CHAPTER 6

ILLUSTRATED EXAMPLES

Five HEN design problems are selected to demonstrate the concept of match operators and the performance of the program. The first two examples, 5SP1 and 6SP1 are selected to demonstrate the capability of the program in a regular match problem. The third, 4TC2 is a splitting problem due to temperature constraint. Next, the problem 10SP1 with five hot streams and five cold streams show the versatility of the program. And the fifth problems, comprised ten hot streams and ten cold streams, is selected to represent a large scale problem of industrial size.

6.1 Problem 5SP1

The problem 5SP1 by Pho and Lapidus (1973), is a heating only problem. The heating requirement for 5SP1 is 876.07 kW. The minimum number of matches is five. The minimum temperature difference is 11.11 ^{o}C. The overall heat transfer coefficient is 1 kW/ ^{o}C m^{2}.

Table 6.1.1 Stream Details of 5SP1.

No.	Name	Supply temperature	Target temperature	Heat Capacity Flowrate	Load
1	HOT1	249	121	16.62	2127.36
2	HOT2	204	66	12.29	1834.02
1	COLD1	38	204	11.40	-1892.40
2	COLD2	66	182	12.92	-1498.72
3	COLD3	93	204	13.03	-1446.33

Using the preanalysis step function, the program finds the pinch temperature for hot streams = 49.11°C, and for cold streams = 38°C. Minimum Hot Utility Requirement = 876.07 kW and Minimum Cold Utility Requirement = 0 kW. Table 6.1.2 shows the problem table of 5SP1 calculated by the preanalysis step function. Because 5SP1 is a heating problem, the hot end design space is only required. The hot end subproblem data is shown in Table 6.1.3.

Table 6.1.2 Problem Table of 5SP1.

Temperature Interval		ΔT	Deficit	Accumulated		Heat Flow	
Upper	Lower			In	Out	In	Out
249	215.11	33.89	563.25	0	563.25	876.07	1439.32
215.11	204	11.11	-86.77	563.25	476.48	1439.32	1352.55
204	193.11	10.89	59.68	476.48	536.16	1352.55	1412.23
193.11	121	72.11	-536.50	536.16	-0.34	1412.23	875.73
121	104.11	16.89	-406.37	-0.34	-406.71	875.73	469.36
104.11	77.11	27	-297.81	-406.72	-704.52	469.36	171.55
77.11	66	11.11	20.99	-704.52	-683.52	171.55	192.55
66	49.11	16.89	-192.55	-683.52	-876.07	192.55	0

Table 6.1.3 Hot End Subproblem Data of 5SP1.

No.	Name	Supply temperature	Target temperature	Heat Capacity Flowrate	Load
1	HOT1	249	121	16.62	2127.36
2	HOT2	204	66	12.29	1834.02
1	COLD1	38	204	11.40	-1892.40
2	COLD2	66	182	12.92	-1498.72
3	COLD3	93	204	13.03	-1446.33

The program found 5 different solutions that are the same as obtained by Pho and Lapidus (1973), Flower and Linnhoff (1980) and Wongsri (1991). Fig. 6.1 shows the states

generated for this problem. On the first solution path, the program finds the first match, as first state or NODE[1], by using match operator B[C] to match HOT1 with COLD3 and generates the next steps until NODE[5] be found. To find the other solutions, program backtracks to the previous state and restarts matching by using the match action that occurred before as the reference point. The program backtracks until back to NODE[1] and finds the second solution. And the other three solutions are found in the same manner. Fig 6.1.2 to 6.1.6 show the grid representation of solutions of 5SP1 problem. The minimum number of match is five. The minimum heat transfer area of the network configuration of the fifth solution is 121.13 m^2.

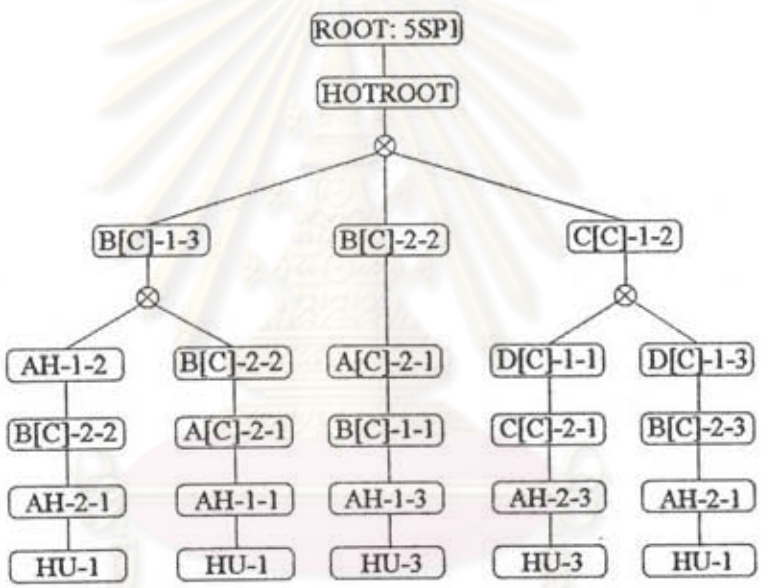

Figure 6.1.1 The States Generated for 5SP1

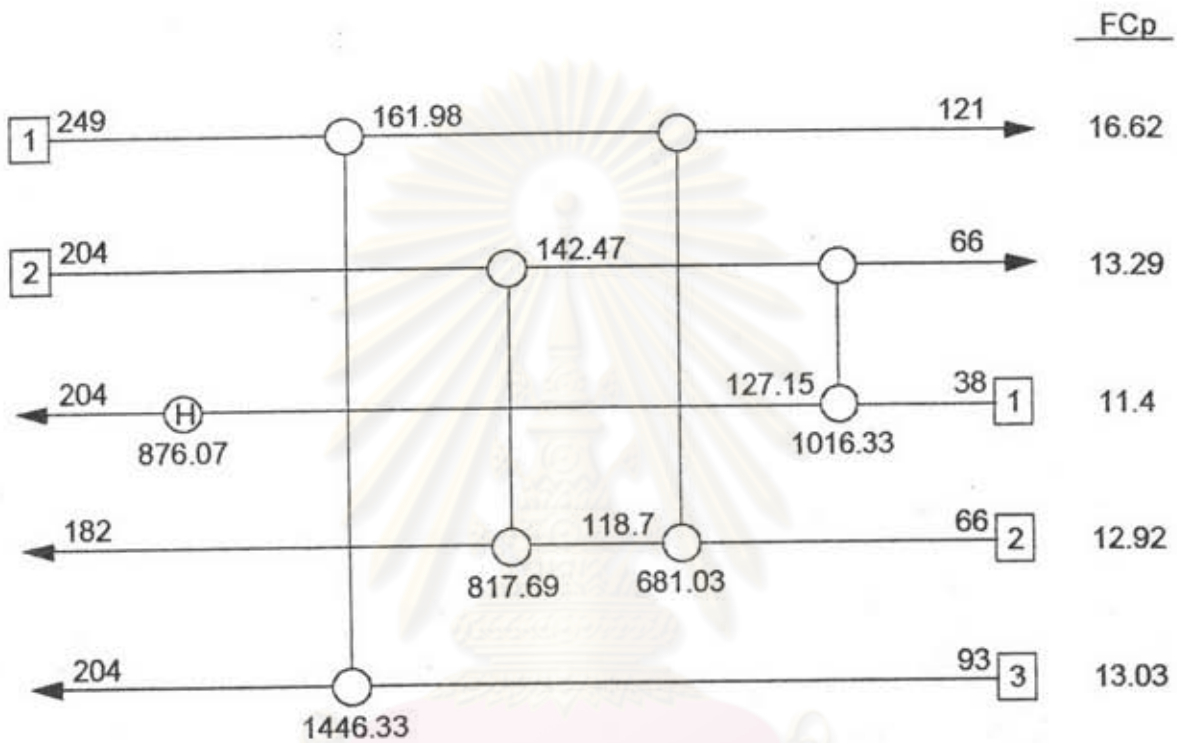

Figure 6.1.2 The Grid Representation of Solution No. 1 / 5 of 5SP1 problem

Hot end solution no.1/5

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	1	3	249	161.9765	93	204	1446.33	25.76407
2	AH	1	2	161.9765	121	66	118.7113	681.0303	13.92752
3	B[C]	2	2	204	142.4733	118.7113	182	817.6898	35.75431
4	AH	2	1	142.4733	66	38	127.1518	1016.33	48.33326
5	HU	1000	1	300	300	127.1518	204	876.0697	6.7040

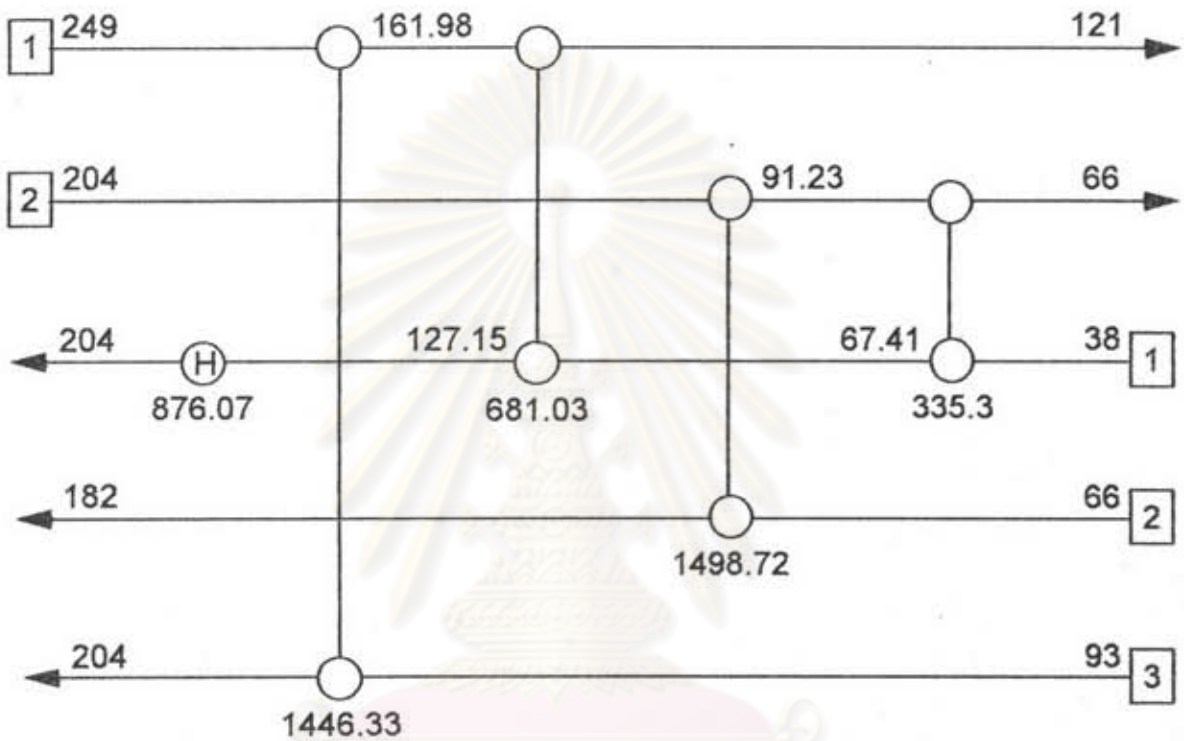

Figure 6.1.3 The Grid Representation of Solution No. 2 / 5 of 5SP1 problem

Hot end solution no.2/5

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	1	3	249	161.977	93	204	1446.33	25.7641
2	B[C]	2	2	204	91.2295	66	182	1498.72	63.5646
3	A[C]	2	1	91.2295	66	38	67.4123	335.3	12.9699
4	AH	1	1	161.977	121	67.4123	127.152	681.030	15.6435
5	HU	1000	1	300	300	127.152	204	876.069	6.7040

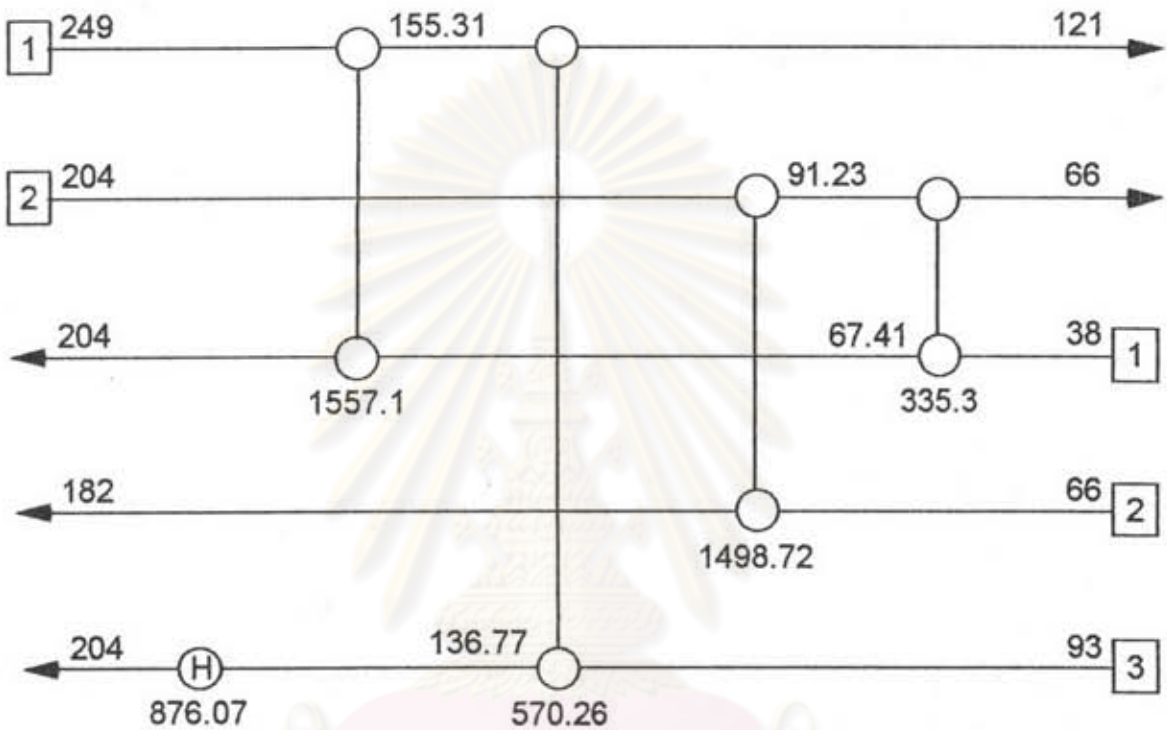

Figure 6.1.4 The Grid Representation of Solution No. 3 / 5 of 5SP1 problem

Hot end solution no.3/5

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	2	2	204	91.2295	66	182	1498.72	63.5646
2	A[C]	2	1	91.2295	66	38	67.4123	335.3	12.9698
3	B[C]	1	1	249	155.312	67.4123	204	1557.1	24.3016
4	AH	1	3	155.312	121	93	136.765	570.260	24.8483
5	HU	1000	3	300	300	136.765	204	876.069	6.9169

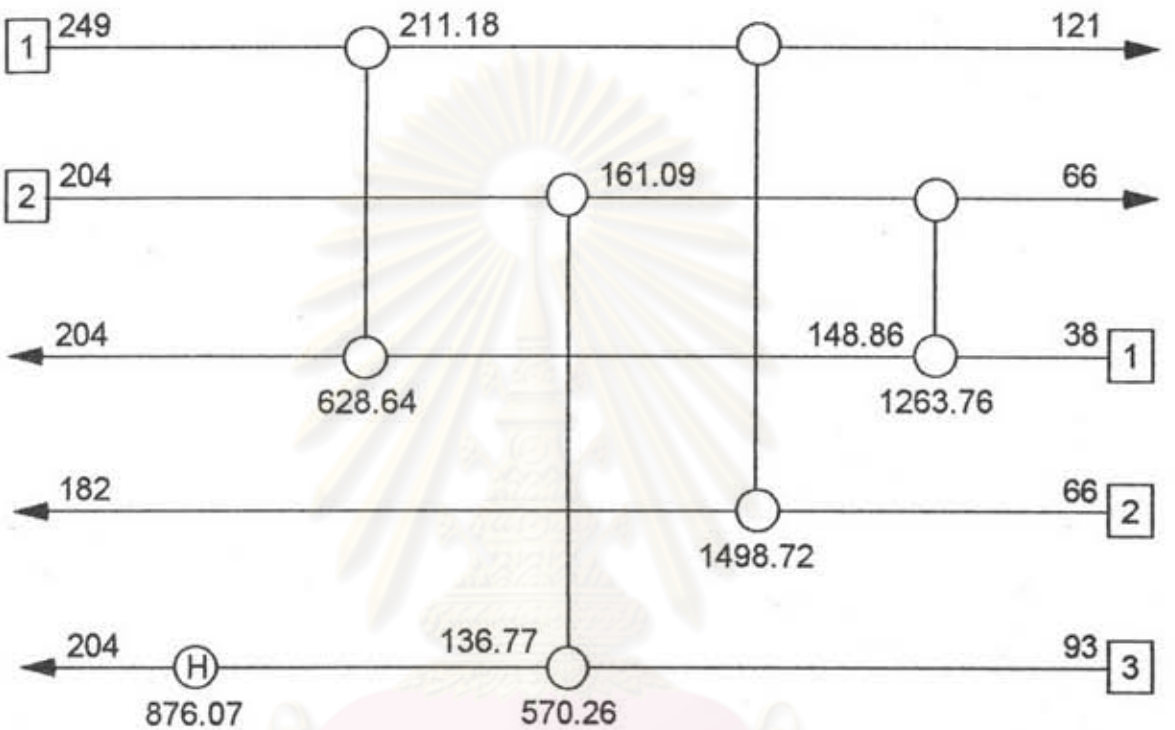

Figure 6.1.5 The Grid Representation of Solution No. 4 / 5 of 5SP1 problem

Hot end solution no.4/5

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	C[C]	1	2	211.176	121	66	182	1498.72	36.7942
2	D[C]	1	1	249	211.176	148.856	204	628.640	11.8186
3	C[C]	2	1	161.091	66	38	148.856	1263.76	66.3669
4	AH	2	3	204	161.091	93	136.765	570.260	8.42807
5	HU	1000	3	300	300	136.765	204	876.069	6.9169

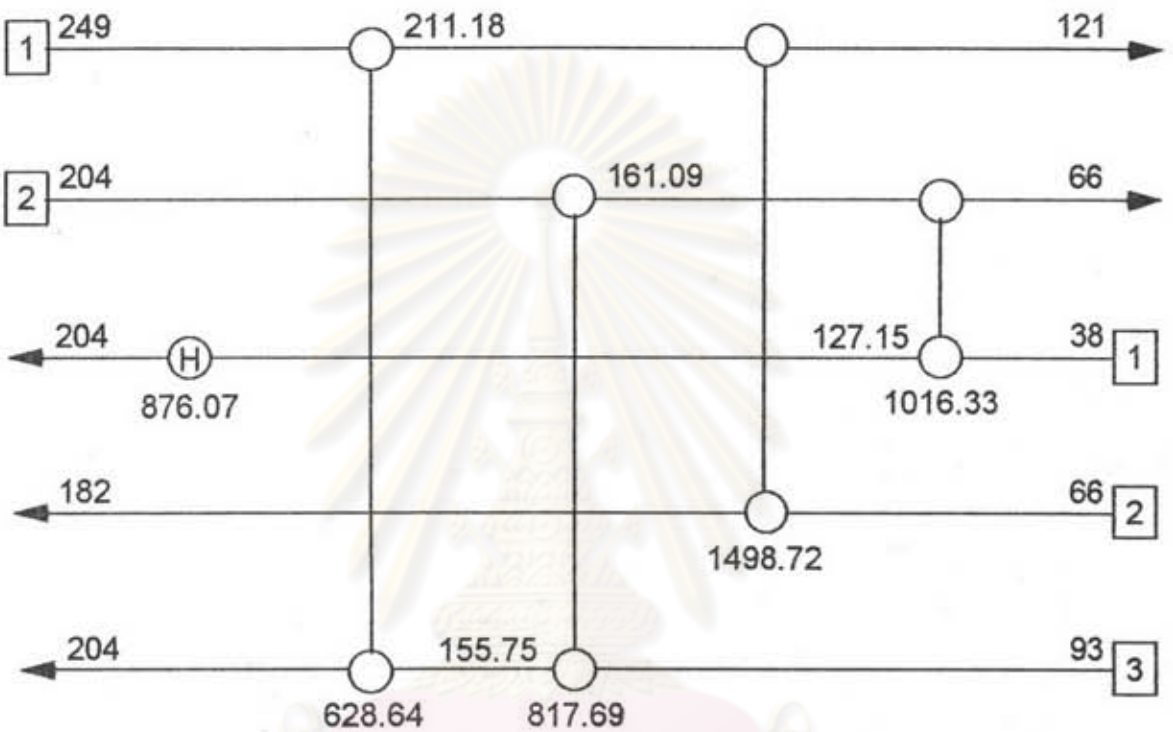

Figure 6.1.6 The Grid Representation of Solution No. 5 / 5 of 5SP1 problem

Hot end solution no.5/5

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	C[C]	1	2	211.176	121	66	182	1498.72	36.7942
2	D[C]	1	3	249	211.176	155.754	204	628.640	12.5653
3	B[C]	2	3	204	142.473	93	155.754	817.689	16.7364
4	AH	2	1	142.473	66	38	127.152	1016.33	48.3332
5	HU	1000	1	300	300	127.152	204	876.069	6.7040

6.2 Problem 6SP1

The problem 6SP1 by Musso and Rudd (1969), is a cooling problem. The minimum temperature difference is 22 K. The overall heat transfer coefficient is 1 kW/K m^2.

Table 6.2.1 Stream Details of 6SP1.

No.	Name	Supply temperature	Target temperature	Heat Capacity Flowrate	Load
1	HOT1	500	339	14.77	2377.97
2	HOT2	544	422	12.56	1532.32
3	HOT3	472	339	17.73	2358.09
1	COLD1	311	494	8.44	-1544.52
2	COLD2	355	450	17.28	-1641.6
3	COLD3	366	478	13.9	-1556.8

Table 6.2.2 shows the problem table of 6SP1. Using the preanalysis step function, the program finds the minimum cold utility requirement = 1525.46 kW. Because 6SP1 is a cooling problem, the hot utility is not required.

Table 6.2.2 Problem Table of 6SP1.

Temperature Interval		ΔT	Deficit	Accumulated		Heat Flow	
Upper	Lower			In	Out	In	Out
544	516	28	351.68	0	351.68	0	351.68
516	500	16	65.92	351.68	417.6	351.68	419.6
500	472	28	139.72	417.6	557.32	417.6	557.32
472	422	50	272	557.32	829.32	557.32	829.32
422	388	34	-242.08	829.32	587.24	829.32	587.24
388	377	11	74.58	587.24	661.82	587.24	661.82
377	339	38	914.28	661.82	1576.1	661.82	1576.1
339	333	6	-50.64	1576.1	1525.46	1576.1	1525.46

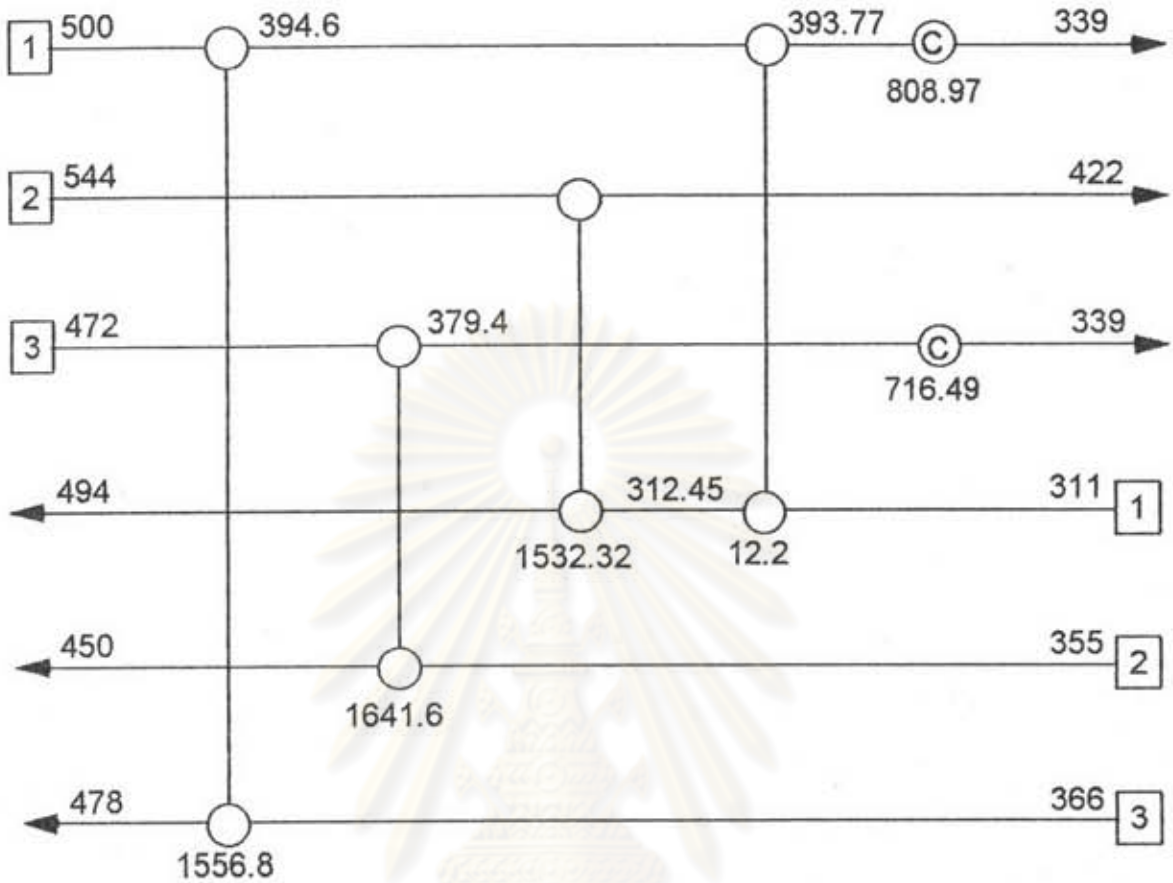

Figure 6.2.1 The Grid Representation of Solution No. 1 / 4 of 6SP1 problem

Cold end solution no. 1/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	BK	1	3	500	394.60	366	478	1556.8	61.89
2	BK	3	2	472	379.41	355	450	1641.6	70.81
3	D[C]	2	1	544	422	312.45	494	1532.32	20.18
4	BK	1	1	394.60	393.77	311	312.45	12.2	0.148
5	CU	1	1001	393.77	339	303	323	808.97	15.73
6	CU	3	1001	379.41	339	303	323	716.49	15.77

