Case – 3 Case of High Suction Superheat

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Case Background:

This is a case as how to design a refrigeration system to handle abnormally high superheated suction gas from the user's reactor evaporator heat exchanger. The refrigeration system is with screw compressor. The basic requirements for the inquiry for the project are as the following:

Compressor:	Screw
Refrigerant:	Ammonia.
Cooling load:	575 TR

The condenser and the evaporator are furnished by the user. The CT and ET of the refrigeration system are to be designed for.

Condensing Temperature:	102°F
Evaporative Temperature:	–10°F

The user would like to have the operating conditions for the water cooled condenser; the user will fabricate the condenser accordingly.

The evaporator is a reactor type heat exchanger which is remote mounted at an elevated platform, therefore, the Ammonia liquid which is leaving the refrigeration system and supplied to the evaporator is to be subcooled.

The refrigerant vapor leaving the reactor heat exchanger (evaporator) nozzle might some times reach 60°F. The external piping suction superheat is 5°F. The external suction line pressure drop is 1.4 Psi. Compressor external piping discharge pressure drop is 0.7 Psi.

Water cooled oil cooler is to be used.
Power supply is 6000-3-50.

The user would like to know the impact of high suction superheat to the refrigeration system.

This is all the information given. A refrigeration system is to be design for this project.

Related Technical Data and Information for the Case:

