Case – 13 Food Storage & Processing Center

Case Background:

The refrigeration system is for a food processing and storage facility. The general specifications and requirements are outlined as the following:

1.0 A central engine room is used. The refrigeration system is to be with a remote mounted evaporative condenser. The outside air design temperatures are 92°FDB and 81°FWB in the summer; the minimum temperature is 45°F in the wintertime.

2.0 Refrigerant shall be Ammonia (R-717). The system shall be designed for multiple evaporative temperature levels. Liquid recirculation is to be used for all the users and the evaporators. One liquid recirculation receiver package shall be arranged independently for each evaporative temperature level.

3.0 Screw compressor shall be used. One compressor shall be allocated for each suction temperature level. The overall compression ratio of each compressor shall not be over 7.5; the system shall be compound system, compressors are without economizing. Flash type vertical Intermediate intercooler, shall be used. Oil coolers shall be water cooled, but the water shall be closed circuit and cooled by evaporative fluid cooler. The nameplate HP for the driving motor for each compressor shall be no more than 550 HP to reduce the inrush current during start-up of the compressor. The condensing temperature of the system shall be allowed to decrease when outdoor ambient temperature decreases for the benefit of operating cost reduction.

4.0 One stand-by compressor unit is to be used and connected in such way to provide service in case of any one of the compressors of the system is in service repair.

5.0 The refrigeration loads and the minimum air coolers to be used for the user as the following:

Blast Freezing Room. The room temperature is -40°F. Total Refrigeration load is 87 TR. Minimum 6 product coolers shall be used.

Cold Storage Room. Room design temperature -3°F. Total refrigeration load is 65 TR, minimum 4 coolers shall be used.

Chilled Room. Room temperature 28°F. Total refrigeration load is 28 TR. Minimum 4 coolers shall be used.

Loading Room. Room temperature 32°F. Total refrigeration load is 54 TR. Minimum 4 coolers shall be used.

Ante Room. Room temperature 35°F. Total refrigeration load is 9.2 TR. Minimum 2 coolers shall be used.

Boxing Room. Room temperature 46°F. Total refrigeration load is 15 TR. Minimum 2 coolers shall be used.

Deboning Room. Room temperature 43°F. Total refrigeration load is 17.9 TR. Minimum 4 units shall be used.

A brine chiller is to cool 464 GPM 45% by weight of Propylene Glycol brine from 49°F to 38°F leaving.

Flake Ice Making. The ice maker is provided by the customer, but, the central refrigeration system is to provide the Ammonia liquid for the refrigeration. The design refrigeration capacity for the ice making is 61 tons of refrigeration. The owner would like to be advised as what ET is to be used for the ice maker.

6.0	The power supply:	Main motors	4160-3-60
		Small motors	460-3-60
		Control & heater	120-1-60

7.0 All the high side equipment and the liquid recirculation packages are located in the engine room, except the evaporative condensers and the fluid coolers. The engine room size is 80' x 40' x 20'H. The farthest cold room from the engine room is the blast freezing room, the distance between the Blast Freezing Room to the engine room is about 200 feet. Minimum of 5 elbows for each suction piping run should be allowed.

Related Technical Data and Information for the Case:

Figure 13-1 Specific Gravity – Propylene Glycol
Figure 13-2 Specific Heat – Propylen Glycol
Figure 13-3 Typical Ammonia Product Cooler
Figure 13-4 Typical Product Coolers Data from Maker 3/4”OD Steel Coils
Figure 13-5 Typical Unit Coolers Data from Maker
Figure 13-6 Typical Induced Draft Evaporative Condenser from a Maker
Figure 13-7 Typical Performance Data for Evaporative Condenser for R-717
Figure 13-8 Typical Performance Curves for Evaporative Fluid Cooler
Figure 13-9 Typical Capacities of Evaporative Fluid Cooler from a Maker
Figure 13-10 Maximum Gas/Liquid Gravity Separation Velocity