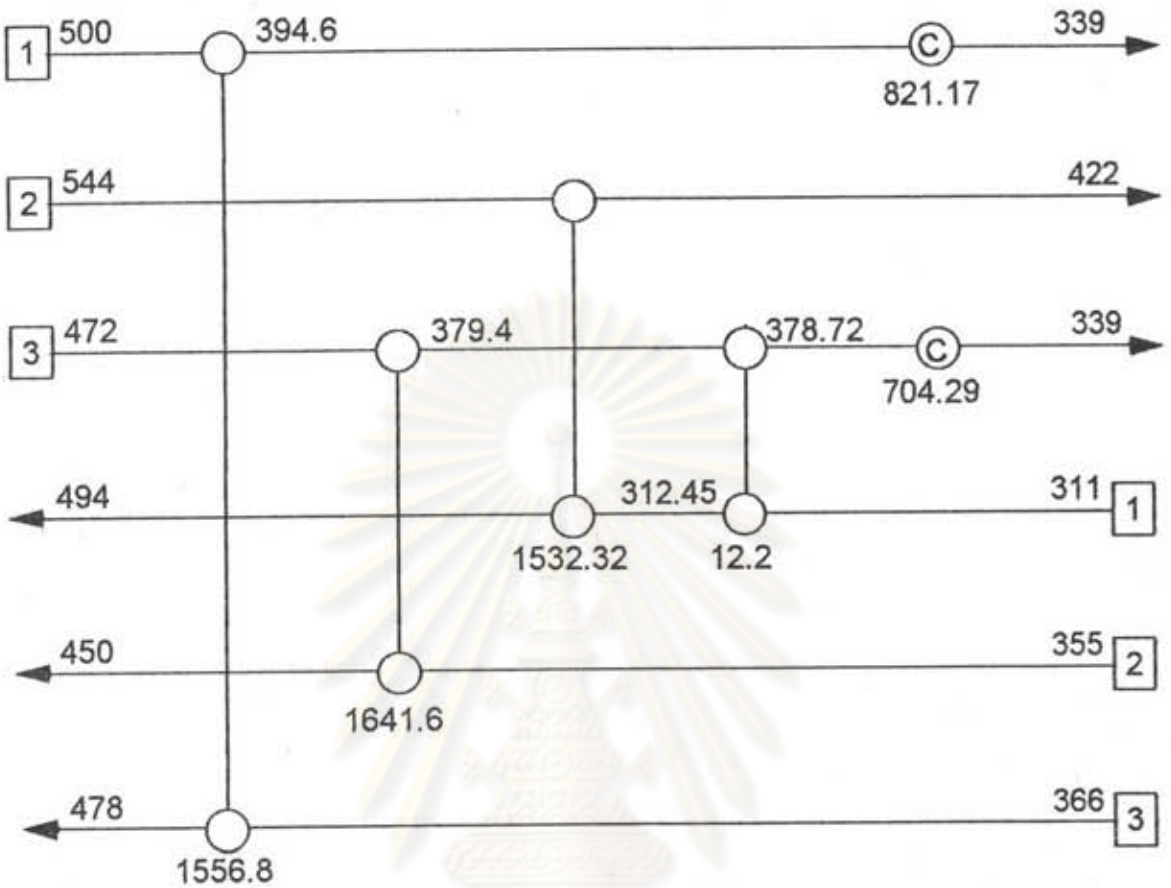

Figure 6.2.2 The Grid Representation of Solution No. 2 / 4 of 6SP1 problem

Cold end solution no. 2/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	BK	1	3	500	394.60	366	478	1556.8	61.889
2	BK	3	2	472	379.41	355	450	1641.6	70.805
3	D[C]	2	1	544	422	312.45	494	1532.32	20.1823
4	BK	3	1	379.41	378.72	311	312.45	12.2	0.1811
5	CU	1	1001	394.60	339	303	323	821.17	15.86
6	CU	3	1001	378.72	339	303	323	704.29	15.6

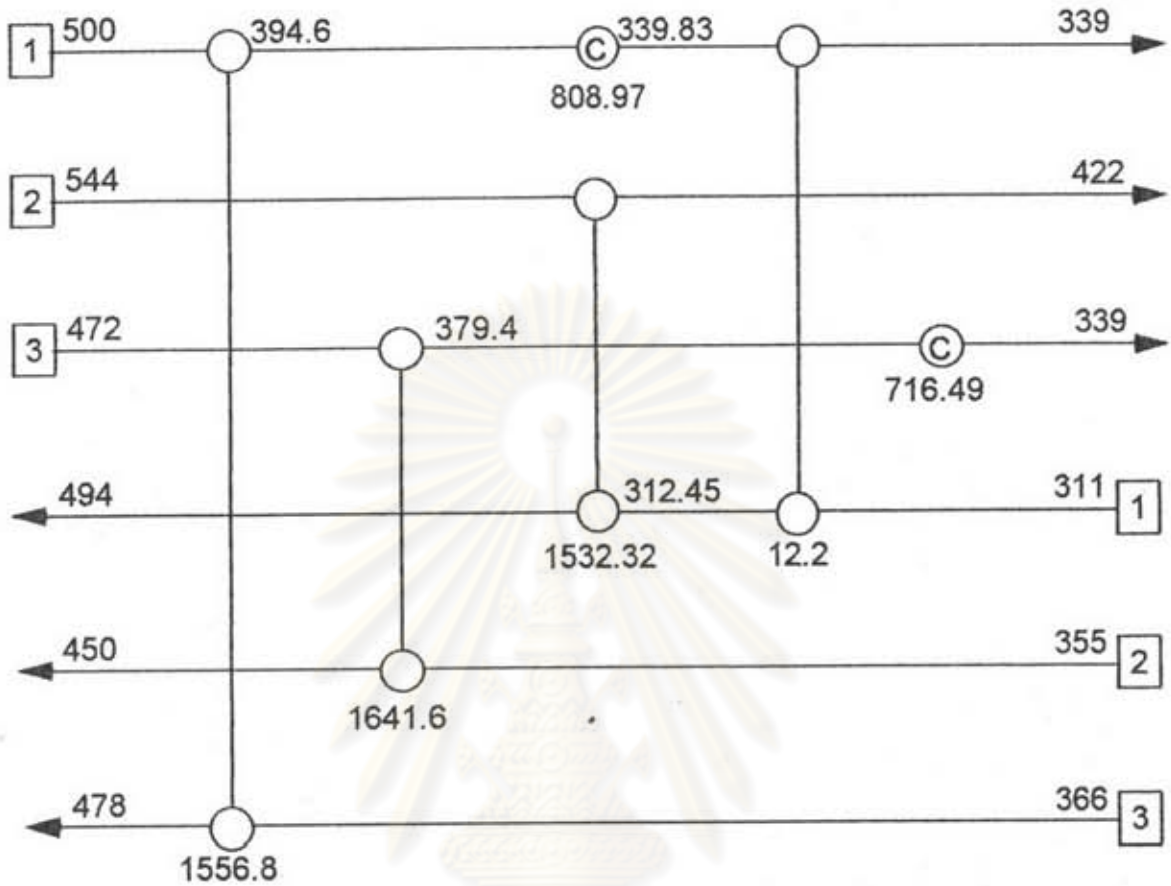

Figure 6.2.3 The Grid Representation of Solution No. 3/ 4 of 6SP1 problem

Cold end solution no. 3/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	BK	1	3	500	394.6	366	478	1556.8	61.889
2	BK	3	2	472	379.41	355	450	1641.6	70.805
3	D[C]	2	1	544	422	312.45	494	1532.32	20.182
4	C[C]	1	1	339.83	339	311	312.45	12.2	0.4406
5	CU	1	1001	394.6	339.83	303	323	808.97	15.468
6	CU	3	1001	379.41	339	303	323	716.49	15.766

There are four solutions found by the cold end design function. All solutions achieve the minimum number of matches and the minimum utility requirement. The minimum heat transfer area is 184.5173 m^2, which is obtained from the first solution. Many researchers, Lee et al. (1970), Hohmann (1971), McGalliard and Westerberg (1972), Pho and Lapidus (1973), have presented similar solutions. However, Nishida et al. (1977) showed the same solution as Hohmann and confirmed Hohmann's solution as the optimum. The first configuration is the same solution as Hohmann (1971) and Nishida et al. (1977) thus confirming the solution as the optimum.

6.3 Problem 4TC3

The 4TC3 problem is obtained from Linnhoff and Hindmarsh (1983). The minimum temperature difference is specified at 20 °C. It is a stream splitting problem due to the temperature constraint.

Table 6.3.1 Stream Details of 4TC3

No.	Name	Supply temperature	Target temperature	Heat Capacity Flowrate	Load
1	HOT1	150	60	2	180
2	HOT2	90	60	8	240
1	COLD1	20	125	2.5	-262.5
2	COLD2	25	100	3	-225

Table 6.3.2 shows the problem table of 4TC3 problem calculated by the program. From the problem table, the pinch temperature for hot streams is 90 °C and for cold streams is 70 °C. Minimum Hot Utility Requirement is 107.5 kW and Minimum Cold Utility Requirement is 40 kW.

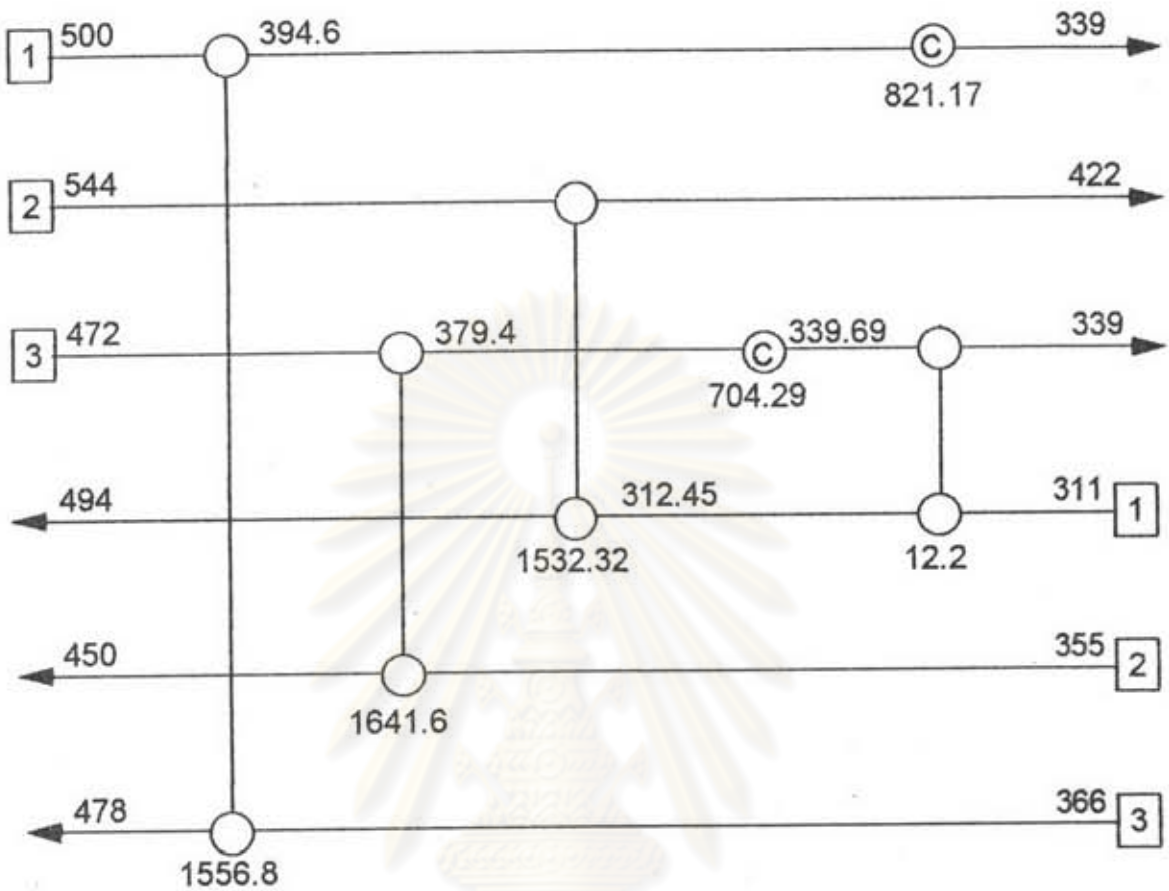

Figure 6.2.4 The Grid Representation of Solution No. 4 / 4 of 6SP1 problem

Cold end solution no. 4/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	BK	1	3	500	394.6	366	478	1556.8	61.889
2	BK	3	2	472	379.41	355	450	1641.6	70.805
3	D[C]	2	1	544	422	312.45	494	1532.32	20.182
4	C[C]	3	1	339.69	339	311	312.45	12.2	0.4417
5	CU	1	1001	394.6	339	303	323	821.17	15.86
6	CU	3	1001	379.41	339.69	303	323	704.29	15.363

The program separates the problem into two parts. The heating subproblem is shown in Table 6.3.3 and the cooling subproblem is shown in Table 6.3.4.

Table 6.3.2 Problem Table of 4TC3

Temperature Interval		ΔT	Deficit	Accumulated		Heat Flow	
Upper	Lower			In	Out	In	Out
150	145	5	10	0	10	107.5	117.5
145	120	25	-12.5	10	-2.5	117.5	105
120	90	30	-105	-2.5	-107.5	105	0
90	60	30	135	-107.5	27.5	0	135
60	45	15	-82.5	27.5	-55	135	52.5
45	40	5	-12.5	-55	-67.5	52.5	40

Table 6.3.3 Heating Subproblem of 4TC3

No.	Name	Supply temperature	Target temperature	Heat Capacity Flowrate	Load
1	HOT1	150	90	2	120
1	COLD1	70	125	2.5	-137.5
2	COLD2	70	100	3	-90

Table 6.3.4 Cooling Subproblem of 4TC3

No.	Name	Supply temperature	Target temperature	Heat Capacity Flowrate	Load
1	HOT1	90	60	2	60
2	HOT2	90	60	8	240
1	COLD1	20	70	2.5	-125
2	COLD2	25	70	3	-135

Figure 6.3.1 shows the states generated for the first two solutions of 4TC3. In the heating subproblem, by using the regular match operators, the design state function finds four solutions. In the cooling subproblem the split match operator, DH2*, is required to

match streams at the first state or NODE[1]. After the first state, program uses only regular match operators to find the solutions.

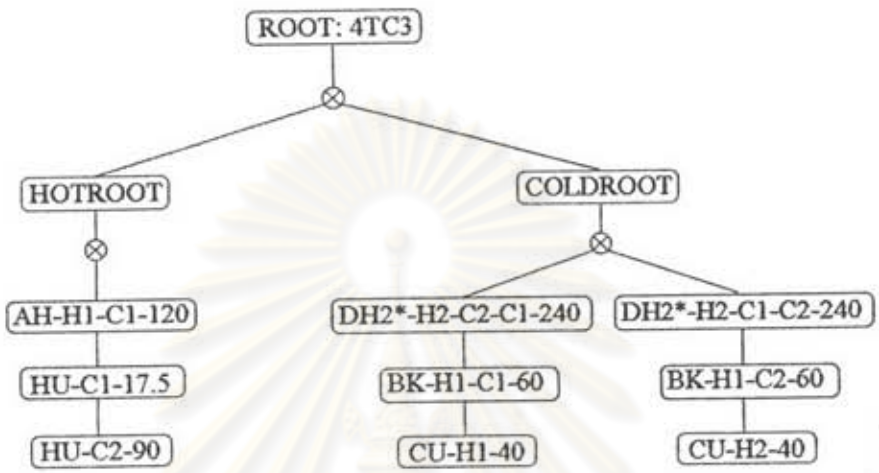

Figure 6.3.1 The States Generated for the First 2 Solutions of 4TC3

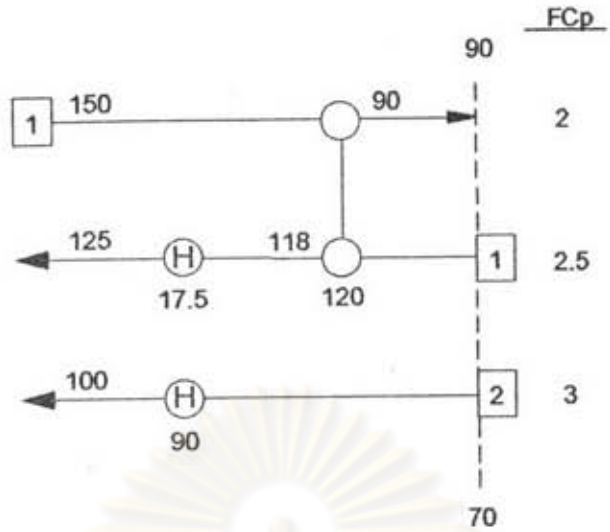

Figure 6.3.2 The Grid Representation of Hot end solution No. 1 / 4 of 4TC3 problem

Hot end solution no.1/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	AH	1	1	150	90	70	118	120	4.7
2	HU	1000	1	200	200	118	125	17.5	.223
3	HU	1000	2	200	200	70	100	90	.787

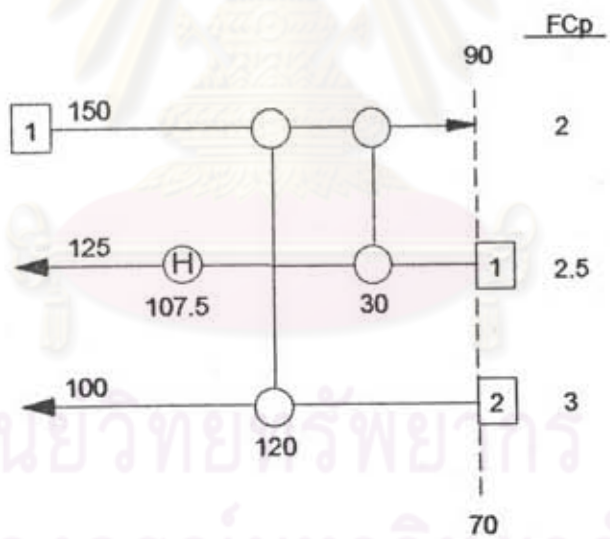

Figure 6.3.3 The Grid Representation of Hot end solution No. 2 / 4 of 4TC3 problem

Hot end solution no.2/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[H]	1	2	150	105	70	100	90	2.14
2	AH	1	1	105	90	70	82	30	1.398
3	HU	1000	1	200	200	82	125	107.5	1.133

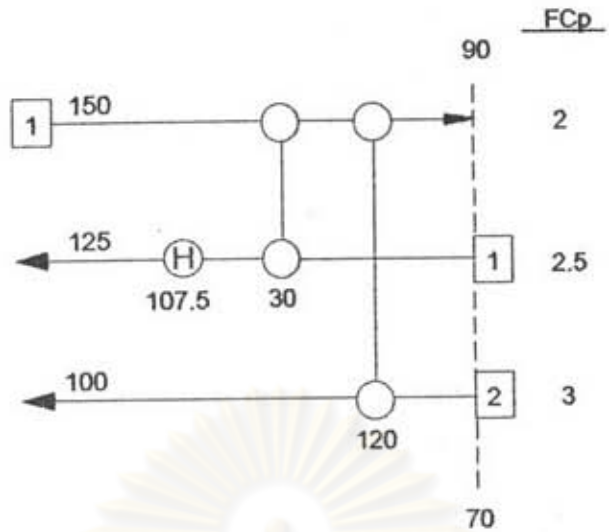

Figure 6.3.4 The Grid Representation of Hot end solution No. 3 / 4 of 4TC3 problem

Hot end solution no.3/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	C[H]	1	2	135	90	70	100	90	3.358
2	AH	1	1	150	135	70	82	30	.4512
3	HU	1000	1	200	200	82	125	107.5	1.133

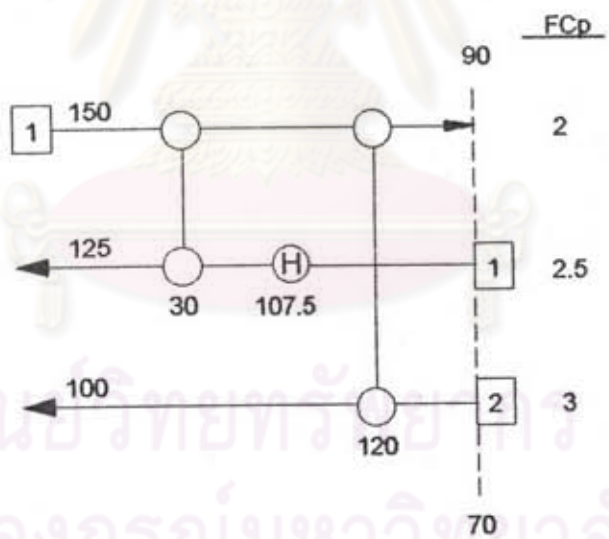

Figure 6.3.5 The Grid Representation of Hot end solution No. 4 / 4 of 4TC3 problem

Hot end solution no.4/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	C[H]	1	2	135	90	70	100	90	3.358
2	D[H]	1	1	150	135	113	125	30	1.278
3	HU	1000	1	200	200	70	113	107.5	1.004

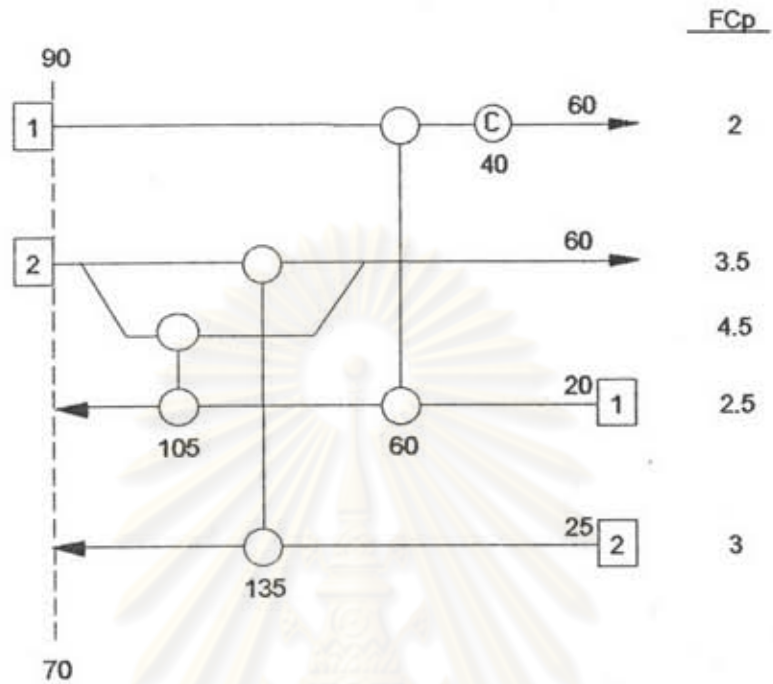

Figure 6.3.6 The Grid Representation of Cold end solution No. 1 / 4 of 4TC3 problem

Cold end solution no.1/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	DH2*	2	2	90	60	25	70	135	5.0365
2	DH2*	2	1	90	60	28	70	105	4.1125
3	BK	1	1	90	80	20	28	20	0.328
4	CU	1	1001	80	60	30	45	40	1.233

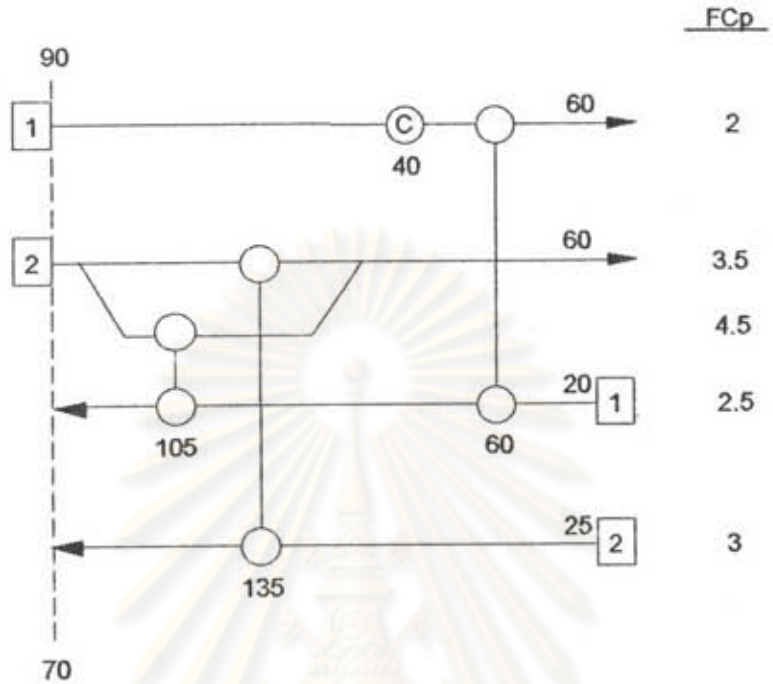

Figure 6.3.7 The Grid Representation of Cold end solution No. 2 / 4 of 4TC3 problem

Cold end solution no.2/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	DH2*	2	2	90	60	25	70	135	5.0365
2	DH2*	2	1	90	60	28	70	105	4.1125
3	C[H]	1	1	70	60	20	28	60	.4879
4	CU	1	1001	90	70	30	45	40	.9423

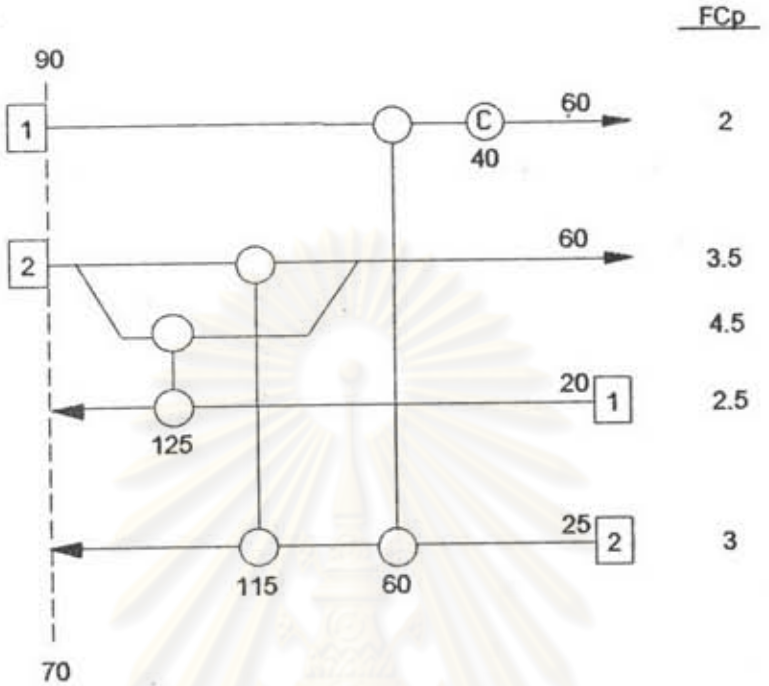

Figure 6.3.8 The Grid Representation of Cold end solution No. 3 / 4 of 4TC3 problem

Cold end solution no.3/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	DH2*	2	1	90	60	20	70	125	4.332
2	DH2*	2	2	90	60	31.6667	70	115	4.807
3	B[H]	1	2	90	80	25	31.6667	60	0.353
4	CU	1	1001	80	60	30	45	40	1.233