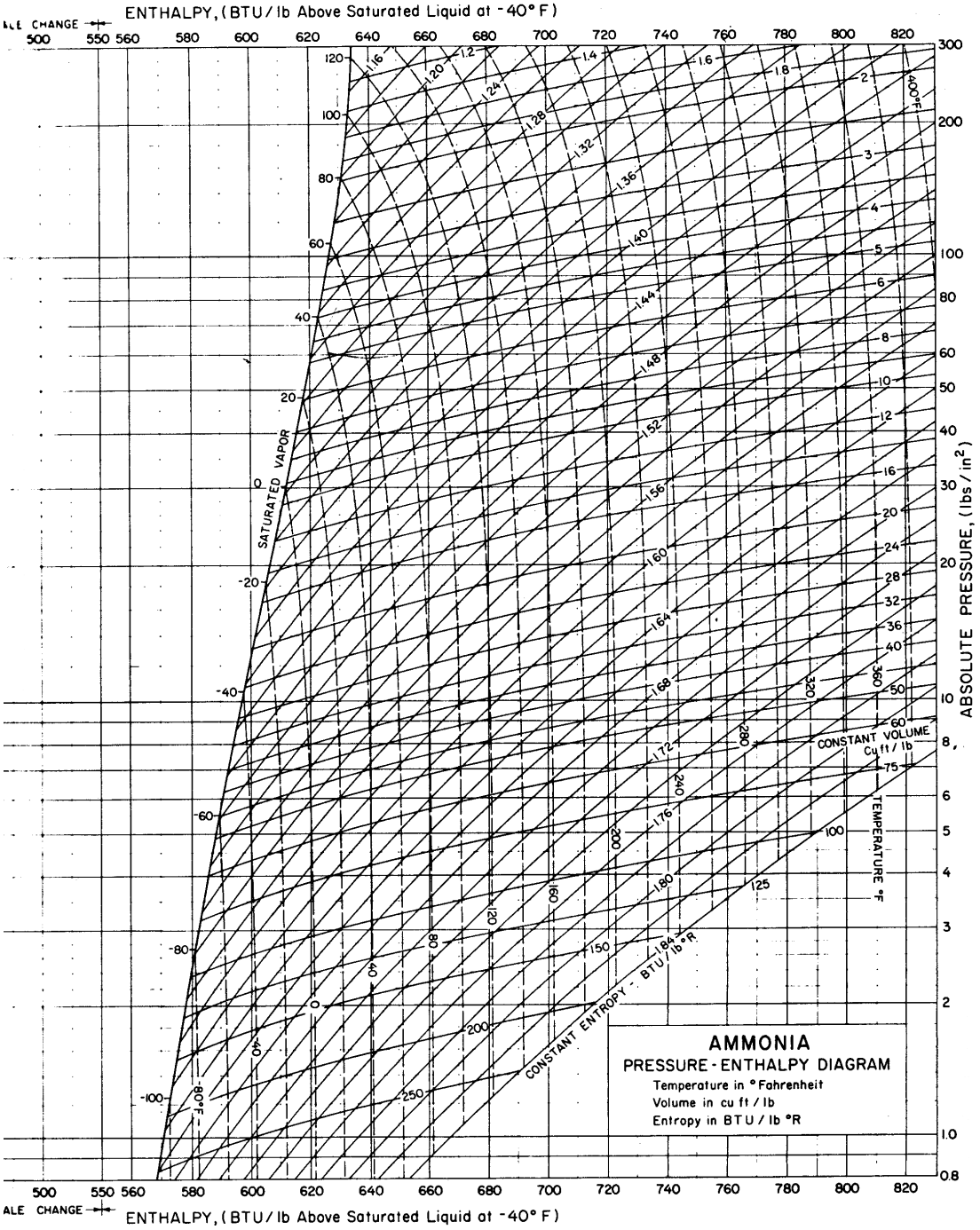

Figure 3-1 R-717 Pressure-Enthalpy Chart

TEMP F	PRESSURE lb per sq in		VOLUME cu ft per lb		DENSITY lb per cu ft		ENTHALPY ** Btu per lb			ENTROPY ** Btu per (lb) (^{o}R)		TEMP F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
-45	8.95	11.7*	0.02310	28.62	43.28	0.03494	- 5.3	600.9	595.6	-0.0127	1.4368	-45
-44	9.23	11.1*	.02313	27.82	43.24	.03595	- 4.3	600.3	596.0	- .0102	1.4342	-44
-43	9.51	10.6*	.02315	27.04	43.20	.03698	- 3.2	599.6	596.4	- .0076	1.4317	-43
-42	9.81	10.0*	.02317	26.29	43.16	.03804	- 2.1	598.9	596.8	- .0051	1.4292	-42
-41	10.10	9.3*	.02320	25.56	43.11	.03912	- 1.1	598.3	597.2	- .0025	1.4267	-41
-40	10.41	8.7*	0.02322	24.86	43.07	0.04022	0.0	597.6	597.6	0.0000	1.4242	-40
-39	10.72	8.1*	.02324	24.18	43.03	.04135	1.1	596.9	598.0	.0025	1.4217	-39
-38	11.04	7.4*	.02326	23.53	42.99	.04251	2.1	596.2	598.3	.0051	1.4193	-38
-37	11.37	6.8*	.02328	22.89	42.95	.04369	3.2	595.5	598.7	.0076	1.4169	-37
-36	11.71	6.1*	.02331	22.27	42.90	.04489	4.3	594.8	599.1	.0101	1.4144	-36
-35	12.05	5.4*	0.02333	21.68	42.86	0.04613	5.3	594.2	599.5	0.0126	1.4120	-35
-34	12.41	4.7*	.02335	21.10	42.82	.04739	6.4	593.5	599.9	.0151	1.4096	-34
-33	12.77	3.9*	.02338	20.54	42.77	.04868	7.4	592.8	600.2	.0176	1.4072	-33
-32	13.14	3.2*	.02340	20.00	42.73	.04999	8.5	592.1	600.6	.0201	1.4048	-32
-31	13.52	2.4*	.02343	19.48	42.69	.05134	9.6	591.4	601.0	.0226	1.4025	-31
-30	13.90	1.6*	0.02345	18.97	42.65	0.05271	10.7	590.7	601.4	0.0250	1.4001	-30
-29	14.30	0.8*	.02347	18.48	42.61	.05411	11.7	590.0	601.7	.0275	1.3978	-29
-28	14.71	0.0	.02350	18.00	42.56	.05555	12.8	589.3	602.1	.0300	1.3955	-28
-27	15.12	0.4	.02352	17.54	42.52	.05701	13.9	588.6	602.5	.0325	1.3932	-27
-26	15.55	0.8	.02355	17.09	42.48	.05850	14.9	587.9	602.8	.0350	1.3909	-26
-25	15.98	1.3	0.02357	16.66	42.44	0.06003	16.0	587.2	603.2	0.0374	1.3886	-25
-24	16.42	1.7	.02360	16.24	42.39	.06158	17.1	586.5	603.6	.0399	1.3863	-24
-23	16.88	2.2	.02362	15.83	42.35	.06317	18.1	585.8	603.9	.0423	1.3840	-23
-22	17.34	2.6	.02364	15.43	42.31	.06479	19.2	585.1	604.3	.0448	1.3818	-22
-21	17.81	3.1	.02367	15.05	42.26	.06644	20.3	584.3	604.6	.0472	1.3796	-21
-20	18.30	3.6	0.02369	14.68	42.22	0.06813	21.4	583.6	605.0	0.0497	1.3774	-20
-19	18.79	4.1	.02371	14.32	42.18	.06985	22.4	582.9	605.3	.0521	1.3752	-19
-18	19.30	4.6	.02374	13.97	42.13	.07161	23.5	582.2	605.7	.0545	1.3729	-18
-17	19.81	5.1	.02376	13.62	42.09	.07340	24.6	581.5	606.1	.0570	1.3708	-17
-16	20.34	5.6	.02378	13.29	42.05	.07522	25.6	580.8	606.4	.0594	1.3686	-16
-15	20.88	6.2	0.02381	12.97	42.00	0.07709	26.7	580.0	606.7	0.0618	1.3664	-15
-14	21.43	6.7	.02383	12.66	41.96	.07898	27.8	579.3	607.1	.0642	1.3643	-14
-13	21.99	7.3	.02386	12.36	41.91	.08092	28.9	578.6	607.5	.0666	1.3621	-13
-12	22.56	7.9	.02388	12.06	41.87	.08289	30.0	577.8	607.8	.0690	1.3600	-12
-11	23.15	8.5	.02391	11.78	41.82	.08490	31.0	577.1	608.1	.0714	1.3579	-11
-10	23.74	9.0	0.02393	11.50	41.78	0.08695	32.1	576.4	608.5	0.0738	1.3558	-10
- 9	24.35	9.7	.02395	11.23	41.74	.08904	33.2	575.6	608.8	.0762	1.3537	- 9
- 8	24.97	10.3	.02398	10.97	41.69	.09117	34.3	574.9	609.2	.0786	1.3516	- 8
- 7	25.61	10.9	.02401	10.71	41.65	.09334	35.4	574.1	609.5	.0809	1.3495	- 7
- 6	26.26	11.6	.02403	10.47	41.60	.09555	36.4	573.4	609.8	.0833	1.3474	- 6
- 5	26.92	12.2	0.02406	10.23	41.56	0.09780	37.5	572.6	610.1	0.0857	1.3454	- 5
- 4	27.59	12.9	.02408	9.991	41.52	.1001	38.6	571.9	610.5	.0880	1.3433	- 4
- 3	28.28	13.6	.02411	9.763	41.47	.1024	39.7	571.1	610.8	.0904	1.3413	- 3
- 2	28.98	14.3	.02414	9.541	41.43	.1048	40.7	570.4	611.1	.0928	1.3393	- 2
- 1	29.69	15.0	.02416	9.326	41.38	.1072	41.8	569.6	611.4	.0951	1.3372	- 1
0	30.42	15.7	0.02419	9.116	41.34	0.1097	42.9	568.9	611.8	0.0975	1.3352	0
1	31.16	16.5	.02422	8.912	41.29	.1122	44.0	568.1	612.1	.0998	1.3332	1
2	31.92	17.2	.02424	8.714	41.25	.1148	45.1	567.3	612.4	.1022	1.3312	2
3	32.69	18.0	.02427	8.521	41.20	.1174	46.2	566.5	612.7	.1045	1.3292	3
4	33.47	18.8	.02429	8.333	41.16	.1200	47.2	565.8	613.0	.1069	1.3273	4
5	34.27	19.6	0.02432	8.150	41.11	0.1227	48.3	565.0	613.3	0.1092	1.3253	5
6	35.09	20.4	.02435	7.971	41.07	.1254	49.4	564.2	613.6	.1115	1.3234	6
7	35.92	21.2	.02438	7.798	41.02	.1282	50.5	563.4	613.9	.1138	1.3214	7
8	36.77	22.1	.02440	7.629	40.98	.1311	51.6	562.7	614.3	.1162	1.3195	8
9	37.63	22.9	.02443	7.464	40.93	.1340	52.7	561.9	614.6	.1185	1.3176	9
10	38.51	23.8	0.02446	7.304	40.89	0.1369	53.8	561.1	614.9	0.1208	1.3157	10
11	39.40	24.7	.02449	7.148	40.84	.1399	54.9	560.3	615.2	.1231	1.3137	11
12	40.31	25.6	.02451	6.996	40.80	.1429	56.0	559.5	615.5	.1254	1.3118	12
13	41.24	26.5	.02454	6.847	40.75	.1460	57.1	558.7	615.8	.1277	1.3099	13
14	42.18	27.5	.02457	6.703	40.71	.1492	58.2	557.9	616.1	.1300	1.3081	14
15	43.14	28.4	0.02460	6.562	40.66	0.1524	59.2	557.1	616.3	0.1323	1.3062	15
16	44.12	29.4	.02463	6.425	40.62	.1556	60.3	556.3	616.6	.1346	1.3043	16
17	45.12	30.4	.02466	6.291	40.57	.1590	61.4	555.5	616.9	.1369	1.3025	17
18	46.13	31.4	.02468	6.161	40.52	.1623	62.5	554.7	617.2	.1392	1.3006	18
19	47.16	32.5	.02471	6.034	40.48	0.1657	63.6	553.9	617.5	0.1415	1.2988	19

* Inches of mercury below one standard atmosphere.

