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Targeting Method of Heat Exchanger Network in Olefin Unit of Oil Refinery

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Abstract – *Optimum design of HEN can cause significant reduction in the total cost of the plant. Targeting method using pinch analysis diagrams was presented to find out investment cost required and the period of return of the investment of optimization of the refinery system. This method can be done by knowing the amount of ΔT_{min} and by pointing the composite curve of saving vs investment (S-I curve).The targeting method is the modification of the system that need to be done to avoid movement of heat exchangers in order to minimize the return of the investment. This method can assist refineries management to make decision in order to optimize the refinery system.Result shows that refinery can reduce the temperature on the main tower until 9.65MW and the investment will be $360,000 with the time of the return cost being 7.7 months.*

Keywords: Heat exchanger network, HEN, Targeting, Pinch Cross Diagram, Optimization

1.0 INTRODUCTION

Heat exchanger network (HEN)'s design is an important part of the synthesis process. Optimum design of HEN can cause significant reduction in the total cost of the plant. Oil refinery industries are always under pressure to meet new environmental limits and to work at higher efficiency to improve the capacity of the production. The problem is highly complex, primarily because the targets set by legislation or industry benchmarks need to be achieved, while on the other hand, investment has to be minimized. This demands an expert solution to keep costs under control while achieving high quality standards. Therefore, there is an inevitable need to develop an optimum system and, simultaneously prevent a huge capital investment for its implementation. It is possible to achieve the goal in several ways without following any specific methodology. One of the solutions is by identifying utility infrastructure improvements that meet immediate needs as well as saving the operating costs. However, the effectiveness of such solutions is a challenge. For example, there might be other different relevant ways or projects that might solve the immediate problem, but they need bigger savings, or lower capital investment. It needs to be ascertained that all such options are considered and evaluated. The solution might be identified but making future improvement is more expensive or impossible to justify. In the mid 80's, famous industrial companies started using a systematic approach to HEN design, called "PINCH METHOD" [1]. This method, which is based on thermodynamic concept, is now the most applicable technique for HEN design. Every project has to work in a longer-term perspective; structuring a solution that can also minimize operating cost, minimize the capital plan investment and minimize engineering time and effort.

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2.0 TARGETING METHOD

Finding the best line in the figure is the important factor. The Figure 1, Linnfhoff 1988 explained the energy usage of the system stands in this network [1].

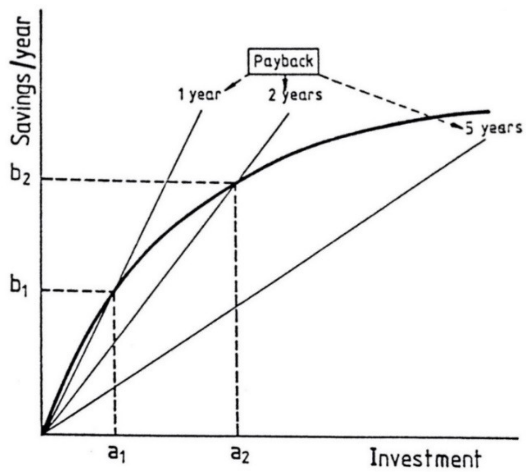

Figure 1: Finding saving (S) based on investment (I) by doing it the best way, [1]

To formulate the work, (α) will be temperature (β) will be energy. The minimum (α) needed is shown by (A_{tx}) and the real value of the temperature in the system will be shown by (A_x) in one year of energy usage [2].

$$\alpha = \left(\frac{A_{tx}}{A_x}\right) \text{ existing energy} \quad (1)$$

The random energy (β) over the minimum energy needed (E_{tx}) and the real usage of energy in the existing network (E_x) at the same temperature in the existing network. [2], more explanation in Figure 2 and 3.

$$\beta = \left(\frac{E_{tx}}{E_x}\right) \text{ existing area} \quad (2)$$

The value of (α) will show the criss-crossing in the network compared to the ideal network, and the minimum value of (α) shows how far the current network from the ideal network is. The value of (β) shows the value of the temperature from the point of optimization compared to the ideal network. The minimum value of (β) shows that the network uses more energy than the ideal network, but putting these two formula together produce to optimize this network in the best way. However, because the passing temperature from optimization is a special case from criss-crossing, using random temperature (α) is advisable.

There are different ways to optimize the network. Less temperature in the network produce better optimization results in the network better and produce the invested money. The higher temperature in the existing system will make the harder process to reach the intended target. Hence, the best way to do this is by bringing the curve in the figure to as low as possible to help optimization of this network, which will be shown in Figure 3.