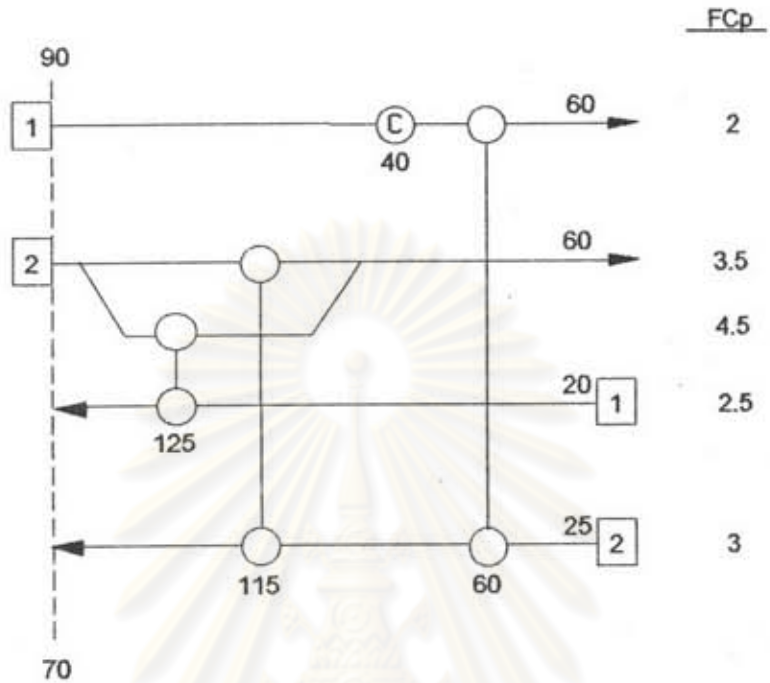

Figure 6.3.9 The Grid Representation of Cold end solution No. 4 / 4 of 4TC3 problem

Cold end solution no.4/4

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	DH2*	2	1	90	60	20	70	125	4.332
2	DH2*	2	2	90	60	31.6667	70	115	4.807
3	C[H]	1	2	70	60	25	31.6667	60	0.546
4	CU	1	1001	90	70	30	45	40	0.942

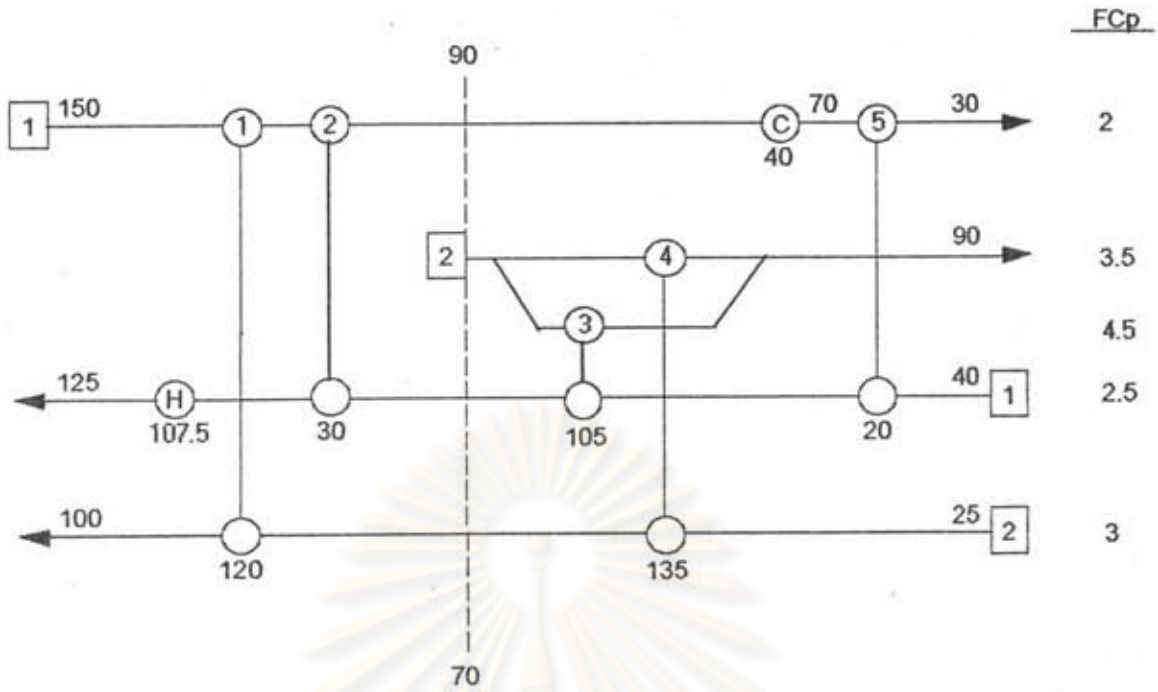

Figure 6.3.10 The Grid Representation of The Minimum Heat Transfer Area Network Configuration of 4TC3 problem

Figures 6.3.2-6.3.5 and Figures 6.3.6-6.3.9 show the hot end and cold end sub-network solutions, respectively. Linnhoff and Hindmarsh (1983) found two hot end solutions that are the same as the first and the third hot end solutions found by the program and found two cold end solutions that are the same as the the first and the third cold end solutions found by the program. Linnhoff presented the network which was obtained by combination of the first solutions of subnetworks. There are two heat loops found and their network requires a heat transfer area more than the minimum. Figure 6.3.10 shows the minimum heat transfer area network, 15.25 m^2, which is obtained by combination of the second solution from the hot end subnetwork and the second one from the cold end subnetwork. The loop searching function found a first level loop, (2-5), and two second level loops, (1-4-3-2) and (1-4-3-5). The developed program does not support function for loop breaking. The user must break the loops manually.

6.4 Problem 10SP1

10SP1 problem is also obtained from Pho and Lapidus (1973). There are five hot streams and five cold streams in this problem. In general, many network solutions are possible for a large problem. The minimum temperature difference is 11.11 K. Assume that the overall heat transfer coefficient for all exchanger unit is 1 kW/ K m^2.

Table 6.4.1 Stream Details of 10SP1

No.	Name	Supply temperature	Target temperature	Heat Capacity Flowrate	Load
1	HOT1	433	366	8.79	588.93
2	HOT2	522	411	10.55	1171.05
3	HOT3	500	339	14.77	2377.97
4	HOT4	544	422	12.56	1532.32
5	HOT5	472	339	17.73	2358.09
1	COLD1	333	433	7.62	-762
2	COLD2	389	495	6.08	-644.48
3	COLD3	311	494	8.44	-1544.52
4	COLD4	355	450	17.28	-1641.6
5	COLD5	366	478	13.9	-1556.8

10SP1 is a cooling problem. Nishida et al. (1977) presented a solution with the minimum number of matches, ten units. There are at least 30 network configurations found by the program which is 18 solutions more than those obtained by Wongsri (1991). The program do not find the same network configuration as Nishida because the search has to be stopped, since the memory are limited. Figures 6.4.1 - 6.4.30 show the first 30 solutions of 10SP1. All solutions achieve the minimum number of matches and minimum utility requirement. The minimum number of matches is ten. The minimum heat transfer area of network configuration, obtained by the nineteenth solution, is 202.08 m^2, while the heat transfer area of the network found by Nishida et al. (1977) is 203.161 m^2. The

minimum utility requirement of the network obtain from the developed program is 1878.96 kW.

Table 6.4.2 Problem Table of 10SP1

Temperature Interval		ΔT	Deficit	Accumulated		Heat Flow	
Upper	Lower			In	Out	In	Out
544	522	22	276.32	0	276.32	0	276.32
522	506.11	15.89	367.2183	276.32	643.5383	276.32	643.5383
506.11	505.11	1	17.03	643.5383	660.5683	643.5383	660.5683
505.11	500	5.11	43.89478	660.5683	704.4631	660.5683	704.4631
500	488.11	11.89	254.3908	704.4631	958.8539	704.4631	958.8539
488.11	463	25.11	161.8605	958.8539	1120.714	958.8539	1120.714
463	461.11	1.89	296.0995	1120.714	1416.814	1120.714	1416.814
461.11	444.11	17	168.47	1416.814	1585.284	1416.814	1585.284
444.11	433	11.11	25.44187	1585.284	1610.726	1585.284	1610.726
433	422	11	121.88	1610.726	1732.606	1610.726	1732.606
422	411	11	-16.28	1732.606	1716.326	1732.606	1716.326
411	400.11	10.89	-131.007	1716.326	1585.319	1716.326	1585.319
400.11	377.11	23	-136.85	1585.319	1448.469	1585.319	1448.469
377.11	366.11	11	87.44999	1448.469	1535.919	1448.469	1535.919
366.11	366	0.11	2.77493	1535.919	1538.694	1535.919	1538.694
366	344.11	21.89	359.8719	1538.694	1898.566	1538.694	1898.566
344.11	339	5.11	122.9463	1898.566	2021.512	1898.566	2021.512
339	322.11	16.89	-142.552	2021.512	1878.96	2021.512	1878.96

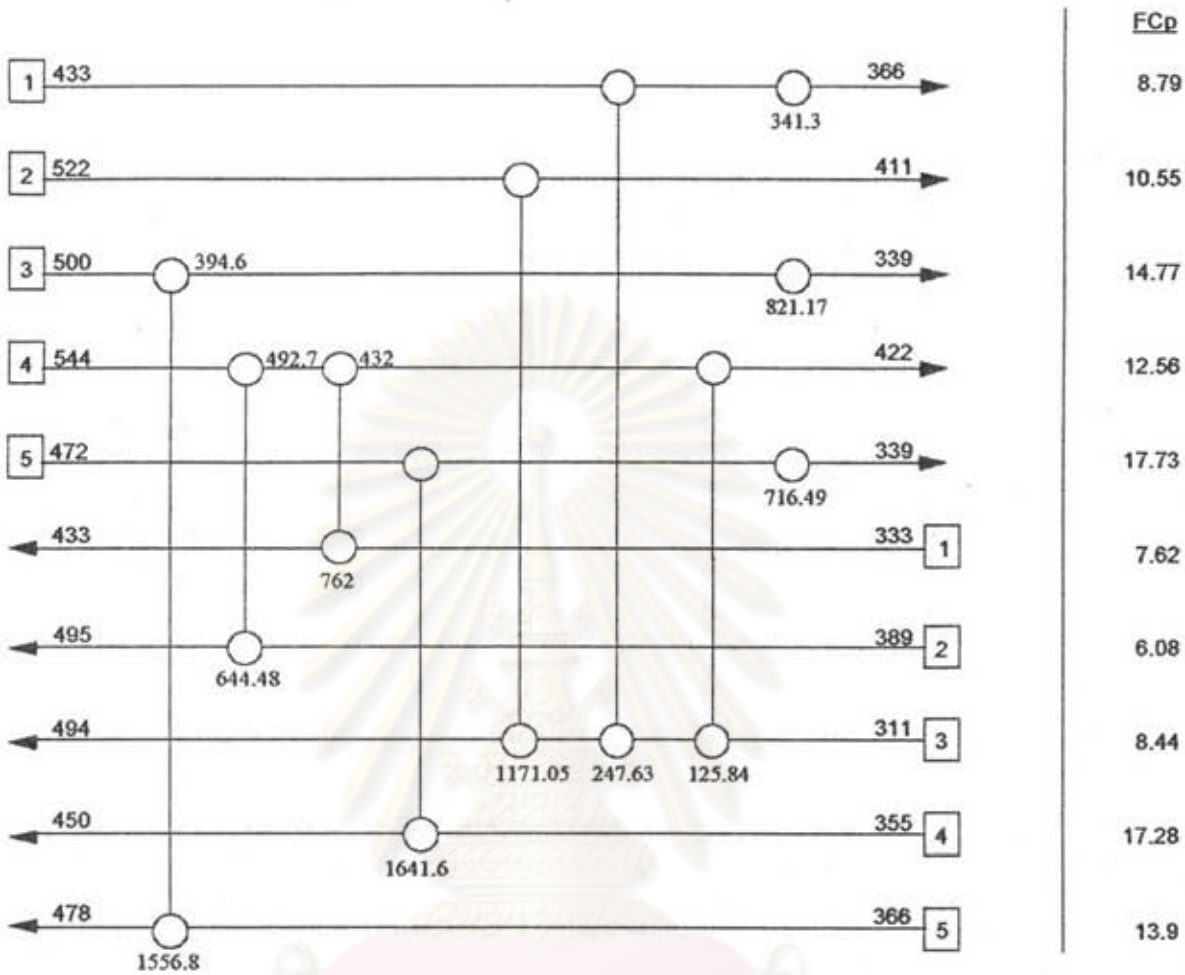

Figure 6.4.1 The Grid Representation of Cold end solution No. 1 / 30 of 10SP1 problem

Cold end solution no. 1/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500.00	394.60	366.00	478.00	1556.80	61.88932
2	B[C]	4	2	544.00	492.69	389.00	495.00	644.48	8.833391
3	B[C]	4	1	492.69	432.02	333.00	433.00	762.00	9.806762
4	B[C]	5	4	472.00	379.41	355.00	450.00	1641.60	70.80531
5	A[C]	4	3	432.02	422.00	311.00	325.91	125.84	1.159428
6	D[C]	2	3	522.00	411.00	355.25	494.00	1171.05	29.06199
7	C[C]	1	3	394.17	366.00	325.91	355.25	247.63	6.268631
8	CU	1	1001	433.00	394.17	303	323	341.30	3.40308
9	CU	3	1001	394.60	339.00	303	323	821.17	15.86037
10	CU	5	1001	379.41	339.00	303	323	716.49	15.76637

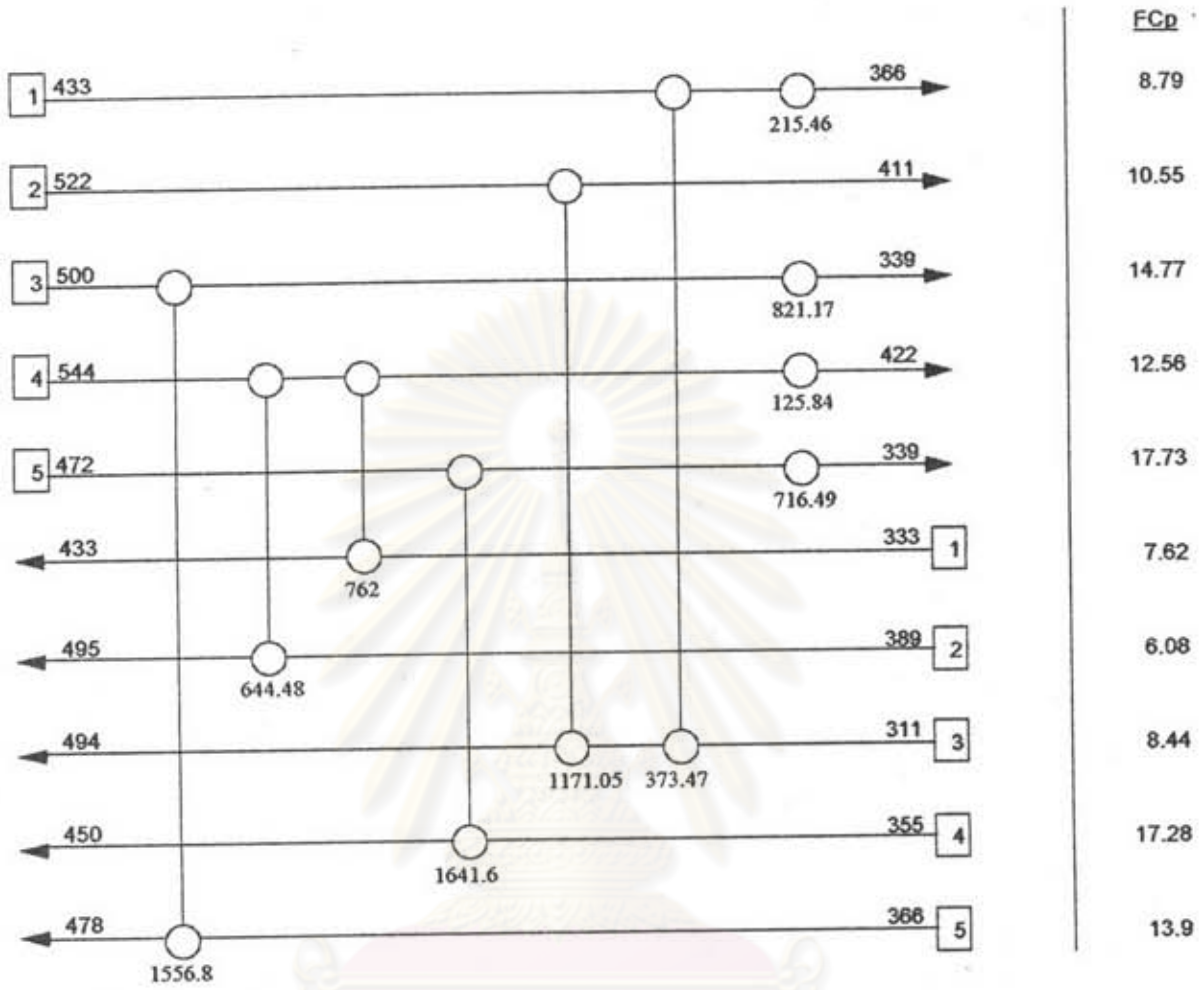

Figure 6.4.2 The Grid Representation of Cold end solution No. 2 / 30 of 10SP1 problem

Cold end solution no. 2/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	BK	1	3	433	390.512	311	355.25	373.47	4.749852
7	CU	1	1001	390.512	366	303	323	215.4602	3.303084
8	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
9	CU	4	1001	432.0191	422	303	323	125.84	1.104472
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

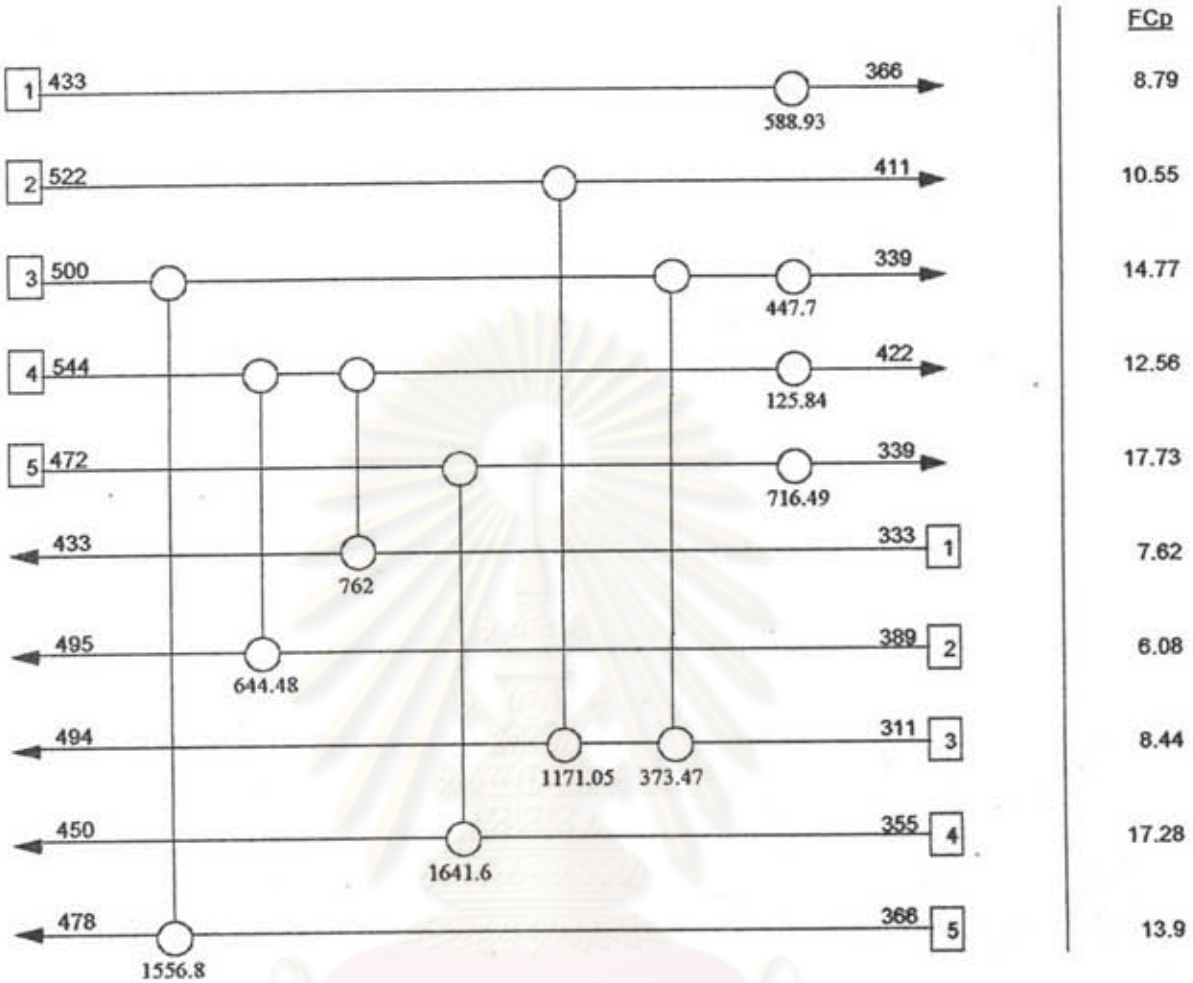

Figure 6.4.3 The Grid Representation of Cold end solution No. 3 / 30 of 10SP1 problem

Cold end solution no. 3/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	BK	3	3	394.5972	369.3115	311	355.25	373.47	7.746852
7	CU	1	1001	433	366	303	323	588.93	6.983777
8	CU	3	1001	369.3115	339	303	323	447.7003	10.93565
9	CU	4	1001	432.0191	422	303	323	125.84	1.104472
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

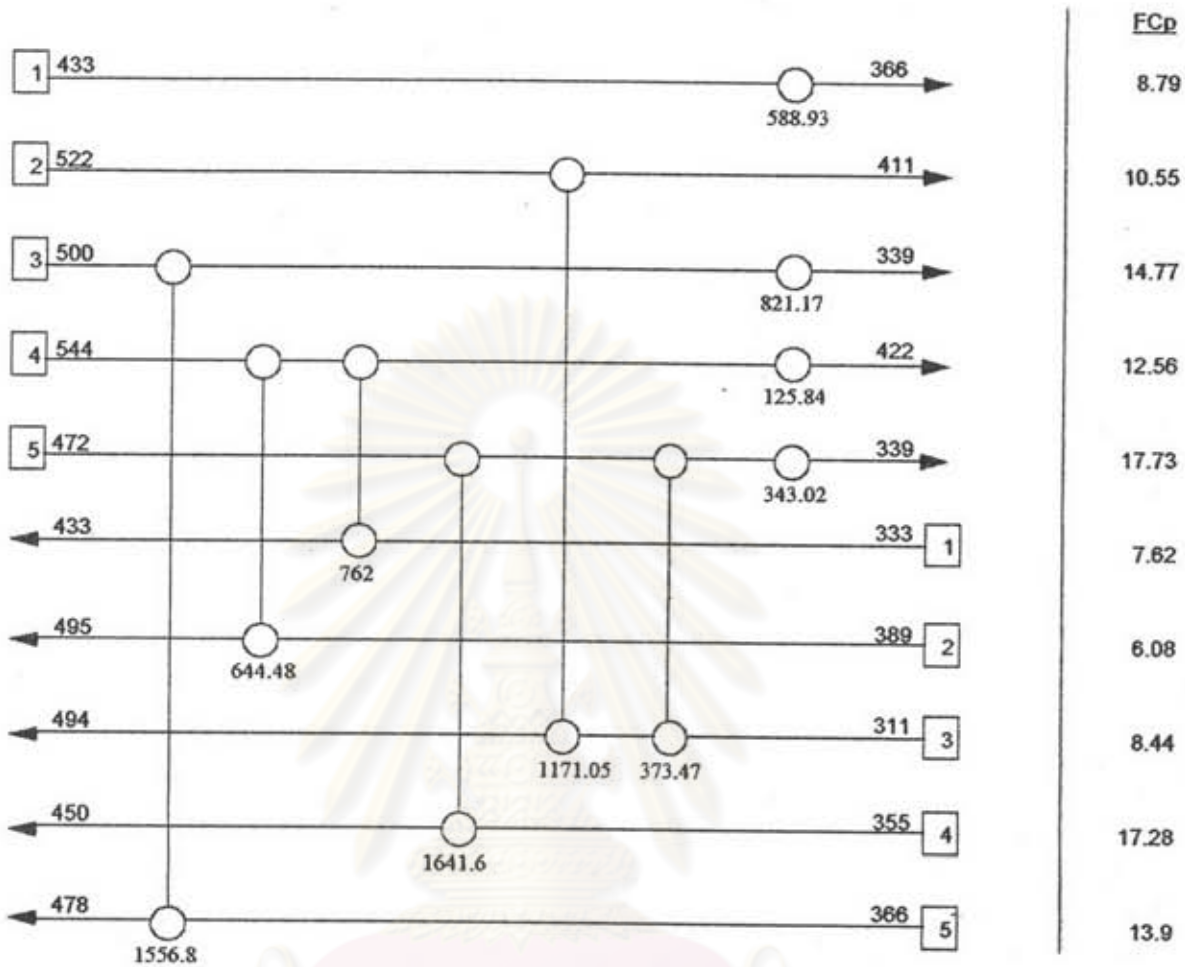

Figure 6.4.4 The Grid Representation of Cold end solution No. 4 / 30 of 10SP1 problem

Cold end solution no. 4/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	BK	5	3	379.4112	358.3469	311	355.25	373.47	10.83657
7	CU	1	1001	433	366	303	323	588.93	6.983777
8	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
9	CU	4	1001	432.0191	422	303	323	125.84	1.104472
10	CU	5	1001	358.3469	339	303	323	343.0199	9.81582

