KMU220
CHEMICAL ENGINEERING THERMODYNAMICS I

REFRIGERATION AND LIQUIFACTION

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Outline

- ☐ Carnot refrigerator

- ☐ Vapor-compression cycle

- ☐ Choice of refrigerant

- ☐ Absorption refrigeration

- ☐ Heat pump

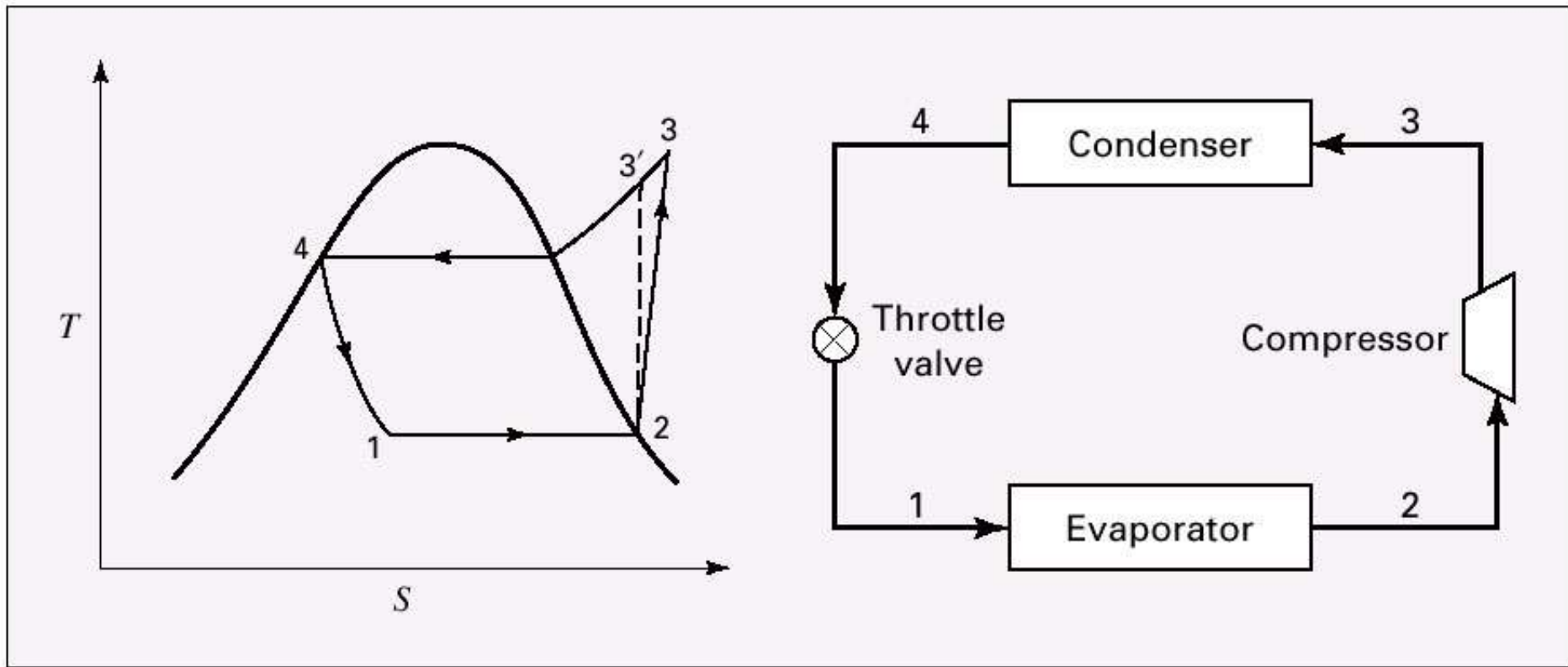- ☐ Liquefaction processes

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Figure 9.1: Vapor-compression refrigeration cycle.