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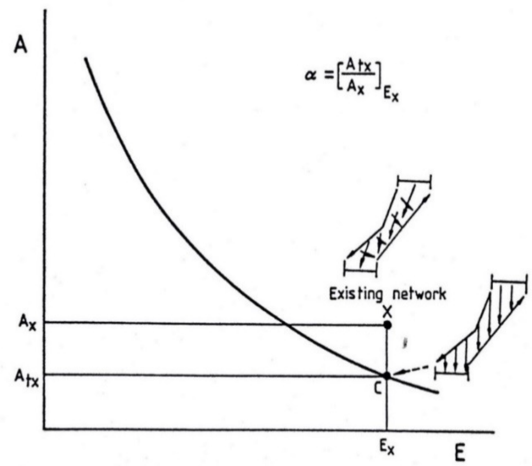

Figure 2: The random temperature (α), [2]

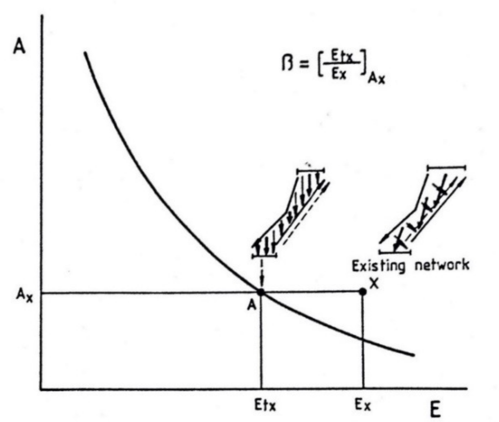

Figure 3: Random of energy (β) [2]

Four points can be found by curves A-E in Figure 4, these four points at A point (two points), at E_x(two points). These two areas are called doubtful economics; the point 1 will be the area that is impractical and point 4 is the best point. The calculation can produce more curves in this figure, but the curve (α – constant) is the best way to choose the optimum, because it shows more energy can be saved. Therefore, based on the curve in Figure 3, the extra heat needed and the value of energy saved can be discovered before the design.

This section discuss about prevailing methods of HENs retrofitting. Modification of RETROFIT for optimization on an existing network is more difficult than GRASS ROOT for optimization in the new design, because the existing network structure generates great limits, which are automatically against the modification [3]. Three methods are developed to retrofit HENs' retrofit by inspection, retrofit as a new design and retrofit by PINCH method. Retrofitting modifications using PINCH laws by HENs modification of a solvent extraction have been used as a real case study. This process is apply in existing refinery system and to find the places that are more efficient for the company to replace or fix to save more energy. In thermodynamics, the designers are capable of controlling each variable and guiding to the

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optimum target points [4]. The methodology of this technique is shown in Figure 5 and Figure 6 [5].