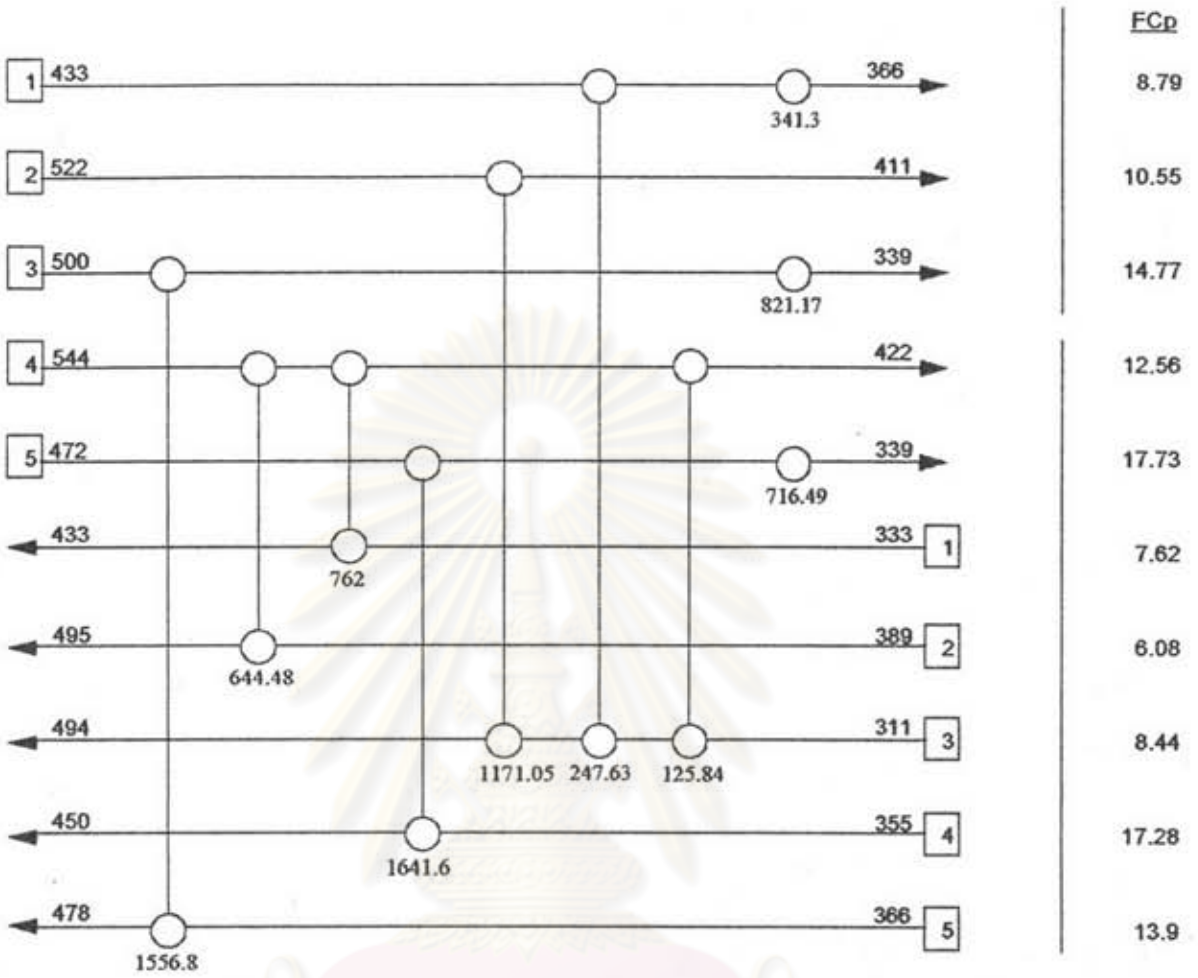

Figure 6.4.5 The Grid Representation of Cold end solution No. 5 / 30 of 10SP1 problem

Cold end solution no. 5/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	A[C]	4	3	432.0191	422	311	325.9099	125.84	1.159428
7	BK	1	3	433	404.8282	325.9099	355.25	247.6301	3.16126
8	CU	1	1001	404.8282	366	303	323	341.3	4.739994
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

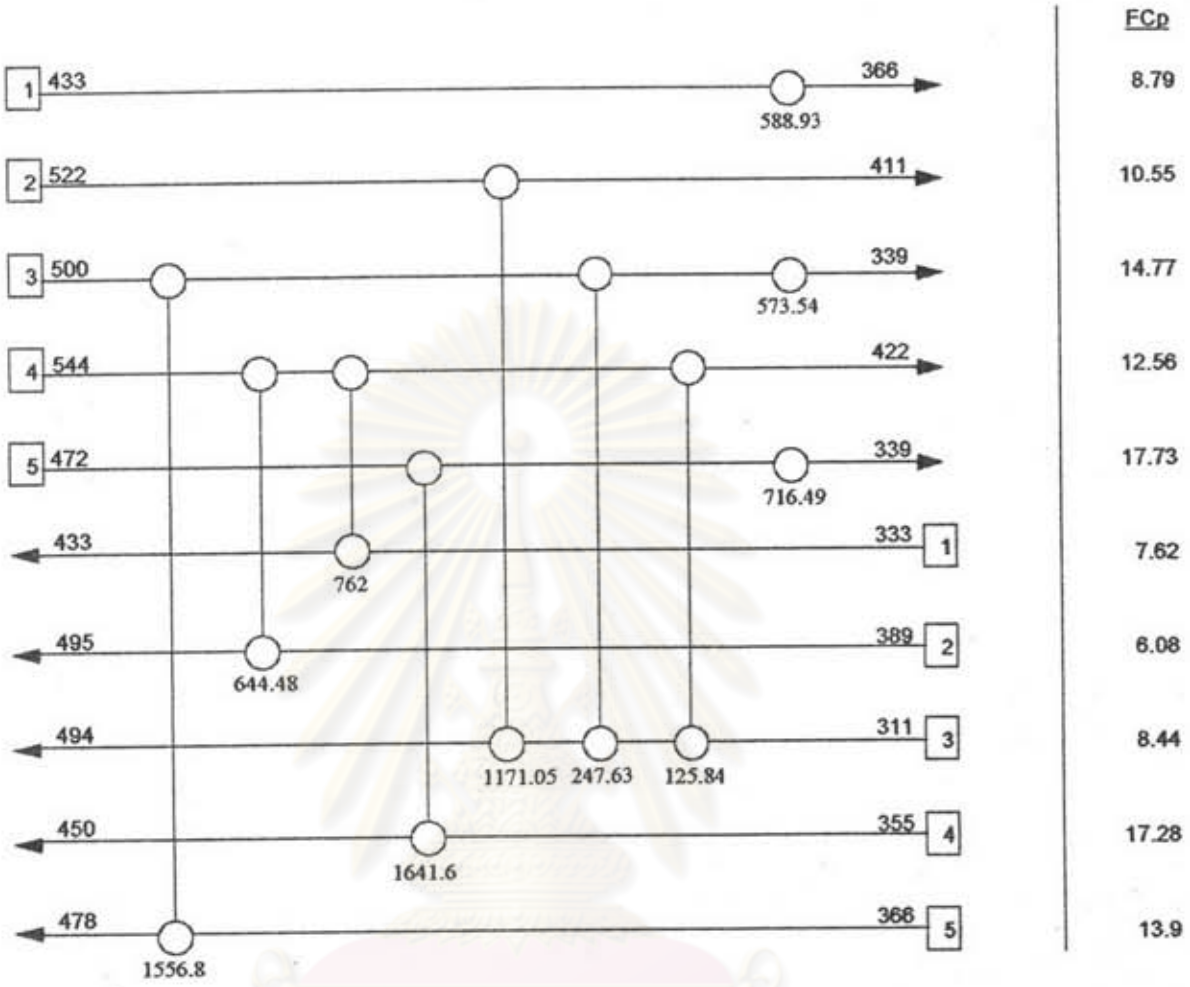

Figure 6.4.6 The Grid Representation of Cold end solution No. 6 / 30 of 10SP1 problem

Cold end solution no. 6/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	A[C]	4	3	432.0191	422	311	325.9099	125.84	1.159428
7	BK	3	3	394.5972	377.8314	325.9099	355.25	247.6301	5.461128
8	CU	1	1001	433	366	303	323	588.93	6.983777
9	CU	3	1001	377.8314	339	303	323	573.5401	12.81442
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

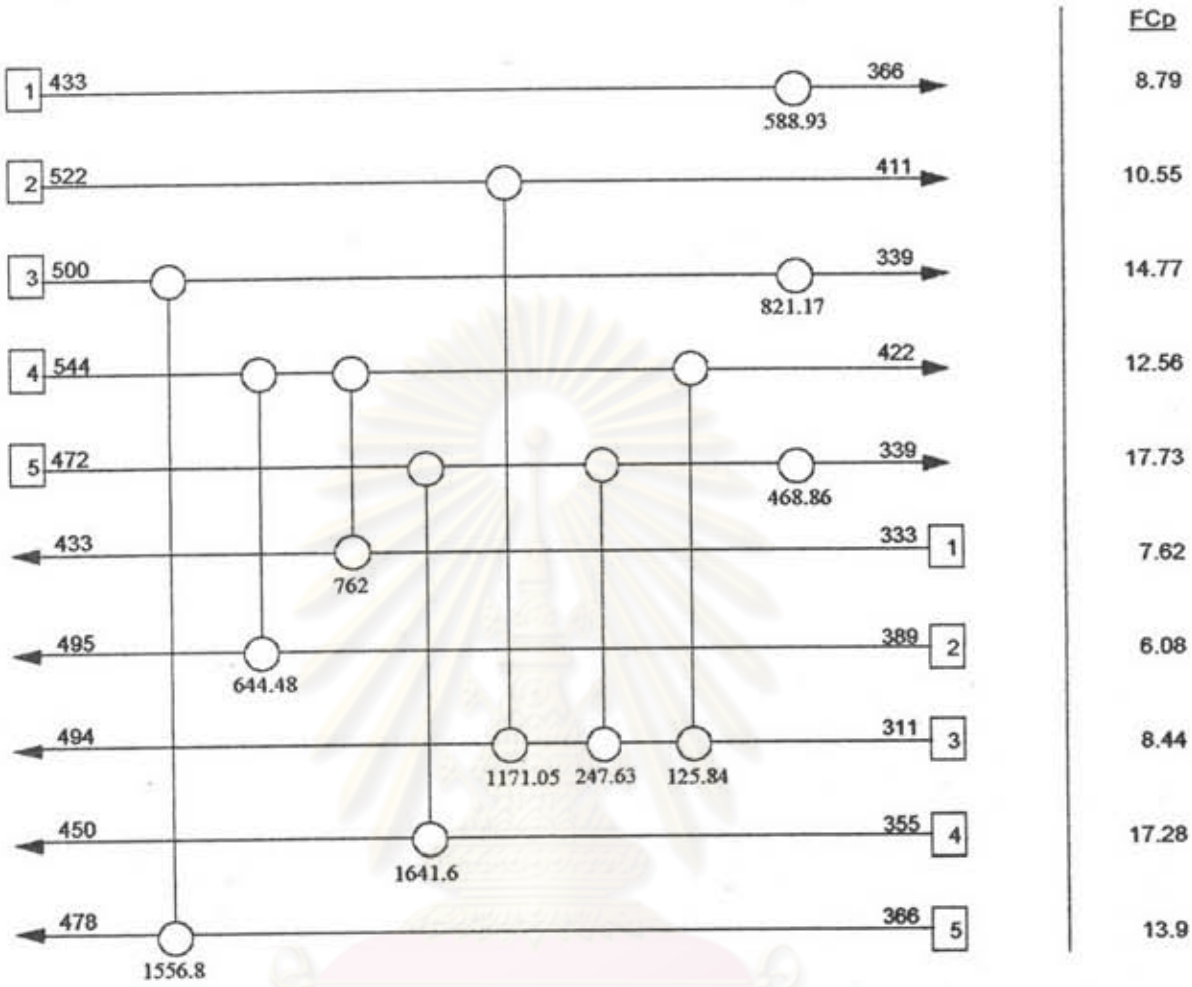

Figure 6.4.7 The Grid Representation of Cold end solution No. 7 / 30 of 10SP1 problem

Cold end solution no. 7/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	A[C]	4	3	432.0191	422	311	325.9099	125.84	1.159428
7	BK	5	3	379.4112	365.4444	325.9099	355.25	247.6301	7.931899
8	CU	1	1001	433	366	303	323	588.93	6.983777
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	365.4444	339	303	323	468.8597	11.98093

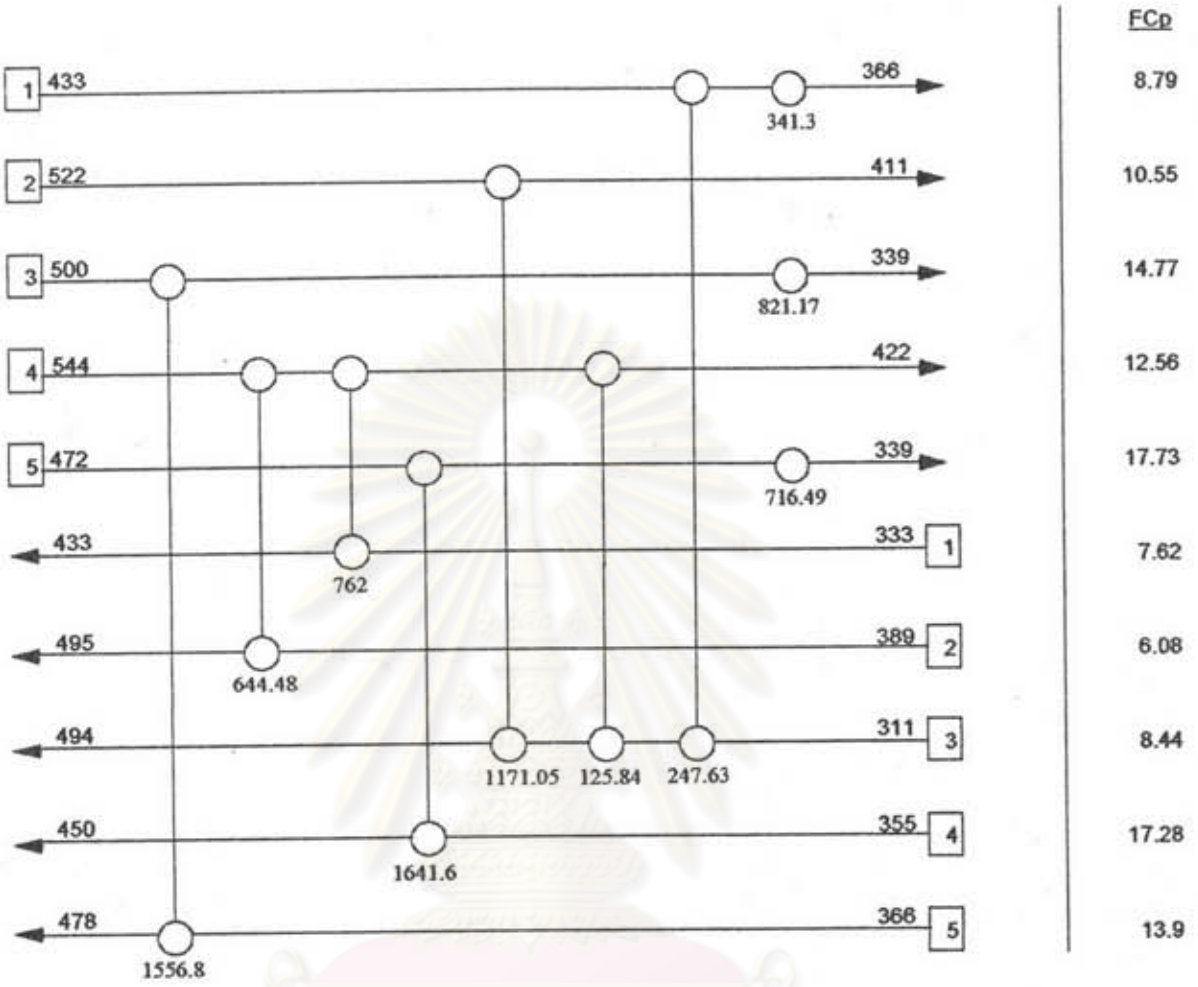

Figure 6.4.8 The Grid Representation of Cold end solution No. 8 / 30 of 10SP1 problem

Cold end solution no. 8/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	D[C]	4	3	432.0191	422	340.3401	355.25	125.84	1.589102
7	BK	1	3	433	404.8282	311	340.3401	247.6301	2.655753
8	CU	1	1001	404.8282	366	303	323	341.3	4.739994
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

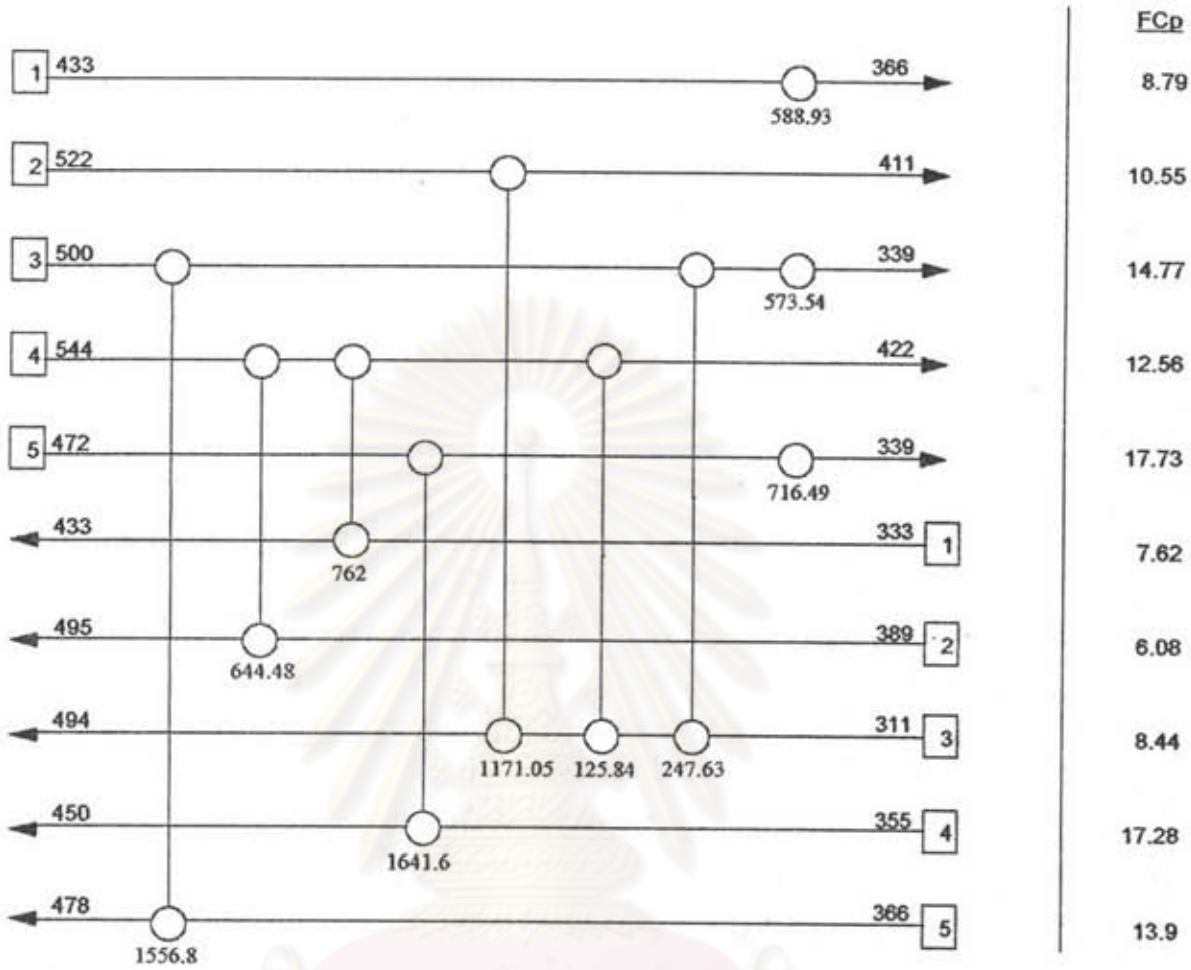

Figure 6.4.9 The Grid Representation of Cold end solution No. 9 / 30 of 10SP1 problem

Cold end solution no. 9/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	D[C]	4	3	432.0191	422	340.3401	355.25	125.84	1.589102
7	BK	3	3	394.5972	377.8314	311	340.3401	247.6301	4.104863
8	CU	1	1001	433	366	303	323	588.93	6.983777
9	CU	3	1001	377.8314	339	303	323	573.5401	12.81442
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

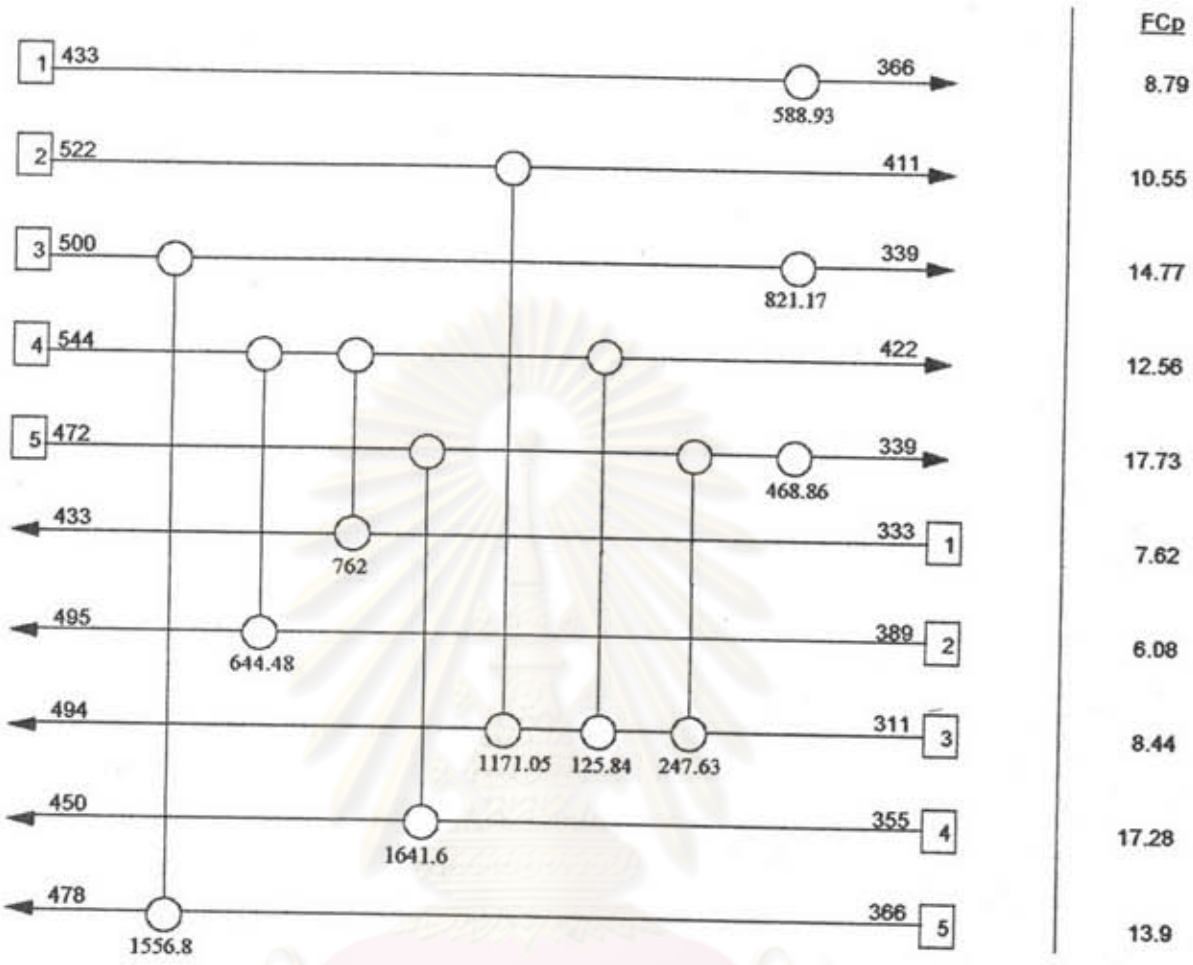

Figure 6.4.10 The Grid Representation of Cold end solution No. 10/ 30 of 10SP1 problem

Cold end solution no. 10/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	D[C]	4	3	432.0191	422	340.3401	355.25	125.84	1.589102
7	BK	5	3	379.4112	365.4444	311	340.3401	247.6301	5.344516
8	CU	1	1001	433	366	303	323	588.93	6.983777
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	365.4444	339	303	323	468.8597	11.98093

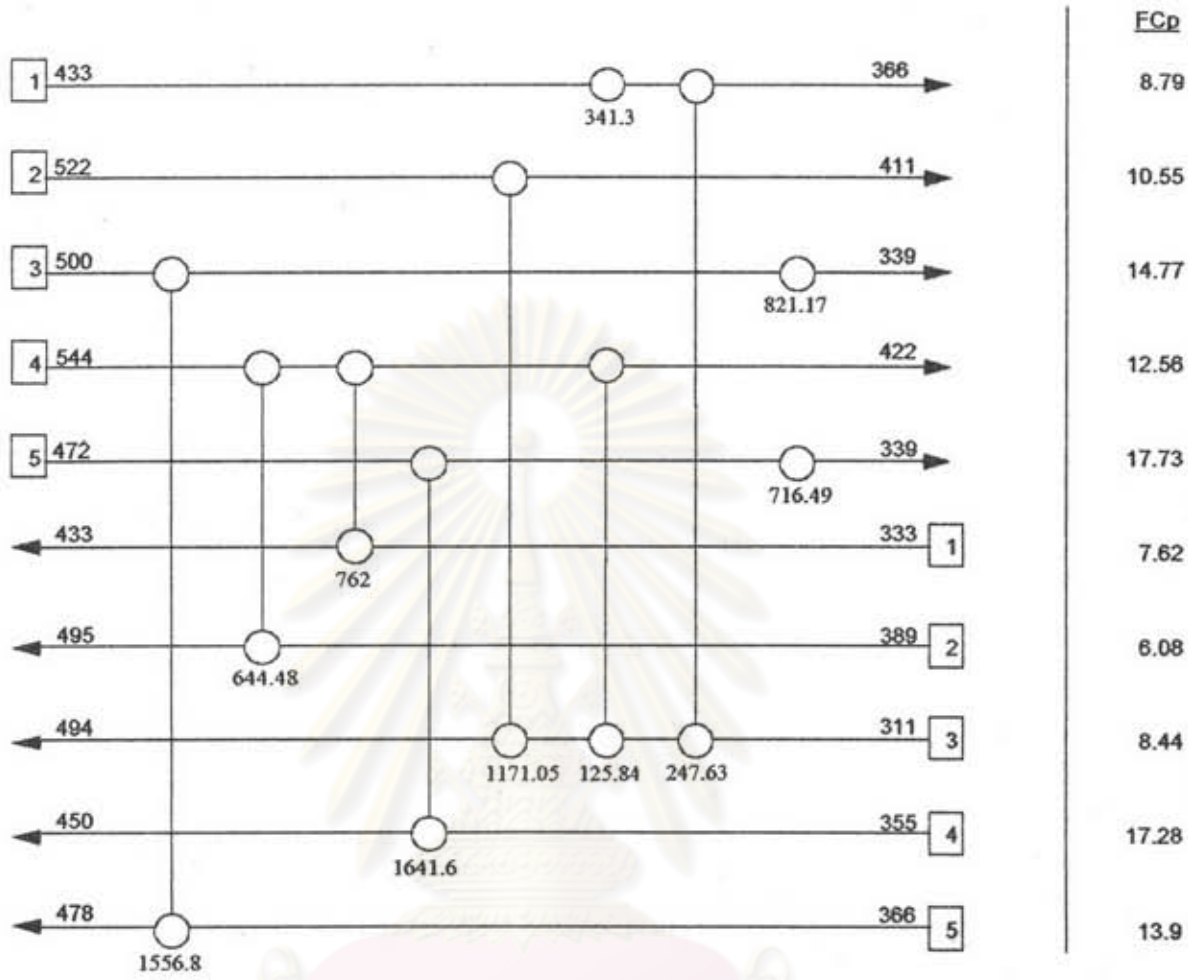

Figure 6.4.11 The Grid Representation of Cold end solution No. 11/ 30 of 10SP1 problem

Cold end solution no. 11/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	D[C]	4	3	432.0191	422	340.3401	355.25	125.84	1.589102
7	C[C]	1	3	394.1718	366	311	340.3401	247.6301	4.55087
8	CU	1	1001	433	394.1718	303	323	341.3	3.40308
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