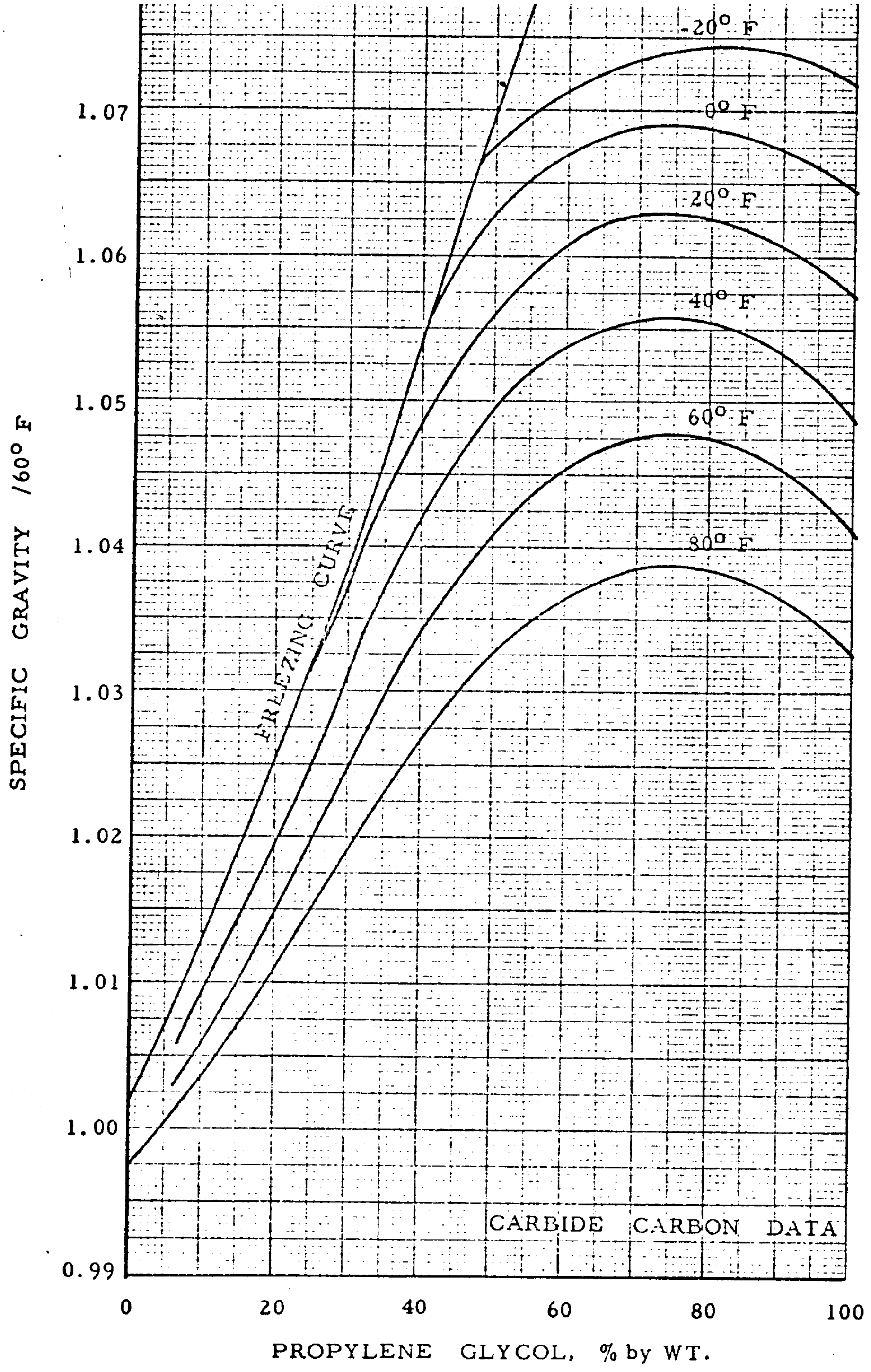


Figure 13-1 Specific Gravity – Propylene Glycol

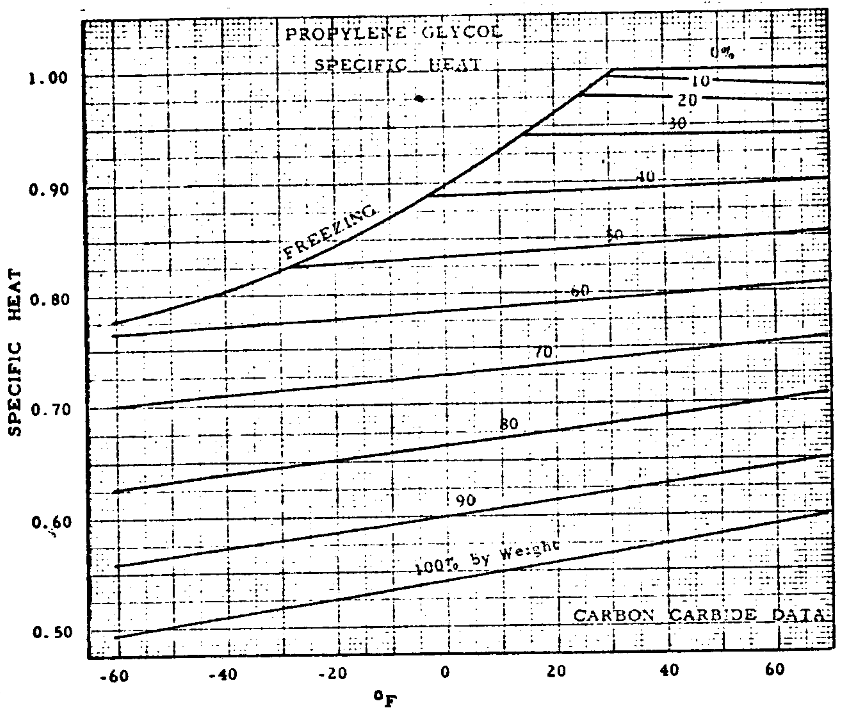


Figure 13-2 Specific Heat – Propylen Glycol

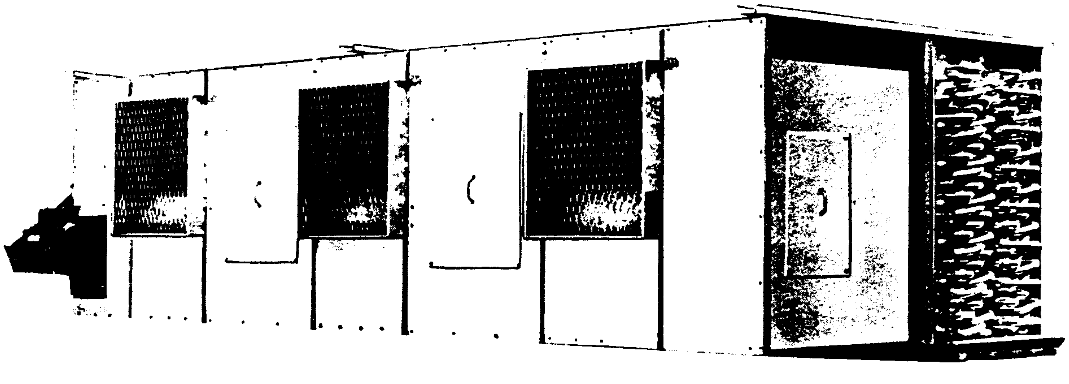


Figure 13-3 Typical Ammonia Product Cooler

MODEL NUMBER	ROW COIL	CFM @ 600 FPM (1)	NO. OF FANS	FAN SIZE INCHES	FAN MOTOR HP (2)	CAPACITIES BTU/HR – °F TD				TOTAL COIL SURFACE (SQ FT)		COIL VOL. (CU FT)	SHIPPING WEIGHT	
						3 FINS/INCH		4 FINS/INCH						
						DX	FLOODED RECIR.	DX	FLOODED RECIR.	3 FPI	4 FPI		UNIT 4 FPI	ADD for LEG MOUNT
CFA-134	4	7,500	2	12	2	2,473	2,875	2,742	3,188	467	603	0.7	1,191	75
CFA-136	6	7,500	2	12	2	3,419	3,975	3,655	4,250	724	935	1.1	1,523	75
CFA-138	8	7,500	2	12	3	4,128	4,800	4,515	5,250	958	1236	1.4	1,757	75
CFA-194	4	11,250	2	17	2	3,711	4,315	4,112	4,781	701	904	1.1	1,710	75
CFA-196	6	11,250	2	17	3	5,128	5,963	5,483	6,375	1086	1398	1.6	2,034	75
CFA-198	8	11,250	2	17	3	6,192	7,200	6,773	7,875	1436	1850	2.1	2,382	75
CFA-234	4	13,500	2	18	3	4,451	5,175	4,935	5,738	841	1085	1.3	1,976	75
CFA-236	6	13,500	2	18	3	6,153	7,155	6,579	7,650	1303	1678	1.9	2,360	75
CFA-238	8	13,500	2	18	5	7,430	8,640	8,127	9,450	1724	2220	2.5	2,762	75
CFA-306	6	18,000	2	21	5	8,204	9,540	8,772	10,200	1737	2243	2.5	2,924	75
CFA-308	8	18,000	2	21	5	9,907	11,520	10,836	12,600	2298	2966	3.4	3,448	75
CFA-3010	10	18,000	2	19	7-1/2	11,739	13,650	12,642	14,700	2859	3689	4.2	3,975	75
CFA-386	6	22,500	3	18	5	10,256	11,925	10,965	12,750	2171	2804	3.2	3,676	100
CFA-388	8	22,500	3	18	7-1/2	12,384	14,400	13,545	15,750	2872	3708	4.2	4,321	100
CFA-3810	10	22,500	3	18	7-1/2	14,674	17,063	15,800	18,375	3573	4612	5.2	4,947	100
CFA-446	6	26,250	3	21	5	11,965	13,913	12,795	14,875	2533	3271	3.7	4,258	100
CFA-448	8	26,250	3	21	7-1/2	14,448	16,800	15,800	18,375	3351	4326	4.9	5,026	100
CFA-4410	10	26,250	3	19	10	17,120	19,906	18,437	21,438	4169	5381	6.1	5,778	100
CFA-536	6	31,500	3	21	7-1/2	14,358	16,695	14,358	17,850	3040	3925	4.4	4,969	100
CFA-538	8	31,500	3	21	7-1/2	17,338	20,160	18,963	22,050	4021	5191	5.9	5,863	100
CFA-5310	10	31,500	3	21	10	20,544	23,888	22,123	25,725	5002	6457	7.3	6,744	100

1. CFM based on 4 FPI
2. Fan motor HP based on +20°F air temperature

COIL DATA

1. Capacity is based on sensible heat removal, medium frosted coil condition and 0" External Static Pressure. Temperature difference is the temperature of the air entering the coil and the coil evaporating temperature.

2. NOTE: DO NOT USE DIRECT EXPANSION FEED BELOW 0°F EVAPORATOR TEMPERATURES WITHOUT PROPER COMPRESSOR SYSTEM PROTECTION.

3. For brine systems capacity ratings, consult factory. Give capacity required, type of brine, room temperature, brine temperature available and brine GPM available. DO NOT USE FLOODED RATINGS FOR BRINES.

4. To rerate unit capacities for vari-fin application, refer to Finned Coil Capacity Correction Factors.

TABLE 1 — FINNED COIL CAPACITY CORRECTION FACTORS

FIN SPACING COIL CONDITION & TYPE	FACTOR			MULTIPLY FACTORS BY:
	ROWS DEEP 6	8	10	
2/3 FPI (1)	.88	.90	.92	3 FPI Rating
2/4 FPI (1)	.85	.89	.91	4 FPI Rating

1. Not available on 4 row coils or CFA units.

EXAMPLE

Determine capacity of CFA-308-4VF with 2 FPI on air entering two rows and remaining 6 rows 4 FPI.

1. From table above CFA-308-4 capacity = 12,600 BTU/HR °F TD.
2. From table 1 coil capacity correction factor for 2/4 FPI on 8 row coil = .89.
3. For corrected capacity multiply step 1 by step 2 12,600 BTU /HR °F TD x .89 = 11,214 BTU/HR °F TD.

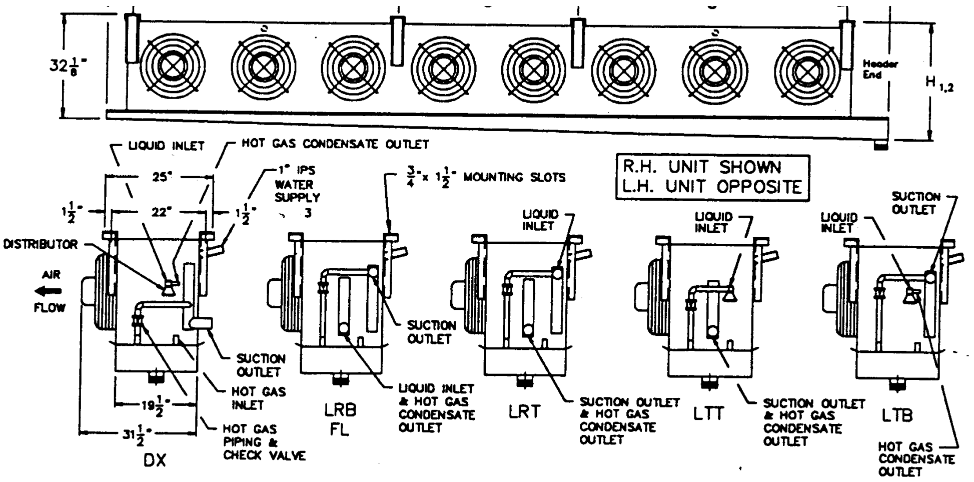
TABLE 2 — LOW SUCTION TEMPERATURE CAPACITY CORRECTION FACTORS

T.D.	SUCTION TEMPERATURE °F				
	-10	-20	-30	-40	-50
10	1.00	1.00	0.95	0.90	0.80
15	1.00	1.00	0.93	0.90	0.80
20	0.95	0.95	0.90	0.85	0.75

MOTOR HORSEPOWER HEAT LOAD

Motor horsepower BTU's have not been applied to the basic rating. Either include these BTU's in the room load or deduct them from unit cooler's sensible heat capacity.

Figure 13-4 Typical Product Coolers Data from Maker
3/4"OD Steel Coils



MODEL NO.	CAPACITY BTUH /°T.D.				FAN & MOTOR DATA			COIL DATA			SHIPPING WEIGHT LBS.
	WET COIL		FROSTED COIL								
	DX	REC./FL.	DX	REC./FL.	QTY./HP	CFM	FPM	FPI	SUR-FACE FT.^{2}	INT. VOL. FT.^{3}	
HTA 254	3523	4098	3171	3688	2-1/3	7140	643	4	681	.77	510
HTA 264	3962	4607	3566	4146	2-1/3	6920	623	4	828	.93	560
HTA 354	5425	6309	4883	5678	3-1/3	10710	612	4	1076	1.22	750
HTA 364	6102	7095	5492	6386	3-1/3	10380	594	4	1308	1.46	860
HTA 454	7095	8250	6386	7425	4-1/3	14280	635	4	1381	1.56	960
HTA 464	7961	9257	7165	8331	4-1/3	13840	615	4	1679	1.88	1100
HTA 554	8993	10456	8093	9410	5-1/3	17850	618	4	1776	2.01	1220
HTA 564	10134	11784	9121	10606	5-1/3	17300	599	4	2159	2.41	1390
HTA 654	10726	12472	9654	11225	6-1/3	21420	607	4	2170	2.46	1440
HTA 664	12194	14179	10974	12761	6-1/3	20760	588	4	2638	2.95	1650
HTA 754	12773	14853	11612	13503	7-1/3	24990	621	4	2475	2.80	1640
HTA 764	14239	16558	12945	15053	7-1/3	24220	602	4	3009	3.36	1880
HTA 854	14419	16768	13109	15244	8-1/3	28560	613	4	2865	3.25	1900
HTA 864	16266	18915	14788	17196	8-1/3	27680	594	4	3484	3.90	2180
LTA 264	–	–	3696	4298	2-1/3	7300	676	4	828	.93	620
LTA 263	–	–	3931	4572	2-1/2	9400	848	3	641		570
LTA 264	–	–	4192	4876	2-1/2	9200	830	4	828		620
LTA 364	–	–	5679	6603	3-1/3	10950	626	4	1308	1.46	925
LTA 363	–	–	5993	6969	3-1/2	14100	806	3	1013		835
LTA 364	–	–	6457	7508	3-1/2	13800	789	4	1308		925
LTA 464	–	–	7450	8663	4-1/3	14600	649	4	1679	1.88	1180
LTA 463	–	–	7861	9140	4-1/2	18800	837	3	1300		1075
LTA 464	–	–	8456	9833	4-1/2	18400	819	4	1679		1180
LTA 564	–	–	9431	10967	5-1/3	18250	631	4	2159	2.41	1485
LTA 563	–	–	10052	11689	5-1/2	23500	814	3	1672		1345
LTA 564	–	–	10707	12451	5-1/2	23000	796	4	2159		1485
LTA 664	–	–	11421	13280	6-1/3	21900	620	4	2638	2.95	1760
LTA 663	–	–	12052	14013	6-1/2	28200	799	3	2043		1585
LTA 664	–	–	12953	15061	6-1/2	27600	782	4	2638		1760
LTA 764	–	–	13135	15274	7-1/3	25550	635	4	3009	3.36	2010
LTA 763	–	–	14011	16293	7-1/2	32900	817	3	2330		1810
LTA 764	–	–	15039	17487	7-1/2	32200	800	4	3009		2010
LTA 864	–	–	15096	17554	8-1/3	29200	627	4	3484	3.90	2330
LTA 863	–	–	16112	18736	8-1/2	37600	807	3	2698		2100
LTA 864	–	–	17216	20018	8-1/2	36800	790	4	3484		2330