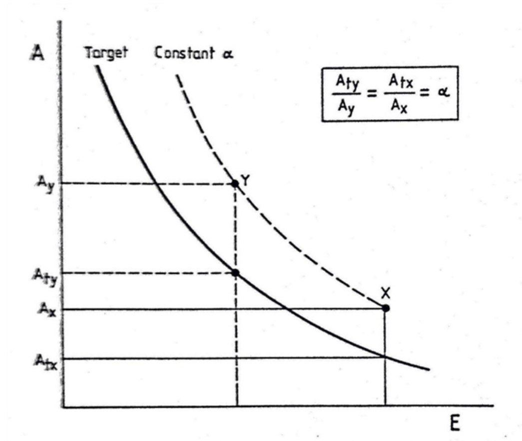

Figure 4: (α – constant) for optimization in the network, Linnhoff 2010

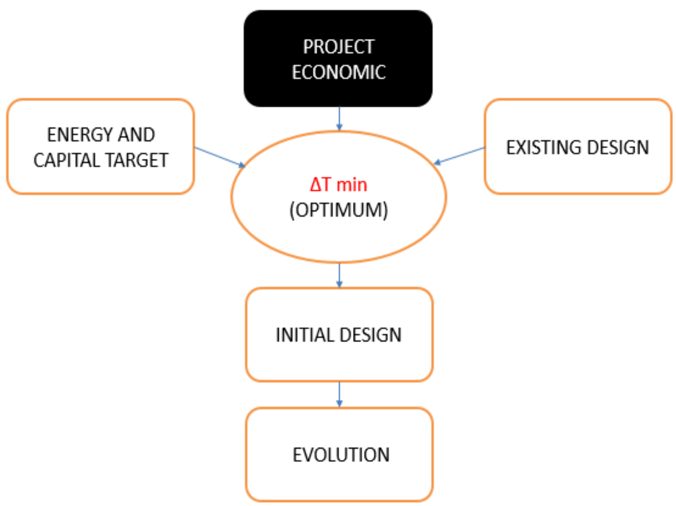

Figure 5: Retrofit by PINCH Method Methodology

Figure 6 shows the schematic flow of action process where the target is always to find ΔT_{min}. If it cannot be found, the issue has to be solved in a different way. A different part of the network has to be explored to customize the optimization process. Linnhoff has presented some options for optimization and control the limitation [6]. The best option for optimization in the network is called random of the surface temperature on the refinery. The constant value is random of the surface temperature on the refinery (α-constant), only an approximation, and the system will not be at the same point after optimization. For instance, the point of target is point Y (a fixed point for ΔE & ΔA) on Figure 7 (α-constant). In this study, reducing the energy cost by ΔE requires the decrease in temperature by ΔA, so by fixing the value for ΔA, which is the extra surface temperature needed or ΔE which is optimized on energy requirement, the point Y point cannot stay on the E-A curve when approximating the target point in the network (Figure 7). Values of both ΔA & ΔE need to be changed simultaneously to keep the target point on the curve.

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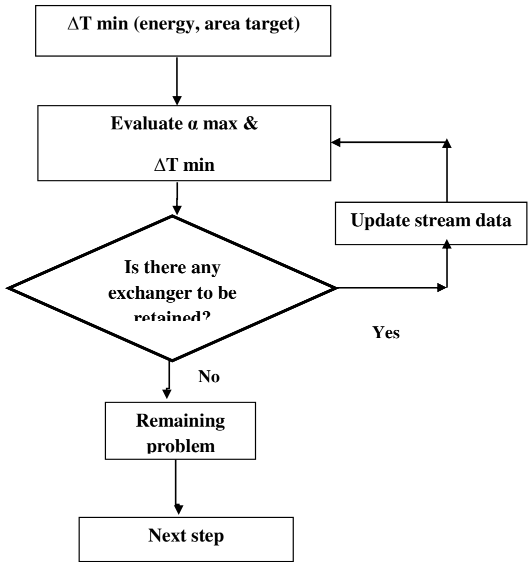

Figure 6: Schematic explanation of the process [6]

Therefore, the last design has to be at the Y (fixed ΔE) point (which normally is not) or to use the two points to find it, which are:

a. The optimized value will be ΔA. In this case, because of the fixing of ΔA, the point of Y will be moved in the Figure 7. Therefore, in this case it cannot reduce the energy because the temperature will be increased and the energy cannot reduced.
b. The optimized value will be as ΔE. In this case, because of fixing point ΔA, the point of Y can be moved in Figure 7 therefore, it is going to reduce the temperature. When the temperature is reduced, less energy is spent in the network.

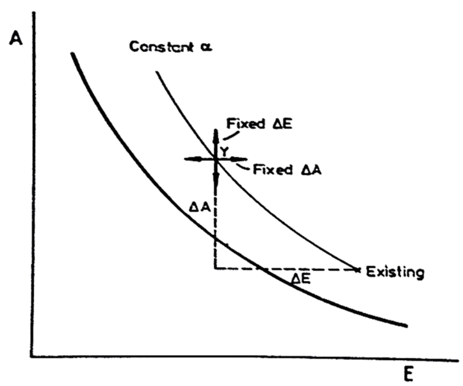

Figure 7: Two points to find ΔE and ΔA, [5]

Any of these points can be used to start the optimization in the network until any of ΔE & ΔA is near the targeted point and is nearer to the value of ΔT_{min}which will be the point to start this project. As has been explained, modifications on the existing network will be harder to make than designing the network from the beginning because the heat exchangers have been installed before and changing the places of heat exchangers will be highly cost [7]. This cannot be to implement into this project because the aim is to reduce the cost, not to increase it. The target is the work to be done as much as it can, heat exchangers should not be moved as to reduce

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cost [8]. All the heat exchangers should be checked to find which the most efficient or the less efficient [9].

3.0 RESULTS AND DISCUSSION

Information of the refinery system is shown in Table 1. Heat transfer coefficient flows, heat transfer coefficient flows in the capacity of 150,000 barrel per day and also fluid heat transfer coefficient inside the tube with a power of 0.8 and the heat transfer coefficient of the fluid inside the shell with a power of 0.5 depend on the velocity for the optimization on this refinery. 25 hot lines and 11 cold lines are apparent in this table. This will also be shown in Figure 8 and Figure 9.The value of the minimum temperature and surface temperature with the use of software HEXTRAN for the network has been calculated and provided in Table 1. With the help of this information, the researcher will come up with the figure A-E that is shown in Figure 10. Based on the information about surface temperature of the process-to-process and the temperature on the heaters in the network, this figure illustrates where the system stands.