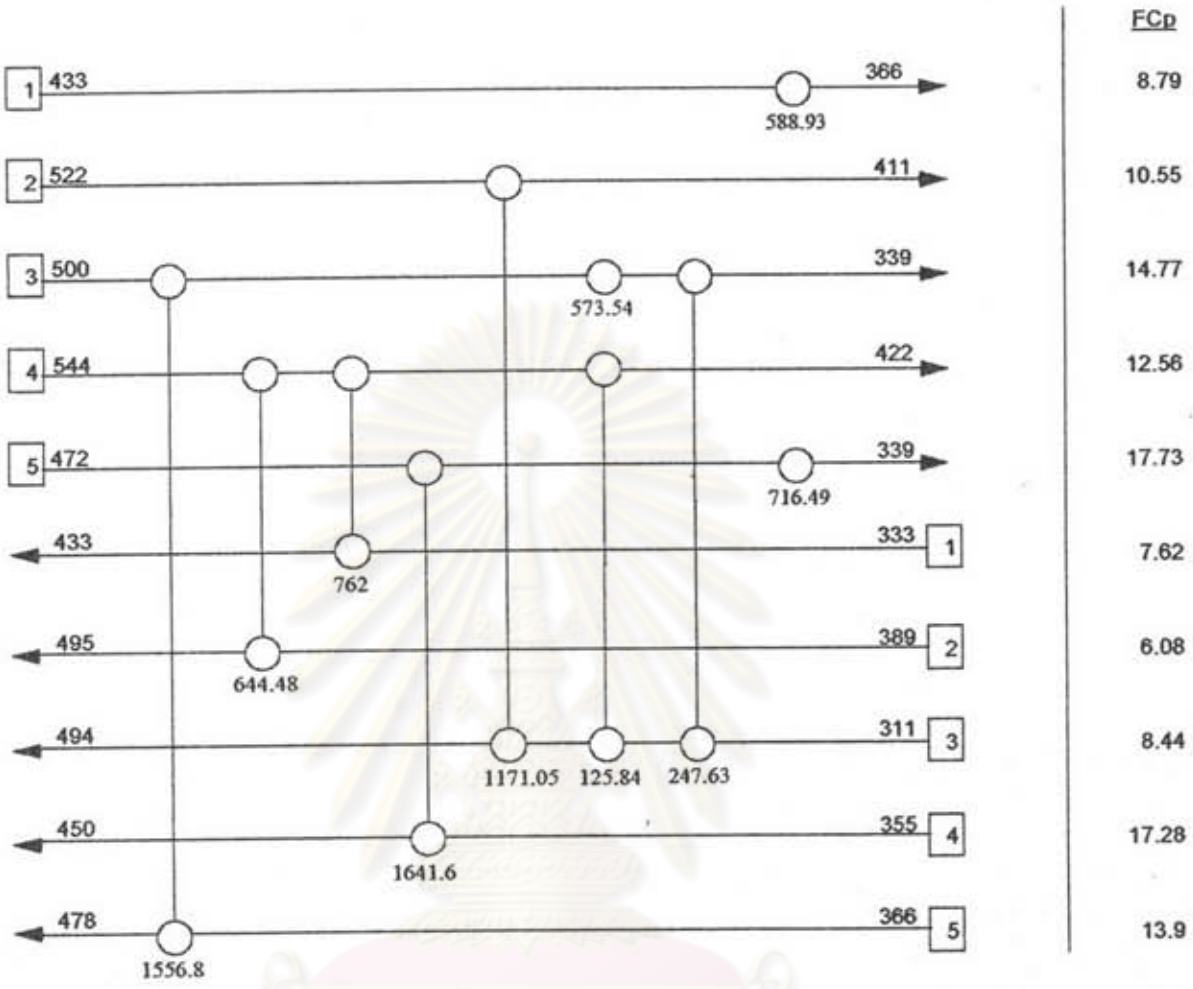

Figure 6.4.12 The Grid Representation of Cold end solution No. 12/ 30 of 10SP1 problem

Cold end solution no. 12/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	D[C]	4	3	432.0191	422	340.3401	355.25	125.84	1.589102
7	C[C]	3	3	355.7657	339	311	340.3401	247.6301	11.74057
8	CU	1	1001	433	366	303	323	588.93	6.983777
9	CU	3	1001	394.5972	355.7657	303	323	573.5401	9.295132
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

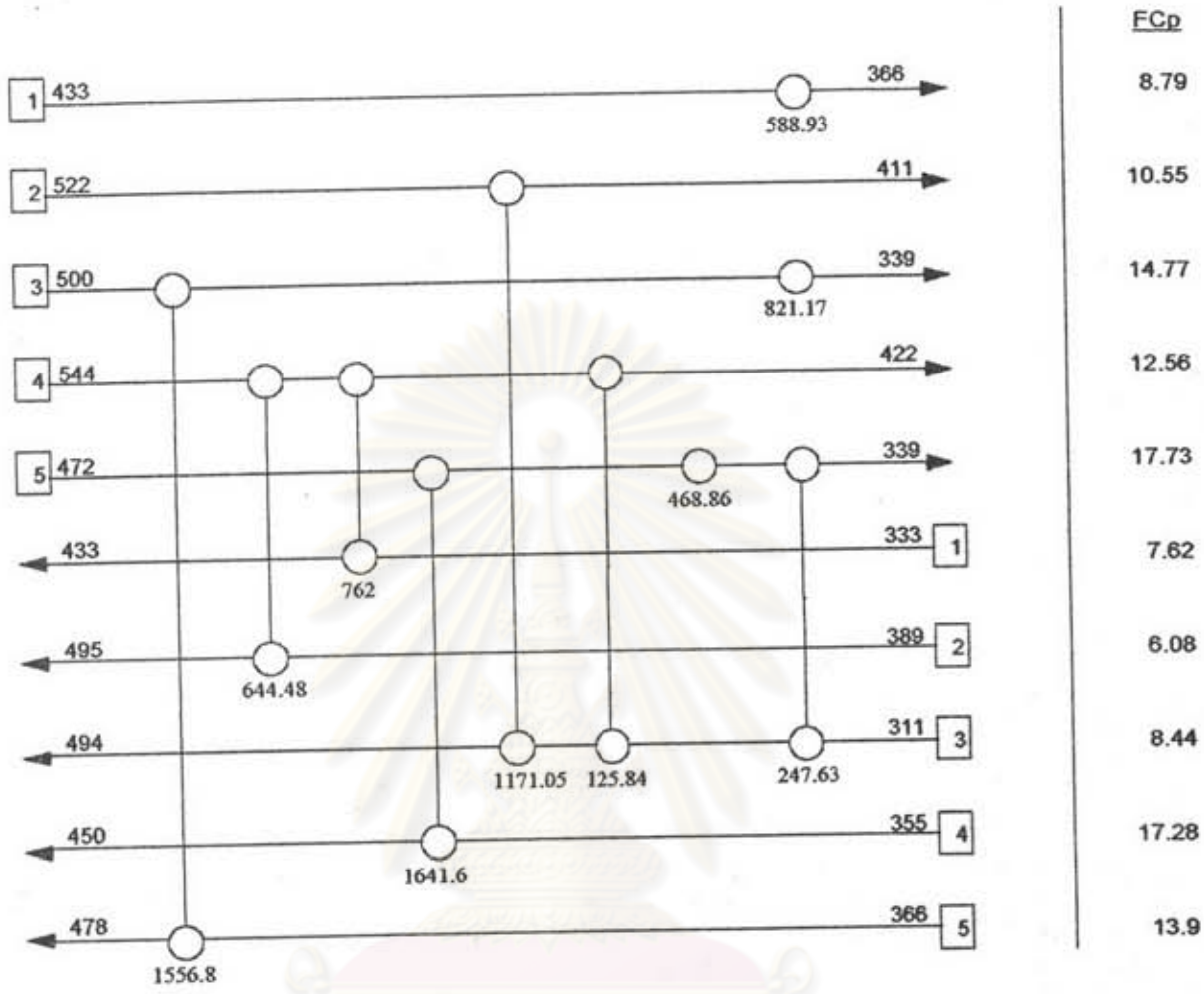

Figure 6.4.13 The Grid Representation of Cold end solution No. 13/ 30 of 10SP1 problem

Cold end solution no. 13/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	D[C]	4	3	432.0191	422	340.3401	355.25	125.84	1.589102
7	C[C]	5	3	352.9667	339	311	340.3401	247.6301	12.82811
8	CU	1	1001	433	366	303	323	588.93	6.983777
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	379.4112	352.9667	303	323	468.8597	8.825788

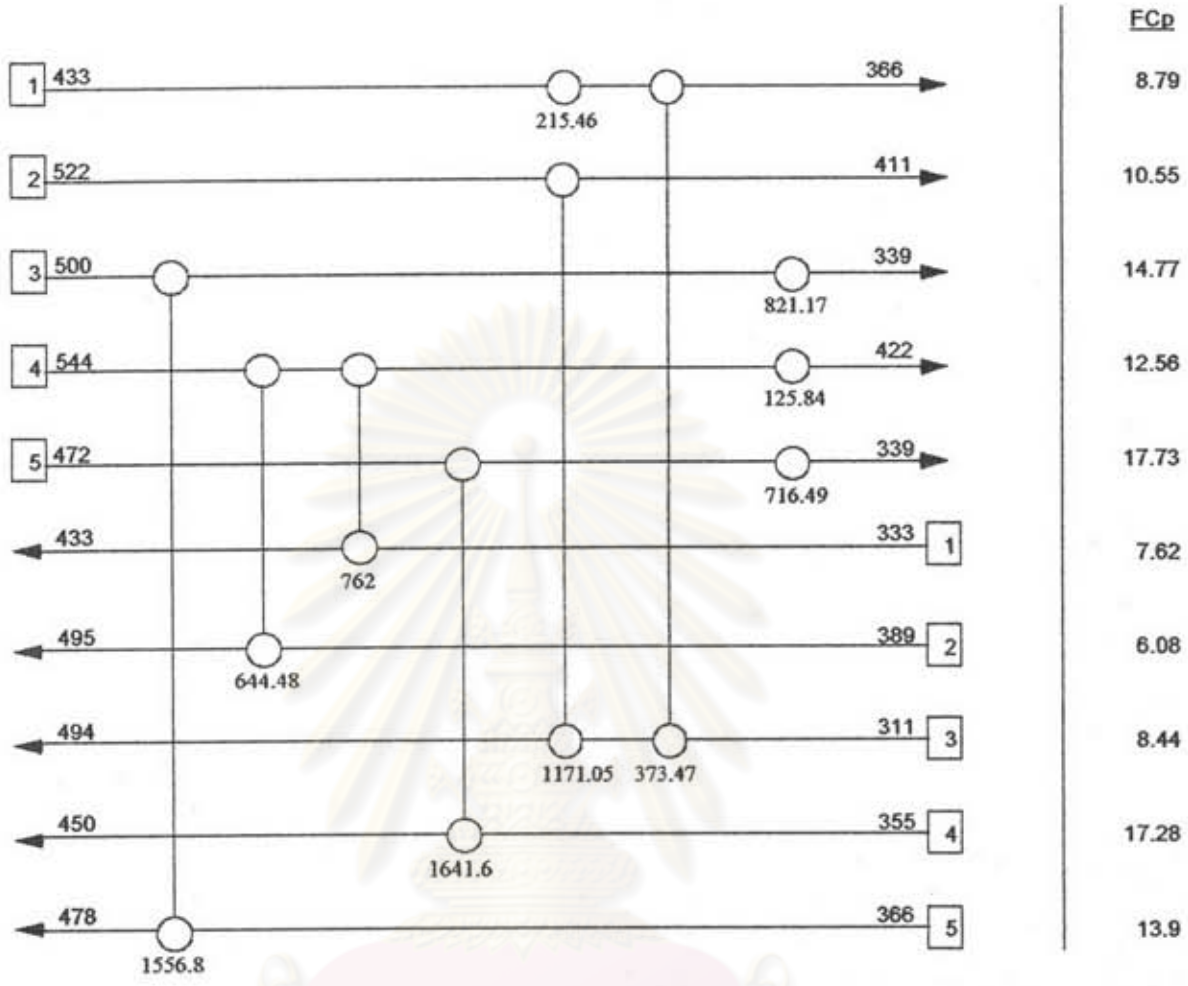

Figure 6.4.14 The Grid Representation of Cold end solution No. 14/ 30 of 10SP1 problem

Cold end solution no. 14/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
5	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
6	C[C]	1	3	408.488	366	311	355.25	373.47	6.901508
7	CU	1	1001	433	408.488	303	323	215.4602	2.000033
8	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
9	CU	4	1001	432.0191	422	303	323	125.84	1.104472
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

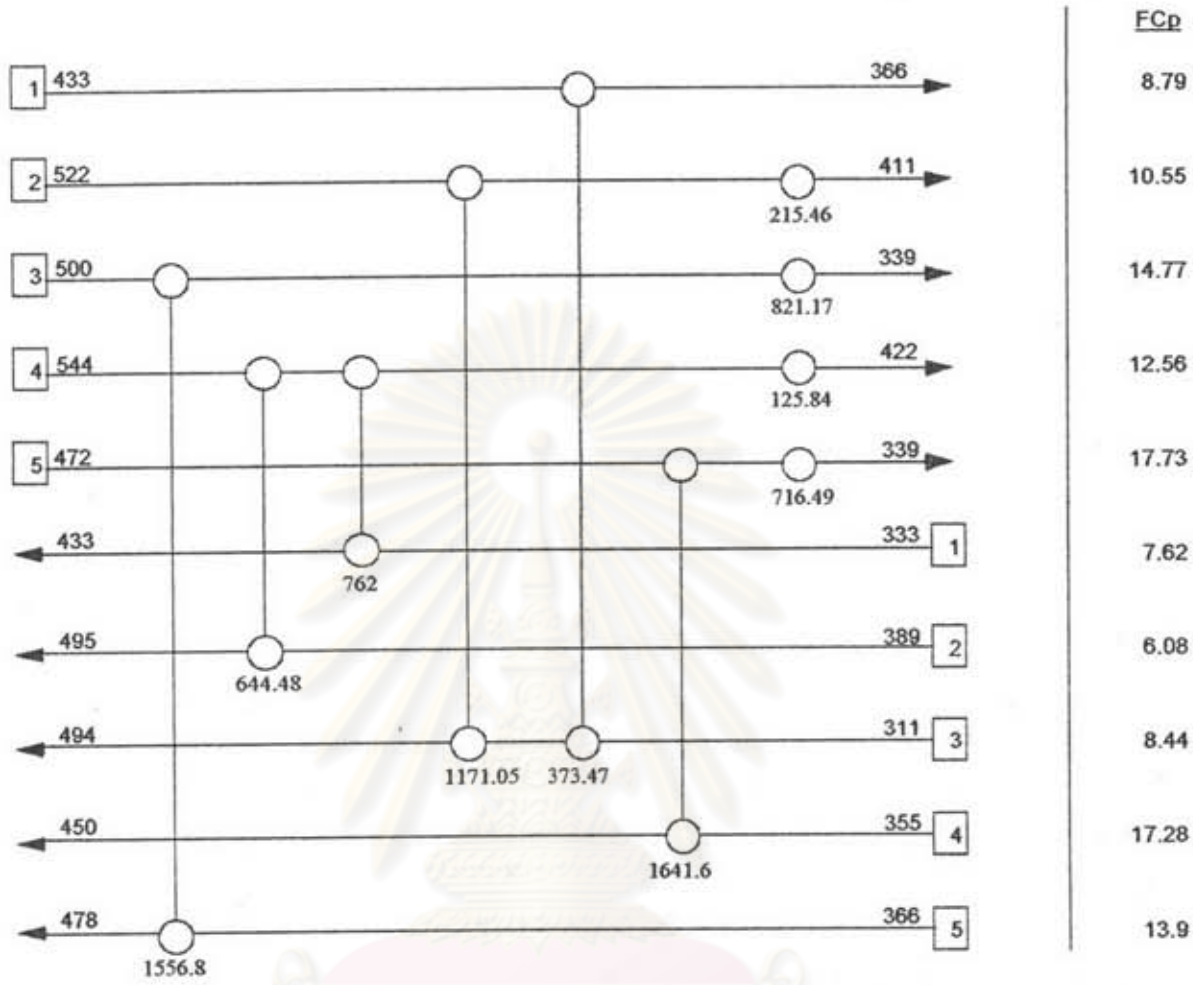

Figure 6.4.15 The Grid Representation of Cold end solution No. 15/ 30 of 10SP1 problem

Cold end solution no. 15/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	A[C]	1	3	433	366	311	380.7784	588.93	10.98775
5	BK	2	3	522	431.4228	380.7784	494	955.5899	25.00865
6	BK	5	4	472	379.4112	355	450	1641.6	70.80531
7	CU	2	1001	431.4228	411	303	323	215.4601	1.991106
8	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
9	CU	4	1001	432.0191	422	303	323	125.84	1.104472
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

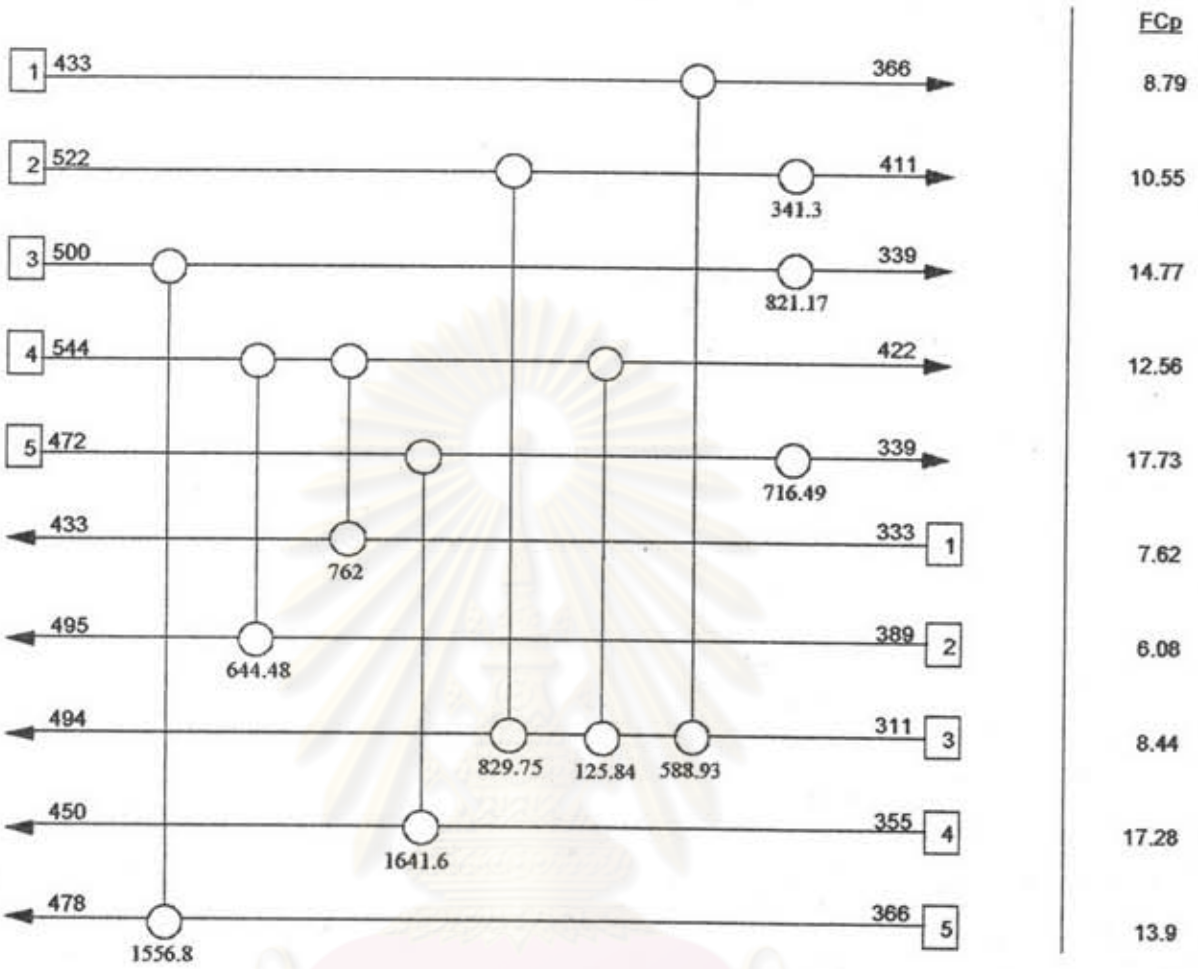

Figure 6.4.16 The Grid Representation of Cold end solution No. 16/ 30 of 10SP1 problem

Cold end solution no. 16/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	A[C]	1	3	433	366	311	380.7784	588.93	10.98775
5	BK	5	4	472	379.4112	355	450	1641.6	70.80531
6	A[C]	4	3	432.0191	422	380.7784	395.6884	125.84	3.249605
7	BK	2	3	522	443.3507	395.6884	494	829.75	22.44772
8	CU	2	1001	443.3507	411	303	323	341.3	2.992181
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

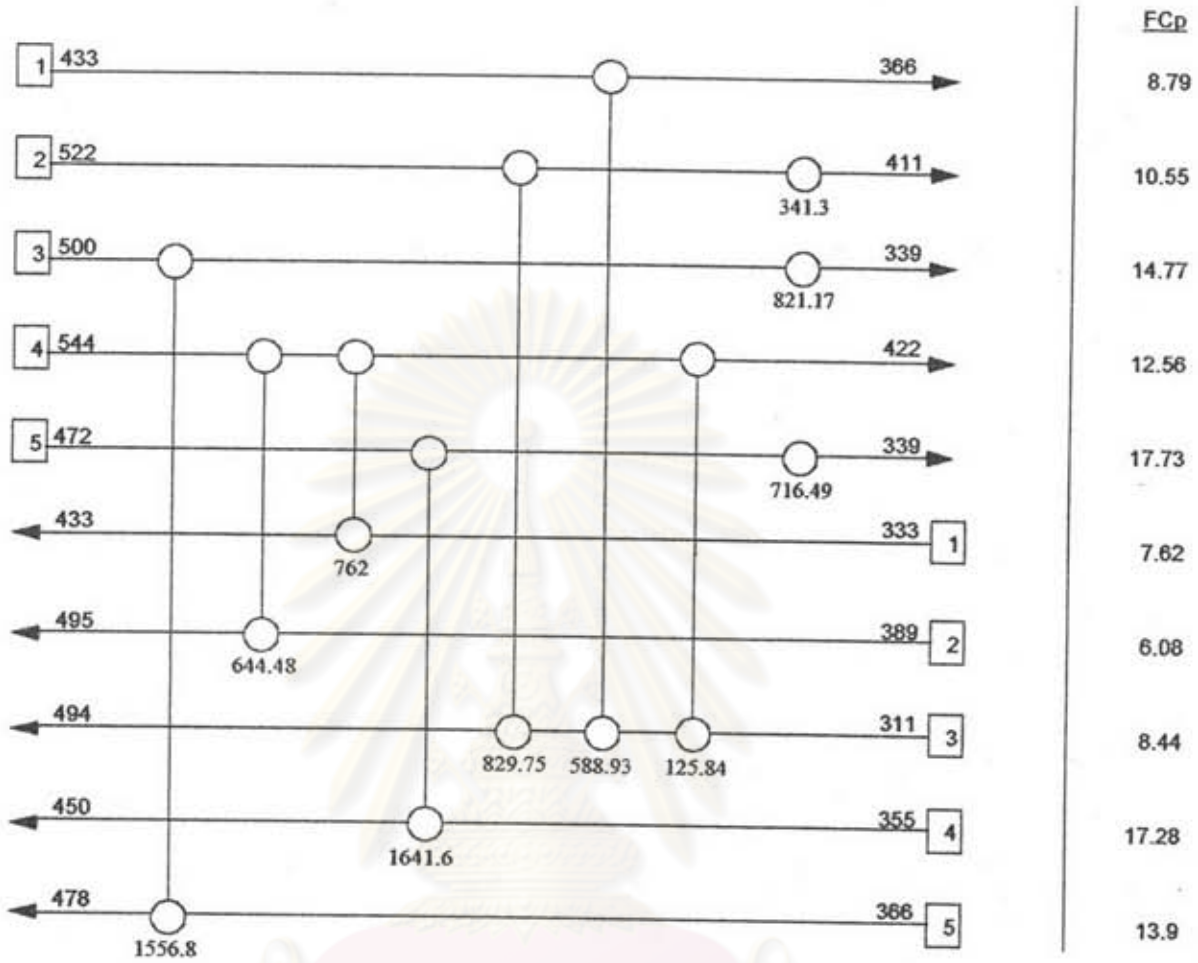

Figure 6.4.17 The Grid Representation of Cold end solution No. 17/ 30 of 10SP1 problem

Cold end solution no. 17/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	4	1	492.6879	432.0191	333	433	762	9.806762
4	A[C]	4	3	432.0191	422	311	325.9099	125.84	1.159428
5	BK	5	4	472	379.4112	355	450	1641.6	70.80531
6	A[C]	1	3	433	366	325.9099	395.6884	588.93	15.22404
7	BK	2	3	522	443.3507	395.6884	494	829.75	22.44772
8	CU	2	1001	443.3507	411	303	323	341.3	2.992181
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

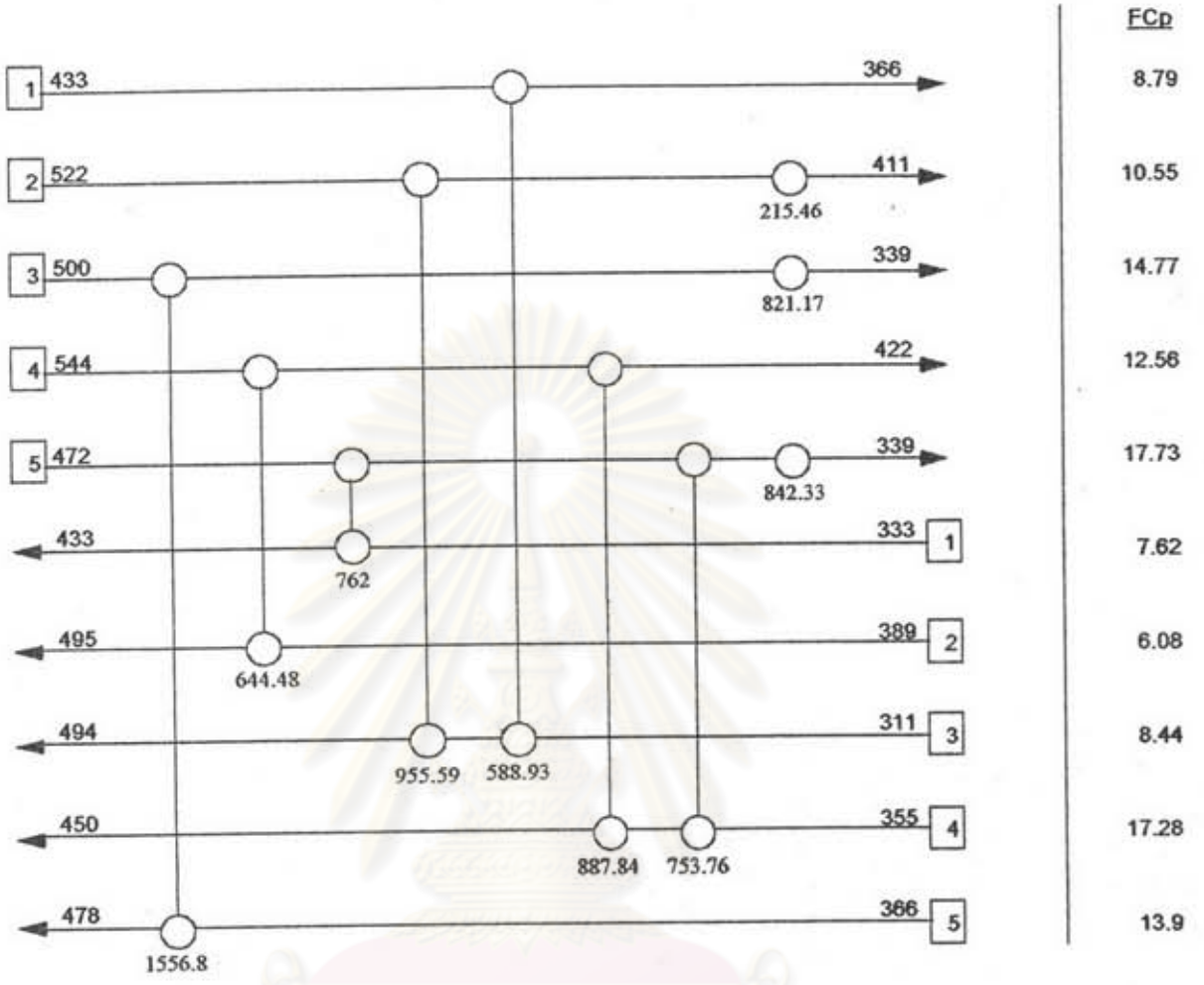

Figure 6.4.18 The Grid Representation of Cold end solution No. 18/ 30 of 10SP1 problem