Figure 3-2 R-717 Properties of Liquid & Saturated Vapor
-45°F to 19°F

TEMP F	PRESSURE lb per sq in		VOLUME cu ft per lb		DENSITY lb per cu ft		ENTHALPY ** Btu per lb			ENTROPY ** Btu per (lb) (^{O}R)		TEMP F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
20	48.21	33.5	0.02474	5.910	40.43	0.1692	64.7	553.1	617.8	0.1437	1.2969	20
21	49.28	34.6	.02477	5.789	40.38	.1728	65.8	552.2	618.0	.1460	1.2951	21
22	50.36	35.7	.02480	5.671	40.34	.1763	66.9	551.4	618.3	.1483	1.2933	22
23	51.47	36.8	.02483	5.556	40.29	.1800	68.0	550.6	618.6	.1505	1.2915	23
24	52.59	37.9	.02485	5.443	40.25	.1837	69.1	549.8	618.9	.1528	1.2897	24
25	53.73	39.0	0.02488	5.334	40.20	0.1875	70.2	548.9	619.1	0.1551	1.2879	25
26	54.90	40.2	.02491	5.227	40.15	.1913	71.3	548.1	619.4	.1573	1.2861	26
27	56.08	41.4	.02494	5.123	40.11	.1952	72.4	547.3	619.7	.1596	1.2843	27
28	57.28	42.6	.02497	5.021	40.06	.1992	73.5	546.4	619.9	.1618	1.2825	28
29	58.50	43.8	.02500	4.922	40.01	.2032	74.6	545.6	620.2	.1641	1.2808	29
30	59.74	45.0	0.02503	4.825	39.96	0.2073	75.7	544.8	620.5	0.1663	1.2790	30
31	61.00	46.3	.02506	4.730	39.92	.2114	76.8	543.9	620.7	.1686	1.2773	31
32	62.29	47.6	.02509	4.637	39.87	.2156	77.9	543.1	621.0	.1708	1.2755	32
33	63.59	48.9	.02512	4.547	39.82	.2199	79.0	542.2	621.2	.1730	1.2738	33
34	64.91	50.2	.02515	4.459	39.77	.2243	80.1	541.4	621.5	.1753	1.2721	34
35	66.26	51.6	0.02518	4.373	39.72	0.2287	81.2	540.5	621.7	0.1775	1.2704	35
36	67.63	52.9	.02521	4.289	39.68	.2332	82.3	539.7	622.0	.1797	1.2686	36
37	69.02	54.3	.02524	4.207	39.63	.2377	83.4	538.8	622.2	.1819	1.2669	37
38	70.43	55.7	.02527	4.126	39.59	.2423	84.6	537.9	622.5	.1841	1.2652	38
39	71.87	57.2	.02530	4.048	39.54	.2470	85.7	537.0	622.7	.1863	1.2635	39
40	73.32	58.6	0.02533	3.971	39.49	0.2518	86.8	536.2	623.0	0.1885	1.2618	40
41	74.80	60.1	.02536	3.897	39.44	.2566	87.9	535.3	623.2	.1908	1.2602	41
42	76.31	61.6	.02539	3.823	39.39	.2616	89.0	534.4	623.4	.1930	1.2585	42
43	77.83	63.1	.02542	3.752	39.34	.2665	90.1	533.6	623.7	.1952	1.2568	43
44	79.38	64.7	.02545	3.682	39.29	.2716	91.2	532.7	623.9	.1974	1.2552	44
45	80.96	66.3	0.02548	3.614	39.24	0.2767	92.3	531.8	624.1	0.1996	1.2535	45
46	82.55	67.9	.02551	3.547	39.20	.2819	93.5	530.9	624.4	.2018	1.2519	46
47	84.18	69.5	.02554	3.481	39.15	.2872	94.6	530.0	624.6	.2040	1.2502	47
48	85.82	71.1	.02557	3.418	39.10	.2926	95.7	529.1	624.8	.2062	1.2486	48
49	87.49	72.8	.02560	3.355	39.05	.2981	96.8	528.2	625.0	.2083	1.2469	49
50	89.19	74.5	0.02564	3.294	39.00	0.3036	97.9	527.3	625.2	0.2105	1.2453	50
51	90.91	76.2	.02567	3.234	38.95	.3092	99.1	526.4	625.5	.2127	1.2437	51
52	92.66	78.0	.02570	3.176	38.90	.3149	100.2	525.5	625.7	.2149	1.2421	52
53	94.43	79.7	.07574	3.119	38.85	.3207	101.3	524.6	625.9	.2171	1.2405	53
54	96.23	81.5	.02577	3.063	38.80	.3265	102.4	523.7	626.1	.2192	1.2389	54
55	98.06	83.4	0.02581	3.008	38.75	0.3325	103.5	522.8	626.3	0.2214	1.2373	55
56	99.91	85.2	.02584	2.954	38.70	.3385	104.7	521.8	626.5	.2236	1.2357	56
57	101.8	87.1	.02587	2.902	38.65	.3446	105.8	520.9	626.7	.2257	1.2341	57
58	103.7	89.0	.02590	2.851	38.60	.3508	106.9	520.0	626.9	.2279	1.2325	58
59	105.6	90.9	.02594	2.800	38.55	.3571	108.1	519.0	627.1	.2301	1.2310	59
60	107.6	92.9	0.02597	2.751	38.50	0.3635	109.2	518.1	627.3	0.2322	1.2294	60
61	109.6	94.9	.02600	2.703	38.45	.3700	110.3	517.2	627.5	.2344	1.2278	61
62	111.6	96.9	.02604	2.656	38.40	.3765	111.5	516.2	627.7	.2365	1.2262	62
63	113.6	98.9	.02607	2.610	38.35	.3832	112.6	515.3	627.9	.2387	1.2247	63
64	115.7	101.0	.02611	2.565	38.30	.3899	113.7	514.3	628.0	.2408	1.2231	64
65	117.8	103.1	0.02614	2.520	38.25	0.3968	114.8	513.4	628.2	0.2430	1.2216	65
66	120.0	105.3	.02618	2.477	38.20	.4037	116.0	512.4	628.4	.2451	1.2201	66
67	122.1	107.4	.02621	2.435	38.15	.4108	117.1	511.5	628.6	.2473	1.2186	67
68	124.3	109.6	.02625	2.393	38.10	.4179	118.3	510.5	628.8	.2494	1.2170	68
69	126.5	111.8	.02628	2.352	38.05	.4251	119.4	509.5	628.9	.2515	1.2155	69
70	128.8	114.1	0.02632	2.312	38.00	0.4325	120.5	508.6	629.1	0.2537	1.2140	70
71	131.1	116.4	.02636	2.273	37.95	.4399	121.7	507.6	629.3	.2558	1.2125	71
72	133.4	118.7	.02639	2.235	37.90	.4474	122.8	506.6	629.4	.2579	1.2110	72
73	135.7	121.0	.02643	2.197	37.85	.4551	124.0	505.6	629.6	.2601	1.2095	73
74	138.1	123.4	.02647	2.161	37.79	.4628	125.1	504.7	629.8	.2622	1.2080	74
75	140.5	125.8	0.02650	2.125	37.74	0.4707	126.2	503.7	629.9	0.2643	1.2065	75
76	143.0	128.3	.02654	2.089	37.69	.4786	127.4	502.7	630.1	.2664	1.2050	76
77	145.4	130.7	.02657	2.055	37.64	.4867	128.5	501.7	630.2	.2685	1.2035	77
78	147.9	133.2	.02661	2.021	37.58	.4949	129.7	500.7	630.4	.2706	1.2020	78
79	150.5	135.8	.02665	1.988	37.53	.5031	130.8	499.7	630.5	.2728	1.2006	79
80	153.0	138.3	0.20668	1.955	37.48	0.5115	132.0	498.7	630.7	0.2749	1.1991	80
81	155.6	140.9	.02672	1.923	37.43	.5200	133.1	497.7	630.8	.2769	1.1976	81
82	158.3	143.6	.02676	1.892	37.37	.5287	134.3	496.7	631.0	.2791	1.1962	82
83	161.0	146.3	.02680	1.861	37.32	.5374	135.4	495.7	631.1	.2812	1.1947	83
84	163.7	149.0	.02683	1.831	37.26	0.5462	136.6	494.7	631.3	0.2833	1.1933	84

Figure 3-3 R-717 Properties of Liquid & Saturated Vapor
20°F to 84°F

TEMP F	PRESSURE lb per sq in		VOLUME cu ft per lb		DENSITY lb per cu ft		ENTHALPY ** Btu per lb			ENTROPY ** Btu per (lb) (^{o}R)		TEMP F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
85	166.4	151.7	0.02687	1.801	37.21	0.5552	137.8	493.6	631.4	0.2854	1.1918	85
86	169.2	154.5	.02691	1.772	37.16	.5643	138.9	492.6	631.5	.2875	1.1904	86
87	172.0	157.3	.02695	1.744	37.10	.5735	140.1	491.6	631.7	.2895	1.1889	87
88	174.8	160.1	.02699	1.716	37.05	.5828	141.2	490.6	631.8	.2917	1.1875	88
89	177.7	163.0	.02703	1.688	36.99	.5923	142.4	489.5	631.9	.2937	1.1860	89
90	180.6	165.9	0.02707	1.661	36.94	0.6019	143.5	488.5	632.0	0.2958	1.1846	90
91	183.6	168.9	.02711	1.635	36.89	.6116	144.7	487.4	632.1	.2979	1.1832	91
92	186.6	171.9	.02715	1.609	36.83	.6214	145.8	486.4	632.2	.3000	1.1818	92
93	189.6	174.9	.02719	1.584	36.78	.6314	147.0	485.3	632.3	.3021	1.1804	93
94	192.7	178.0	.02723	1.559	36.72	.6415	148.2	484.3	632.5	.3041	1.1789	94
95	195.8	181.1	0.02727	1.534	36.67	0.6517	149.4	483.2	632.6	0.3062	1.1775	95
96	198.9	184.2	.02731	1.510	36.62	.6620	150.5	482.1	632.6	.3083	1.1761	96
97	202.1	187.4	.02735	1.487	36.56	.6725	151.7	481.1	632.8	.3104	1.1747	97
98	205.3	190.6	.02739	1.464	36.51	.6832	152.9	480.0	632.9	.3125	1.1733	98
99	208.6	193.9	.02743	1.441	36.45	.6939	154.0	478.9	632.9	.3145	1.1719	99
100	211.9	197.2	0.02748	1.419	36.40	0.7048	155.2	477.8	633.0	0.3166	1.1705	100
101	215.2	200.5	.02752	1.397	36.34	.7159	156.4	476.7	633.1	.3187	1.1691	101
102	218.6	203.9	.02756	1.375	36.29	.7270	157.6	475.6	633.2	.3207	1.1677	102
103	222.0	207.3	.02760	1.354	36.23	.7384	158.7	474.6	633.3	.3228	1.1663	103
104	225.4	210.7	.02764	1.334	36.18	.7498	159.9	473.5	633.4	.3248	1.1649	104
105	228.9	214.2	0.02769	1.313	36.12	0.7615	161.1	472.3	633.4	0.3269	1.1635	105
106	232.5	217.8	.02773	1.293	36.07	.7732	162.3	471.2	633.5	.3289	1.1621	106
107	236.0	221.3	.20778	1.274	36.01	.7852	163.5	470.1	633.6	.3310	1.1607	107
108	239.7	225.0	.20782	1.254	35.96	.7972	164.6	469.0	633.6	.3330	1.1593	108
109	243.3	228.6	.02786	1.235	35.90	.8095	165.8	467.9	633.7	.3351	1.1580	109
110	247.0	232.3	0.02790	1.217	35.84	0.8219	167.0	466.7	633.7	0.3372	1.1566	110
111	250.8	236.1	.02794	1.198	35.79	.8344	168.2	465.6	633.8	.3392	1.1552	111
112	254.5	239.8	.02799	1.180	35.73	.8471	169.4	464.4	633.8	.3413	1.1538	112
113	258.4	243.7	.02804	1.163	35.67	.8600	170.6	463.3	633.9	.3433	1.1524	113
114	262.2	247.5	.02808	1.145	35.61	.8730	171.8	462.1	633.9	.3453	1.1510	114
115	266.2	251.5	0.02813	1.128	35.55	0.8862	173.0	460.9	633.9	0.3474	1.1497	115
116	270.1	255.4	.02817	1.112	35.50	.8996	174.2	459.8	634.0	.3495	1.1483	116
117	274.1	259.4	.02822	1.095	35.44	.9132	175.4	458.6	634.0	.3515	1.1469	117
118	278.2	263.5	.02826	1.079	35.38	.9269	176.6	457.4	634.0	.3535	1.1455	118
119	282.3	267.6	.02831	1.063	35.32	.9408	177.8	456.2	634.0	.3556	1.1441	119
120	286.4	271.7	0.02836	1.047	35.26	0.9549	179.0	455.0	634.0	0.3576	1.1427	120
121	290.6	275.9	.02840	1.032	35.20	0.9692	180.2	453.8	634.0	.3597	1.1414	121
122	294.8	280.1	.02845	1.017	35.14	0.9837	181.4	452.6	634.0	.3618	1.1400	122
123	299.1	284.4	.02850	1.002	35.08	0.9983	182.6	451.4	634.0	.3638	1.1386	123
124	303.4	288.7	.02855	0.987	35.02	1.0132	183.9	450.1	634.0	.3659	1.1372	124
125	307.8	293.1	0.02860	0.973	34.96	1.028	185.1	448.9	634.0	0.3679	1.1358	125