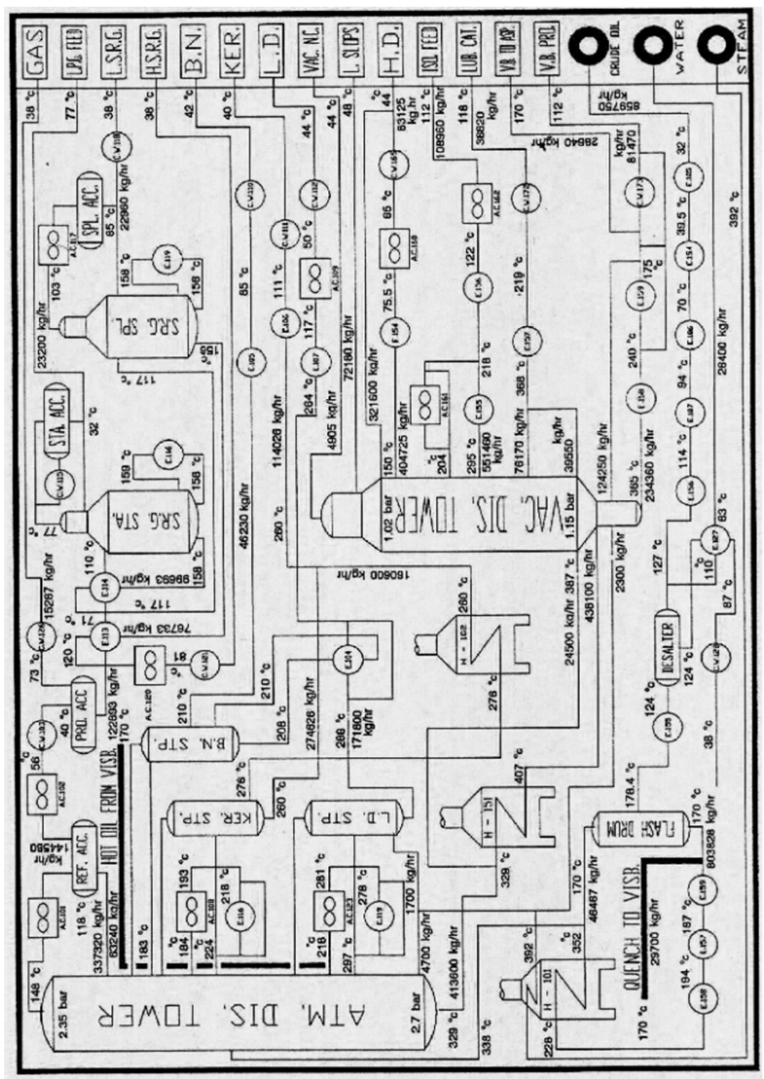

Figure 8: Flow diagram for the capacity of 150,000 barrels per day, Isfahan refinery

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Table 1: Process information for the capacity of 150,000

ΔT_{min}(°C)	$Q_{cmin}(MW)$	$Q_{hmin}(MW)$	Area (m^2)	$T_{pinch,h}$(°C)	$T_{pinch,c}$(°C)
30	98.05	88.84	11483	288	257.1
32	99.11	89.9	11055	288	255.6
34	100.8	91.59	10427	288	253.2
36	102.15	92.93	9959	288	251.3
38	103.55	94.34	9529	288	249.3
40	104.95	95.74	9119	288	247.3
42	106.36	97.15	8739	288	245.3
44	107.76	98.55	8378	288	243.3
46	109.16	99.95	8059	288	241.3
48	110.57	101.36	7747	288	239.3
50	111.97	102.76	7428	218.5	168
52	113.51	104.29	7157	220	168
54	116.57	107.36	6612	222	168
56	117.71	108.5	6418	224.1	168
58	119.41	110.2	6160	226.1	168
60	121.11	111.89	5935	228.1	168
62	123.54	114.33	5599	231	168
64	125.54	116.02	5385	233	168
66	126.93	117.72	5182	235	168
68	128.63	119.42	4988	237	168
70	130.33	121.12	4807	239	168
72	132.04	122.83	4639	241	168
74	133.75	124.54	4471	243	168
76	135.47	126.26	4316	245	168
78	137.18	127.97	4240	247	168
80	138.9	129.69	4025	249	168
82	140.62	131.4	3889	251	168
84	141.6	132.39	3814	252.2	168
86	143.32	134.11	3688	254.2	168
88	145.76	136.55	3509	257	168
90	147.47	138.26	3393	259	168
92	149.27	140.06	3283	261	168
94	150.49	141.28	3211	262.3	168
96	152.15	142.93	3108	264.1	168
98	153.8	144.59	3014	266.1	168
100	156.21	147	2878	269	168