FILE NAME: HTA02

For Air Deforst, Water Defrost, Hot Gas Defrost

Figure 13-5 Typical Unit Coolers Data from Maker

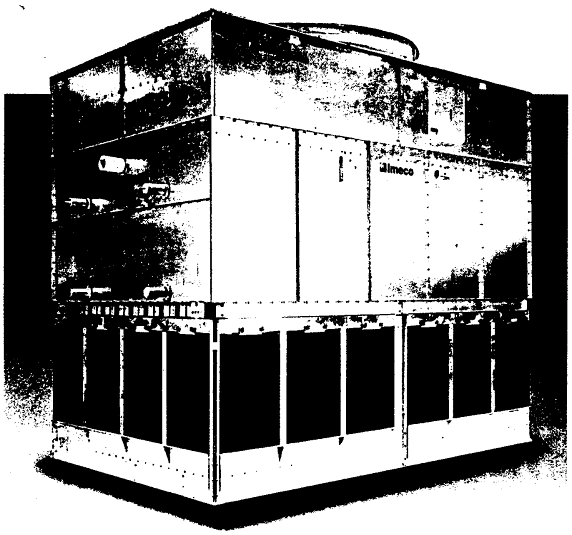


Figure 13-6 Typical Induced Draft Evaporative Condenser from a Maker

— HEAT OF REJECTION CAPACITY FACTORS — AMMONIA

Cond. Temp.	Condensing Pressure (psig)	Entering Air Wet Bulb Temperature (°F)																	
(°F)	R-717	50°	55°	60°	62°	64°	66°	68°	70°	72°	74°	75°	76°	77°	78°	79°	80°	82°	84°
60	92.9	3.78	7.56	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
65	103.1	2.47	3.49	6.48	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
70	114.1	1.86	2.34	3.24	4.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–
75	125.8	1.46	1.72	2.19	2.47	2.89	3.49	4.39	6.18	–	–	–	–	–	–	–	–	–	–
80	138.3	1.17	1.33	1.60	1.77	1.94	2.19	2.52	2.96	3.68	4.86	5.91	–	–	–	–	–	–	–
85	151.7	1.01	1.11	1.26	1.37	1.46	1.60	1.74	1.94	2.19	2.52	2.72	3.02	–	–	–	–	–	–
90	165.9	0.86	0.91	1.03	1.10	1.16	1.25	1.33	1.45	1.58	1.74	1.84	1.94	2.06	2.19	2.34	2.52	2.89	–
95	181.1	0.73	0.78	0.88	0.92	0.96	1.01	1.05	1.11	1.17	1.25	1.30	1.35	1.40	1.48	1.56	1.64	1.86	2.16
96.3	185.1	0.71	0.75	0.83	0.87	0.90	0.94	0.99	1.04	1.09	1.16	1.20	1.26	1.31	1.36	1.43	1.51	1.72	1.97
100	197.2	0.64	0.69	0.75	0.77	0.80	0.82	0.86	0.89	0.93	0.98	1.01	1.04	1.08	1.11	1.16	1.21	1.33	1.48
105	214.2	0.57	0.60	0.64	0.66	0.68	0.70	0.73	0.76	0.79	0.82	0.84	0.87	0.88	0.91	0.94	0.96	1.03	1.11
110	232.3	0.51	0.53	0.56	0.58	0.59	0.61	0.63	0.65	0.67	0.70	0.71	0.73	0.75	0.76	0.78	0.80	0.84	0.89
115	251.5	–	0.47	0.50	0.51	0.52	0.53	0.55	0.56	0.58	0.60	0.61	0.62	0.63	0.64	0.65	0.67	0.70	0.73
120	271.7	–	–	–	–	–	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.53	0.54	0.55	0.56	0.58	0.60

IDC PERFORMANCE TABLES

IDC Model	Heat Rejection MBH
420	6,174.0
435	6,394.5
450	6,615.0
490	7,203.0
505	7,423.5
520	7,644.0
540	7,938.0

IDC Model	Heat Rejection MBH
575	8,452.5
615	9,040.5
645	9,481.5
670	9,849.0
700	10,290.0
735	10,804.5
765	11,245.5
800	11,760.0
835	12,274.5

IDC Model	Heat Rejection MBH
840-2	12,348.0
870-2	12,789.0
900-2	13,230.0
980-2	14,406.0
1010-2	14,847.0
1040-2	15,288.0
1080-2	15,876.0

IDC Model	Heat Rejection MBH
1150-2	16,905.0
1230-2	18,081.0
1290-2	18,963.0
1340-2	19,698.0
1400-2	20,580.0
1470-2	21,609.0
1530-2	22,491.0
1600-2	23,520.0
1670-2	24,549.0

Figure 13-7 Typical Performance Data for Evaporative Condenser for R-717

RANGE (°F)–water inlet temperature minus water outlet temperature.

APPROACH (°F)–water outlet temperature minus the wet bulb temperature.

To locate the performance number, enter the performance number curve at the appropriate wet bulb temperature, read down to the approach line, move horizontally right to the range line, at this point read the performance number to the nearest tenth.

FIGURE 1

FIGURE 1

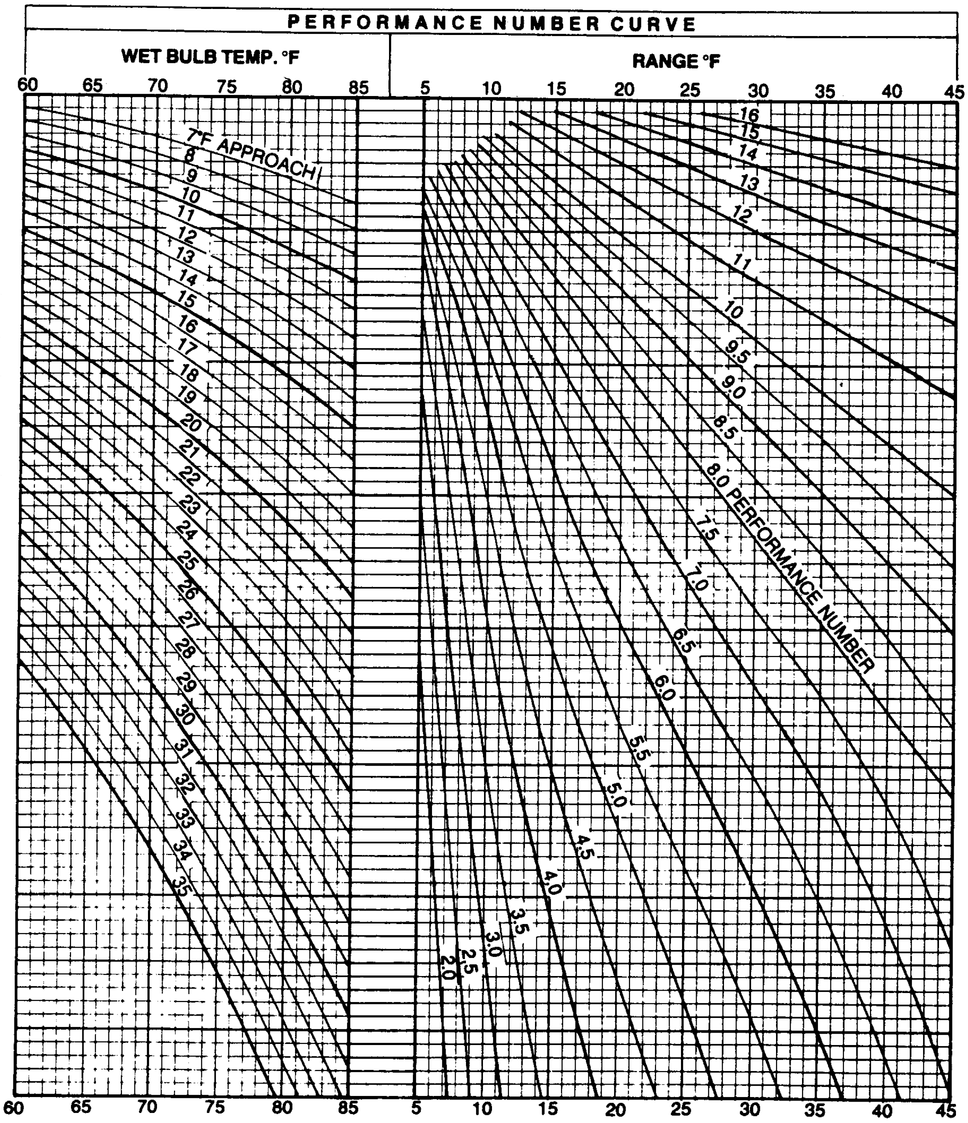


Figure 13-8 Typical Performance Curves for Evaporative Fluid Cooler

IMPORTANT

1. Unit selections made in the unshaded areas are most economical. Shaded areas should be considered when required to meet physical and/or operating limitations, such as horsepower or pressure drop limits.
2. Selections with flow rates larger than cataloged can be handled by multiple units, i.e. three units at one third the total flow each or two units at one half the total flow each.
3. It may be practical to consider alternate coil circuiting if the initial unit selection has a coil pressure drop of approximately 3.2 PSI or less. This may improve the performance enough to result in a more economical selection. Consult factory for assistance.

