Pinch Technology Second Generation

Analysis with crisscross optimisation prior to design

Design with loop optimisation for minimum area and minimum cost

Example Case 5

Example from Björk and Pettersson

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Case 5 ï Example from Björk and Pettersson

Case 5 is a 15 stream problem first presented by Björk and Pettersson. The data are given in Table 5.1.

The data set is characterised by a high number of potential matches between heat loads and heat capacity flow rates, offering the alternative of multiple independent systems in view of reducing the number of heat exchanger units. However, having more independent systems will reduce overall heat integration and the flexibility to respond to changing energy prices. Moreover, such networks are seldom operable in reality in view of start up and variations of process conditions. Consequently, this data set is for academic interest in the first place, rather than for industrial practice but, nevertheless, solving the case is a challenge.

Table 5.1

Tsupply °C	Ttarget °C	Heat kW	U*f kW/K,m²	Descript. -	Optim.shift K
180	75	3150	2.0	H1	0.0
280	120	9600	1.0	H2	4.0
180	75	3150	2.0	H3	0.0
140	40	3000	1.0	H4	4.0
220	120	5000	1.0	H5	4.0
180	55	4375	2.0	H6	0.0
200	60	4200	0.4	H7	13.0
120	40	8000	0.5	H8	12.0
40	230	3800	1.0	C1	3.0
100	220	7200	1.0	C2	3.0
40	190	5250	2.0	C3	0.0
50	190	4200	2.0	C4	0.0
50	250	12000	2.0	C5	0.0
90	190	5000	1.0	C6	4.0
160	250	5400	3.0	C7	0.0
325	325		1.0	Heating	
25	40		2.0	Cooling	

Heating 80/kW, Cooling 10/kW
Annual HEX cost = 8000 + 500 x $A^{0.75}$

The trade-off curves for a pinched configuration (with a heat exchanger network above the pinch and a network below the pinch and a total of 26 heat exchanger units) and for one independent system (16 units) are shown in Fig.5.1. Expectedly, networks should be feasible for an annual cost of around 1500 k and with a heating below 11 MW. The minimum number of units could also be lower if networks with more than one independent system could be developed. Actually, it appears that a very large number of networks can be designed with an annual cost below 1530 k.

The best solutions elaborated for a configuration of respectively 2, 3 and 4 independent systems are shown in Fig.5.2, Fig.5.3 and Fig.5.4. For the networks with 2 and 3 independent systems, the cost is lower than for any network published, as can be seen in the comparison in Table 5.2. No networks are known to have been published for 4 independent systems.