Figure 3-4 R-717 Properties of Liquid & Saturated Vapor
85℉ to 125℉

Temp F	Abs Pressure 5.0 psi Gage Pressure 19.8 in. Vac (Sat'n Temp -63.11 F)			Abs Pressure 6.0 psi Gage Pressure 17.7 in. Vac (Sat'n Temp -57.64 F)			Abs Pressure 7.0 psi Gage Pressure 15.7 in. Vac (Sat'n Temp -52.88 F)			Abs Pressure 8.0 psi Gage Pressure 13.6 in. Vac (Sat'n Temp -48.64 F)		
t	v	h	s	v	h	s	v	h	s	v	h	s
(Sat'n)	(49.31)	(588.3)	(1.4857)	(41.59)	(590.6)	(1.4703)	(36.01)	(592.5)	(1.4574)	(31.79)	(594.2)	(1.4462)
- 50	51.05	595.2	1.5025	42.44	594.6	1.4803	36.29	594.0	1.4611	....	....	....
- 40	52.36	600.3	.5149	43.55	599.8	.4928	37.25	599.3	.4739	32.52	598.8	1.4573
- 30	53.67	605.4	.5269	44.64	604.9	.5049	38.19	604.5	.4861	33.36	604.1	.4697
- 20	54.97	610.4	.5385	45.73	610.0	.5166	39.13	609.6	.4979	34.19	609.3	.4816
- 10	56.26	615.4	.5498	46.82	615.1	.5280	40.07	614.7	.5094	35.01	614.4	.4932
0	57.55	620.4	1.5608	47.90	620.1	1.5391	41.00	619.8	1.5206	35.83	619.5	1.5044
10	58.84	625.4	.5716	48.98	625.2	.5499	41.93	624.9	.5314	36.64	624.6	.5154
20	60.12	630.4	.5821	50.05	630.2	.5605	42.85	629.9	.5421	37.45	629.7	.5261
30	61.41	635.4	.5925	51.12	635.2	.5708	43.77	635.0	.5525	38.26	634.7	.5365
40	62.69	640.4	.6026	52.19	640.2	.5810	44.69	640.0	.5627	39.07	639.8	.5467
50	63.96	645.5	1.6125	53.26	645.2	1.5910	45.61	645.0	1.5727	39.88	644.8	1.5568
60	65.24	650.5	.6223	54.32	650.3	.6008	46.53	650.1	.5825	40.68	649.9	.5666
70	66.51	655.5	.6319	55.39	655.3	.6104	47.44	655.2	.5921	41.48	655.0	.5763
80	67.79	660.6	.6413	56.45	660.4	.6199	48.36	660.2	.6016	42.28	660.1	.5858
90	69.06	665.6	.6506	57.51	665.5	.6292	49.27	665.3	.6110	43.08	665.2	.5952
100	70.33	670.7	1 6598	58.58	670.6	1.6384	50.18	670.4	1.6202	43.88	670.3	1.6044
110	71.60	675.8	.6689	59.64	675.7	.6474	51.09	675.5	.6292	44.68	675.4	.6135
120	72.87	680.9	.6778	60.70	680.8	.6563	52.00	680.7	.6382	45.48	680.5	.6224
130	74.14	686.1	.6865	61.76	685.9	.6651	52.91	685.8	.6470	46.27	685.7	.6312
140	75.41	691.2	.6952	62.82	691.1	.6738	53.82	691.0	.6557	47.07	690.9	.6399
150	76.68	696.4	1.7038	63.87	696.3	1.6824	54.73	696.2	1.6643	47.87	696.1	1.6485
160	77.95	701.6	.7122	64.93	701.5	.6909	55.63	701.4	.6727	48.66	701.3	.6570
170	79.21	706.8	.7206	65.99	706.7	.6992	56.54	706.6	.6811	49.46	706.5	.6654
180	80.48	712.1	1.7289	67.05	712.0	1.7075	57.45	711.9	1.6894	50.25	711.8	1.6737

Temp F	Abs Pressure 9.0 psi Gage Pressure 11.6 in. Vac (Sat'n Temp -44.38 F)			Abs Pressure 10.0 psi Gage Pressure 9.6 in. Vac (Sat'n Temp -41.34 F)			Abs Pressure 11.0 psi Gage Pressure 7.5 in. Vac (Sat'n Temp -38.14 F)			Abs Pressure 12.0 psi Gage Pressure 5.5 in. Vac (Sat'n Temp -35.16 F)		
(Sat'n)	(28.48)	(595.7)	(1.4363)	(25.81)	(597.1)	(1.4276)	(23.61)	(598.3)	(1.4196)	(21.77)	(599.4)	(1.4124)
- 40	28.85	598.3	1.4426	....	....	....	....	....	....	....	....	....
- 30	29.59	603.6	.4551	26.58	603.2	1.4420	24.12	602.7	1.4300	22.07	602.3	1.4190
- 20	30.34	608.9	.4672	27.26	608.5	.4542	24.74	608.1	.4423	22.64	607.7	.4314
- 10	31.07	614.0	.4788	27.92	613.7	.4659	25.35	613.3	.4542	23.20	613.0	.4434
0	31.80	619.2	1.4902	28.58	618.9	1.4773	25.95	618.5	1.4656	23.75	618.2	1.4549
10	32.53	624.3	.5012	29.24	624.0	.4884	26.55	623.7	.4768	24.31	623.4	.4661
20	33.26	629.4	.5119	29.90	629.1	.4992	27.15	628.9	.4876	24.86	628.6	.4770
30	33.98	634.5	.5224	30.55	634.2	.5097	27.74	634.0	.4982	25.41	633.7	.4877
40	34.70	639.5	.5327	31.20	639.3	.5200	28.34	639.1	.5085	25.95	638.9	.4980
50	35.42	644.6	1.5427	31.85	644.4	1.5301	28.93	644.2	1.5187	26.49	644.0	1.5082
60	36.13	649.7	.5526	32.49	649.5	.5400	29.52	649.3	.5286	27.03	649.1	.5182
70	36.85	654.8	.5623	33.14	654.6	.5497	30.10	654.4	.5383	27.57	654.3	.5279
80	37.56	659.9	.5718	33.78	659.7	.5593	30.69	659.6	.5479	28.11	659.4	.5375
90	38.27	665.0	.5812	34.42	664.8	.5687	31.28	664.7	.5573	28.65	664.5	.5470
100	38.98	670.1	1.5904	35.07	670.0	1.5779	31.86	669.8	1.5666	29.19	669.7	1.5562
110	39.70	675.3	.5995	35.71	675.1	.5870	32.44	675.0	.5757	29.72	674.8	.5654
120	40.40	680.4	.6085	36.35	680.3	.5960	33.03	680.1	.5847	30.26	680.0	.5744
130	41.11	685.6	.6173	36.99	685.4	.6049	33.61	685.3	.5936	30.79	685.2	.5833
140	41.82	690.7	.6260	37.62	690.6	.6136	34.19	690.5	.6023	31.33	690.4	.5920
150	42.53	695.9	1.6346	38.26	695.8	1.6222	34.77	695.7	1.6109	31.86	695.6	1.6006
160	43.24	701.2	.6431	38.90	701.1	.6307	35.35	700.9	.6194	32.39	700.8	.6092
170	43.95	706.4	.6515	39.54	706.3	.6391	35.93	706.2	.6278	32.92	706.1	.6176
180	44.65	711.7	1.6598	40.17	711.6	.6474	36.51	711.5	.6362	33.46	711.4	.6259
190	....	....	....	40.81	716.9	.6556	37.09	716.8	.6444	33.99	716.7	.6341
200	....	....	....	41.45	722.2	1.6637	37.67	722.1	1.6525	34.52	722.0	1.6422

Figure 3-4A R-717 Properties of Superheat Vapor

These refrigerant property data are for reference. It is more accurate to use a computer program if available.

