273.2	+ 90.0	**+ 194**	+ 381.2
-9.4	**+ 15**	+59.0	+ 23.9	**+ 75**	+ 167.0	+ 57.2	**+135**	+ 275.0	+ 90.6	**+ 195**	+ 383.0
-8.9	**+ 16**	+60.8	+ 24.4	**+ 76**	+ 168.8	+ 57.8	**+136**	+ 276.8	+ 91.1	**+ 196**	+ 384.8
-8.3	**+ 17**	+ 62.6	+ 25.0	**+ 77**	+ 170.6	+ 58.3	**+137**	+ 278.6	+ 91.7	**+ 197**	+ 386.6
-7.8	**+ 18**	+ 64.4	+ 25.6	**+ 78**	+ 172.4	+ 58.9	**+138**	+ 280.4	+ 92.2	**+ 198**	+ 388.4
-7.2	**+ 19**	+ 66.2	+ 26.1	**+ 79**	+ 174.2	+ 59.4	**+139**	+ 282.2	+ 92.8	**+ 199**	+ 390.2

*Inches of HG = Vacuum

Refrigeration Box Load Calculation Form

Customer _____ By _____ Date _____

GIVEN DATA:

BOX DIMENSIONS: Length _____ ft. Depth _____ ft. Height _____ ft.

WALLS: Insulation Type _____ Insulation Thickness _____ Studs? _____

CEILING: Insulation Type _____ Insulation Thickness _____ Studs? _____

FLOOR: Insulation Type _____ Insulation Thickness _____ Studs? _____

Box Temperature _____°F Ambient Temp, (corrected for sun effect) _____°F

Product: _____ lbs/day of. _____ (must be adjusted to 24 hour per day load)

Entering Temp. _____°F Final Temp _____ °F Pull down time _____ hrs

Additional Loads:

Motors _____ HP Lights (or assume 2 Watts/sq. ft. of floor space). _____ Watts

No. of people _____ No. of lift trucks _____

LOAD CALCULATION

1. Walls: 2 X (L+D) x H = _____ sq. ft. X factor (p. 10) _____ Btu/hr-sq.ft. = _____
2. Ceiling: LxD = _____ sq. ft. X factor (p. 10) _____ Btu/hr-sq.ft. = _____
3. Floor: LxD = _____ sq. ft. X factor (p. 10) _____ Btu/hr-sq.ft. = _____
4. Infiltration:

   Box volume = L x D x H = _____ cu. ft. Load (p. 11) = _____

5a. Product Pulldown (See pages 14 thru 25 for specific heats, etc)

Cooler

_____ lbs/day x 1/24 x _____ spec. heat above freezing x _____ °F temp drop = _____

Freezer - Product Freezing temp °F.

_____ lbs/day x 1/24 x _____ spec. heat above freezing x _____ °F temp drop = _____

_____ lbs/day x 1/24 x _____latent heat

_____ lbs/day x 1/24 x _____ spec. heat above freezing x _____ °F temp drop = _____

TOTAL FREEZER PRODUCT LOAD = _____

5b. Product Respiration:

_____ lbs. stored x _____ Btu/ton-24 hrs. (p.24) x 1 /48000 = _____

6. Additional Loads:

   Motors - _____ HP x 3500 = _____

   Lights: _____ Watts x 3.416 or _____ sq.ft. x 2 Watts/sq.ft. x 3.416 = _____

   No. of people _____ x 900 = _____

7. Lift Trucks: No. trucks x 5000 Btu/hr = _____

Subtotal Refrigeration Load (1+2+3+4+5+6+7) Btu/hr. = _____ A

10% Safety Factor (of above Subtotal A) = _____ B

Subtotal (A+B) = _____ C

Correct for compressor run time:

0.50 x Subtotal C (16 Hrs / day-Cooler) = _____ D

or 0.33 x Subtotal C (18 Hrs / day-Freezer) = _____ E

(Note: some special applications may require different run times - such as 20 hrs/day.)