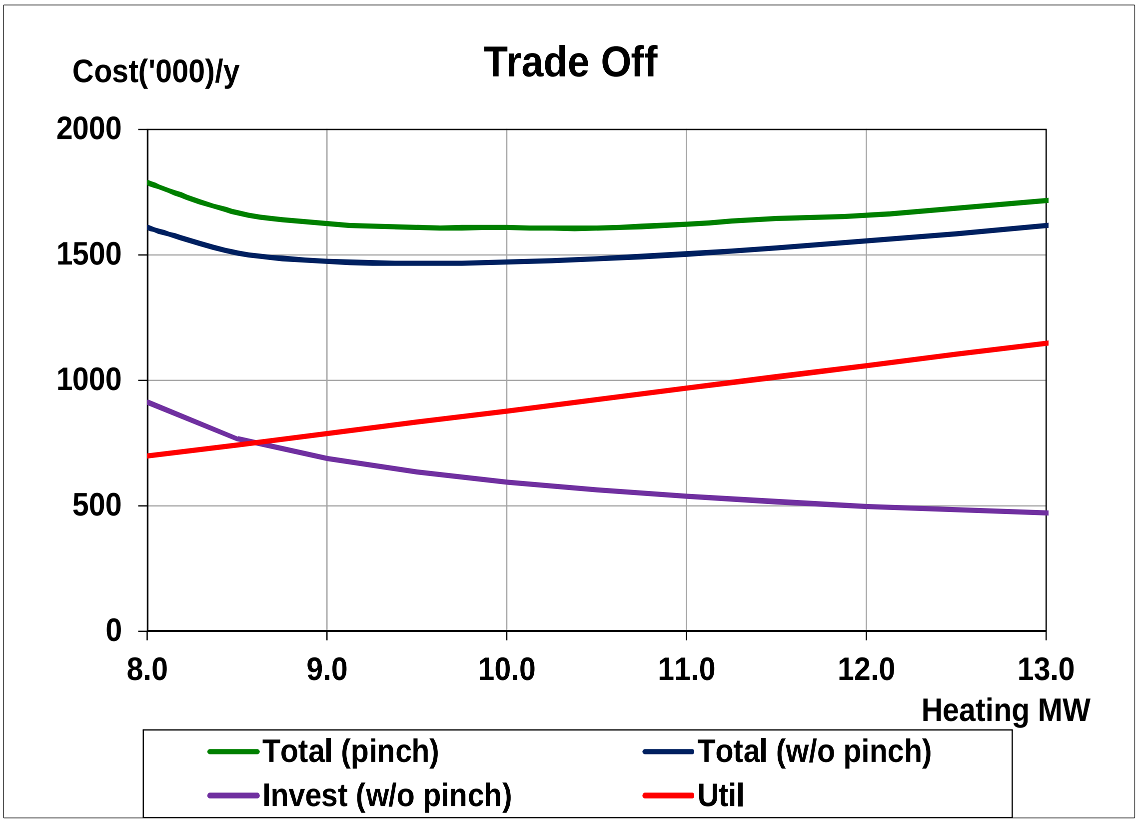


Fig.5.1

	NS[1]	QHot (MW)	Area (m²)	Cost ('000)	HEX	splits	SD(K)[2]
Published optimum HEN's							
Björk & Nordman (2004)				1530.06			
NTNU (2006, reviewed)	2	11.539	3319.63	1530.70	15	4	5.0
Fieg et al. (2009)	3	10.615	4121.98	1510.89	15	1	5.5
This research	2	10.235	4343.00	1496.65	15	2	10.0
	2	10.265	4332.00	1514.58	16	2	5.0
	2	10.195	4393.00	1521.67	17	2	5.0
	2	9.980	4475.00	1521.86	18	2	5.0
	2	11.485	3423.00	1524.83	15	1	5.5
	3	10.616	4215.17	1510.61	15	1	5.5
	3	11.096	3870.98	1516.06	14	2	10.0
	4	11.975	3521.74	1549.50	13	2	10.0

[1] Number of Independent Systems
[2] Smallest DeltaT (K)