This case is to use manufacturer's compressor selection program for compressor selection or ask the compressor manufacturer to make compressor selection and rating if screw computer selection software is not available form the maker.

Specifications and requirements for the refrigeration system:

A single compression screw compressor is used with a shell-and-tube economizer to subcool Ammonia liquid for the evaporator to meet the requirements set by the user.

A suction trap is to be provided before the suction of the compressor because of remote location of the evaporator.

Water cooled oil cooler and pre-lube pump are used for the compressor.

Compressor speed: 2.950 RPM

Cooling load is 575 TR.

CT = 102°F
Condensing pressure = 218.5 Psia

ET = –10°F
Evaporative pressure = 23.7 Psia

Compressor operating conditions:

Superheat inside the Reactor is {60°F – (-10°F)} = 70°F
External piping superheat is 5°F
Total superheat is {70°F + 5°F} = 75°F

Suction pressure drop = 1.4 Psi

Discharge external pressure drop = 0.7 Psi

System Design Logic and Approach:

This is a simple refrigeration system. However, because of the high superheat inside of the reactor (evaporator), it generates two technical problems for the system as the following:

(1) The superheat is occurred inside of the heat exchanger (evaporator), it is not sure that if the internal superheat is to be counted or considered as part of the NRE (Net Refrigeration Effect) for the refrigeration system design or not. The refrigeration system shall be under designed if the superheat is counted as part of the NRE, but actually it is not due to the reactor design and heat load being calculated for the process. See Figure 3-5

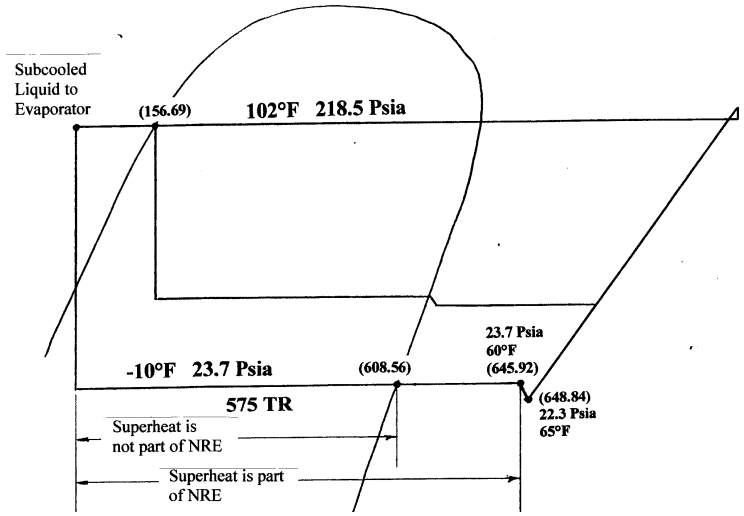

Figure 3-5 P-H Diagram for Cycle Without Quench

(2) The compressor discharge temperature will be too high and the power consumption will be higher as well due to the high suction superheat; Also, high discharge temperature is harmful to the compressor operation. Therefore, it is suggested that the refrigeration system is to equip with a suction gas quench arrangement. This quench arrangement is a desuperheator to cool the high superheat suction gas to a preset temperature point where is close to the saturated suction temperature.

Because the user is unable to confirm and clarify the reactor design and the process heat load calculation for the reactor, for comparison purpose, the refrigeration system design is to evaluate four options which are based on four possible scenarios as the following:

Cogitation	System Description
Option-1	Internal superheat is considered part of NRE, but no suction gas quench
Option-2	Internal superheat is not considered part of NRE, no suction gas quench
Option-3	Internal superheat is considered part of NRE and system is to be equipped with suction gas quench
Option-4	Internal superheat is not considered part of NRE and system is to be equipped with suction gas quench

System Option Evaluations and Cogitation:

Option-1: The internal superheat is counted as part of the NRE.

The P-H diagram for the refrigeration system for Option-1 is shown in Figure 3-6.

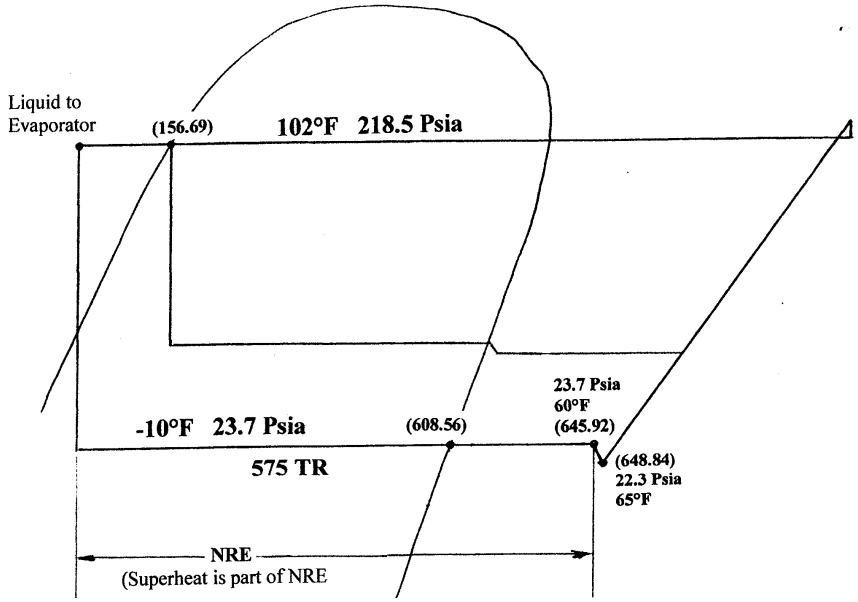

Figure 3-6 P-H Diagram for Refrigeration System Option-1

The data which are required for the compressor manufacturer to make the compressor selection are as the following:

Refrigerant:	R-717
Capacity:	575 TR
Economizing:	Yes, Shell-and-tube liquid subcooling
Condensing temperature:	102°F
Condensing pressure:	218.5 Psia
Evaporative temperature:	–10°F
Evaporative pressure:	23.7 Psia
Suction temperature:	65°F
Superheat contributing to NRE:	70°F
External piping pressure drop:	1.4 Psi
Discharge external pressure drop:	0.7 Psi
Compressor speed:	2,950 RPM

Oil pump:	Pre-lube
Oil cooling:	Water cooled
Discharge and suction valves:	Maker's Standard

The compressor selected for the operating conditions for system Option-1 is as the following:

Capacity:	575 TR
Compressor size:	RW-676 with shell-and-tube economizer
Power consumption:	1,234.2 BHP
Suction mass flow:	201.4 Lbs/Min
Oil cooling heat removal:	2,408,100 Btu/Hr
Subcooled liquid to evaporator:	29.1°F

Option-2: The internal superheat in not counted as part of the NRE.

The P-H diagram for the refrigeration system for Option-1 is shown in Figure 3-7.

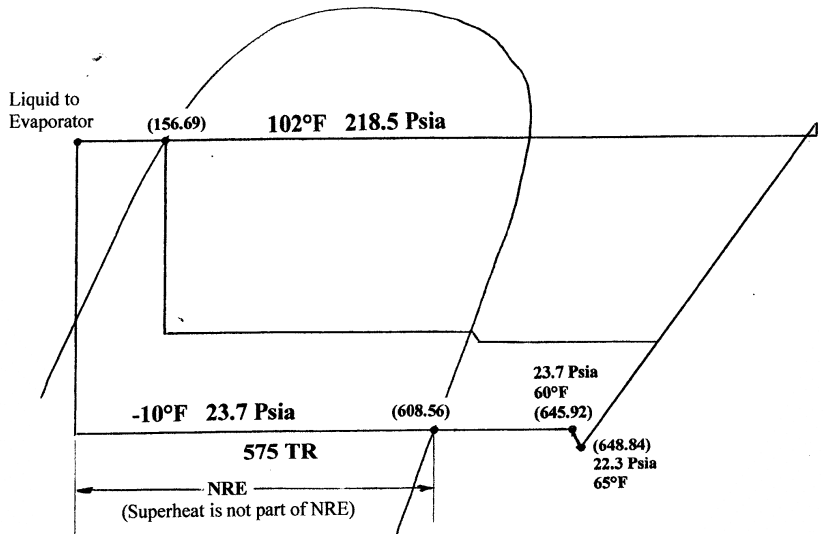

Figure 3-7 P-H Diagram for Refrigeration System Option-2

The data which are required for the compressor manufacturer to make the compressor selection are as the following:

Refrigerant:	R-717
Capacity:	575 TR

Economizing:	Yes, Shell-and-tube liquid subcooling
Condensing temperature:	102°F
Condensing pressure:	218.5 Psia
Evaporative temperature:	–10°F
Evaporative pressure:	23.7 Psia
Suction temperature:	65°F
Superheat contributing to NRE:	0°F
External piping pressure drop:	1.4 Psi
Discharge external pressure drop:	0.7 Psi
Compressor speed:	2,950 RPM
Oil pump:	Pre-lube
Oil cooling:	Water cooled
Discharge and suction valves:	Maker's Standard

The compressor selected for the operating conditions for system Option-1 is as the following:

Capacity:	575 TR
Compressor size:	RW-856 with shell-and-tube economizer
Power consumption:	1,418.5 BHP
Suction mass flow:	215.1 Lbs/Min
Oil cooling heat removal:	2,892,100 Btu/Hr
Subcooled liquid to evaporator:	28.4°F

Note: The compressor is smaller and the power consumption is also smaller if the superheat is considered as part of the NRE due to larger NRE. However, the compressor selected based on this assumption might just be under sized for the process load, in case the reactor heat exchanger design and the process load originally estimated did not include this extra cooling by the superheated gas.