–EFC-C CAPACITIES

Unit Size	Performance Numbers/GPM Capacities														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
112-0	171	111	75	52	36	25	18	13	10	8	6	6	5	5	5
112-1	197	132	92	66	[illegible]	36	27	21	17	14	12	11	10	9	[illegible]
112-2	220	151	108	79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19	16	14	[illegible]	12	[illegible]
112-3	242	167	121	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22	18	16	14	13	12
112-4	261	182	133	99	75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19	16	[illegible]	12	[illegible]
113-1	277	186	130	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20	17	15	14	13	13
113-2	312	213	152	112	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
113-3	342	237	172	127	96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25	23	20	18	17
113-4	371	259	189	141	107	82	64	50	40	[illegible]	27	23	20	18	16
122-1	446	304	217	159	119	91	70	55	44	36	29	24	20	16	12
122-2		347	252	188	143	111	87	70	57*	47	39	[illegible]	[illegible]	[illegible]	18
122-3		387	284	215	165	129	103	83	67	56*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
122-4			313	238	185	145	116	93	76	63	52*	44*	[illegible]	[illegible]	[illegible]
123-1	620	422	301	221	165	126	98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
123-2		483	351	262	199	155	122	97	79*	[illegible]	[illegible]	[illegible]	[illegible]	31	[illegible]
123-3		541	398	300	231	181	144	116	94	78*	[illegible]	[illegible]	[illegible]	38	31
123-4			442	336	261	205	163	132	107	88	73*	61*	52	43	36
222-1	892	607	433	318	238	181	140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40	31	23
222-2		694	504	376	287	222	175	140	113*	[illegible]	[illegible]	[illegible]	64	45	36
222-3		778	571	431	332	260	206	166	135	112*	93	78	66	55	45
222-4			636	484	375	295	235	189	154	127	105*	88*	74	62	51
223-1	1237	842	601	441	330	251	194	155	122	99	[illegible]	[illegible]	55	44	32
223-2	[illegible]	959	696	520	396	307	242	193	157*	129	107	90	75	62	50
223-3	[illegible]	1071	786	594	457	358	284	229	186	154*	128	108	91	76	62
223-4	[illegible]	[illegible]	872	663	514	404	322	259	211	174	145*	121	102	85	71
232-2	[illegible]	1065	777	584	448	351	279	225	185	154	129	109*	91*	75	60
232-3	[illegible]	[illegible]	[illegible]	662	514	405	325	264	218	182	154	130	111*	94*	77
232-4	[illegible]	[illegible]	[illegible]	726	574	456	367	299	247	207	174	148	127	108*	91*
233-1	[illegible]	[illegible]	932	690	522	402	315	252	204	168	139	115	94	74	54
233-2	[illegible]	[illegible]	[illegible]	807	619	485	385	311	256	212	178	150*	126*	104	83
233-3	[illegible]	[illegible]	[illegible]	[illegible]	713	562	451	367	302	253	213	181	154*	130*	107
233-4	[illegible]	[illegible]	[illegible]	[illegible]	801	635	511	417	345	288	243	207	177	151*	127*
422-1	1783	1214	866	635	476	362	280	[illegible]	[illegible]	[illegible]	[illegible]	97	79	63	[illegible]
422-2		1388	1008	752	573	444	350	280	227*	[illegible]	155	130	109	90	72
422-3		1556	1143	863	665	520	413	332	271	223*	186	157	132	110	91
422-4			1271	967	749	589	469	378	308	254	211*	177*	148	124	103
423-1	2474	1684	1201	881	660	502	389	[illegible]	[illegible]	[illegible]	[illegible]	135	110	87	[illegible]
423-2		1918	1392	1039	792	614	483	386	313*	[illegible]	214	180	150	124	99
423-3			1572	1187	915	716	568	457	373	307*	256	215	181	152	125
423-4			1744	1327	1028	808	644	519	423	348	289*	242	203	170	141
432-2	[illegible]	[illegible]	[illegible]	1168	897	701	558	451	370	307	258	218*	183*	151	120
432-3	[illegible]	[illegible]	[illegible]	[illegible]	1028	811	650	529	436	364	307	261	222*	187*	155
432-4	[illegible]	[illegible]	[illegible]	[illegible]	1149	911	734	598	494	413	349	297	253	216*	182*
433-1	[illegible]	[illegible]	1865	1380	1044	804	631	503	408	335	278	230	188	149	108
433-2	[illegible]	[illegible]	[illegible]	1613	1239	969	771	623	511	425	357	301*	252*	209	166
433-3	[illegible]	[illegible]	[illegible]	[illegible]	1425	1125	902	733	605	505	426	362	308*	259*	215
433-4	[illegible]	[illegible]	[illegible]	[illegible]	1602	1271	1023	834	689	576	486	414	353	301*	254*

Figure 13-9 Typical Capacities of Evaporative Fluid Cooler from a Maker

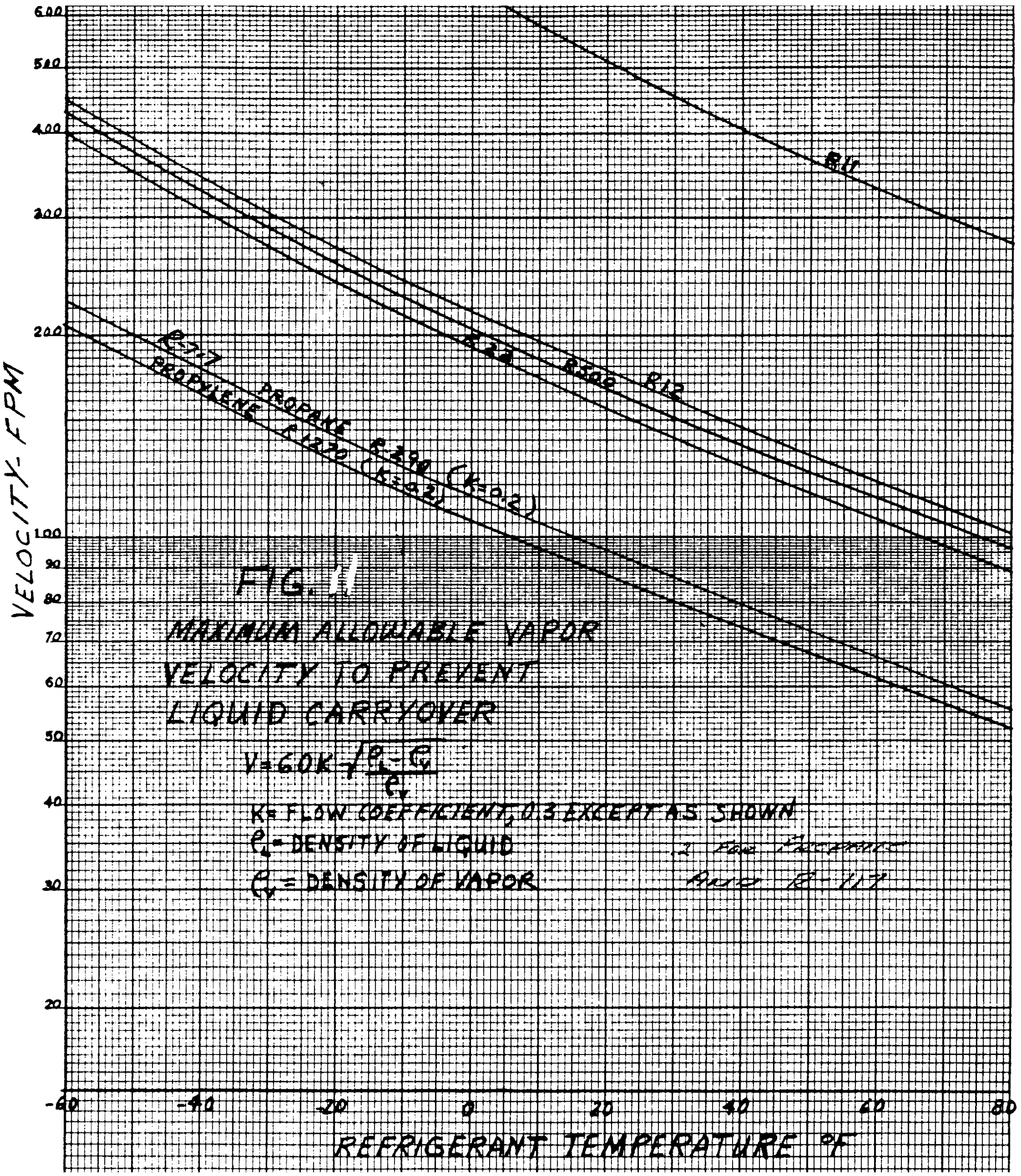


Figure 13-10 Maximum Gas/Liquid Gravity Separation Velocity

All there related data and curves for this job are for reference only. It is suggested to obtain the up-to-date information from a manufacturer. Compressor selection and refrigerant computer program are available from the manufacturer or to obtain the compressor selection from a manufacturer.

System Design Logic and Approach:

User Load Summary and Temperature Group Assignment:

The specification indicated to have one compressor to service one liquid recirculation package and one recirculation package is to be assigned for each temperature group, therefore, it is not economical to have too many recirculation packages. In view of this, users having almost same room design temperature are initially grouped together as the following:

(a) User Group No. 1, Design Evaporative Temperature is -50°F:
This Group is for the Blast freezing room. Room temperature -40°F. Refrigeration load is 87 TR. Minimum 6 product coolers shall be used.

(b) User Group No. 2, Design Evaporative Temperature is -15°F:

This Group is for Cold Storage Room. Room temperature -3°F. Total refrigeration load is 65 TR, minimum 4 coolers shall be used.

(c) User Group No. 3, Design Evaporative Temperature is 20°F: This Group covers the following areas:

Chilled Room. Room temperature 28°F. Total refrigeration load is 28 TR. Minimum 4 coolers shall be used.

Loading Room. Room temperature 32°F. Total refrigeration load is 54 TR. Minimum 4 coolers shall be used.

Ante Room. Room temperature 35°F. Total refrigeration load is 9.2 TR. Minimum 2 coolers shall be used.

(d) User Group No. 4, Design Evaporative Temperature of 30°F: This Group covers:

Boxing Room. Room temperature 46°F. Total refrigeration load is 15 TR. Minimum 2 coolers shall be used.

Deboning Room. Room temperature 43°F. Total refrigeration load is 17.9 TR. Minimum 4 units shall be used.

(e) User Group No. 5. Brine chiller. Design Evaporative Temperature to be determined later.

(f) User Group No. 6. Flake Ice Maker. Design evaporative temperature to be determined later.

Evaporative condenser is used and the design web bulb temperature is 81°FWB. It is reasonable to use 100°F design condensing temperature for the evaporative condenser.