Table 5.2

Fig.5.2

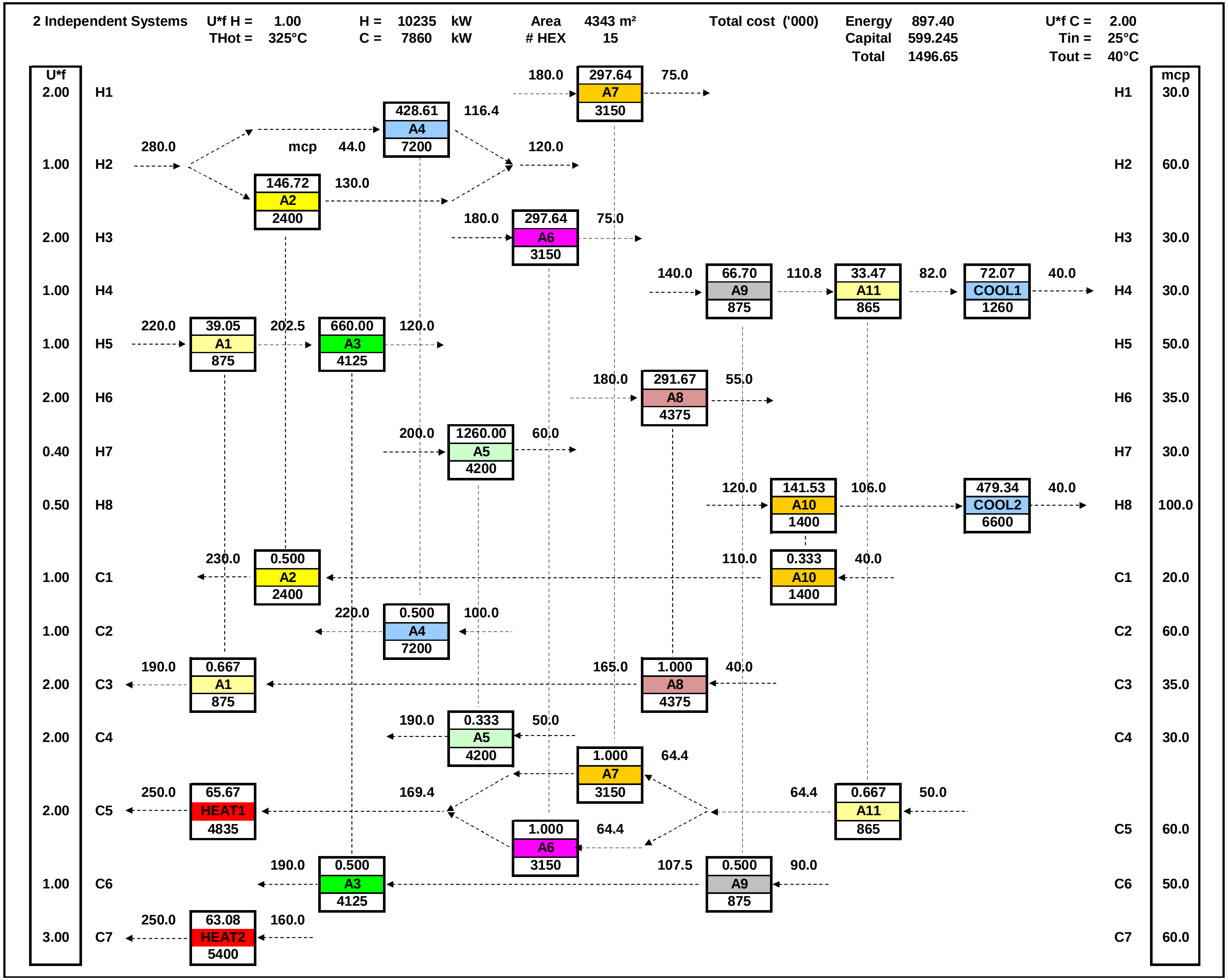

2 Independent Systems
U*f H = 1.00
THot = 325°C
H = 10235 kW
C = 7860 kW
Area 4343 m²
HEX 15
Total cost ('000)
Energy 897.40
Capital 599.245
Total 1496.65
U*f C = 2.00
Tin = 25°C
Tout = 40°C
U*f
mcp
H1 H2 H3 H4 H5 H6 H7 H8
C1 C2 C3 C4 C5 C6 C7
A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11
COOL1 COOL2
HEAT1 HEAT2