Option-3 System With Quench & Superheat Is Part of the NRE:

This Option is to quench (desuperheat) the superheated gas to a point which is close to dew point at the suction pressure of 22.3 Psia, say to have a 5°F superheat, then, the refrigeration cycle for this system is as shown in Figure 3-8; the compressor suction conditions for the compressor are as the following:

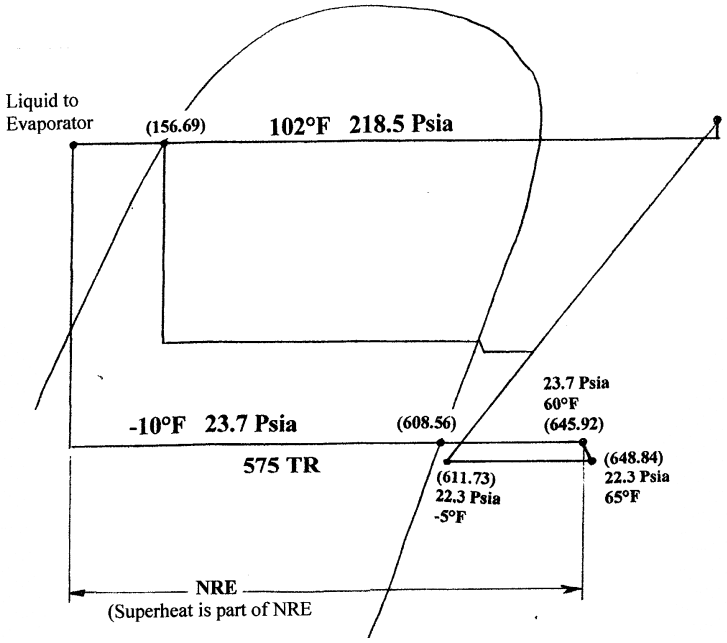

Figure 3-8 Refrigeration System P-H Diagram

Suction operating conditions for the compressor are now as the following:

Suction temperature =	-5°F
Suction pressure =	22.3 Psia

Reference Case:

This Reference Case is to find out the enthalpy and temperature of the liquid leaving the subcooler. This Reference Case is to assume the same CT, ET and TR for the Option-3 and Option-4 except without the abnormal superheat and the suction conditions are:

Suction temperature =	*-5°F*
Suction pressure =	*22.3 Psia*

The P-H diagram for the refrigeration system for this Reference Case is shown as the Figure 3-9:

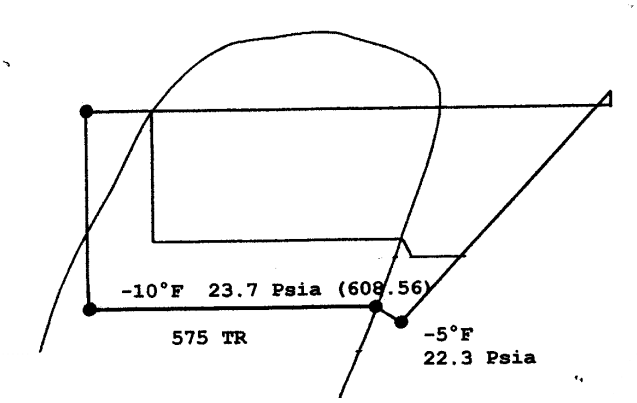

Figure 3-9 Refrigeration Cycle for Reference Case

The purpose of this Reference Case is to find out the temperature and the enthalpy leaving the subcooler.

The data for computer selection input:

Refrigerant:	*R-717*
Capacity:	*575 TR*
Economizing:	*Yes, Shell-and-tube liquid subcooling*
Condensing temperature:	*102°F*
Evaporative temperature:	*-10°F*
Suction superheat:	*5°F*
Superheat contributing to NRE:	*0°F*
External piping pressure drop:	*1.4 Psi*
Discharge external pressure drop:	*0.7 Psi*
Compressor speed:	*2,950 RPM*
Oil pump:	*Pre-lube*
Oil cooling:	*Water cooled*
Discharge and suction valves:	*Maker's Standard*

The compressor selected for the operating conditions for the Reference Case is as the following:

Capacity:	*575 TR*
Compressor size:	*RW-676 with shell-and-tube economizer*
Power consumption:	*1,191 BHP*
Suction mass flow:	*217.5 Lbs/Min*
Oil cooling heat removal:	*1,897,600 Btu/Hr*
Subcooled liquid to evaporator:	*33.7°F*

The subcooled liquid to evaporator is ***33.7°F. the enthalpy for this point is 79.88 Btu/Lb.***

The P-H Diagram for the refrigeration system Option-3 is shown in Figure 3-10.

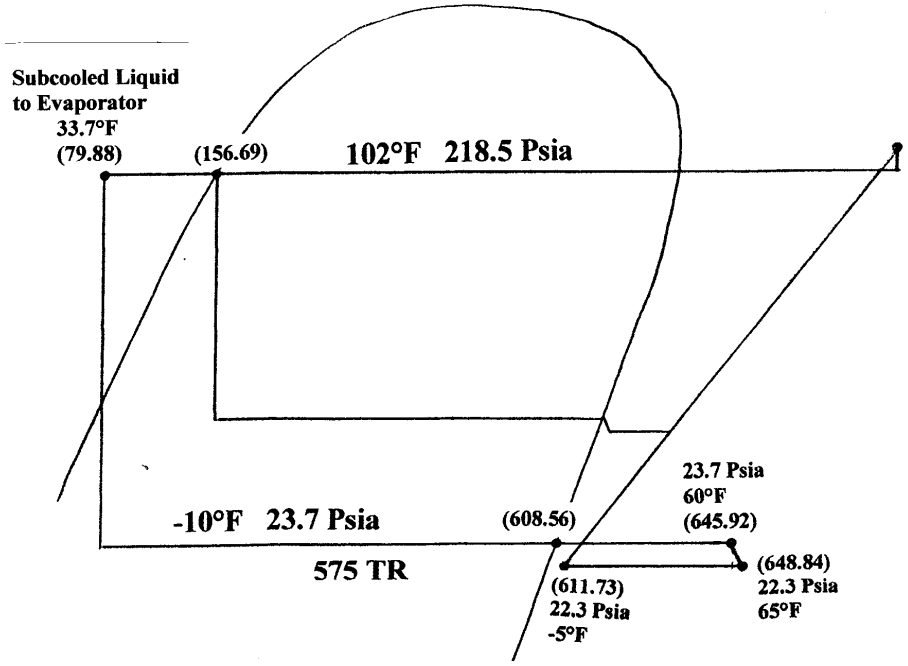

Figure 3-10 P-H Diagram for Refrigeration System Option-3

From the Figure 3-10, it is noted that the liquid leaving condenser is subcooled by the economizer from 102°F to 33.7°F; the superheated gas at 22.3 Psia is cooled by the liquid from 65 to -5°F. The corresponding refrigerant flow diagram for this system is shown in Figure 3-11.

Figure 3-12 shows the flooded type desuperheator-suction trap; the superheated gas returns from evaporator, cooled by the liquid inside the desuperheator-suction trap; the superheated gas is cooled down to almost saturated under suction pressure of 22.3 Psia. The liquid level inside the desuperheator-suction trap is maintained by a liquid level control valve and the liquid is from the economizer. The liquid for the desuperheating process is evaporated and returns to the compressor suction together with the main suction gas. The desuperheating process is therefore completed.