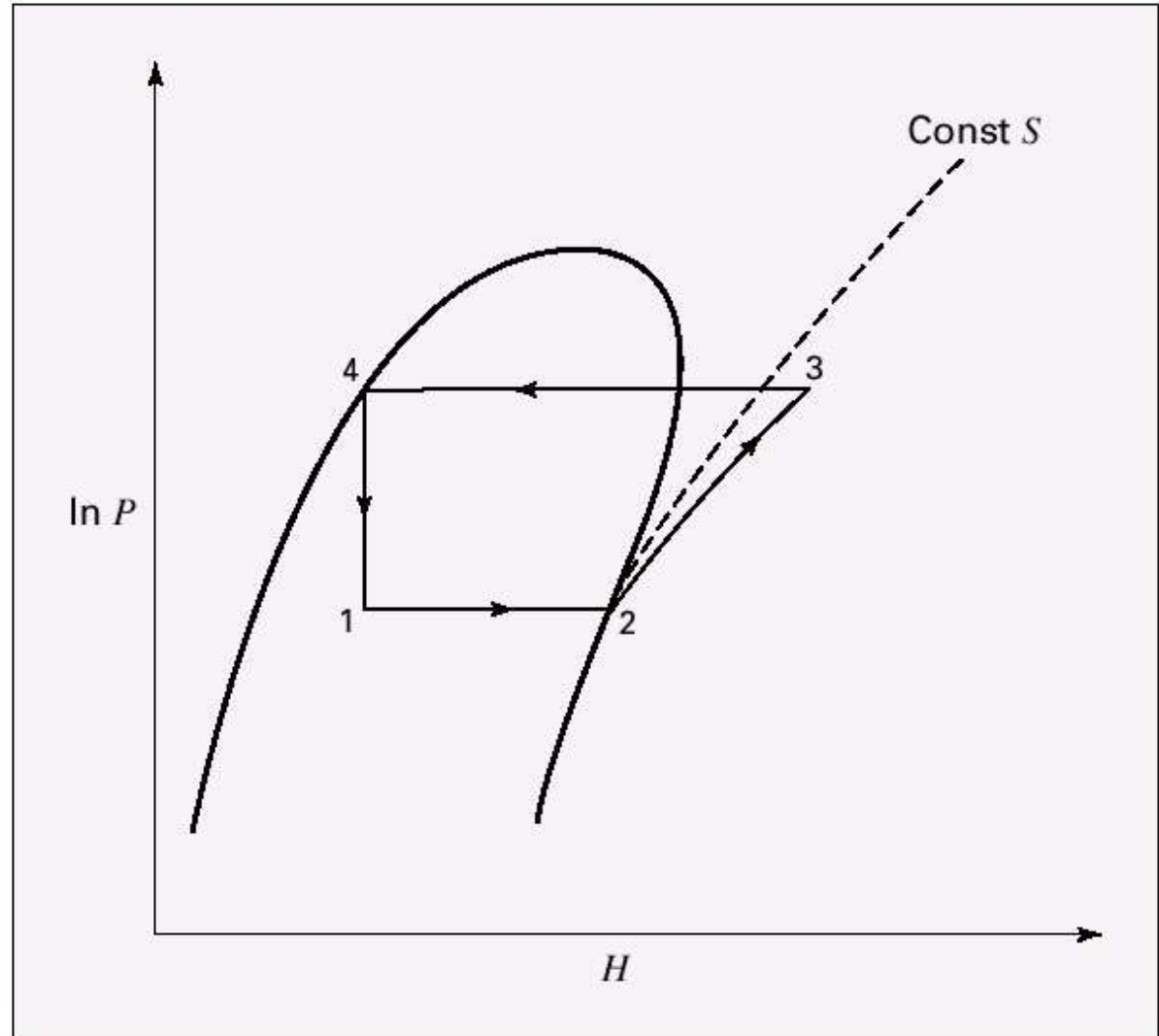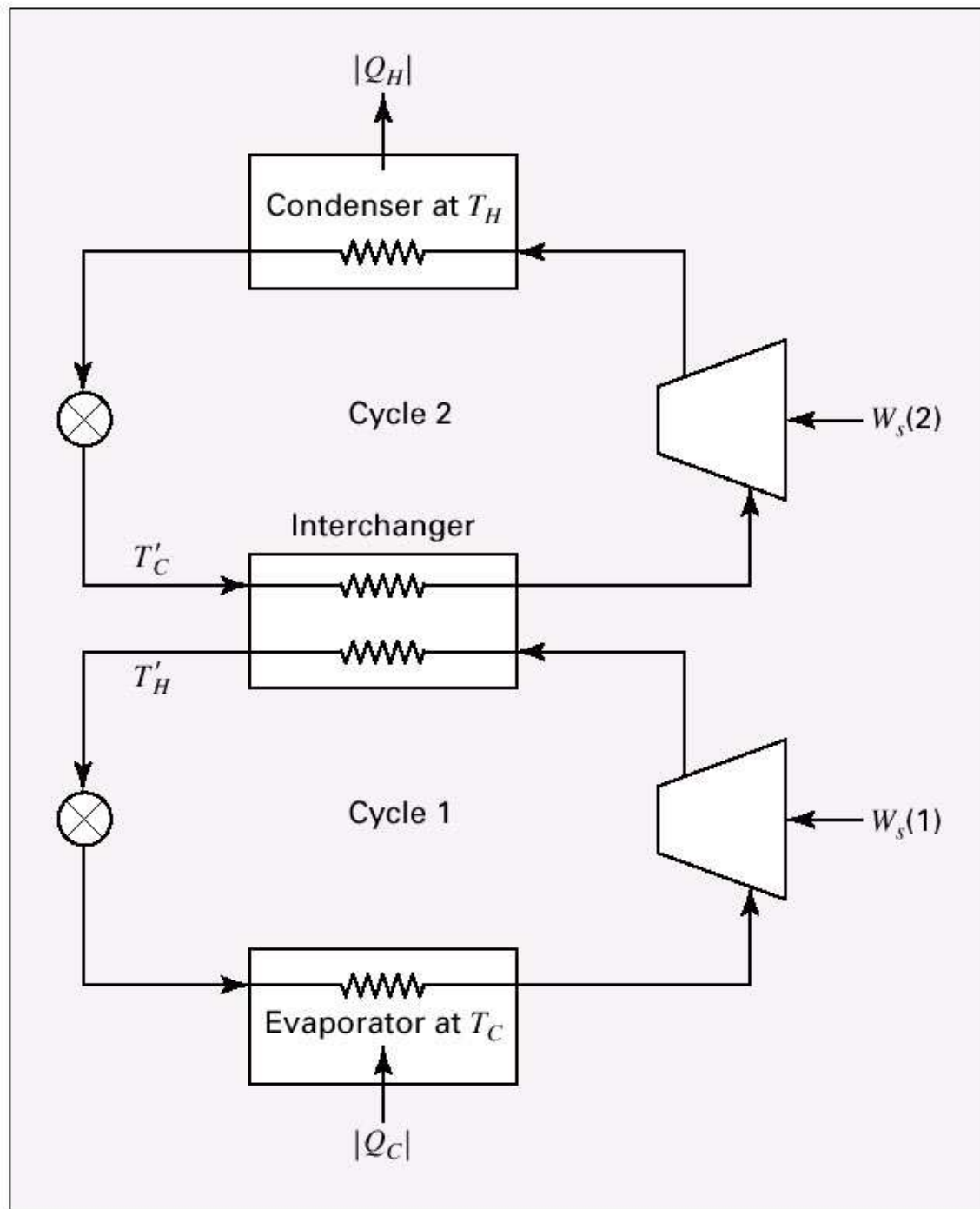**Figure 9.2**: Vapor-compression refrigeration cycle on a PH diagram.