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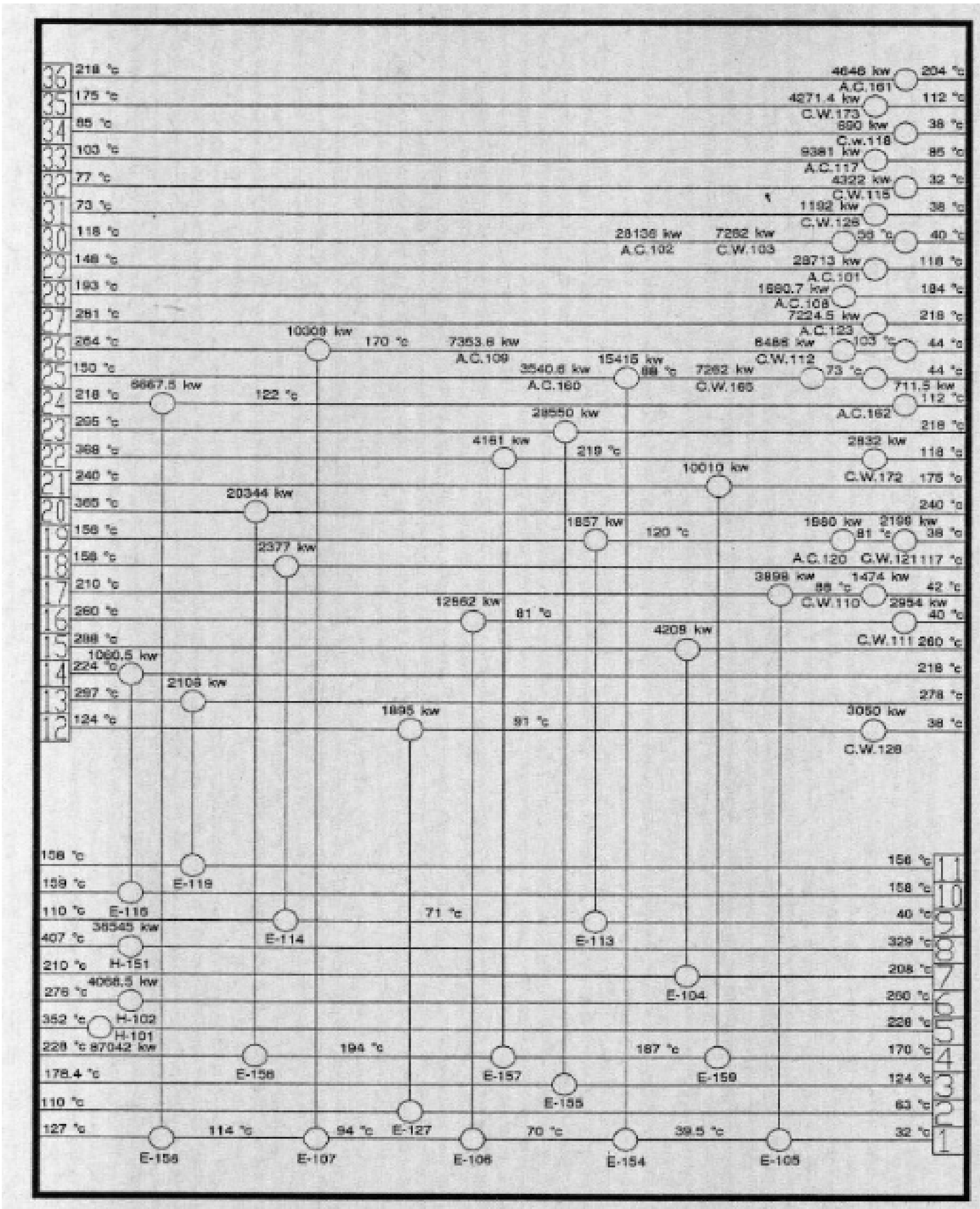

Figure 9: Exchanger view window for the capacity of 150,000, Isfahan refinery

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Table 2: Cooling and heating exchangers' information of Isfahan refinery 150,000 barrels per day