Total with safety factor and run time correction C +(D or E) = _____

Equipment Selection

Condensing Unit(s): Qty _____ Model_____

Capacity @ _____ °F suct. temp, and_____°F ambient temp. = _____ Btu/hr

Unit Cooler(s): Qty _____ Model_____

Capacity @ _____ °F suct. temp, and_____°F ambient temp. = _____ Btu/hr

Fractions, Decimals and Metric Equivalents

Fractions	Decimal In.	Metric MM.
1/64	.015625	.39688
1/32	.03125	.79375
3/64	.046875	1.19062
1/16	.0625	1.58750
5/64	.078125	1.98437
3/32	.09375	2.38125
7/64	.109375	2.77812
1/8	.125	3.1750
9/64	.140625	3.57187
5/32	.15625	3.96875
11/64	.171875	4.36562
3/16	1875	4.76250
13/64	.203125	5.15937
7/32	.21875	5.55625
15/64	.234375	5.95312
1/4	.250	6.35000
17/64	.265625	6.74687
9/32	.28125	7.14375
19/64	.296875	7.54062
5/16	.3125	7.93750
21/64	.328125	8.33437
11/32	.34375	8.73125
23/64	.359375	9.12812
3/8	.375	9.52500
25/64	.390625	9.92187
13/32	.40625	10.31875
27/64	.421875	10.71562
7/16	.4375	11.11250
29/64	.453125	11.50937
15/32	.46875	11.90625
31/64	.484375	12 30312
1/2	.500	12.70000

Fractions	Decimal In.	Metric MM.
33/64	.515625	13.09687
17/32	.53125	13.49375
35/64	.546875	13.89062
9/16	.5625	14.28750
37/64	.578125	14.68437
19/32	.59375	15.08125
39/64	.609375	15.47812
5/8	.625	15.87500
41/64	.640625	16.27187
21/32	.65625	16.66875
43/64	.671875	17,06562
11/16	.6875	17.46250
45/64	.703125	17.85937
23/32	.71875	18.25625
47/64	.734375	18.65312
3/4	.750	19.05000
49/64	.765625	19.44687
25/32	.78125	19.84375
51/64	.796875	20.24062
13/16	.8125	20.63750
53/64	.828125	21.03437
27/32	.84375	21.43125
55/64	.859375	21.82812
7/8	.875	22.22500
57/64	.890625	22.62187
29/32	.90625	23.01875
59/64	.921875	23.41562
15/16	.9375	23.81250
61/64	.953125	24.20937
31/32	.96875	24,60625
63/64	.984375	25.00312
1	1.00	25.40000

Terminology

absolute zero: the zero point on the absolute temperature scale, 459.69 degrees below the zero of the Fahrenheit scale, 273.16 degrees below the zero, on the Celsius scale.

air, dry: air without contained water vapor; air only.

air, standard: dry air at a pressure of 760 mm (29.92 in.) Hg at 21 C (69.8 F) temperature and with a specific volume of 0.833 m3/kg (13.33 ft3/lb.).

brine: any liquid cooled by the refrigerant and used for the transmission of heat without a change in its state, having no flash point or a flash point above 150 F as determined by American Society for Testing and Materials Method D93.

British thermal unit (Btu): the Btu is defined as 778.177 foot-pounds if it is related to the IT calorie in such a way that 1 IT calorie per (kg) (C deg) =1 Btu per (lb) (F deg), with 1 lb =453.5924 g. Approximately, it is the heat required to raise the temperature of a pound of water from 59 F to 60 F.

calorie: heat required to raise the temperature of 1 gram of water 1 C, actually from 4C to 5 C. Mean calorie = 1/100 part of the heat required to raise 1 gram of water from 0 to 100 C.

capillary tube: in refrigeration practice a tube of small internal diameter used as a liquid refrigerant flow control or expansion device between high and low sides; also used to transmit pressure from the sensitive bulb of some temperature controls to the operating element.

Celsius: a thermometric scale in which the freezing point of water is called 0 deg and its boiling point 100 deg at normal atmospheric pressure (14.696 psi).

change of air: introduction of new, cleansed or recirculated air to conditioned space, measured by the number of complete changes per unit time.

change of state: change from one phase, such as solid, liquid, or gas, to another.

coefficient of performance, compressor, heat pump: the ratio of the compressor heating effect (heat pump) to the rate of energy input to the shaft of the compressor, in consistent units, in 3 complete heat pump, under designated operating conditions.

compression ratio of: ratio of absolute pressures after and before compression.