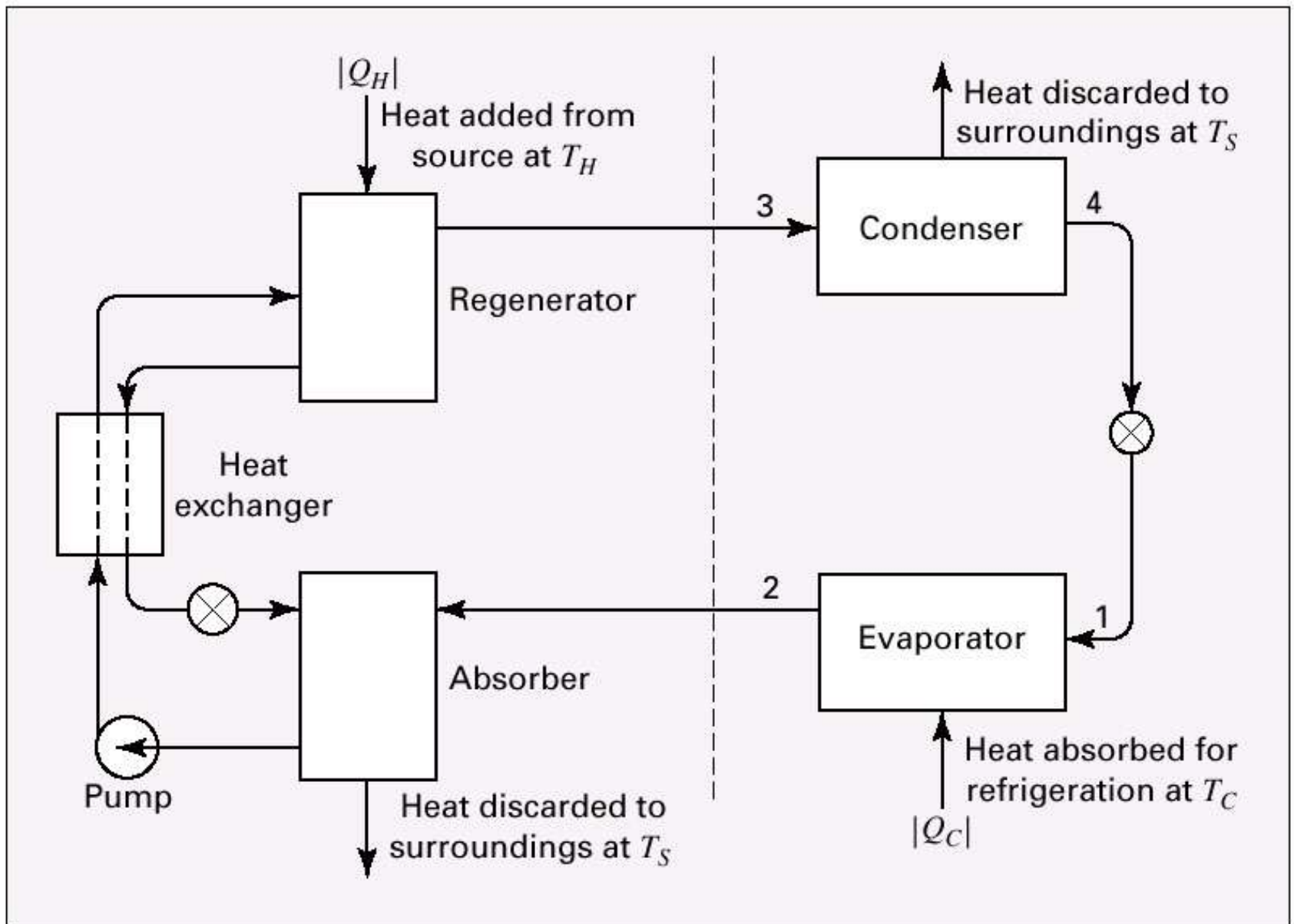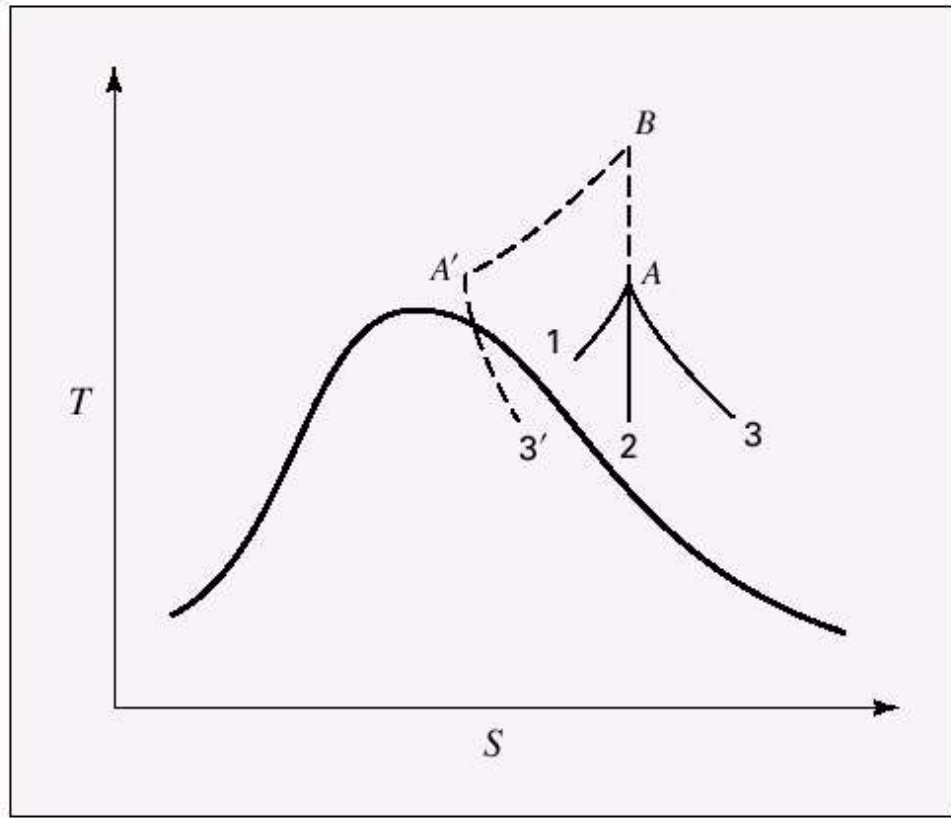**Figure 9.3**: A two-stage cascade refrigeration system.