The users which are having about the same evaporative temperature are grouped together and the four evaporative temperatures are shown in Figure 13-11:

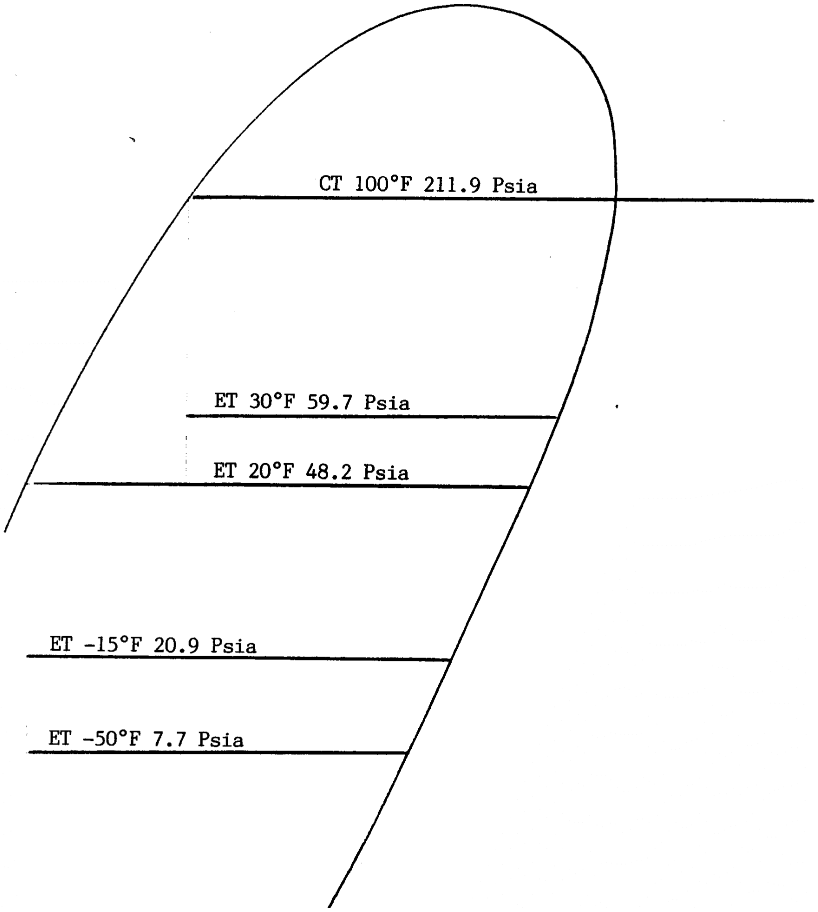


Figure 13-11 Allocating Evaporative Temperatures

The User Group No. 6, Flake Ice Maker requires ET below 25°F. Therefore, it is reasonable to set the ET for the ice maker at 20°F and is to be combined with the User Group No. 3.

Brine Chiller leaving brine temperature required is 38°F. Therefore, it is suggest use of 30°F ET for the brine chiller (Group No.5) and it is merged with Group 4 which is having 30°F evaporative temperature.

The temperature levels are now combined into four temperature groups. If each temperature group is connected to be serviced with one compressor, the initial liquid recirculation packages and compressor layout are shown in Figure 13-12:

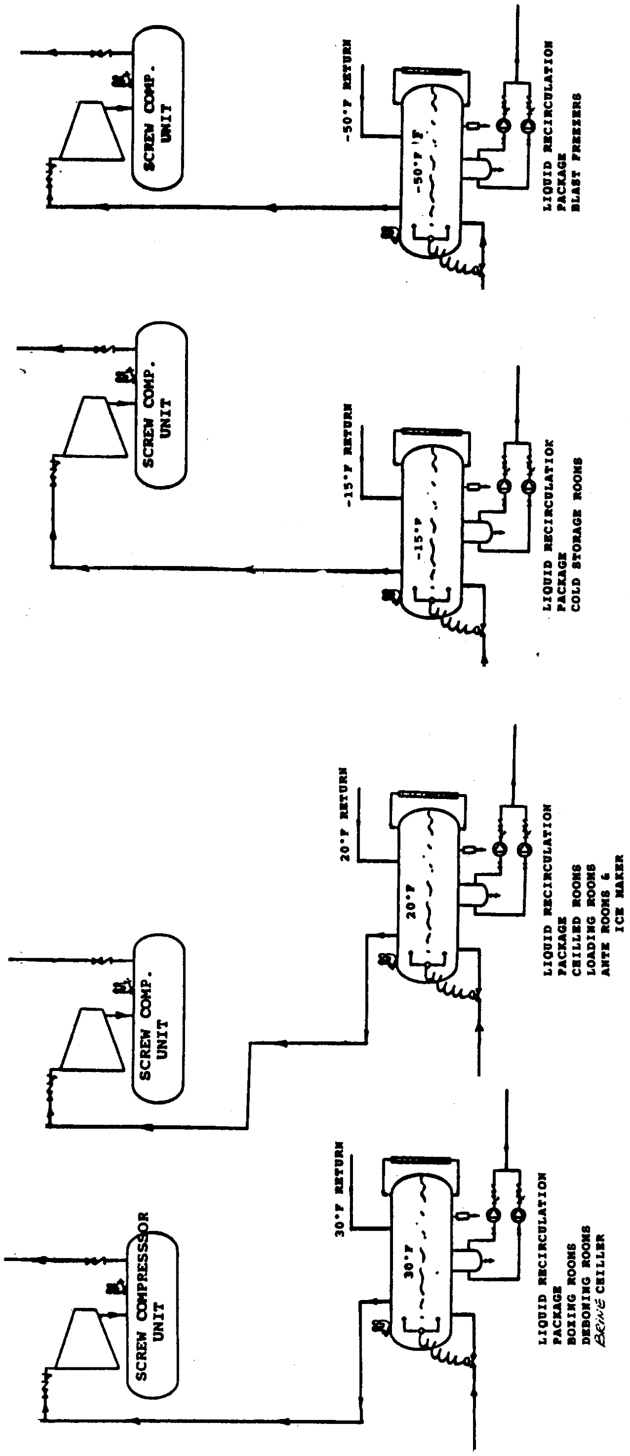


Figure 13-12 Liquid Recirculation Packages and Compressor Layout

-50°F ET temperature level exceeding 7.5 CR for single stage compression. Therefore, 2-stage compression required. -15°F ET temperature level also exceeds 7.5 CR for single stage compression. Therefore, also 2-stage compression is used for this ET.

Designate the intermediate intercooling temperature same as the Group 3 evaporative temperature.

Decision is made to discharge both the booster compressor of both -50°F and the booster compressor of -15°F to an intermediate temperature of 20°F; Therefore, this load can be combined with the evaporative load at 20°F. One compressor is used for 20°F and another compressor is used for 30°F ET; both compressor discharge to condensing temperature of 100°F. The P-H diagram of Figure 13-11 is now transformed to Figure 13-13:

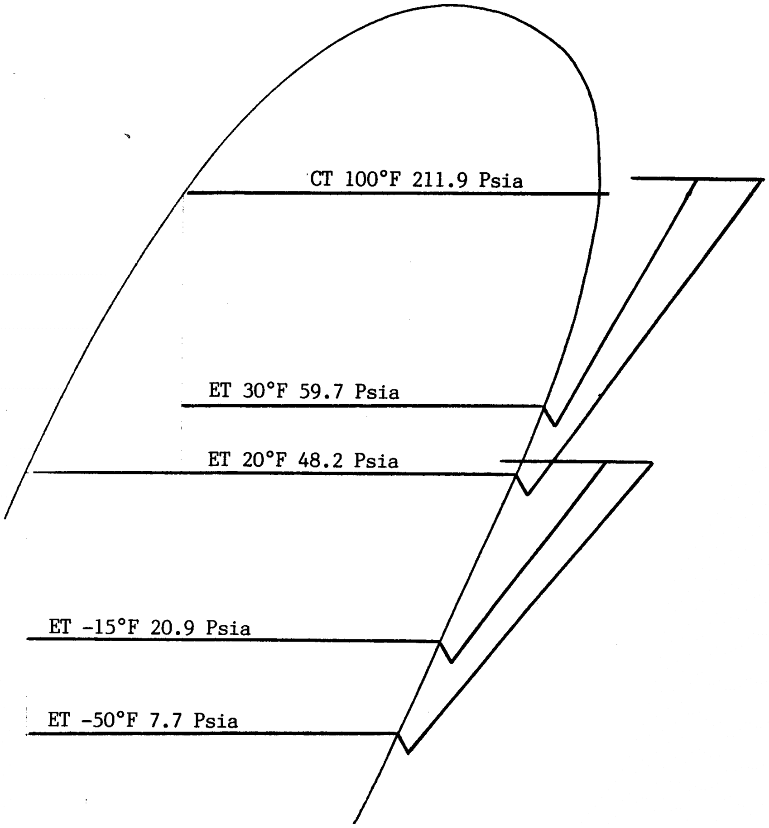


Figure 13-13 Preliminary P-H Diagram for the Compound System

Air Side Equipment Design Guide Lines:

In order to make the selections of the unit coolers, product coolers, evaporative condenser and the evaporative fluid coolers, based on the general application and experiences, the general guide lines are established as the following:

(a) Product coolers are to be used for room temperature below 0°F.
(b) Unit coolers are to be used for room temperature above 0°F.
(c) 2/3 FPI coil is to be used for -40°F room temperature.
(d) 2/4 FPI coil is for room temperature from 0°F to -20°F.
(e) 4 FPI coil is to be used for all other room temperature units.
(f) All the coolers are to be selected with hot gas defrost.

Product and equipment to be used for selection for the project are as the following:

Compressor:	RW screw
Product cooler:	CFA series product coolers
Unit coolers:	HTA series.
Evaporative condenser:	IDC models.
Evaporative Fluid Cooler:	EFC-C models.

Superheat and Pressure Drops Assumptions:

The design pressure drops and superheat for the screw compressors:

Minimum external suction:	
High stage pressure drop:	0.5 Psi
Booster pressure drop:	0.5 Psi
Minimum external discharge	
Pressure drop for booster:	0.5 Psi
Pressure drop for high stage:	3.0 Psi
Minimum suction superheat:	10°F

Selection and System Calculations:

Product Cooler Selectionn for Users Group No. 1, Evaporative Temperature of -50°F:

Blast freezing room.

Room temperature = -40°F.
Total Refrigeration load = 87 TR.
6 product coolers shall be used.

Capacity for each product cooler
= 87/6 = 14.5 TR
= 174,000 Btu/Hr.
TD = Room Temp. - ET
= -40 - (-50)

= 10°F

2/3 FPI, assume 10 rows deep coil

-50°F correction factor = 0.8
2/3 FPI correction factor = 0.92

$$\text{Btu/°F-TD required} = \frac{174{,}000 \text{ Btu/Hr.}}{10 \times 0.92 \times 0.8}$$

$$= 23{,}641 \text{ Btu/°F-TD}$$

Model CFA-5310 is selected.

Product Cooler Selection for User Group No. 2, Evaporative Temperature of -15°F:

Cold Storage Room.

Room temperature = -3°F.
Total Refrigeration load = 65 TR.
4 product coolers shall be used.

Capacity for each product cooler
= 65/4 = 16.25 TR
= 195,000 Btu/Hr.
TD = Room Temp. - ET
= -3 - (-15)
= 12°F

2/4 FPI coil required, assume 10 rows deep coil

-15°F correction factor = 1.0
2/4 FPI correction factor = 0.91

$$\text{Btu/°F-TD required} = \frac{195{,}000 \text{ Btu/Hr.}}{12 \times 0.91 \times 1.0}$$

$$= 17{,}857 \text{ Btu/°F-TD}$$

Model CFA-3810 is selected.