Fig.5.3

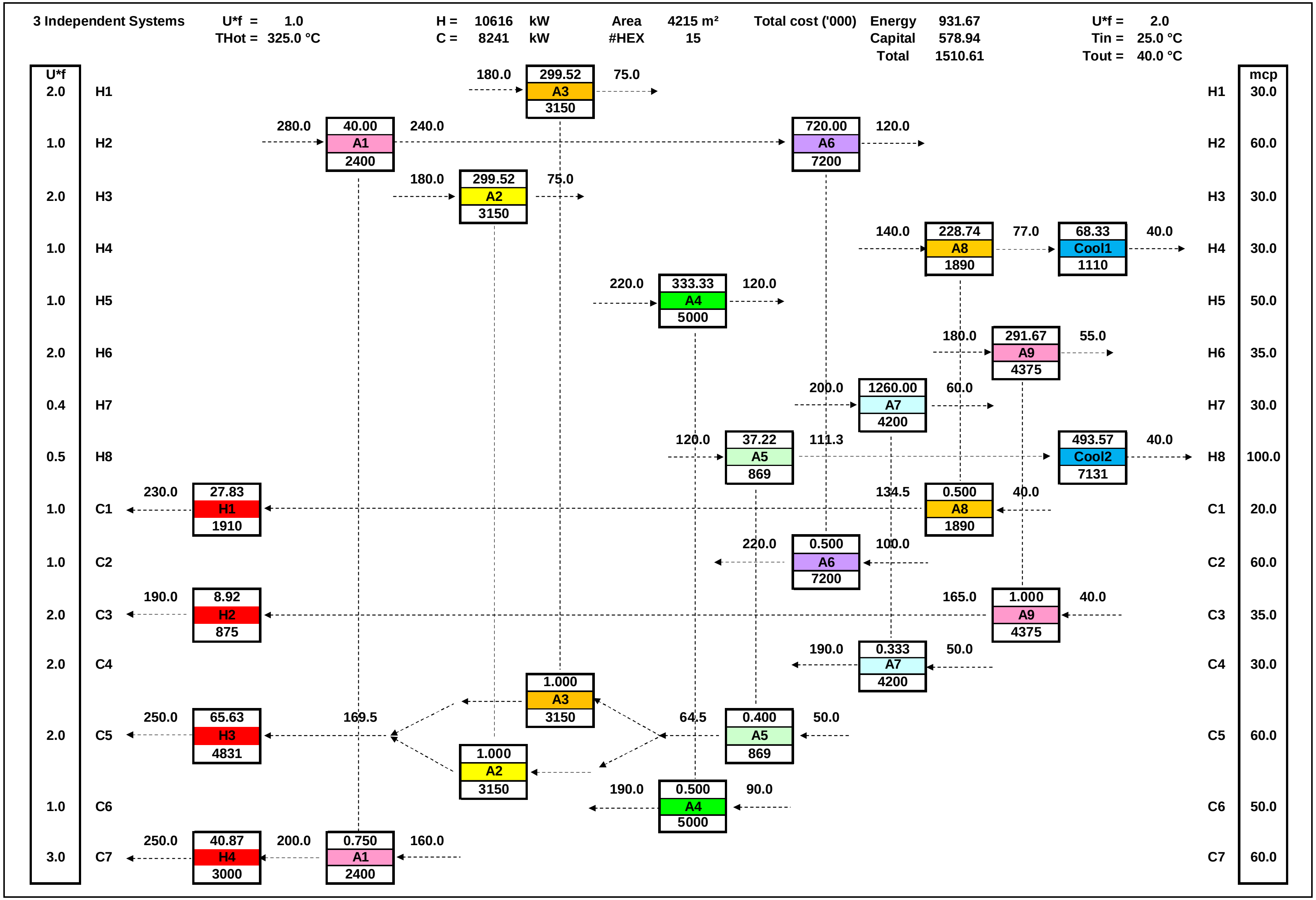
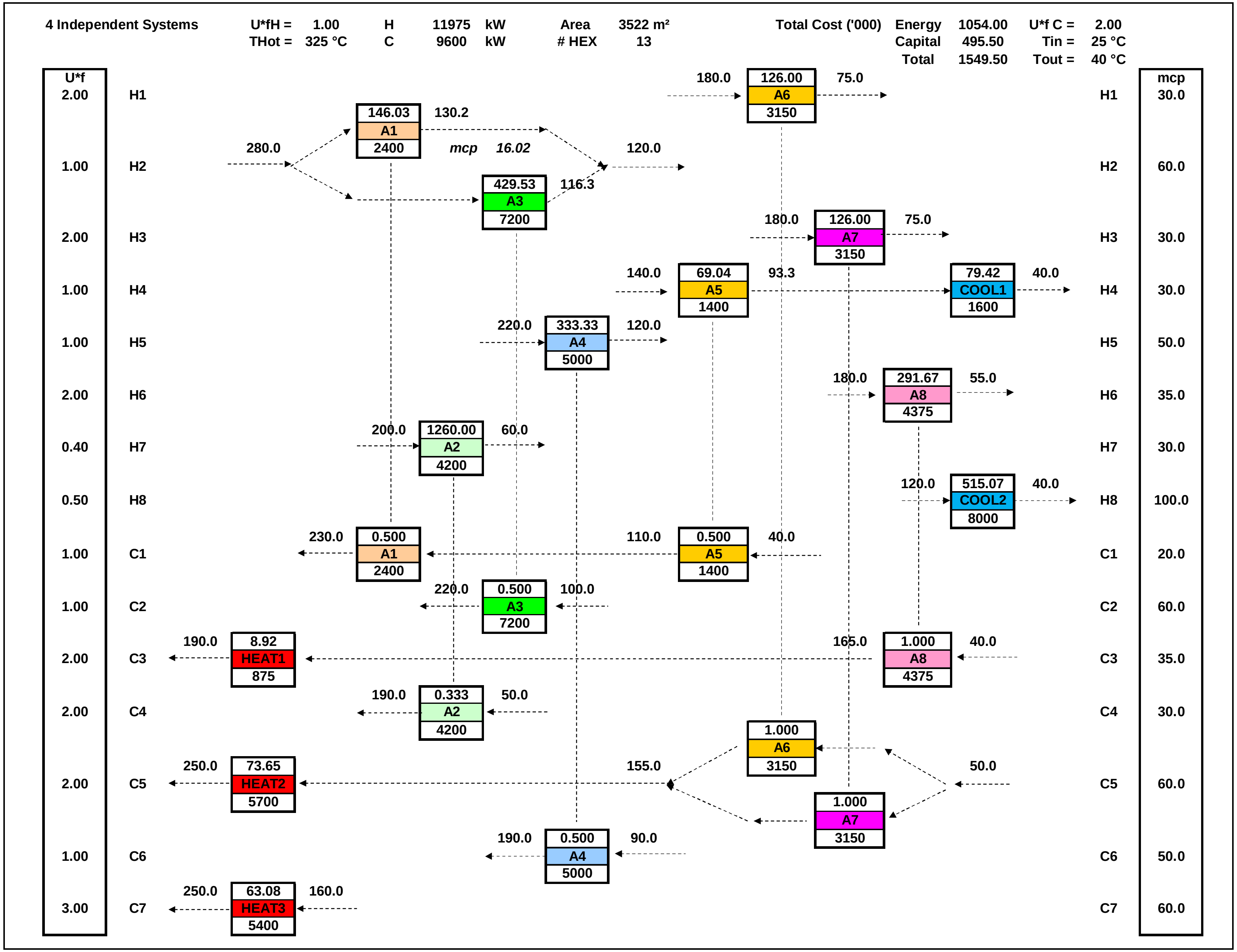