Cold end solution no. 18/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	1	472	429.022	333	433	762	12.04051
4	A[C]	1	3	433	366	311	380.7784	588.93	10.98775
5	BK	2	3	522	431.4228	380.7784	494	955.5899	25.00865
6	D[H]	4	4	492.6879	422	398.6204	450	887.84	27.68369
7	BK	5	4	429.022	386.5088	355	398.6204	753.7599	24.35261
8	CU	2	1001	431.4228	411	303	323	215.4601	1.991106
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	386.5088	339	303	323	842.3303	17.38196

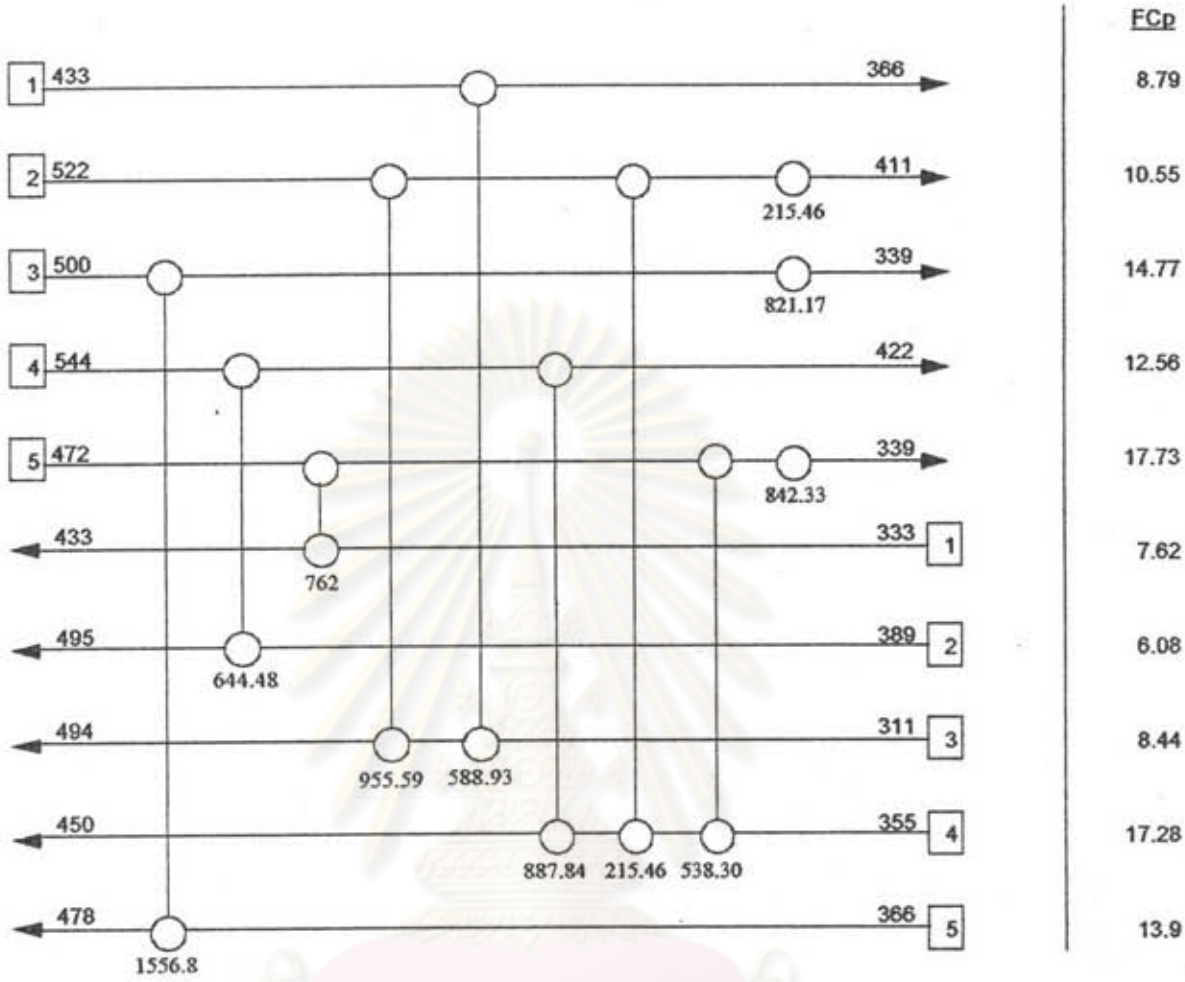

Figure 6.4.19 The Grid Representation of Cold end solution No. 19/ 30 of 10SP1 problem

Cold end solution no. 19/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	1	472	429.022	333	433	762	12.04051
4	A[C]	1	3	433	366	311	380.7784	588.93	10.98775
5	BK	2	3	522	431.4228	380.7784	494	955.5899	25.00865
6	D[H]	4	4	492.6879	422	398.6204	450	887.84	27.68369
7	D[H]	2	4	431.4228	411	386.1516	398.6204	215.4601	7.522637
8	BK	5	4	429.022	398.661	355	386.1516	538.2999	12.44206
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	398.661	339	303	323	1057.79	19.80956

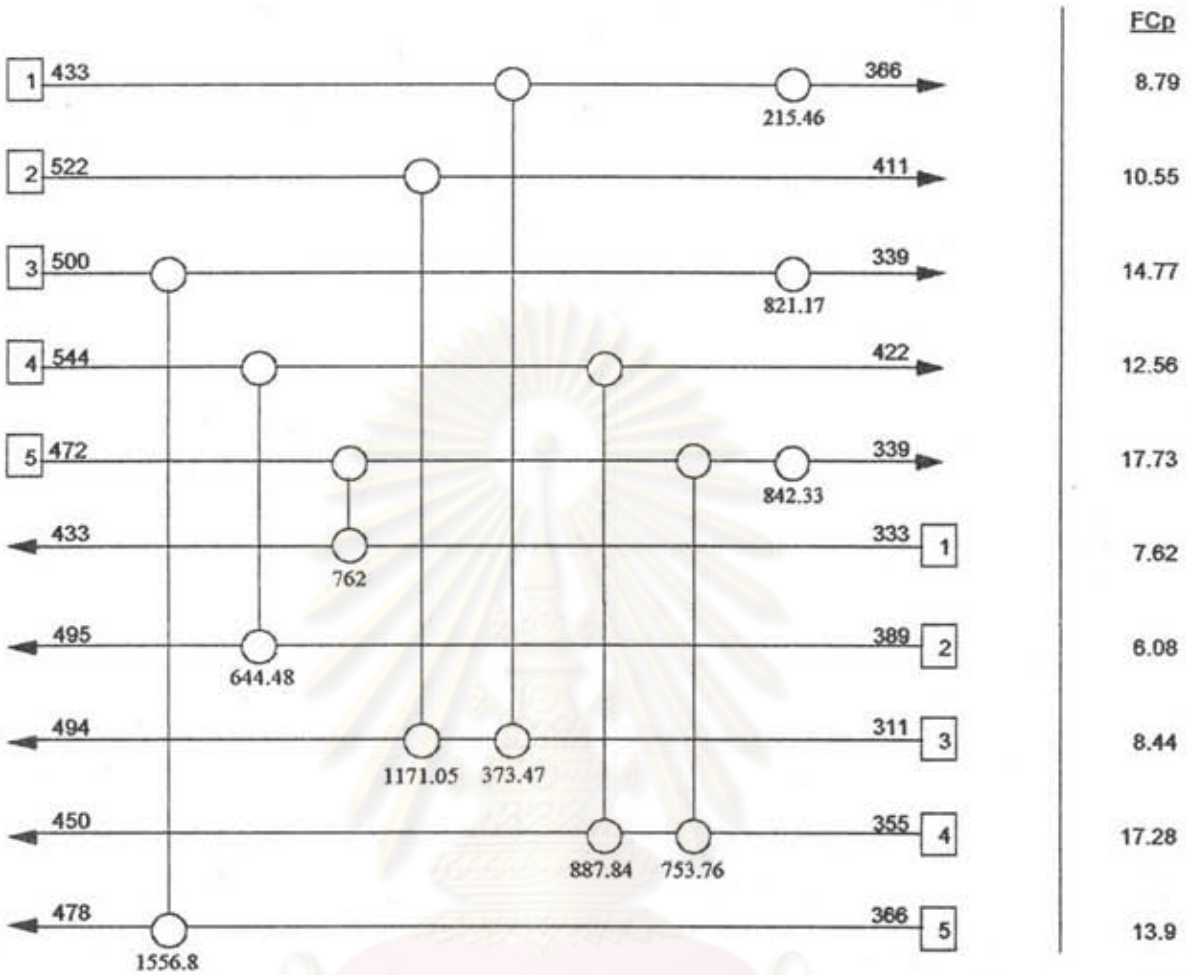

Figure 6.4.20 The Grid Representation of Cold end solution No. 20/ 30 of 10SP1 problem

Cold end solution no. 20/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	1	472	429.022	333	433	762	12.04051
4	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
5	BK	1	3	433	390.512	311	355.25	373.47	4.749852
6	D[H]	4	4	492.6879	422	398.6204	450	887.84	27.68369
7	BK	5	4	429.022	386.5088	355	398.6204	753.7599	24.35261
8	CU	1	1001	390.512	366	303	323	215.4602	3.303084
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	386.5088	339	303	323	842.3303	17.38196

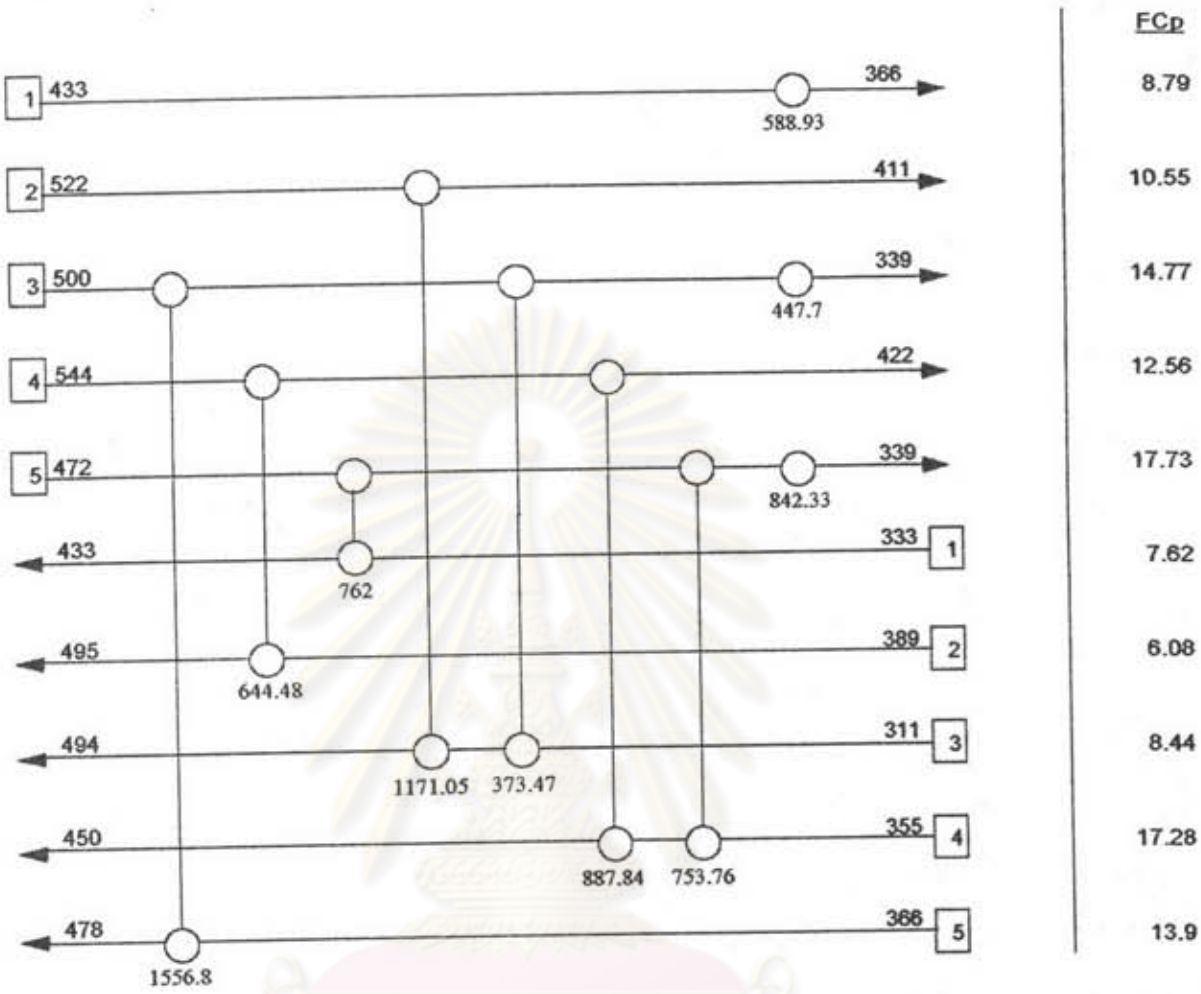

Figure 6.4.21 The Grid Representation of Cold end solution No. 21/ 30 of 10SP1 problem

Cold end solution no. 21/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	1	472	429.022	333	433	762	12.04051
4	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
5	BK	3	3	394.5972	369.3115	311	355.25	373.47	7.746852
6	D[H]	4	4	492.6879	422	398.6204	450	887.84	27.68369
7	BK	5	4	429.022	386.5088	355	398.6204	753.7599	24.35261
8	CU	1	1001	433	366	303	323	588.93	6.983777
9	CU	3	1001	369.3115	339	303	323	447.7003	10.93565
10	CU	5	1001	386.5088	339	303	323	842.3303	17.38196

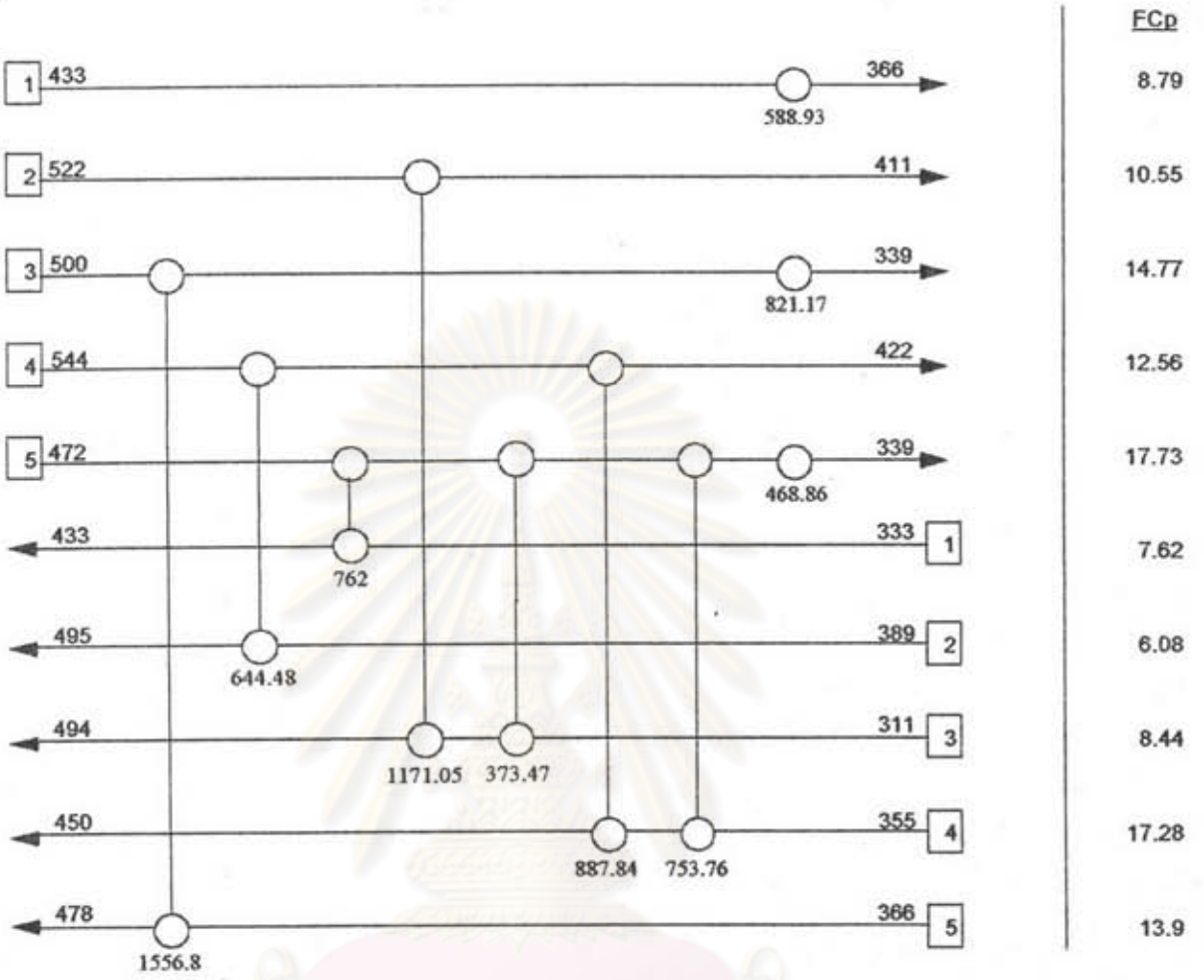

Figure 6.4.22 The Grid Representation of Cold end solution No. 22/ 30 of 10SP1 problem

Cold end solution no. 22/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	1	472	429.022	333	433	762	12.04051
4	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
5	D[H]	4	4	492.6879	422	398.6204	450	887.84	27.68369
6	BK	5	4	429.022	386.5088	355	398.6204	753.7599	24.35261
7	BK	5	3	386.5088	365.4445	311	355.25	373.47	8.937901
8	CU	1	1001	433	366	303	323	588.93	6.983777
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	365.4445	339	303	323	468.8602	11.98094

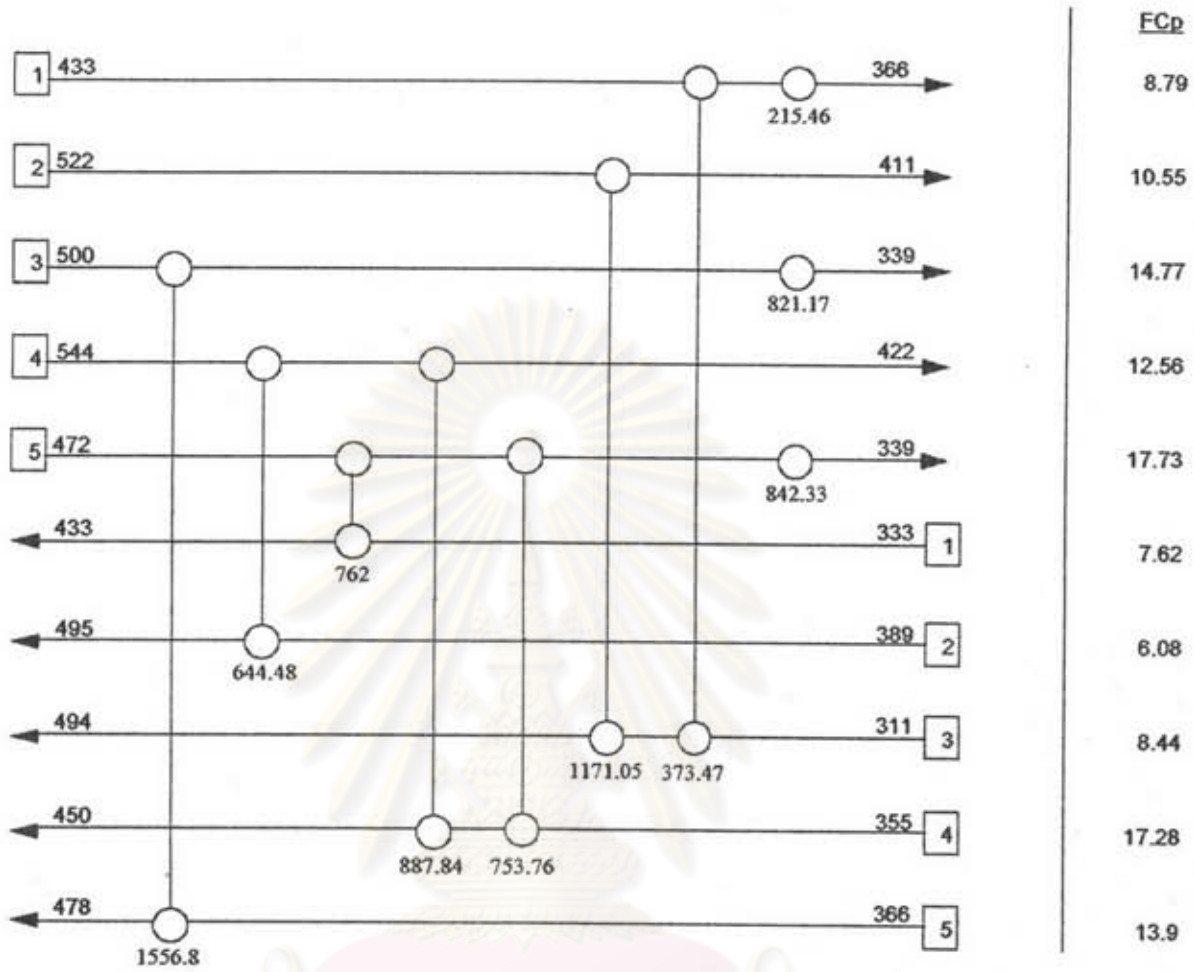

Figure 6.4.23 The Grid Representation of Cold end solution No. 23/ 30 of 10SP1 problem

Cold end solution no. 23/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	1	472	429.022	333	433	762	12.04051
4	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
5	D[H]	4	4	492.6879	422	398.6204	450	887.84	27.68369
6	BK	5	4	429.022	386.5088	355	398.6204	753.7599	24.35261
7	C[C]	1	3	408.488	366	311	355.25	373.47	6.901508
8	CU	1	1001	433	408.488	303	323	215.4602	2.000033
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	386.5088	339	303	323	842.3303	17.38196

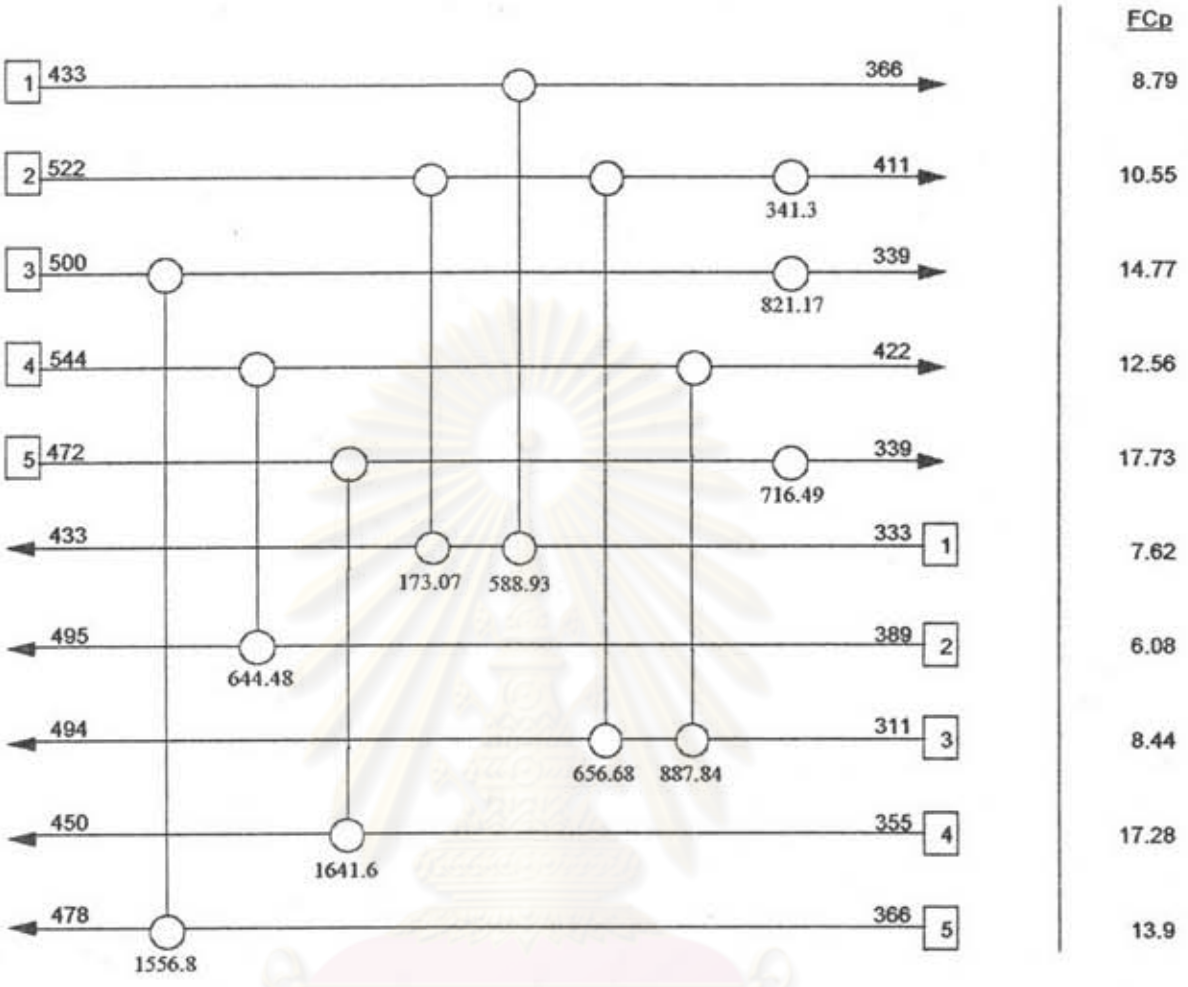

Figure 6.4.24 The Grid Representation of Cold end solution No. 24/ 30 of 10SP1 problem