Unit Cooler Slection for User Group No. 3 and User Group No. 6, Evaporative Temperature of 20°F:

Chilled Room.

Room temperature = 28°F.
Total Refrigeration load = 28 TR.
4 product coolers shall be used.

Capacity for each product cooler
= 28/4 = 7 TR
= 84,000 Btu/Hr.

TD = Room Temp. - ET
= 28 - 20
= 8°F

4 FPI coil required.

$$\text{Btu/°F-TD required} = \frac{84{,}000\ \text{Btu/Hr.}}{8}$$

$$= 10{,}500\ \text{Btu/°F-TD}$$

Model HTA-564 is selected.

Loading Room:

Room temperature = 32°F.
Total Refrigeration load = 54 TR.

4 product coolers shall be used.

Capacity for each product cooler
= 54/4 = 13.5 TR
= 162,000 Btu/Hr.

TD = Room Temp. - ET
= 32 - 20
= 12°F

4 FPI coil is required.

$$\text{Btu/°F-TD required} = \frac{162{,}000 \text{ Btu/Hr.}}{12}$$

$$= 13{,}500 \text{ Btu/°F-TD}$$

Model HTA-754 is selected.

Ante Room.

Room temperature = 35°F.
Total Refrigeration load = 9.2 TR.

2 product coolers shall be used.

Capacity for each product cooler
= 9.2/2 = 4.6 TR
= 55,200 Btu/Hr.

TD = Room Temp. - ET
= 35 - 20
= 15°F

4 FPI coil required.

$$\text{Btu/°F-TD required} = \frac{55{,}200 \text{ Btu/Hr.}}{15}$$

$$= 3{,}680 \text{ Btu/°F-TD}$$

Model HTA-254 is selected.

Ice Making Facility:

Refrigeration capacity = 61 TR

The ice maker requires ET is to be set at 20°F.

Unit Cooler Selection for User Group No. 4 and User Group No. 5, Evaporative Temperature of 30°F:

Boxing Room.

Room temperature = 46°F.
Total Refrigeration load = 15 TR.
2 product coolers shall be used.

Capacity for each product cooler
= 15/2 = 7.5 TR
= 90,000 Btu/Hr.

TD = Room Temp. - ET
= 46 - 30
= 16°F

4 FPI coil required.

$$\text{Btu/°F-TD required} = \frac{90{,}000\ \text{Btu/Hr.}}{16}$$

$$= 5{,}625\ \text{Btu/°F-TD}$$

Model HTA-354 is selected.

Deboning Room.

Room temperature = 43°F.
Total Refrigeration load = 17.9 TR.
4 product coolers shall be used.

Capacity for each product cooler
= 17.9/4 = 4.475 TR
= 53,700 Btu/Hr.

TD = Room Temp. - ET
= 43 - 30
= 13°F

4 FPI coil required.

$$\text{Btu/°F-TD required} = \frac{53{,}700\ \text{Btu/Hr.}}{13}$$

$$= 4{,}131\ \text{Btu/°F-TD}$$

Model HTA-264 is selected.

Refrigeration load from brine chiller:

Brine leaving temperature is 38°F. The evaporative temperature is set for 30°F:

45% by weight of Propylene Glycol
Brine circulation = 464 GPM
Brine entering temp = 49°F
Brine leaving temp. = 38°F
Specific Gravity = 1.048
Specific Heat = 0.875

Brine average temperature = (49 + 38) /2 = 43.5°F

Btu/Hr = 499.8 x GPM x Sp.Gr. x Sp.Ht. (T_1 - T_2)

= 499.8 x 464 x 1.048 x 0.875 x (49 - 38)

= 2,339,248 Btu/Hr

or 195 TR.

Refrigeration loads for the system:

The refrigeration system shall be designed for four (4) evaporative temperature levels, the refrigeration load for each temperature level is as the following:

For -50°F ET temperature level: = 87 TR

For -15°F ET temperature level: = 65 TR

For 20°F ET temperature level: = 152.2 TR
  Chilled room 28 TR
  Loading room 54 TR
  Ante room 9.2 TR
  Ice making 61 TR

For 30°F ET temperature level: = 227.9 TR
  Boxing room 15 TR
  Deboning room 17.9 TR
  Brine chiller 195 TR

System Layout:

The system is a compound system, flash type intermediate intercooler is used; intermediate temperature is 20°F. The liquid for ET 20°F and 30°F and the intermediate intercooler is from condenser; the liquid to ET -15°F and -50°F is from the intermediate intercooler. The P-H for the system is formed and as shown in Figure 13-14.

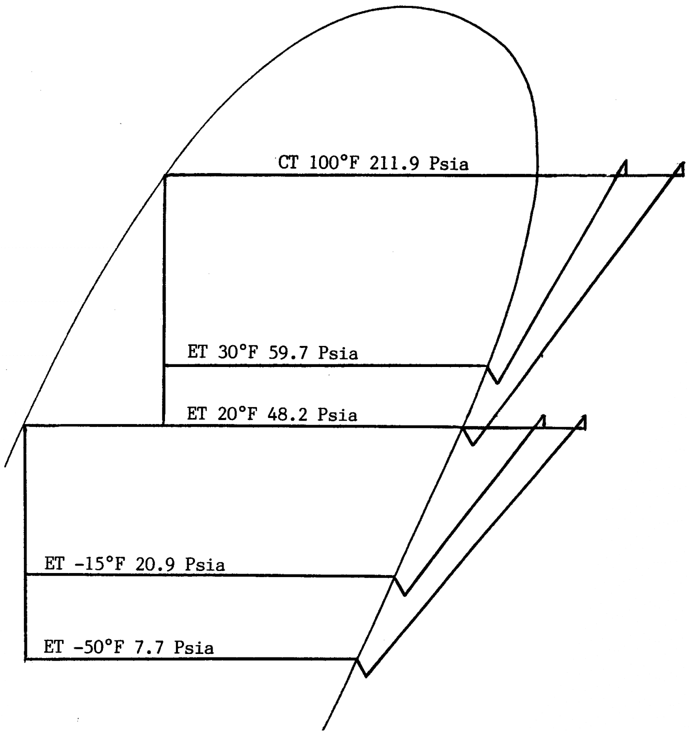


Figure 13-14P-H Diagram for the Compound System

Screw compressors selection:

Recap Pressure drops and superheat:

Minimum external suction:	
Suction pressure drop, Booster:	0.5 Psi
Suction pressure drop, High Stage:	0.5 Psi
Minimum external discharge:	
Pressure drop for booster:	0.5 Psi
Pressure drop for high stage:	3.0 Psi
Minimum suction superheat:	10°F

The compressor selections for –50°F and –15°F suction with 20°F intermediate temperature is as the following:

The Booster compressor selection for the –50°F ET:

The data for the computer program input for the compressor selection:

Refrigerant: R-717
Capacity: ` 87 TR
Intermediate temperature: 20°F
Evaporative temperature: -50°F
External discharge pressure drop: 0.5 Psi
External suction pressure drop: 0.5 Psi
Suction superheat: 10°F
Discharge valves: Maker's standard
Suction valve: Maker's standard
Oil cooling: Water cooled

Compressor selected: RW-316
87 TR.
BHP = 149.9 BHP
Oil cooling heat removal = 149,600 Btu/Hr.

Compression ratio = 48.21/7.67 = 6.29 which is smaller CR = 7.5 specified, O.K.

The Booster compressor selection for the –15°F ET:

The data for the computer program input for the compressor selection:

Refrigerant: R-717
Capacity: ` 65 TR
Intermediate temperature: 20°F
Evaporative temperature: -15°F
External discharge pressure drop: 0.5 Psi
External suction pressure drop: 0.5 Psi
Suction superheat: 10°F
Discharge valves: Maker's standard
Suction valve: Maker's standard
Oil cooling: Water cooled

Compressor selected: RW-76
65 TR.
BHP = 44.8 BHP
Oil cooling heat removal = 16,000 Btu/Hr

Compressor selection for 20° F ET 30° F

The total load for 20°F ET temperature level
= LOAD(1) + LOAD(2) + LOAD(3)

$$\text{LOAD(1) from -50°F} = 87 + \frac{149.9 \times 2545 - 149{,}600}{12000}$$

$$= 87 + 19.32$$

$$= 106.32 \text{ TR}$$

$$\text{LOAD(2) from -15°F} = 65 + \frac{44.8 \times 2545 - 16{,}800}{12000}$$

$$= 65 + 8.1$$

$$= 73.1 \text{ TR}$$

LOAD(3) from 20°F = 152.2 TR

Total refrigeration load for the compressor is

= LOAD(1) + LOAD(2) + LOAD(3)

= 106.32 + 73.1 + 152.2
= 331.62 TR

The data for the computer program input for the compressor selection:

Refrigerant:	R-717
Capacity: `	331.6 TR
Condending temperature:	100°F
Evaporative temperature:	20°F
External discharge pressure drop:	3.0 Psi
External suction pressure drop:	0.5 Psi
Suction superheat:	10°F
Discharge valves:	Maker's standard
Suction valve:	Maker's standard
Oil cooling:	Water cooled

Compressor selected: RW-222
331.6 TR.
BHP = 423.4 BHP

Oil cooling heat removal = 563,900 Btu/Hr.

Compression ratio = 211.87/48.21 = 4.4 which is smaller than 7.5 specified, O.K.

Compressor selection for 30° F ET:

The data for the computer program input for the compressor selection:

Refrigerant:	R-717
Capacity: `	227.9 TR
Condending temperature:	100°F
Evaporative temperature:	30°F
External discharge pressure drop:	3.0 Psi
External suction pressure drop:	0.5 Psi
Suction superheat:	10°F
Discharge valves:	Maker's standard
Suction valve:	Maker's standard
Oil cooling:	Water cooled

Compressor selected: RW-134
227.9 TR.
BHP = 254.1 BHP
Oil cooling heat removal = 319,200 Btu/hr.