3 Independent Systems
U*f = 1.0
THot = 325.0 °C
H = 10616 kW
C = 8241 kW
Area 4215 m²
#HEX 15
Total cost ('000)
Energy 931.67
Capital 578.94
Total 1510.61
U*f = 2.0
Tin = 25.0 °C
Tout = 40.0 °C
U*f
mcp
2.0 H1 30.0
1.0 H2 60.0
2.0 H3 30.0
1.0 H4 30.0
1.0 H5 50.0
2.0 H6 35.0
0.4 H7 30.0
0.5 H8 100.0
1.0 C1 20.0
1.0 C2 60.0
2.0 C3 35.0
2.0 C4 30.0
2.0 C5 60.0
1.0 C6 50.0
3.0 C7 60.0
180.0 299.52 A3 3150 75.0
280.0 40.00 A1 2400 240.0
720.00 A6 7200 120.0
180.0 299.52 A2 3150 75.0
140.0 228.74 A8 1890 77.0
68.33 Cool1 1110 40.0
220.0 333.33 A4 5000 120.0
180.0 291.67 A9 4375 55.0
200.0 1260.00 A7 4200 60.0
120.0 37.22 A5 869 111.3
493.57 Cool2 7131 40.0
230.0 27.83 H1 1910
134.5 0.500 A8 1890 40.0
220.0 0.500 A6 7200 100.0
190.0 8.92 H2 875
165.0 1.000 A9 4375 40.0
190.0 0.333 A7 4200 50.0
1.000 A3 3150
250.0 65.63 H3 4831 169.5
64.5 0.400 A5 869 50.0
1.000 A2 3150
190.0 0.500 A4 5000 90.0
250.0 40.87 H4 3000 200.0
0.750 A1 2400 160.0

Fig.5.4


4 Independent Systems
U*fH = 1.00
THot = 325 °C
H 11975 kW
C 9600 kW
Area 3522 m²
HEX 13
Total Cost ('000)
Energy 1054.00
Capital 495.50
Total 1549.50
U*f C = 2.00
Tin = 25 °C
Tout = 40 °C
U*f
mcp
2.00 H1 30.0
1.00 H2 60.0
2.00 H3 30.0
1.00 H4 30.0
1.00 H5 50.0
2.00 H6 35.0
0.40 H7 30.0
0.50 H8 100.0
1.00 C1 20.0
1.00 C2 60.0
2.00 C3 35.0
2.00 C4 30.0
2.00 C5 60.0
1.00 C6 50.0
3.00 C7 60.0
180.0 126.00 A6 3150 75.0
146.03 A1 2400 130.2
280.0
mcp 16.02
120.0
429.53 A3 7200 116.3
180.0 126.00 A7 3150 75.0
140.0 69.04 A5 1400 93.3
79.42 COOL1 1600 40.0
220.0 333.33 A4 5000 120.0
180.0 291.67 A8 4375 55.0
200.0 1260.00 A2 4200 60.0
120.0 515.07 COOL2 8000 40.0
230.0 0.500 A1 2400
110.0 0.500 A5 1400 40.0
220.0 0.500 A3 7200 100.0
190.0 8.92 HEAT1 875
165.0 1.000 A8 4375 40.0
190.0 0.333 A2 4200 50.0
1.000 A6 3150
250.0 73.65 HEAT2 5700
155.0
50.0
1.000 A7 3150
190.0 0.500 A4 5000 90.0
250.0 63.08 HEAT3 5400 160.0