Counter flow: in heat exchange between two fluids, opposite direction of flow, coldest portion of one meeting coldest portion of the other,

cutting room: cold room in which animal carcasses are cut up into commercial sizes such as rib roast, legs, etc.

cycle, defrosting: the portion of a refrigeration operation which permits the cooling unit to defrost.

cycle, refrigerating: a sequence of thermodynamic processes through which a refrigerant passes, in a closed or open system, to absorb heat at a relatively low temperature level and reject heat at a higher temperature level.

drier: a manufactured device containing a desiccant (water absorbing material) placed in the refrigerant circuit, its primary purpose being to collect and hold within the desiccant all water in the system in excess of the amount which can be tolerated in the circulating refrigerant.

enthalpy: the sum of the internal energy of a body and the product of it's volume multiplied by the pressure. Occasionally called heat content.

equalizer, external: in a thermostatic expansion value, a tube connection from a selected control point in the low-side circuit to the pressure sensing side of the control element such that the control-point pressure is transmitted to the actuating element (diaphragm or bellows). This connection provides a means for compensating for the pressure drop through accessories and the evaporator.

equalizer, internal: in a thermostatic expansion valve, an integral internal part of passage which provides exposure of the actuating element (diaphragm or bellows) to pressure leaving the valve.

flash gas: the gas resulting from the instantaneous evaporation of refrigerant in a pressure-reducing device to cool the refrigerant to the evaporation temperature obtained at the reduced pressure.

foaming: the formation of a foam or froth of an oil-refrigerant mixture due to rapid boiling out of the refrigerant dissolved in the oil when the pressure is suddenly reduced. This occurs when the compressor starts operating and, if large quantities of refrigerant were dissolved, large quantities of oil may boil out and be carried through the refrigerant lines.

freeze-up: failure of a refrigerating unit to operate normally due to formation of ice at the expansion device. A valve may freeze shut or open, causing improper refrigeration in either case. On a coil, frost formation to the extent that air flow stops or is severly restricted.

freezing point: temperature at which a given liquid substance will solidify or freeze upon removal of heat. Freezing point for water is 32 F.

gas, foul (noncondensable gas): gas in a refrigerating system which does not condense at the temperature and partial pressure at which it exists in the condenser and therefore imposes a higher head pressure on the system.

heat, latent: change of enthalpy during a change of state. With pure substances, latent heat is absorbed or rejected at constant pressure.

heat, sensible: heat which is associated with a change in temperature; specific heat exchange of temperature; in contrast to a heat interchange in which a change of state (latent heat) occurs.

heat, specific: the ratio of the quantity of heat required to raise the temperature of a given mass of any substance one deg to the quantity required to raise the temperature of an equal mass of a standard substance (usually water at 59 F) one deg.

motor, capacitor: a single-phase induction motor with a main winding arranged for direct connection to a source of power and an auxiliary winding connected in series with a capacitor.

pressure drop: static pressure loss in fluid pressure, as from one end of pipe to the other, due to friction, etc.

pressure regulator, evaporator (back-pressure valve): an auto¬matic valve located between the evaporator outlet and compressor inlet that is responsive to its own inlet pressure or to the evaporator or refrigerator temperature and functions to throttle the vapor flow when necessary to prevent the evaporator pressure from falling below a selected value.

pump down (refrigeration system): the operation by which the refrigerant in a charged system is pumped into the liquid receiver.

refrigerating effect, total: the product of the weight rate o1 refrigerant flow and the difference in enthalpy of the entering and leaving refrigerant fluid, expressed in heat units per unit of time.

sub cooling: process of cooling refrigerant below condensing temperature, for a given pressure. Also cooling a liquid below its freezing point

temperature, dewpoint: the temperature at which the condensation of water vapor in a space begins for a given state of humidity and pressure as the temperature of the vapor is reduced. The temperature corresponding to saturation (100 percent relative humidity) for a given absolute humidity at constant pressure.

temperature, dry-bulb: the temperature of a gas or mixture of gases indicated by an accurate thermometer after correction for radiation.

temperature, wet-bulb: thermodynamic wet-bulb temperature is the temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature (without qualification) is the temperature indicated by a wet-bulb psychrometer constructed and used according to specifications.

throw: the horizontal or vertical axial distance an air stream travels after leaving an air outlet before the maximum stream velocity is reduced to a specified terminal level, e.g., 200, 150, 100, or 50 fpm. (usually 50 fpm)

ton of refrigeration: a useful description of refrigerating effect equal to 12,000 Btu per hr; 200 Btu per min.

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