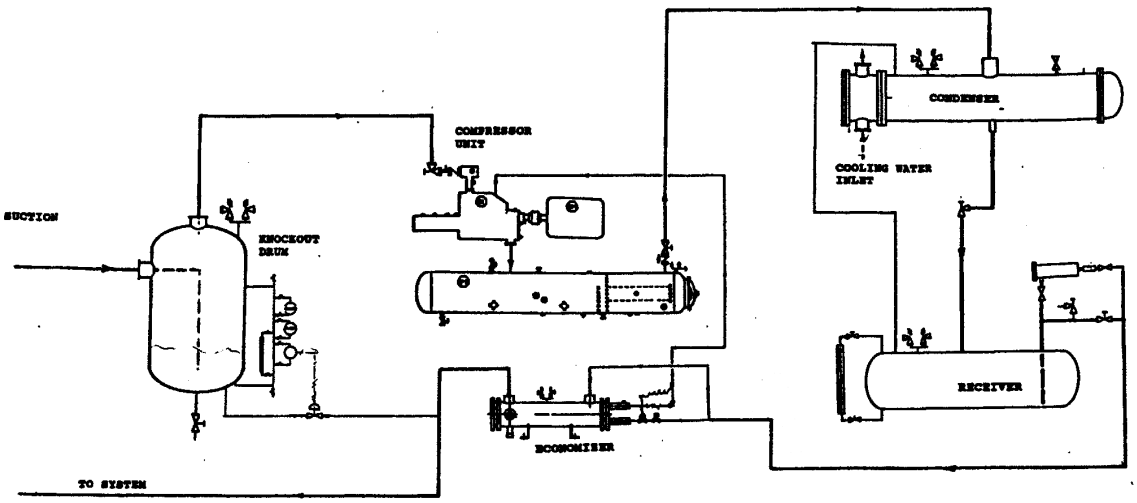

Figure 3-11 Refrigerant Flow Diagram for System Option-3

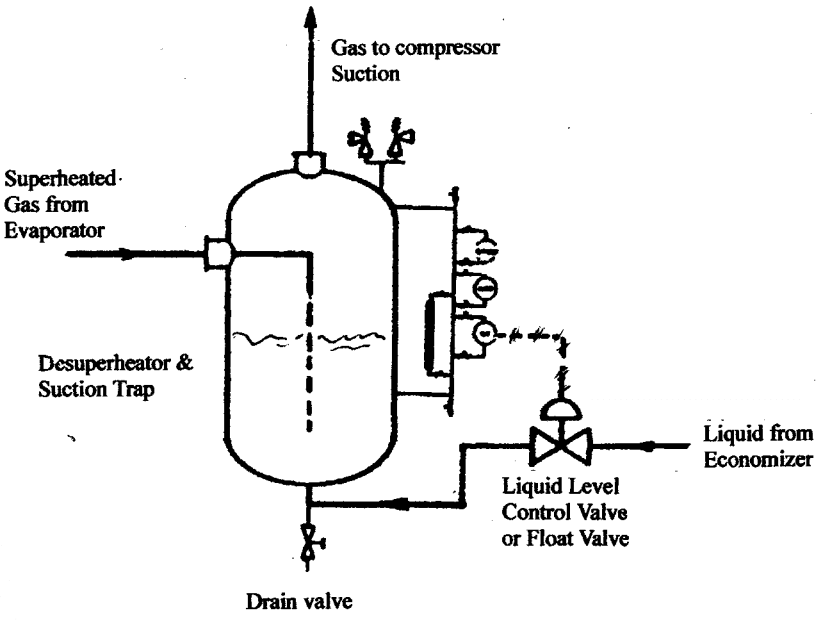

Figure 3-12 Flooded Type Desuperheator-Suction Trap

Compressor selection and 33.7°F liquid verification:

Refrigerant flow calculation:

FLOW(1) is the refrigerant flow from the system:

Suction condition for the compressor: -5°F
22.3 Psia

Superheat is part of the NRE
Therefore:

NRE = 645.92 – 79.88 = 566.04 Btu/Lb

Refrigeration Load = 575 TR

$$\text{Suction Flow, Reactor} = \frac{200}{\text{NRE}} \times 575$$

$$= \frac{200}{566.04} \times 575$$

$$= 203.17 \text{ Lbs/Min.}$$

FLOW(1) = 203.17 Lbs/Min.

FLOW(2) = Liquid needed to quench the superheated gas from 65°F to -5°F.

The superheated gas is to be quenched back to saturated condition.
Assuming suction temperature to compressor is –5°F

Desuperheating load = 203.17 x (648.84 – 611.73)

= 7,539.64 Btu/Min

$$\text{Liquid required for desuperheating} = \frac{200}{608.56 - 79.88} \times \frac{7{,}539.64}{200}$$

= 14.26 Lbs/Min

FLOW(2) = 14.26 Lbs/Min

Total flow for compressor suction = FLOW(1) + FLOW(2)

= 203.17 + 14.26

= 217.39 Lbs/Min

Input suction flow of 217.39 Lbs/Min
Suction condition for the compressor: -5°F
22.3 Psia

The data for computer selection input:

Refrigerant:	R-717
Refrigerant flow:	217.39 Lbs/Min
Economizing:	Yes, Shell-and-tube liquid subcooling
Condensing temperature:	102°F
Evaporative temperature:	-10°F
Suction superheat:	5°F
Superheat contributing to NRE:	0°F
External piping pressure drop:	1.4 Psi
Discharge external pressure drop:	0.7 Psi
Compressor speed:	2,950 RPM
Oil pump:	Pre-lube
Oil cooling:	Water cooled
Discharge and suction valves:	Maker's Standard

The compressor selected for the operating conditions for the Option-3 for refrigerant flow of 217.39 Lbs/Min is as the following:

Equivalent TR:	575 TR
Compressor size:	RW-676 with shell-and-tube economizer
Power consumption:	1,191 BHP
Suction mass flow:	217.5 Lbs/Min
Oil cooling heat removal:	1,897,100 Btu/Hr
Subcooled liquid to evaporator:	33.7°F

It verifies the subcooled liquid to evaporator of 33.7°F which is the temperature assumed for the flow calculation.

From this Option-3, if the superheat is counted as part of the NRE, the power consumption and the TR are the same as the Reference Case.

Option-4 System With Quench Superheat Is Not part of the NRE:

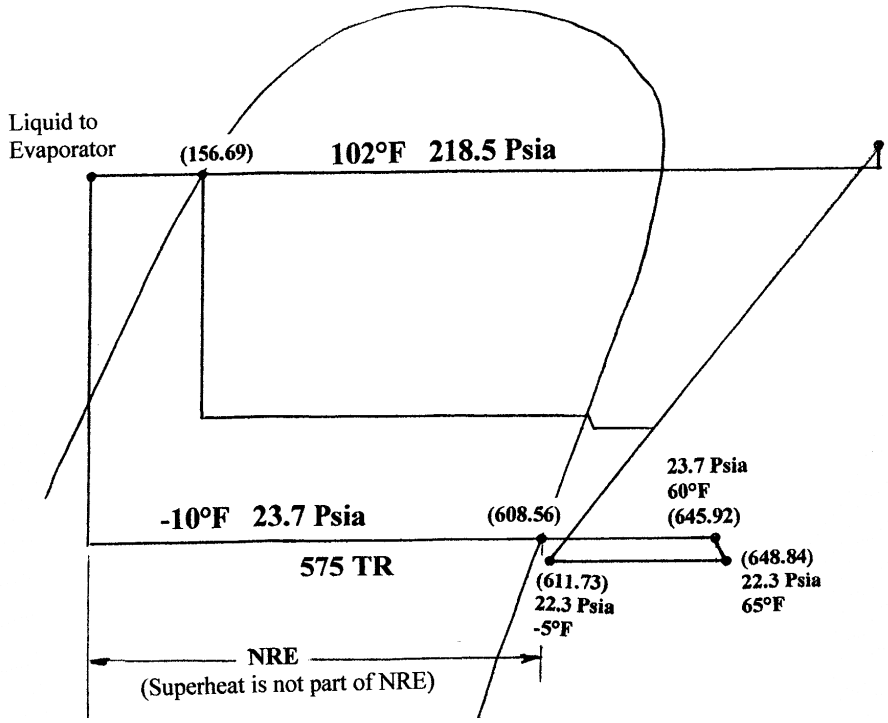

Figure 3-13 P-H Diagram – Superheat Not Part of NRE

This Option is that the superheat is not part of the NRE (New Refrigerant Effect). This will increase the liquid refrigerant flow for the 575 TR and also will increase the liquid refrigerant flow to quench the superheated gas.

The P-H diagram and the Refrigerant Flow Diagram are the same as the Figure 3-10, 3-11 and 3-12. The flow and compressor calculation procedures are the same as Option-3 except that the data are somewhat different.