Exchanger			Shell Side				Tube Side				Overall			
Ex. No.	**Ex. Name**	**No. of Sh.para./Set**	**St. No**	**CP (KW/℃)**	T_{in} **(℃)**	T_{out} **(℃)**	**St. No**	**CP (KW/℃)**	T_{in} **(℃)**	T_{out} **(℃)**	**Q (KW)**	ΔT_{LM}℃	**U(KW/M^2 °C)**	**Area(m^2)/Sh**
1	E-104	1/1	7	2104.5	208	210	15	150.3	288	260	4209	64	1.34	49
2	E-105	1/1	17	31.98	210	85	1	516.75	35	44	3898	96.7	0.395	102
3	E-106A/B	2/1	16	71.9	260	111	1	516.75	70	95	12682	89	0.396	182.6
4	E-107A/B	1/2	26	109.76	264	117	1	60.48	95	113	10309	67	0.4	190
5	E-113	1/1	19	51.16	156	119.7	9	60.48	40	70.7	1857	82.4	0.73	30.7
6	E-114A/B	1/2	18	72	150	117	9	171	70.7	110	2377	431	0.485	57
7	E-116	1/1	10	1060.5	158	159	14	110.85	224	218	1060.5	62.4	0.0384	442.6
8	E-119	1/1	11	1053	156	158	13	57.5	297	278	2106	130	0.07	224
9	E-127A/B	1/2	2	40.315	63	110	12	516.75	124	87	1895	18.6	0.837	121.7
10	E-154A/B	1/2	25	247.3	150	75.5	1	525	44	70	15415	52	0.4	368.5
11	E-155A/C	1/3	23	371	295	218	3	516.75	124	178.4	28550	105	0.175	515.6
12	E-156A/B	2/1	24	69.6	218	153	1	27.97	113	127	6667.5	62	0.11	477.41
13	E-157	1/1	4	595	193	204	22	595	368	225	4161	80.7	0.32	161
14	E158A/D	1/4	20	162.75	365	240	4	595	204	228	20344	75.7	0.39	171
15	E-159A/E	1/5	21	154	240	175	4	702	170	193	10010	18.7	0.27	396.4
16	H-101	-	-	-	-	-	5	254.3	228	352	87042	-	-	-
17	H-102	-	-	-	-	-	6	468.5	260	276	4068.5	-	-	-
18	H-151	-	-	-	-	-	8	-	329	407	36545	-	-	-
19	E-103A/B	1/2	30	453.8	56	40	C.W.	-	25	40	7262	15.5	0.375	624.8
20	E-110A/B	1/2	17	31.98	85	42	C.W.	-	50	61	1474	17.3	1.35	31.5
21	E-111A/B	1/2	16	71.9	111	40	C.W.	-	15	68	2954	33.1	0.48	93.4
22	E-112A/B	1/2	26	109.76	50	44	C.W.	-	27	35	6486	16	2.9	69.8
23	E-115A/B	1/2	32	96	77	32	C.W.	-	15	60	4322	17	0.46	273.6
24	E-118	1/1	34	14.67	85	38	C.W.	-	20	68	690	17.5	0.91	43.2
25	E-121	1/1	19	51.16	81	38	C.W.	-	20	60	2199	19.5	1.24	90.9
26	E-126A/B	1/2	31	34.06	73	38	C.W.	-	50	63	1192	11	2.35	23
27	E-128	1/1	C.W.	-	23	42	12	57.5	87	38	3050	27.3	0.855	130.6
28	E-165A/B	1/2	25	247.3	65	44	C.W.	-	31	41	7262	18	0.904	223
29	E-172	1/1	22	27.97	225	118	C.W.	-	57.6	85	2832	94.7	0.23	128.7
30	E-173A/C	1/3	35	67.8	175	112	C.W.	-	57.6	83	4271.4	71.5	0.06	336.4
31	E-101A/D	1/4	A.C.	-	40.6	120	29	957	148	118	28713	48.5	0.02	7518
32	E-102A/D	1/4	A.C.	-	40.6	65	30	453.8	118	56	28136	30.4	0.043	7208
33	E-108	1/1	A.C.	-	40.6	120	28	186.74	193	184	1680.7	104.3	0.02	803.6
34	E-109	1/1	A.C.	-	40.6	65	26	109.76	117	50	7353.6	25	0.065	4519
35	E-117A/B	1/2	A.C.	-	40.6	65	33	521.2	103	85	9381	41.1	0.022	5135
36	E-120	1/1	A.C.	-	40.6	65	19	51.16	119.7	81	1980	31	0.0397	1609
37	E-123	1/1	A.C.		40.6	120	27	114.67	281	218	7224.5	169	0.093	459
38	E-160	1/1	A.C.	-	40.6	65	25	247.3	75.5	65	3540.6	16	0.0363	6093
39	E-161	1/1	A.C.	-	40.6	120	36	331.9	218	204	4646	128	0.0188	1934
40	E-162	1/1	A.C.	-	40.6	65	24	69.5	153	112	711.5	79	0.0022	3950

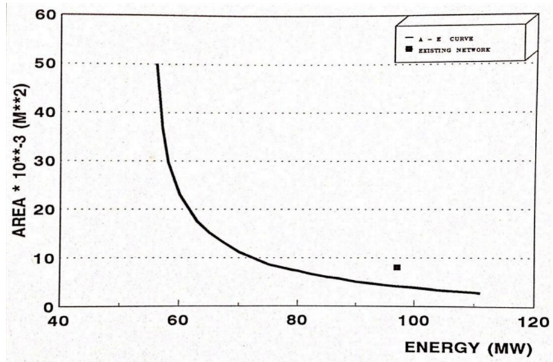

Figure 10: Figure A-E for the network, Isfahan refinery

Table 3: Information about α-constant and α-incremental for the network exchangers