Cold end solution no. 24/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
4	A[C]	1	1	433	366	333	410.2874	588.93	21.38703
5	BK	2	1	522	505.5953	410.2874	433	173.0699	1.878786
6	A[C]	4	3	492.6879	422	311	416.1943	887.84	9.579771
7	BK	2	3	505.5953	443.3507	416.1943	494	656.6797	35.91282
8	CU	2	1001	443.3507	411	303	323	341.3003	2.992183
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

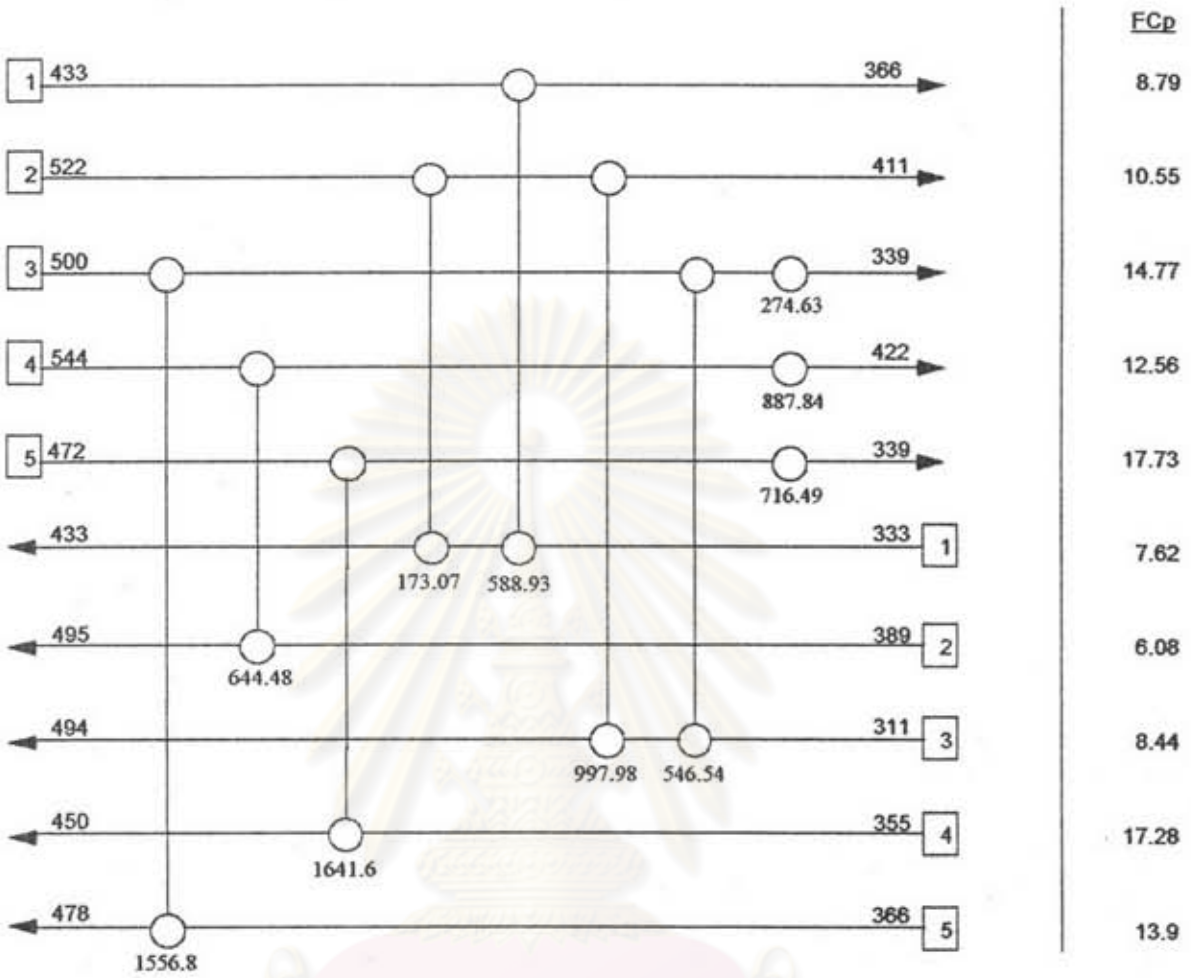

Figure 6.4.25 The Grid Representation of Cold end solution No. 25/ 30 of 10SP1 problem

Cold end solution no. 25/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
4	A[C]	1	1	433	366	333	410.2874	588.93	21.38703
5	BK	2	1	522	505.5953	410.2874	433	173.0699	1.878786
6	D[C]	2	3	505.5953	411	375.7559	494	997.9802	46.9137
7	BK	3	3	394.5972	357.5938	311	375.7559	546.5397	17.83068
8	CU	3	1001	357.5938	339	303	323	274.6306	7.781611
9	CU	4	1001	492.6879	422	303	323	887.84	6.215266
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

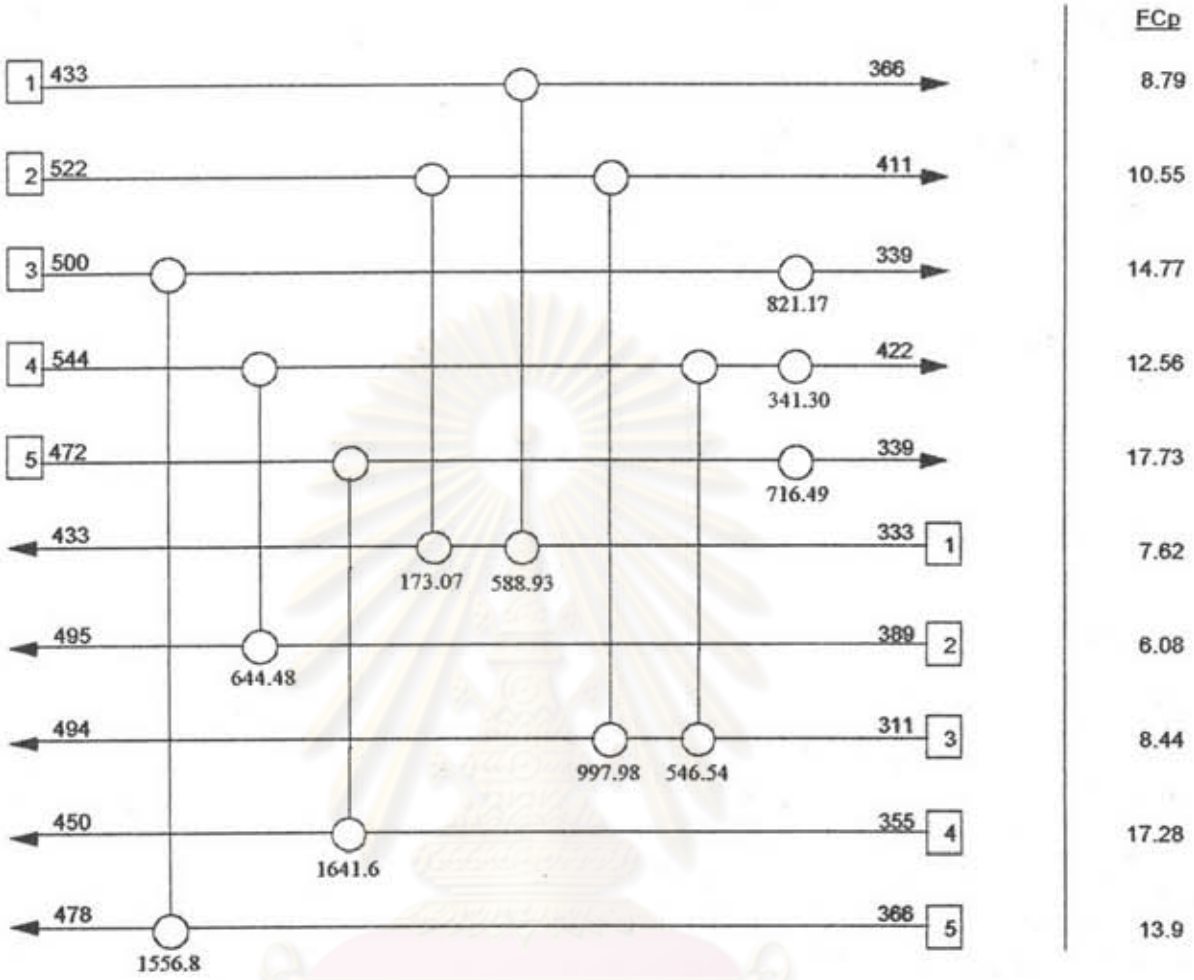

Figure 6.4.26 The Grid Representation of Cold end solution No. 26/ 30 of 10SP1 problem

Cold end solution no. 26/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
4	A[C]	1	1	433	366	333	410.2874	588.93	21.38703
5	BK	2	1	522	505.5953	410.2874	433	173.0699	1.878786
6	D[C]	2	3	505.5953	411	375.7559	494	997.9802	46.9137
7	BK	4	3	492.6879	449.1736	311	375.7559	546.5397	4.294755
8	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
9	CU	4	1001	449.1736	422	303	323	341.3002	2.784946
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

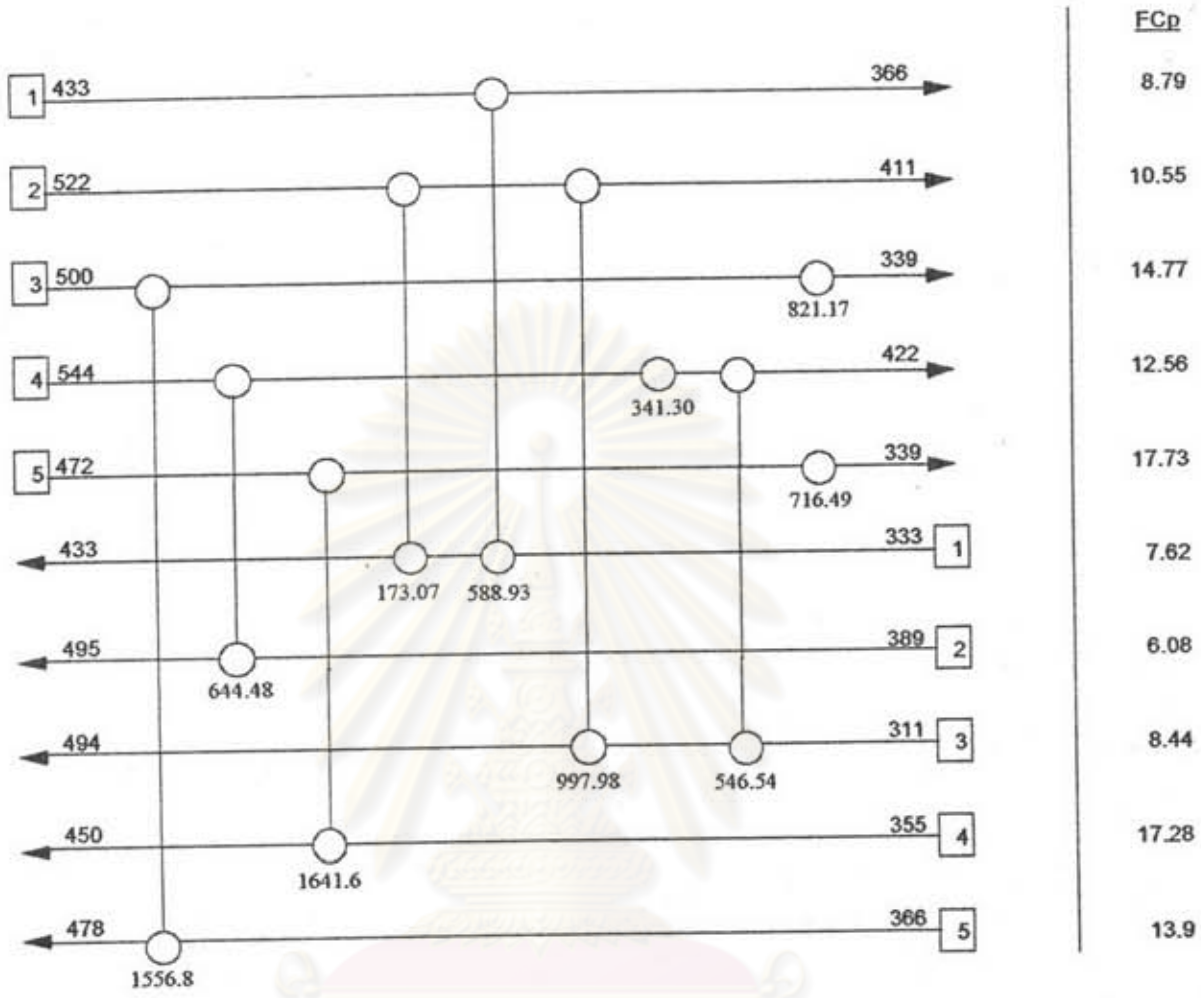

Figure 6.4.27 The Grid Representation of Cold end solution No. 27/ 30 of 10SP1 problem

Cold end solution no. 27/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
4	A[C]	1	1	433	366	333	410.2874	588.93	21.38703
5	BK	2	1	522	505.5953	410.2874	433	173.0699	1.878786
6	D[C]	2	3	505.5953	411	375.7559	494	997.9802	46.9137
7	C[C]	4	3	465.5143	422	311	375.7559	546.5397	5.465205
8	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
9	CU	4	1001	492.6879	465.5143	303	323	341.3002	2.055093
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

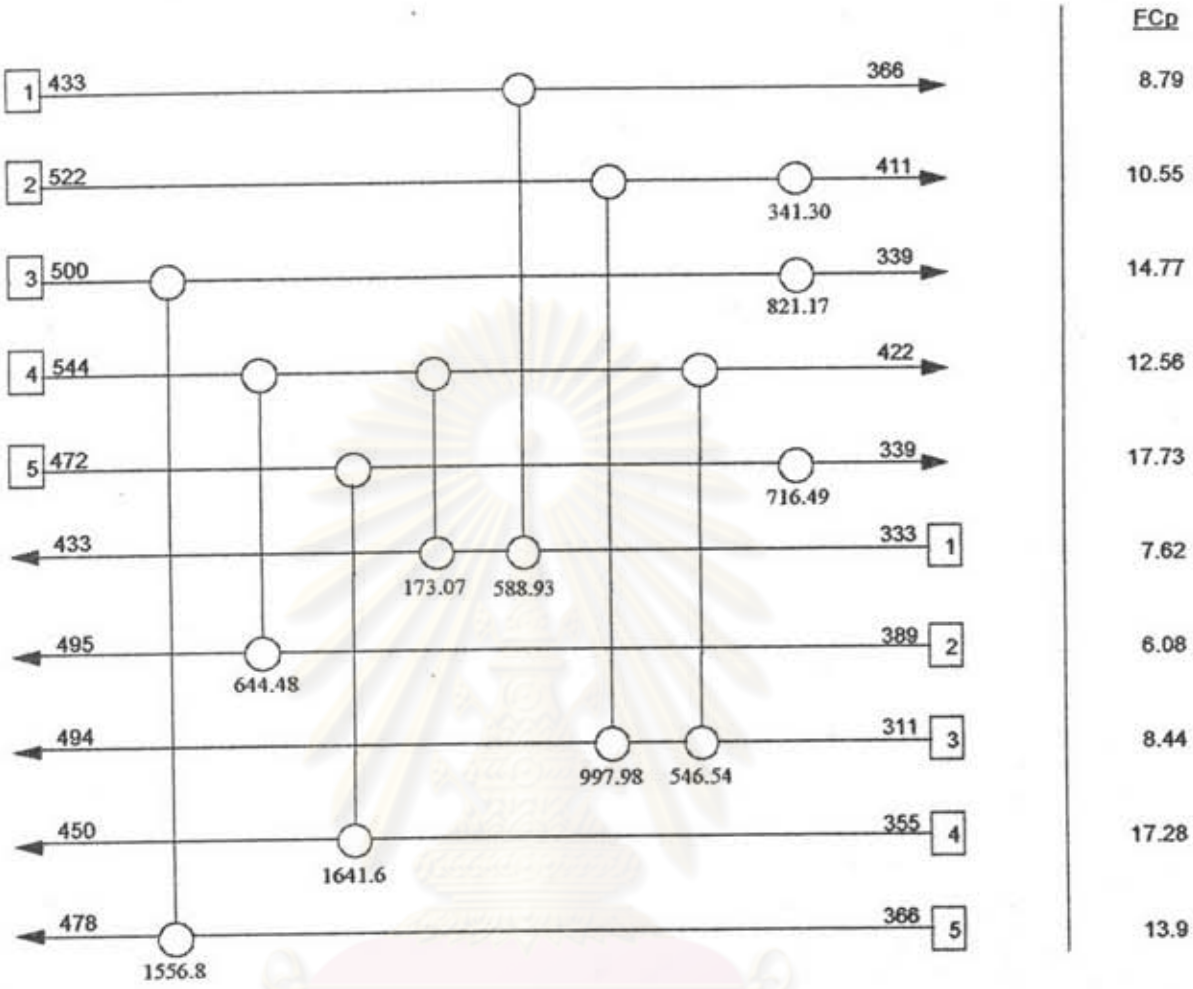

Figure 6.4.28 The Grid Representation of Cold end solution No. 28/ 30 of 10SP1 problem

Cold end solution no. 28/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
4	A[C]	1	1	433	366	333	410.2874	588.93	21.38703
5	BK	4	1	492.6879	478.9084	410.2874	433	173.0699	2.702077
6	A[C]	4	3	478.9084	422	311	395.6884	714.7701	7.411235
7	BK	2	3	522	443.3507	395.6884	494	829.7498	22.44771
8	CU	2	1001	443.3507	411	303	323	341.3003	2.992183
9	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

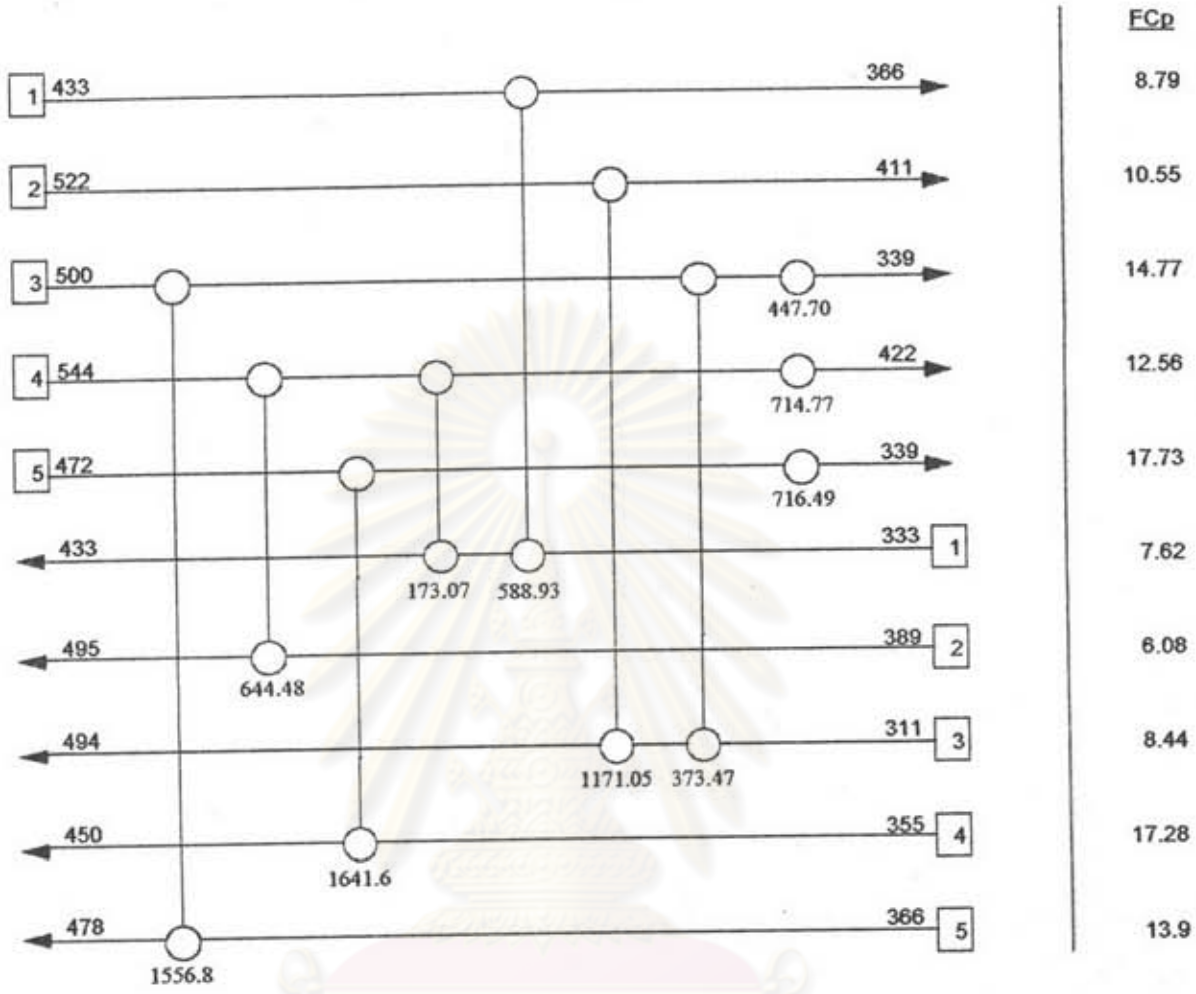

Figure 6.4.29 The Grid Representation of Cold end solution No. 29/ 30 of 10SP1 problem

Cold end solution no. 29/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
4	A[C]	1	1	433	366	333	410.2874	588.93	21.38703
5	BK	4	1	492.6879	478.9084	410.2874	433	173.0699	2.702077
6	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
7	BK	3	3	394.5972	369.3115	311	355.25	373.47	7.746852
8	CU	3	1001	369.3115	339	303	323	447.7003	10.93565
9	CU	4	1001	478.9084	422	303	323	714.7701	5.231645
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

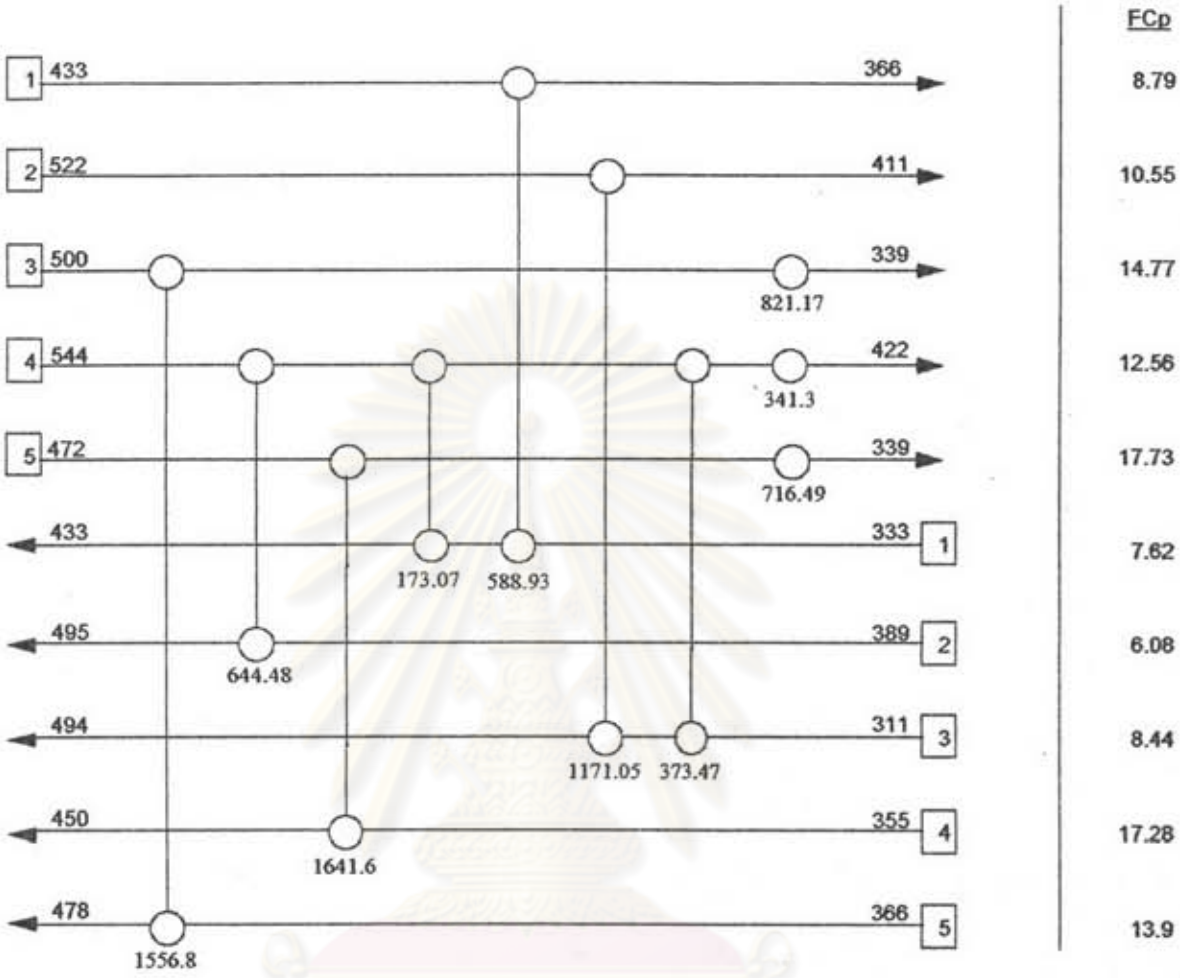

Figure 6.4.30 The Grid Representation of Cold end solution No. 30/ 30 of 10SP1 problem

Cold end solution no. 30/30

Unit No.	Match Pattern	Hot Stream	Cold Stream	TH in	TH out	TC in	TC out	Load Change	AREA
1	B[C]	3	5	500	394.5972	366	478	1556.8	61.88932
2	B[C]	4	2	544	492.6879	389	495	644.48	8.833391
3	B[C]	5	4	472	379.4112	355	450	1641.6	70.80531
4	A[C]	1	1	433	366	333	410.2874	588.93	21.38703
5	BK	4	1	492.6879	478.9084	410.2874	433	173.0699	2.702077
6	D[C]	2	3	522	411	355.25	494	1171.05	29.06199
7	BK	4	3	478.9084	449.1736	311	355.25	373.47	2.855672
8	CU	3	1001	394.5972	339	303	323	821.1702	15.86037
9	CU	4	1001	449.1736	422	303	323	341.3002	2.784946
10	CU	5	1001	379.4112	339	303	323	716.4899	15.76637

6.5 A Large Problem

This problem is obtained from Grossmann et al. (1973). There are ten hot streams and ten cold streams in this problem. The minimum temperature difference is 50 ^{o}F. This problem is selected to demonstrate the program capability in solving a relatively large problem. Assume that the overall heat transfer coefficient for all exchanger units is 50 BTU/ ^{o}F ft^{2}.