Suction condition for the compressor: -5°F
22.3 Psia

Superheat is not part of the NRE
Therefore:

NRE = 608.56 – 79.88 = 528.68 Btu/Lb

Refrigeration Load = 575 TR

$$\text{Suction Flow, Reactor} = \frac{200}{\text{NRE}} \times 575$$

$$= \frac{200}{528.68} \times 575$$

$$= 217.52 \text{ Lbs/Min.}$$

FLOW(1) = 217.52 Lbs/Min.

The superheated gas is to be quenched back to saturated condition.
Assuming suction temperature to compressor is –5°F

Desuperheating load = 217.52 x (648.84 – 611.73)

= 8,072.17 Btu/Min

$$\text{Liquid required for desuperheating} = \frac{200}{608.56 - 79.88} \times \frac{8{,}072.17}{200}$$

= 15.27 Lbs/Min

FLOW(2) = 15.27 Lbs/Min

Total flow for compressor suction = FLOW(1) + FLOW(2)

= 217.52 + 15.27

= 232.79 Lbs/Min

The data for computer selection input:

Refrigerant:	R-717
Refrigerant flow:	232.79 Lbs/Min
Economizing:	Yes, Shell-and-tube liquid subcooling

Condensing temperature:	102°F
Evaporative temperature:	-10°F
Suction superheat:	5°F
Superheat contributing to NRE:	0°F
External piping pressure drop:	1.4 Psi
Discharge external pressure drop:	0.7 Psi
Compressor speed:	2,950 RPM
Oil pump:	Pre-lube
Oil cooling:	Water cooled
Discharge and suction valves:	Maker's Standard

The compressor selected for the operating conditions for the Option-4 for refrigerant flow of 232.79 Lbs/Min is as the following:

Equivalent TR:	615 TR
Compressor size:	RW-676 with shell-and-tube economizer
Power consumption:	1,239 BHP
Suction mass flow:	232.8 Lbs/Min
Oil cooling heat removal:	1,932,900 Btu/Hr
Subcooled liquid to evaporator:	34.0°F

The subcooled liquid to evaporator should be 34°F, the 33.7°F assumed for calculation is close enough and it is on safe side.

From this Option-4 if the superheat is not counted as part of the NRE, the power consumption and the equivalent TR are higher.

The final P-H diagram for this Option is shown in Figure 3-14:

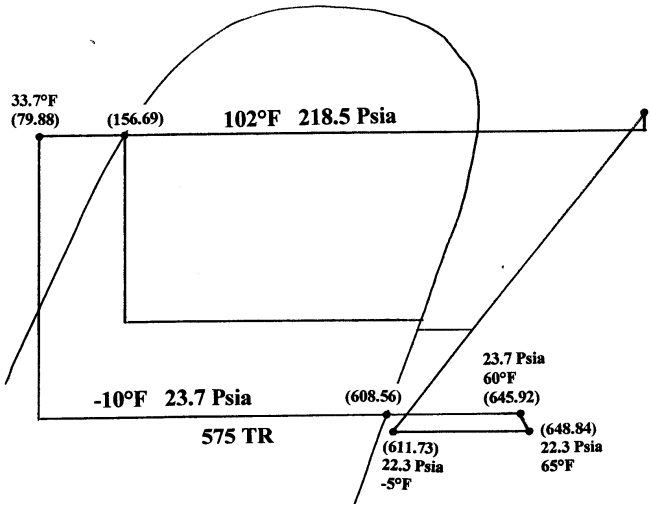

Figure 3-14 P-H Diagram for Refrigeration System Option-4

The refrigerant flow diagram for this Option-4 is shown in Figure 3-15:

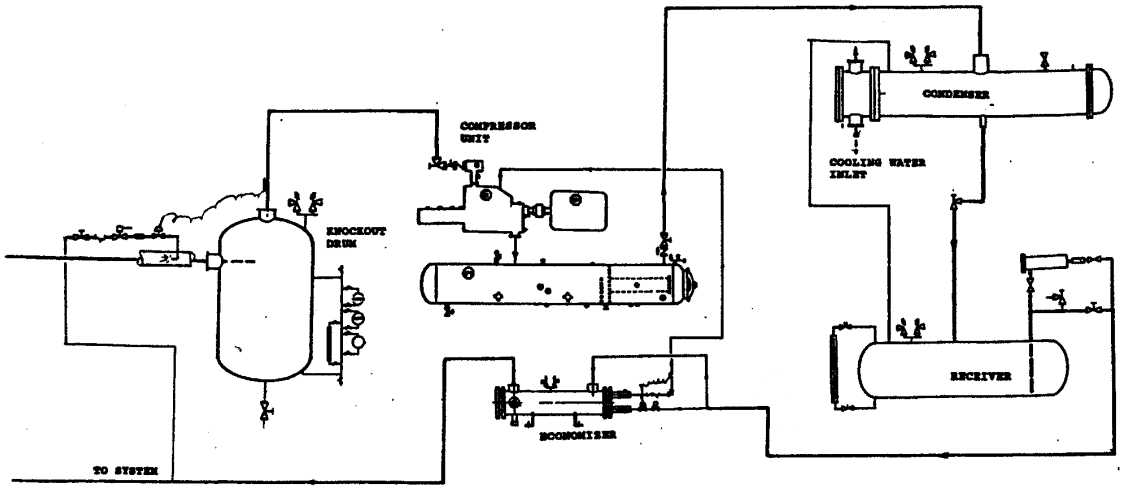

Figure 3-15 Refrigerant Flow Diagram for Refrigeration System Option-4

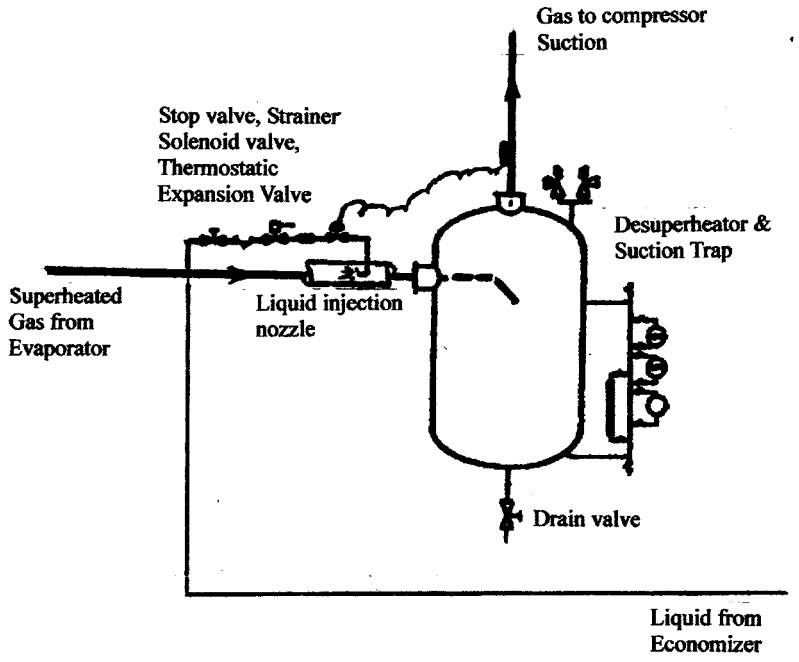

Figure 3-16 Liquid Injection Type Desuperheater-Suction Trap

The desuperheater-suction trap arrangement shown in Figure 3-15 and 3-16 are somewhat differ from Figure 3-11 and 3-12 of Option-3. Figure 3-16 shows the liquid injection type desuperheator-Suction trap; the liquid for desuperheating is injected into a nozzle where it is mixed with the superheated suction gas; the flow of liquid is controlled by a thermostatic expansion valve which injects just enough liquid, the liquid evaporated to cool the superheat gas from evaporator at 65°F down to -5°F. The evaporated gas and the suction gas return to compressor suction.

Comparison:

User Heat Load: 575 TR specified

With liquid subcooling economizer

Case	Compressor Load Equivalent TR	Compressor Suction Flow Lbs/Min	Compressor Size	Compressor Design SHP
Option-1 Superheat Part of NRE No quenching	575 TR	201.4 Lbs/Min	RW-676	1,234 BHP
Option-2 Superheat Not part of NRE No quenching	575 TR	215.1 Lbs/Min	RW-856	1,419 BHP
Reference Case Normal	575 TR	217.5 Lbs/Min	RW-676	1,191 BHP
Option-3 Superheat Part of NRE. Quenching	575 TR	217.3 Lbs/Min	RW-676	1,191 BHP
Option-4 Superheat Not part of NRE. Quenching	615 TR	232.8 Lbs/Min	RW-676	1,239 BHP

Conclusion:

It is obvious that the systems with desuperheating (quenching) are having lower power consumption as compared to Option-1 and Option-2. Option-3 is having the smallest compressor and lowest power consumption for the same user load of 575 TR. The main driving motor for the compressor shall be 1,500 HP which provides enough safety margin for the operation for Option-4. Therefore, Option-3 is to be recommended and proposed for the installation.