Figure 9.4: Schematic diagram of an absorption-refrigeration unit.

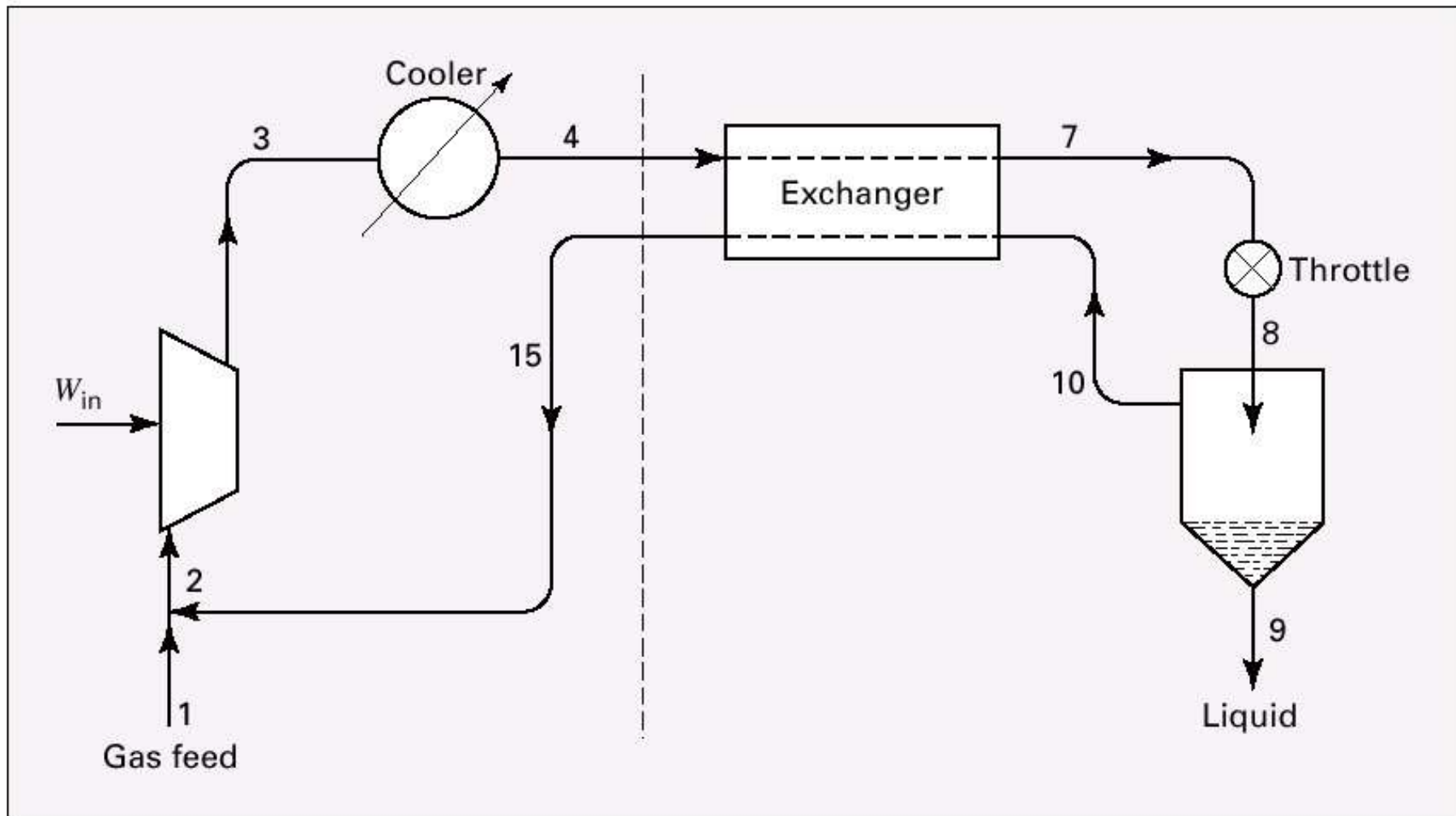**Figure 