Table 6.5.1 Stream Details of the Large Problem

No.	Name	Supply temperature	Target temperature	Heat Capacity Flowrate	Load
1	HOT1	550	450	28.4	2840
2	HOT2	520	480	28.37	1134.8
3	HOT3	500	440	24.6	1476
4	HOT4	460	370	17	1530
5	HOT5	415	340	30.69	2301.75
6	HOT6	400	300	19.36	1936
7	HOT7	365	320	25.5	1147.5
8	HOT8	300	250	12.4	620
9	HOT9	240	170	20.72	1450.4
10	HOT10	170	140	18.9	567
1	COLD1	375	420	22.32	-1004.4
2	COLD2	300	370	23.87	-1670.9
3	COLD3	320	360	34.96	-1398.4
4	COLD4	280	340	26.04	-1562.4
5	COLD5	260	330	13.44	-940.8
6	COLD6	225	280	32	-1760
7	COLD7	240	265	11.1	-277.5
8	COLD8	170	220	22.96	-1148
9	COLD9	140	200	14.4	-864
10	COLD10	80	140	13.92	-835.2

Table 6.5.2 Problem Table of the Large Problem

Temperature Interval		ΔT	Deficit	Accumulated		Heat Flow	
Upper	Lower			In	Out	In	Out
550	520	30	852	0	852	0	852
520	500	20	1135.4	852	1987.4	852	1987.4
500	480	20	1627.4	1987.4	3614.8	1987.4	3614.8
480	470	10	530	3614.8	4144.8	3614.8	4144.8
470	460	10	306.8	4144.8	4451.6	4144.8	4451.6
460	450	10	476.8	4451.6	4928.399	4451.6	4928.399
450	440	10	192.8	4928.399	5121.199	4928.399	5121.199
440	425	15	-79.8	5121.199	5041.399	5121.199	5041.399
425	420	5	85	5041.399	5126.399	5041.399	5126.399
420	415	5	-34.35001	5126.399	5092.049	5126.399	5092.049
415	410	5	119.1	5092.049	5211.149	5092.049	5211.149
410	400	10	-111.4	5211.149	5099.75	5211.149	5099.75
400	390	10	82.2	5099.75	5181.95	5099.75	5181.95
390	380	10	-178.2	5181.95	5003.75	5181.95	5003.75
380	370	10	-312.6	5003.75	4691.149	5003.75	4691.149
370	365	5	-66.50001	4691.149	4624.649	4691.149	4624.649
365	350	15	183	4624.649	4807.649	4624.649	4807.649
350	340	10	360.7	4807.649	5168.35	4807.649	5168.35
340	330	10	53.8	5168.35	5222.149	5168.35	5222.149
330	320	10	-5.799988	5222.149	5216.35	5222.149	5216.35
320	315	5	-130.4	5216.35	5085.95	5216.35	5085.95
315	310	5	-185.9	5085.95	4900.05	5085.95	4900.05
310	300	10	-237.4	4900.05	4662.65	4900.05	4662.65
300	290	10	-307	4662.65	4355.65	4662.65	4355.65
290	275	15	-294	4355.65	4061.65	4355.65	4061.65
275	270	5	62	4061.65	4123.65	4061.65	4123.65
270	250	20	-211.2	4123.65	3912.45	4123.65	3912.45
250	240	10	-373.6	3912.45	3538.85	3912.45	3538.85
240	220	20	-332.8	3538.85	3206.05	3538.85	3206.05
220	190	30	189.6	3206.05	3395.65	3206.05	3395.65
190	170	20	136	3395.65	3531.65	3395.65	3531.65
170	140	30	149.4	3531.65	3681.05	3531.65	3681.05
140	130	10	-139.2	3681.05	3541.85	3681.05	3541.85

From the preanalysis step function, the program found that this problem is a cooling problem. Table 6.5.2 shows the problem table of this case. The minimum cool utility requirement is 3541.85×10^3 BTU/hr.

There are at least 30 network configurations obtained from the program. All solutions achieve the MNU and MER. The minimum number of matches is 20. Figure

shows the first solution which is similar to the network found by Grossmann. Figures 6.5.2-6.5.6 present five network configurations that require the heat transfer area in ascending order. Figure 6.5.2 shows the best configuration with the minimum transfer area = 2371.104 ft^2.

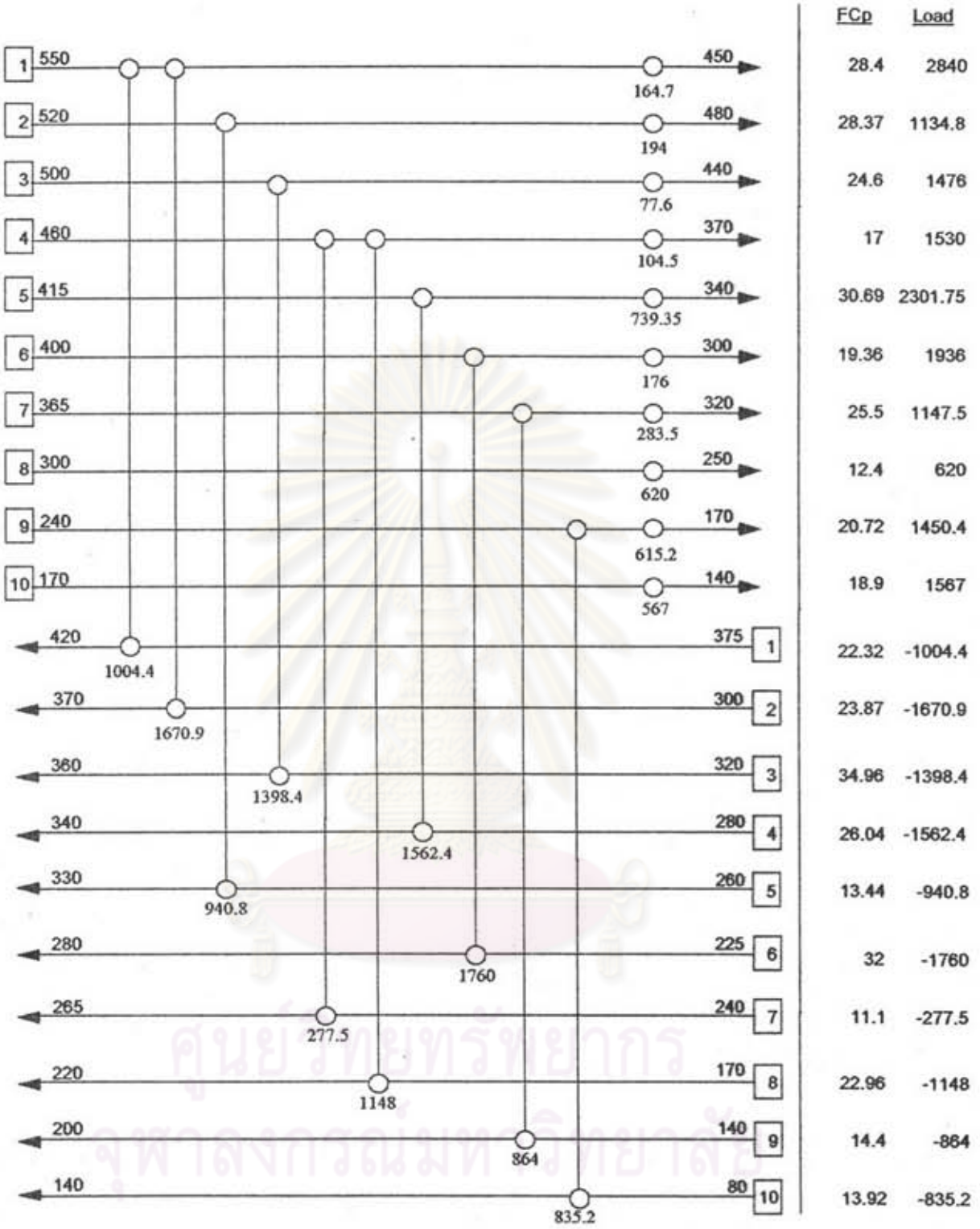

Figure 6.5.1 The Grid Representation of Cold end solution No. 1/ 30 of the Large Problem

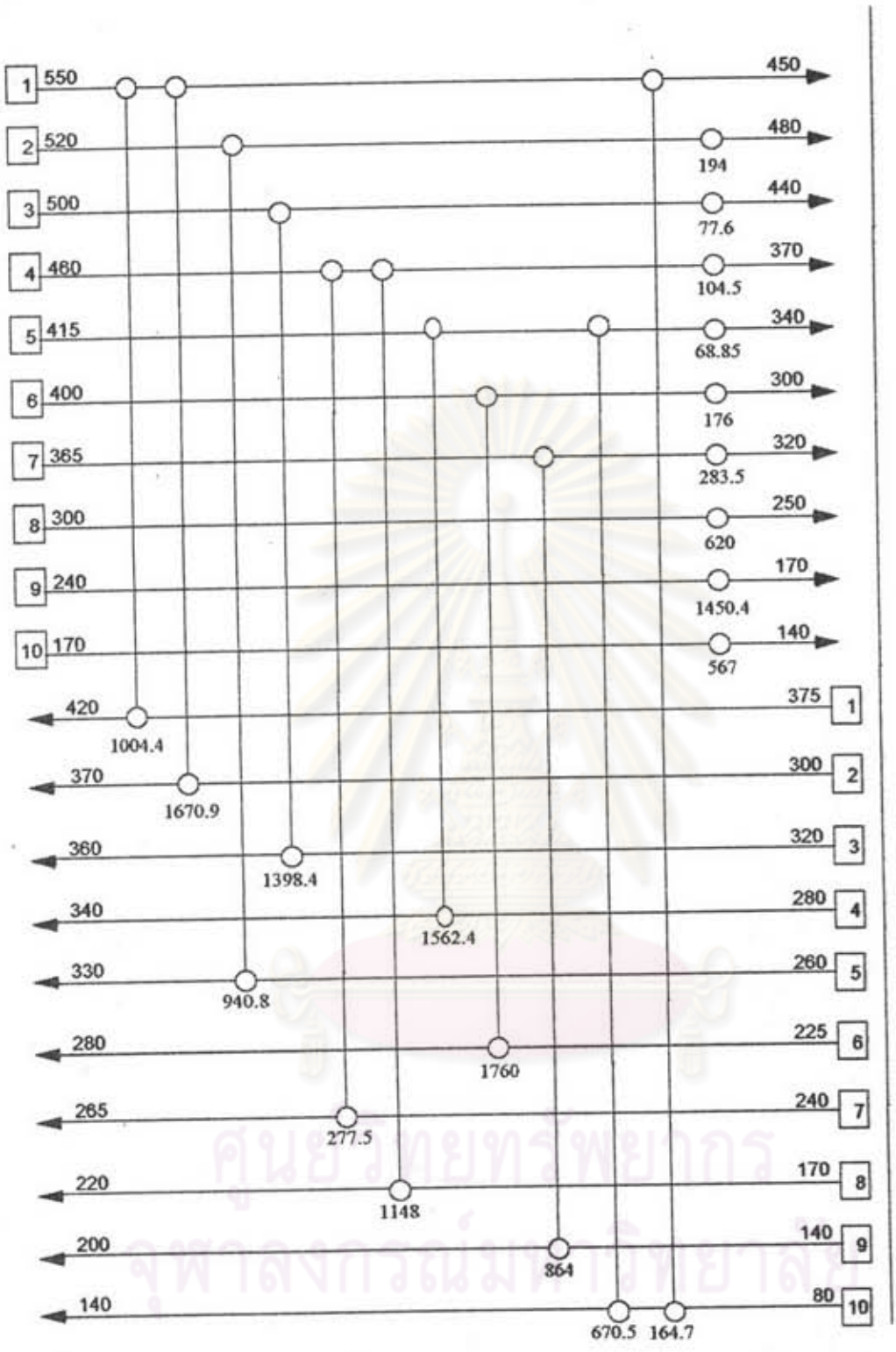

Figure 6.5.2 The Grid Representation of Cold end solution No. 2/ 30 of the Large

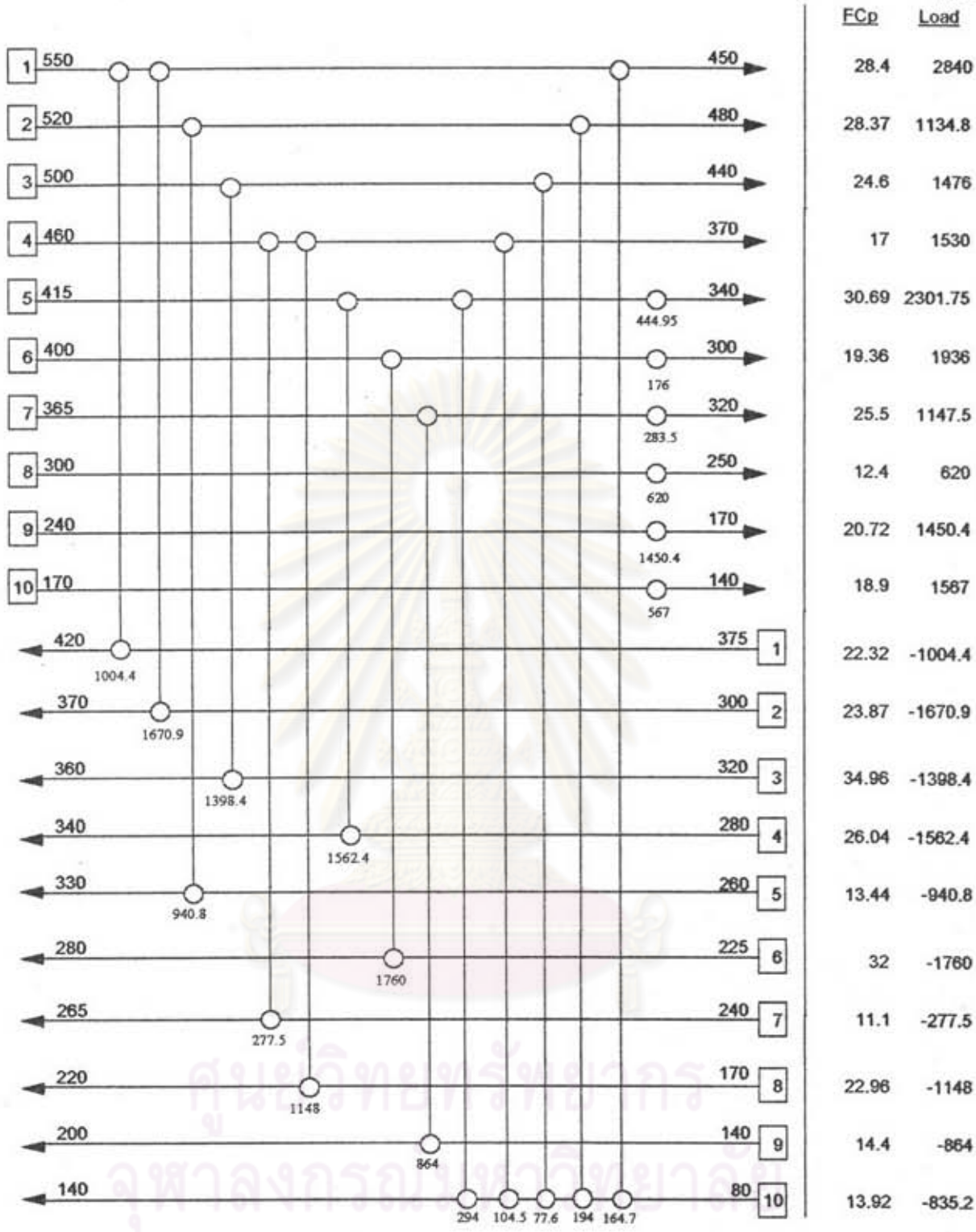

Figure 6.5.3 The Grid Representation of Cold end solution No. 10/ 30 of the Large Problem

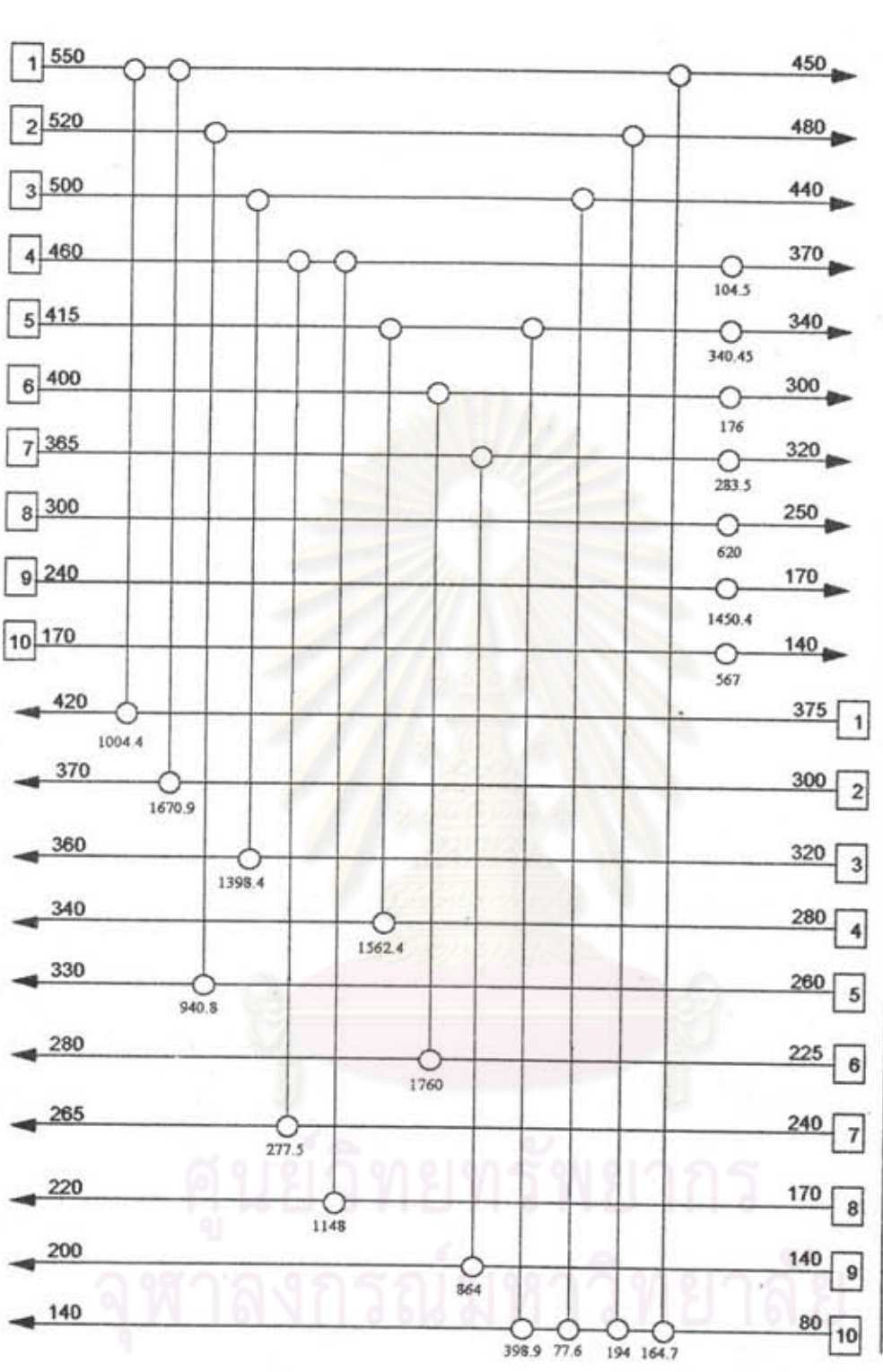

Figure 6.5.4 The Grid Representation of Cold end solution No. 7/ 30 of the Large Problem

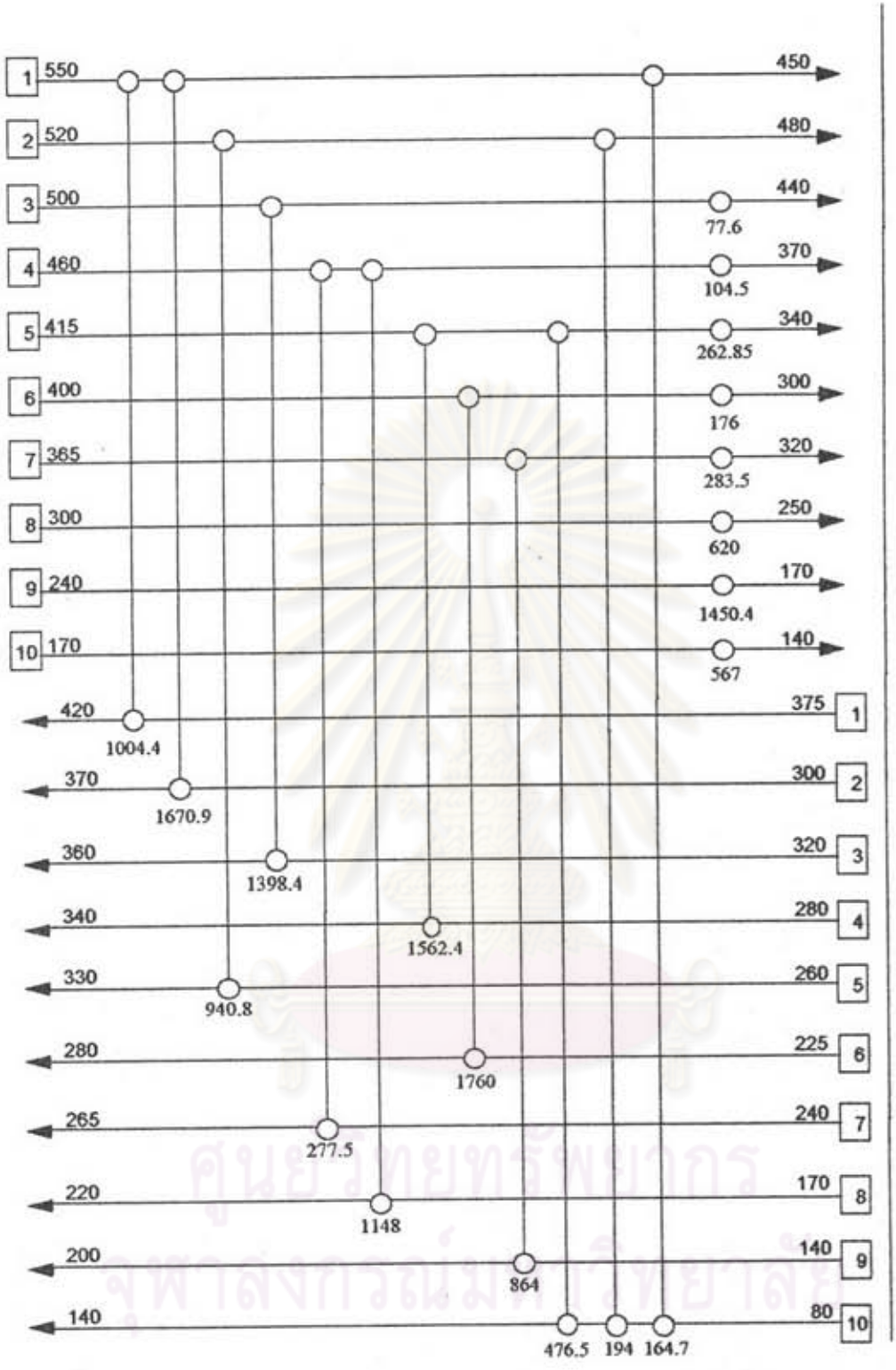

Figure 6.5.5 The Grid Representation of Cold end solution No. 4/ 30 of the Large Problem

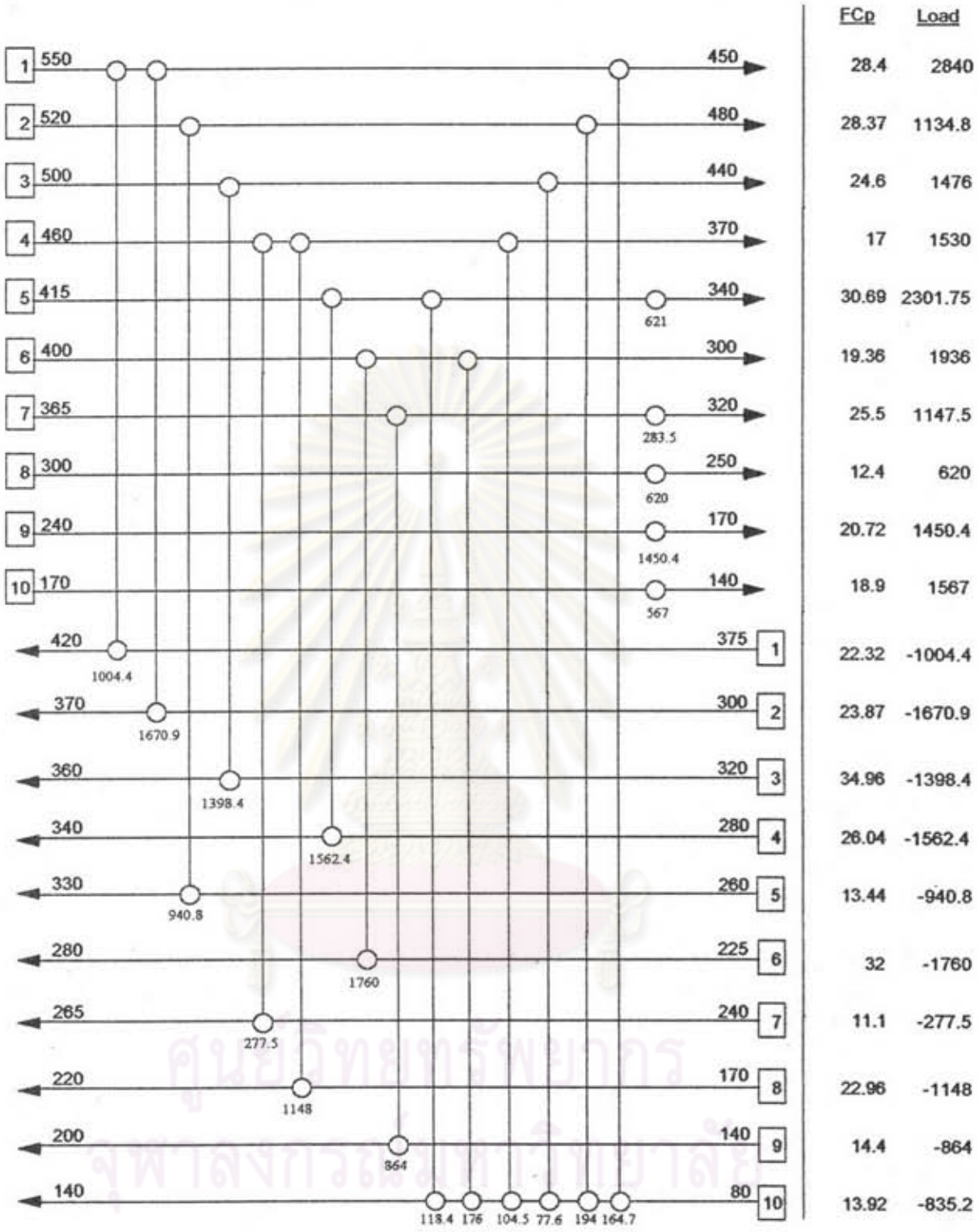

Figure 6.5.6 The Grid Representation of Cold end solution No. 13/ 30 of the Large Problem