Energy (MW)	$A_{target}(m^2)$	$A_{\alpha-constant}(m^2)$	$A_{\alpha-incremental}(m^2)$
70.54	37432	70626	------
75.74	21777	41088	------
76.94	20118	37958	------
77.84	19040	35924	------
78.89	17937	33843	------
80.26	16659	31432	------
82.18	15149	28583	------
84.09	13865	26160	------
85.95	12829	24205	------
86.93	12383	23364	------
88.84	11483	21666	------
89.9	11055	20858	------
91.95	10427	19673	------
92.93	9959	18790	------
94.34	9529	17979	12240
95.74	9119	17205	12820
97.15	8739	16488	12380
98.55	8378	15807	12100
99.95	8059	15205	11800
101.36	7747	14617	11400
102.76	7458	14071	11200
104.29	7157	13504	10900
107.36	6612	12475	10540
108.5	6418	12109	10320
110.2	6160	11622	10040
111.89	5935	11198	9860
114.33	5599	10564	9600
117.72	5182	9777	9080
119.42	4988	9411	8900
121.12	4807	9070	8700
121.83	4639	8752	8440
124.54	4471	8436	8200
126.26	4316	8143	8050
127.97	4240	8016	8016

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At this point, the minimum needed surface temperature for the same energy usage with the existing network is 4100M^2 , therefore, random surface temperature is α = 0.511. It is becausethe random surface temperature is low for the optimization, the α-incremental figure has to be considered.

$\alpha = (\frac{A_{tx}}{A_x})\, E_x$ = (4100/8016) = 0.511

In Table 4, information about this figure and α-constant has been compared and the figure is also shown in Figure 11.

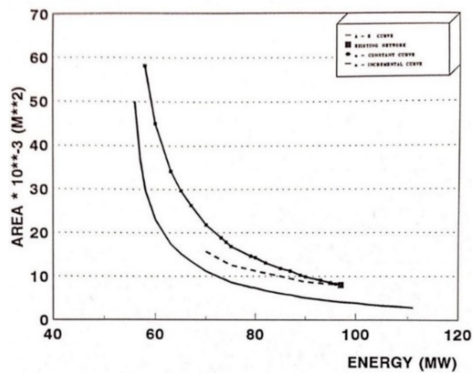

Figure 11: Figure for α-constant and α-incremental for the network exchangers, Isfahan refinery

With the help of Table 3, the curve α-incremental changed to curve S-I, whereby all the information about it is in Table 4 and will be shown as a figure in Figure 12. With the assistance of this figure and the table, different situations where the system can be optimized can be checked. This information will be important for the use and the production of 150,000 barrels per day. Therefore, in this process, the ΔT_{min} should be considered as $\Delta T_{\min opt}$. Figure 13 will show that $\Delta T_{\min opt}$ is 55℃ . Therefore, in this condition, the researcher can reduce the temperature on the main tower until 9.65MW and the investment will be $360,000with the time of the return cost being 7.7 months.

Table 4: Information about the figure S-I for the network

ΔA (M^2)	ΔE (MW)	Investment (MM$)	Saving (MM$/Yr)
400	4.72	0.153	
800	9.5	0.306	0.551
1200	13.43	0.459	0.779
1600	16.38	0.612	0.95
2000	19.07	0.765	1.106
2400	21.36	0.918	1.239
2800	23.66	1.0714	1.372
3200	26.02	1.224	1.509
3600	28.17	1.378	1.634
4000	30.6	1.531	1.775
4400	32.43	1.684	1.881
4800	33.41	1.837	1.938
5200	35.38	1.99	2.052
6000	38	2.296	2.204
6400	39.31	2.449	2.28
6800	40.62	2.602	2.356
7200	40.93	2.756	2.394
7600	41.93	2.908	2.432
8000	42.24	3.061	2.45

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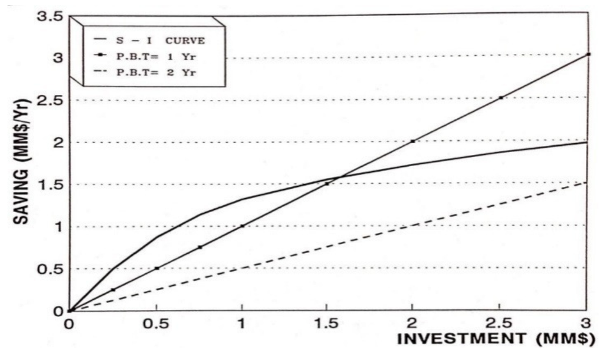