Evaporative Condenser Selection:

The outside air design temperatures are 92°FDB and 81°FWB

Total heat rejection:

From 20°F = 331.6 x 12000 + 423.4 x 2545 - 563900
= 4,492,853 Btu/Hr.
= 4,493 MBH

From 30°F = 227.9 x 12000 + 254.1 x 2545 - 319200
= 3,622,285 Btu/Hr.
= 3,623 MBH

Total heat rejection = 4,493 + 3,623
= 7,556 MBH

Wetbulb 81°F correction factor = 1.27

MBH (corrected) = 7,556 x 1.27

= 9,596.12

Evaporative Condenser selected: Model IDC-670

Evaporative Fluid Cooler Selection:

Total heat rejection from oil coolers

= 563,900 + 319,200 + 16,800 + 149,600
= 1,049,500 Btu/Hr.
= 1,050 MBH

Water temperature requirement:

Oil is to be cooled down to 120°F
The wet bulb air temperature is 81°F

Set water temperature 90°F to 110°F

$$\text{GPM Water required} = \frac{1{,}050{,}000}{499.8 \times (110 - 90)}$$

$$= 105 \text{ GPM}$$

Approach = 90 - 81 = 9°F
Range = 110 - 90 = 20°F

Performance number of EFC-C condenser - 10.1

Evaporative Fluid Cooler selection: EFC-C-123-4

Liquid recirculation rates for -50° F load:

$$\text{Refrigerant Flow} = \frac{200}{H_2 - H_1} \times \text{TR}$$

$$= \frac{200}{593.7 - 64.7} \times 87$$

= 32.89 Min/Min

$$\text{Liquid evaporized} = \frac{593.7 - 64.7}{593.7 - (-10.6)} \times 32.89$$

= 28.79 Lbx/Min.

Recirculation ratio recommended = 4:1

Therefore, recirculation rate = 28.79 x 4
= 115.16 Lbs/Min.

$$\text{GPM} = \frac{62.478 \times \text{Lbs/Min}}{8.33 \times \text{Density}}$$

Density of R-717 at -50°F = 43.49 Lbs/Ft^3

$$= \frac{62.478 \times 115.16}{8.33 \times 43.49}$$

= 19.86 GPM

Say, recirculation rate = 20 GPM

Liquid recirculation rate for -15° F loads:

$$\text{Refrigerant Flow} = \frac{200}{H_2 - H_1} \times \text{TR}$$

$$= \frac{200}{606.7 - 64.7} \times 65$$

= 23.99 Min/Min

$$\text{Liquid evaporized} = \frac{606.7 - 64.7}{606.7 - 26.7} \times 23.99$$

= 22.42 Lbx/Min.

Recirculation ratio recommended = 4:1

Therefore, recirculation rate = 22.42 x 4
= 89.68 Lbs/Min.

$$\text{GPM} = \frac{62.478 \text{ x Lbs/Min}}{8.33 \text{ x Density}}$$

Density of R-717 at -15°F = 42.00 Lbs/Ft^3

$$= \frac{62.478 \text{ x } 89.68}{8.33 \text{ x } 42.00}$$

= 16.02 GPM

Say, recirculation rate = 16 GPM

Liquid recirculation rate for 20°F loads:

$$\text{Refrigerant Flow} = \frac{200}{H_2 - H_1} \text{x TR}$$

$$= \frac{200}{617.8 - 155.2} \text{ x } 152.2$$

= 65.80 Min/Min

$$\text{Liquid evaporized} = \frac{617.8 - 155.2}{617.8 - 64.7} \text{ x } 65.8$$

= 55.03 Lbx/Min.

Recirculation ratio recommended = 4:1

Therefore, recirculation rate = 55.03 x 4

$$= 220.12 \text{ Lbs/Min.}$$

$$\text{GPM} = \frac{62.478 \text{ x Lbs/Min}}{8.33 \text{ x Density}}$$

Density of R-717 at 20°F = 40.8 Lbs/Ft^3

$$= \frac{62.478 \text{ x } 220.12}{8.33 \text{ x } 40.8}$$

$$= 40.8 \text{ GPM}$$

Say, recirculation rate = 41 GPM

Liquid recirculation rate for 30° F loads:

$$\text{Refrigerant Flow} = \frac{200}{H_2 - H_1} \text{ x TR}$$

$$= \frac{200}{620.5 - 155.2} \text{ x } 227.9$$

$$= 97.96 \text{ Min/Min}$$

$$\text{Liquid evaporized} = \frac{620.5 - 155.2}{620.5 - 75.7} \text{ x } 83.67$$

$$= 55.03 \text{ Lbx/Min.}$$

Recirculation ratio recommended = 4:1

Therefore, recirculation rate = 83.67 x 4
= 334.68 Lbs/Min.

$$\text{GPM} = \frac{62.478 \text{ x Lbs/Min}}{8.33 \text{ x Density}}$$

Density of R-717 at 30°F = 39.96 Lbs/Ft^3

$$= \frac{62.478 \times 334.68}{8.33 \times 39.96}$$

= 62.82 GPM

Say, 63 GPM

Size of Intermediate flash intercooler.

The suction gas flow through the flash intercooler:

$$= \frac{200}{617.8 - 155.2} \times (19.32 \text{ TR} + 73.1 \text{ TR})$$

= 39.96 Lbs/Min.

Suction gas volume flow = Lbs/Min x Vg

= 39.96 x 5.91

= 236.16 CFM

Maximum separation velocity (V)
for Ammonia at 20°F = 95 Ft/Min.

$$\text{Minimum diameter} = \sqrt{\frac{576 \times \text{CFM}}{\pi \times V}}$$

$$= \sqrt{\frac{576 \times 236.16}{\pi \times 95}}$$

= 21.3" ϕ

Say, intercooler size 24"ϕ x 5'-0"

Suction piping size for -50° F booster compressor suction:

Engine room size 80' x 40' x 20'H

The booster suction pipe run is from the -50°F liquid recirculation package to the suction of the screw compressor.

Estimated pipe run in the engine room = 80' + 40' + 20' = 140'

Maximum 5 each of 90° elbows

Refrigerant flow = 32.89 Lbs/Min

Assume 6"ϕ suction pipe.

6"ϕ elbow equivalent pipe run = 9'

Total pipe run = 140' + 5 x 9 = 185'

Friction loss = 0.06 psi/100'

PD = 0.06 x 185/100 = 0.111 Psi

Suction external pressure drop allowed is 0.5 Psia.

Therefore, the 6"ϕ pipe is too large.

Assume 4"ϕ suction pipe.

4"ϕ elbow equivalent pipe run = 6'

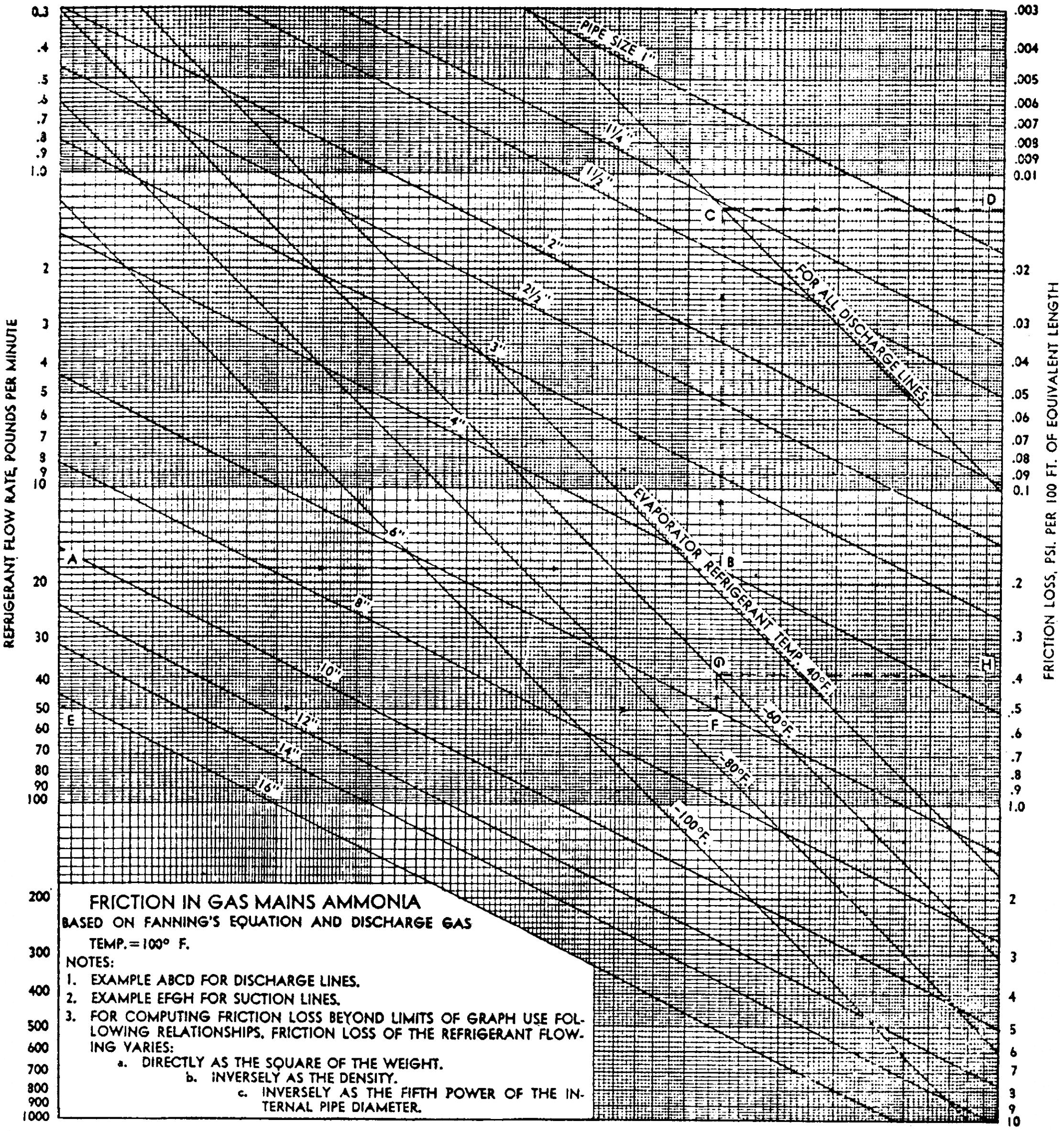
Total pipe run = 140' + 5 x 6 = 170'

Friction loss = 0.24 psi/100'

PD = 0.24 x 175/100 = 0.408 Psi

Suction external pressure drop allowed is 0.5 Psia.

Therefore, the 4"ϕ pipe is ok.



FRICTION IN GAS MAINS AMMONIA

BASED ON FANNING'S EQUATION AND DISCHARGE GAS TEMP. = 100° F.

NOTES:

1. EXAMPLE ABCD FOR DISCHARGE LINES.
2. EXAMPLE EFGH FOR SUCTION LINES.
3. FOR COMPUTING FRICTION LOSS BEYOND LIMITS OF GRAPH USE FOLLOWING RELATIONSHIPS. FRICTION LOSS OF THE REFRIGERANT FLOWING VARIES:
   - a. DIRECTLY AS THE SQUARE OF THE WEIGHT.
   - b. INVERSELY AS THE DENSITY.
   - c. INVERSELY AS THE FIFTH POWER OF THE INTERNAL PIPE DIAMETER.