9.5**: Cooling processes on a TS diagram.
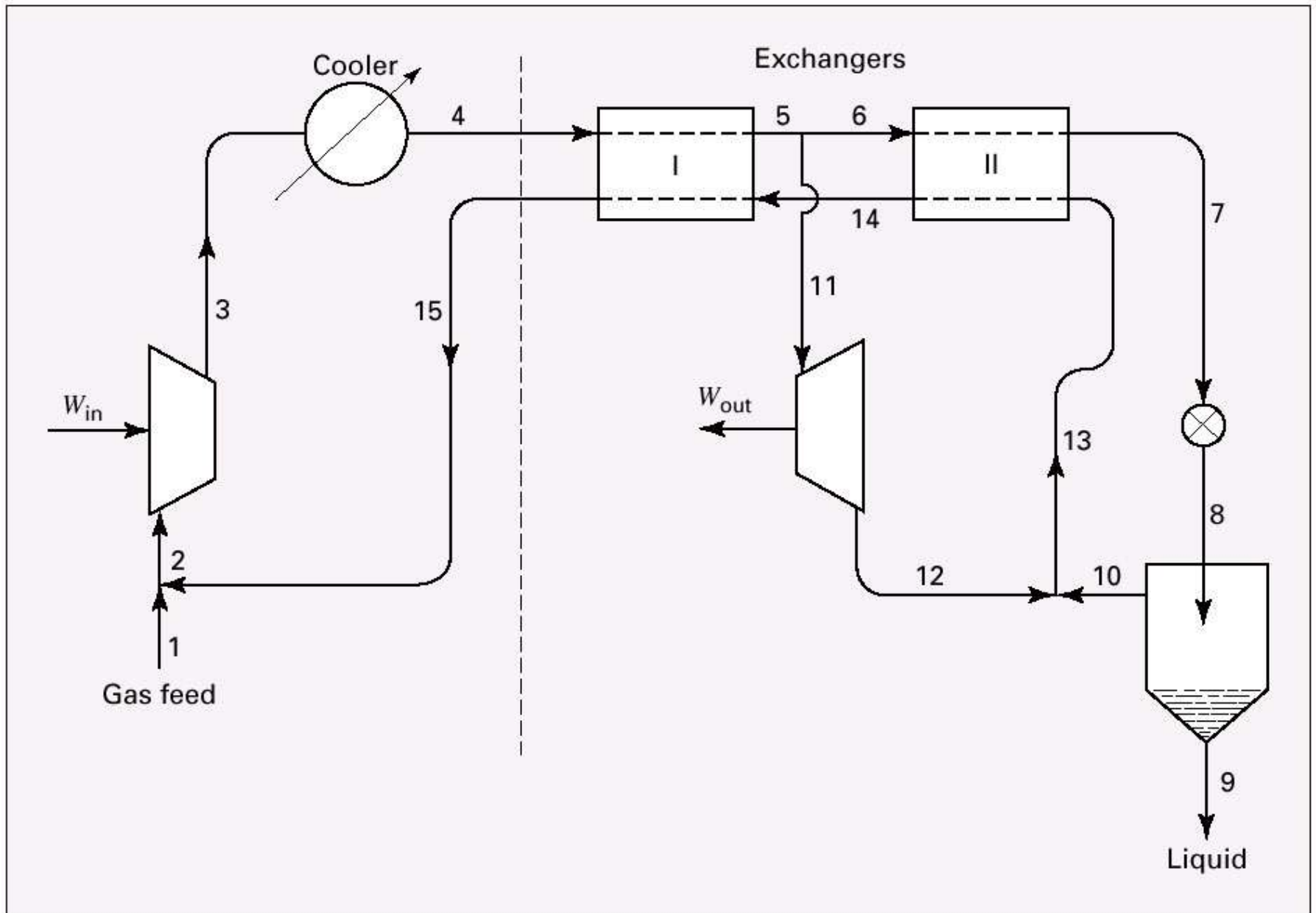
Figure 9.6: Linde liquefaction process.