Figure 12: S-I figure for the network, Isfahan refinery

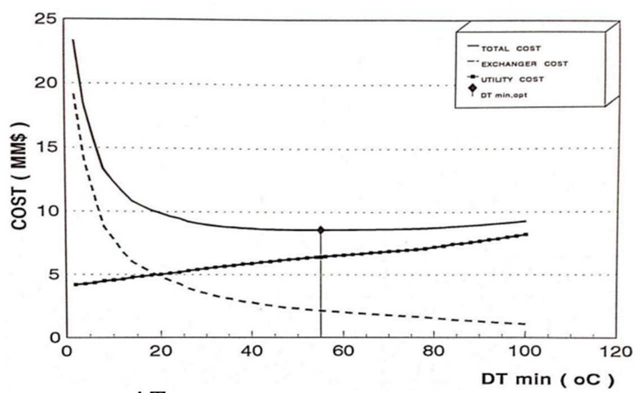

Figure 13: $\Delta T_{\min\, opt}$ for the network, Isfahan refinery

In Table 5, the researcher has compared the new result with the result of the ΔT_{min}=55°C.

Table 5: Comparing the result after optimization with minimum value

No.	Names	The fixed network	Minimum value
1	Heat surface temperature process to process	8768	5556
2	Temperature of heaters	87.27	87.27
3	Temperature of coolers	90.07	92.93

Table 6: Comparing the limitation in designing the network with the result

		Limitation in design	The result of optimization
1	Investment $	$\leq 360{,}000$	437,460
2	Savings ($ and Yr)	$\geq 559{,}700$	587,947
3	Time of return investment (month)	≤ 7.7	≈ 9

As can be seen in Table 6, the result is very near to the target result and the temperature on the cooler system in lower than the minimum value. It is impossible for the result to be lower than the minimum result, and there is a good explanation. When the researcher started to work on

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this research, most of the exchangers did not need to be touched; that is why this work is possible. Minimum value can follow when all the exchangers in the network follow ΔT_{min}=55 °C. Most of the exchangers have not been touched and this was done when the value of the ΔT_{min} =13°C and this is much lesser than 55 °C. (At least the value for the ΔT_{min}=13°C will be 68.84).

As can be seen, the saving is more than what is accepted in the design. This is because of not counting the out services of the cooling systems in targeting. The investment and time of the return investment have also become very long and all this is because of not following the limitation in designing. This work is not practical and it is only used to compare and study, therefore, because the $\Delta T_{\min,opt}$ of the network is the base for optimization in this step, $\Delta T_{\min,opt}$ will be considered and the result can be accepted. The final standing of the network will be explained in Figure 14and the final design of it will be in depicted Figure 15.

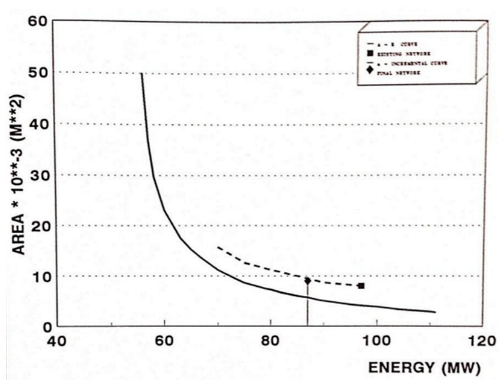

Figure 14: Final standing of the network, Isfahan refinery

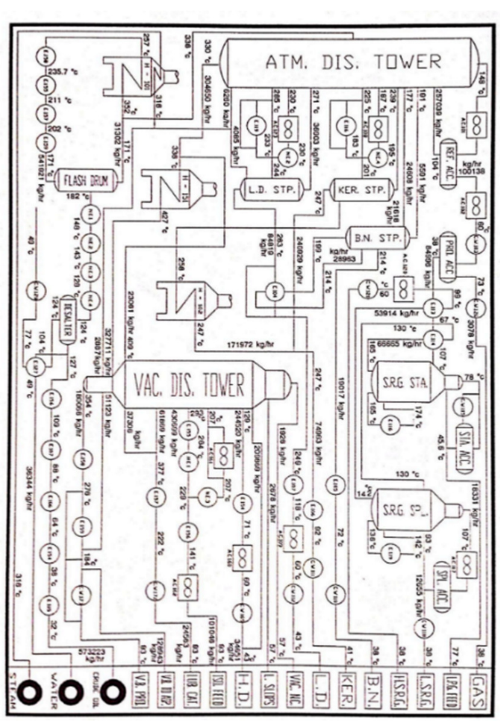

Figure 15: Flow diagram for the network, Isfahan refinery

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4.0 CONCLUSSION

With the assistance of this figure and the table, different situations where the system can be optimized can be checked. The investment and time of the return investment have become very long due to not following the limitation in designing. Therefore, in this process, the ΔT_{min} is considered as $\Delta T_{min,opt}$ which is 55 °C. It was found the saving is more than what is accepted in the design. This is because of not considered the breakdown of the cooling systems in targeting. Therefore, the researcher can reduce the temperature on the main tower until 9.65MW and the investment will be $360,000 with the time of the return cost being 7.7 months.

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