Figure 13-15 Ammonia Vapor Friction Loss

SUMMARY REPORT:

The refrigeration system is designed to have 2-stage compression for the -50°F and -15°F loads with intermediate temperature of 20°F; single stage compression for 20°F and 30°F loads.

The P-H diagram to show the refrigeration system designed with enthalpy, temperature, pressure for the vital points is attached.

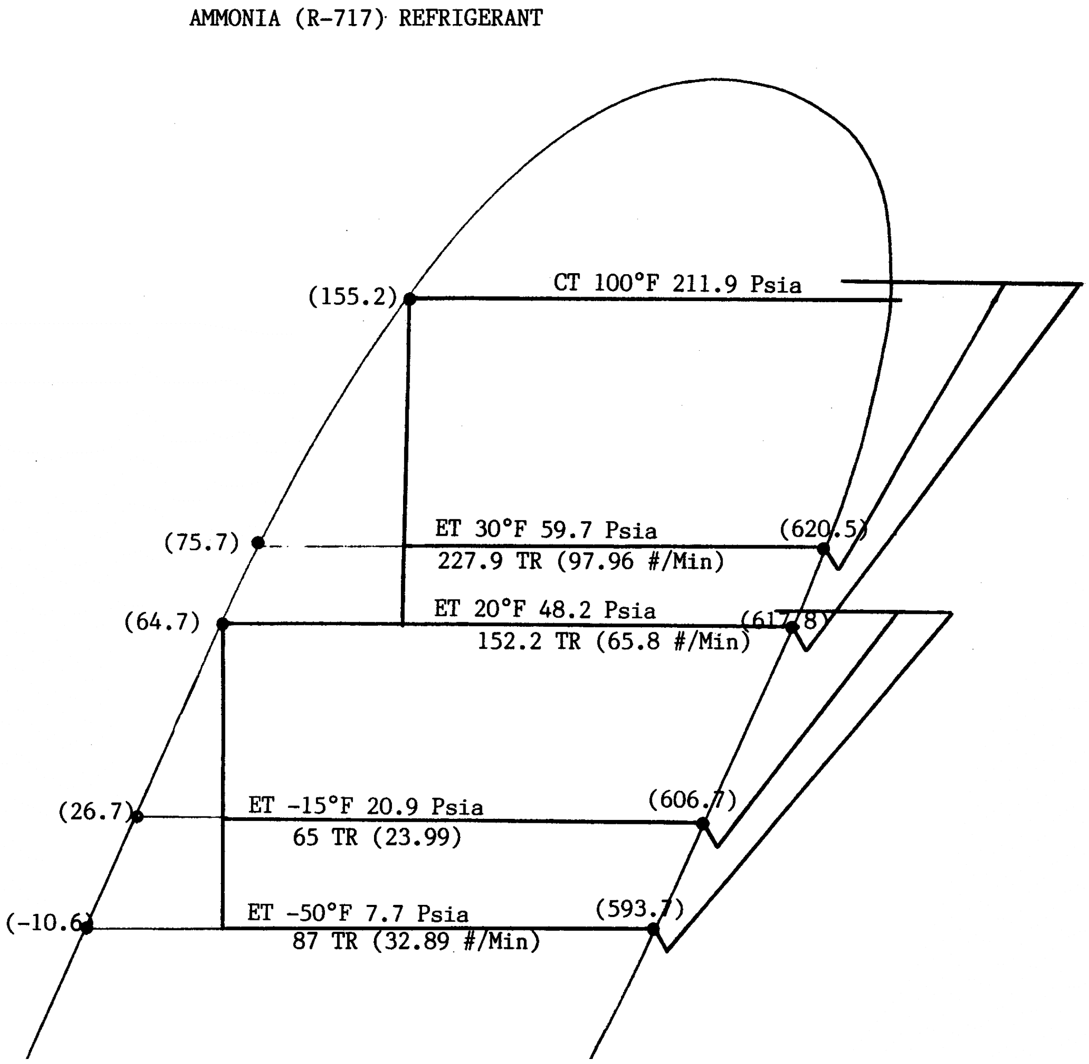


Figure 13-16P-H Diagram for the Compound System

The refrigerant flow diagram is shown in Figure 13-17.

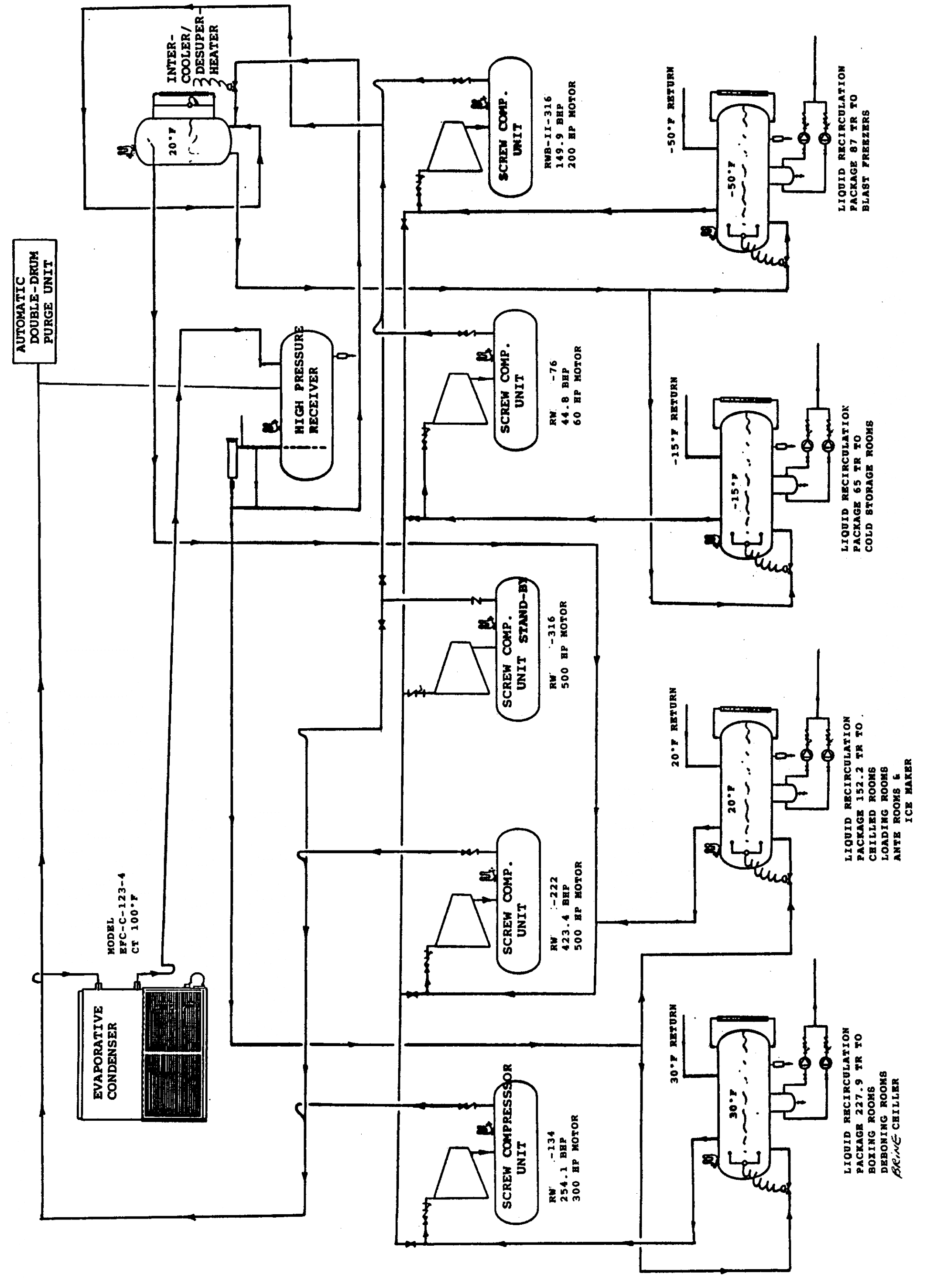


Figure 13-17Refrigerant Flow Diagram for the Compound System

The Equipment List:

Screw compressors:

For -50°F temp.	: TR 87	Model RW316	Bhp 149.9
For -15°F temp.	: TR 65	Model RW-76	Bhp 44.8
For 20°F temp.	: TR 331.6	Model RW-222	Bhp 423.4
For 30°F temp.	: TR 227.9	Model RW-134	Bhp 254.1

Product Cooler and Unit coolers:

Each cooler:

For Blast Freezing Room	:	TR 14.5	Unit Model CFA-5310
For Cold Storage Room	:	TR 16.25	Unit Model CFA-3810
For Chilled Room	:	TR 7.0	Unit Model HTA-564
For Loading Room	:	TR 13.5	Unit Model HTA-254
For Ante Room	:	TR 4.6	Unit Model HTA-254
For Boxing Room	:	TR 7.5	Unit Model HTA-354
For Deboning Room	:	TR 4.475	Unit Model HTA-264

Brine chiller : TR 195

Propylene Glycol :

Specific Gravity : 1.048

Specific Heat : 0.875

Ammonia liquid flow : GPM 180

Evaporative condenser : Model IDC-670

Total heat rejection : MBH 7,556

Evaporative Fluid Cooler : Model EFC-C-123-4

Total heat rejection : MBH 1,050

The diameter of the vertical intermediate flash intercooler = 24" Diam.

The total TR for each temperature level for liquid recirculation:

For -50°F temperature level : 87 TR
For -15°F temperature level : 65 TR
For 20°F temperature level : 152.2 TR
For 30°F temperature level : 227.9 TR

The GPM refrigerant flow of the pump of each liquid recirculation package.

For -50°F temperature level:	20	GPM
For -15°F temperature level:	16	GPM
For 20°F temperature level:	41	GPM
For 30°F temperature level:	63	GPM

The stand-by screw compressor unit.

Model: RW-316 Motor HP: 500

The suction pipe size required for the -50°F screw compressor suction is 4" Diameter.

Total BHP of the refrigeration system:

For -50°F temp.	: TR 87	Model RWB-II-316B	Bhp 149.9
For -15°F temp.	: TR 65	Model RWB-II-76B	Bhp 44.8
For 20°F temp.	: TR 152.2	Combined with high stage	
For 30°F temp.	: TR 227.9	Model RWB-II-134	Bhp 254.1
For high stage	: TR 331.6	Model RWB-II-222	Bhp 423.4

		Total BHP:	872.2 Bhp