Figure 9.7: Claude liquefaction process.

Table 9.1: Thermodynamic Properties of Saturated Tetrafluoroethane[†]

$t(°F)$	P(psia)	Volume $(ft)^3(lb_m)^{-1}$		Enthalpy $(Btu)(lb_m)^{-1}$		Entropy $(Btu)(lb_m)^{-1}(R)^{-1}$	
		V^l	V^v	H^l	H^v	S^l	S^v
−40	7.429	0.01132	5.782	0.000	97.050	0.00000	0.23125
−35	8.577	0.01139	5.053	1.489	97.804	0.00352	0.23032
−30	9.862	0.01145	4.432	2.984	98.556	0.00701	0.22945
−25	11.297	0.01152	3.901	4.484	99.306	0.01048	0.22863
−20	12.895	0.01158	3.445	5.991	100.054	0.01392	0.22786
−15	14.667	0.01165	3.052	7.505	100.799	0.01733	0.22714
−10	16.626	0.01172	2.712	9.026	101.542	0.02073	0.22647
−5	18.787	0.01180	2.416	10.554	102.280	0.02409	0.22584
0	21.162	0.01187	2.159	12.090	103.015	0.02744	0.22525
5	23.767	0.01194	1.934	13.634	103.745	0.03077	0.22470
10	26.617	0.01202	1.736	15.187	104.471	0.03408	0.22418
15	29.726	0.01210	1.563	16.748	105.192	0.03737	0.22370
20	33.110	0.01218	1.410	18.318	105.907	0.04065	0.22325
25	36.785	0.01226	1.275	19.897	106.617	0.04391	0.22283
30	40.768	0.01235	1.155	21.486	107.320	0.04715	0.22244
35	45.075	0.01243	1.048	23.085	108.016	0.05018	0.22207
40	49.724	0.01252	0.953	24.694	108.705	0.05359	0.22172
45	54.732	0.01262	0.868	26.314	109.386	0.05679	0.22140
50	60.116	0.01271	0.792	27.944	110.058	0.05998	0.22110
55	65.895	0.01281	0.724	29.586	110.722	0.06316	0.22081
60	72.087	0.01291	0.663	31.239	111.376	0.06633	0.22054
65	78.712	0.01301	0.608	32.905	112.019	0.06949	0.22028
70	85.787	0.01312	0.558	34.583	112.652	0.07264	0.22003
75	93.333	0.01323	0.512	36.274	113.272	0.07578	0.21979
80	101.37	0.01335	0.472	37.978	113.880	0.07892	0.21957
85	109.92	0.01347	0.434	39.697	114.475	0.08205	0.21934
90	119.00	0.01359	0.400	41.430	115.055	0.08518	0.21912
95	128.63	0.01372	0.369	43.179	115.619	0.08830	0.21890
100	138.83	0.01386	0.341	44.943	116.166	0.09142	0.21868
105	149.63	0.01400	0.315	46.725	116.694	0.09454	0.21845
110	161.05	0.01415	0.292	48.524	117.203	0.09766	0.21822
115	173.11	0.01430	0.270	50.343	117.690	0.10078	0.21797
120	185.84	0.01447	0.250	52.181	118.153	0.10391	0.21772
125	199.25	0.01464	0.231	54.040	118.591	0.10704	0.21744
130	213.38	0.01482	0.214	55.923	119.000	0.11018	0.21715
135	228.25	0.01502	0.198	57.830	119.377	0.11333	0.21683
140	243.88	0.01522	0.184	59.764	119.720	0.11650	0.21648
150	277.57	0.01567	0.157	63.722	120.284	0.12288	0.21566
160	314.69	0.01620	0.134	67.823	120.650	0.12938	0.21463
170	355.51	0.01683	0.114	72.106	120.753	0.13603	0.21329

[†]Adapted by permission from *ASHRAE Handbook: Fundamentals*, p. 17.29, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, 1993.