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Optimization of Heat Exchanger Network in Olefin Unit of Oil Refinery

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Abstract – *One of the steps to start the optimization is to check the energy use of cold and hot streams from the HEN to utility. In this process, the movement can be either from the first layer to the last layer or from the last layer to the first layer with the purpose of achieving the optimization results in the system. The objectives of the study are to identify the network and exchangers that use more than the energy required, to analyse exchangers required energy saving techniques and to apply the process of optimization in refinery. The analysis were done by formulating the problem and generating mathematical formula to get the best optimization result, which is known as* ΔT_{min}*. This study investigates the systematic approach to retrofit an existing plant using the "Pinch Method". The method was applied on the distillation unit of Isfahan refinery preheat train. Results show that it is possible to reduce the load of the atmospheric furnace up to 25% and restore the normal operational condition, only by 1MM USD investment. This implies a payback time of 9 months.*

Keywords: Optimization, Heat exchanger network, Heat transfer process, Refinery

1.0 INTRODUCTION

The design of HEN is very important in the heat transfer process. The core of the heat transfer process is known as the reactor and the second layer is called a separator. This layer separates the reactor from the other layers and also separates the materials. The third layer is called Heat Exchanger Network (HEN), in which all the separation of hot and cold process is done. The last layer is referred to as utilities, which consist the water, electricity, smoke, and fuel. The onion diagram shown below includes reactor, separator, HEN and utility. Figure 1 illustrates the role of Pinch Technology in the overall process design. The design of a process starts with the reactors which represents the analysis of chemical reaction route. Once feeds, products, recycle concentrations and flow rates are known which the water use system is the separators can be designed. One of the steps to start the optimization is to check the energy use of cold and hot streams from the HEN to utility. In this process, the movement can be either from the first layer to the last layer or from the last layer to the first layer with the purpose of achieving the optimization results in the system.

After the establishment of this analysis, researchers started to develop a new process that is called process integration. In this system, all the processes are integrated into a system to

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calculate and optimize the use of energy. The prerequisite of this process was a preliminary research on the following two subjects which are pinch technology and energy analysis.

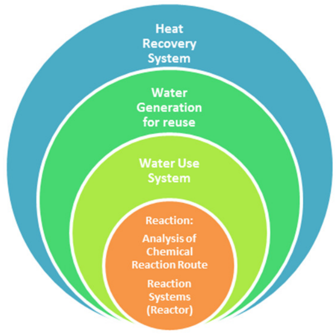

Figure 1: Onion diagram, [1]

1.1 Basic Concept of Heat Exchange

The basic concept of heat exchanger is to increase or reduce the temperature in the production line of the refineries. Figure 2 shows a chemical reactor, and how it will be treated as a 'black box' in supplying liquid to the reactor and the need to be heated from the closer ambient temperature to the operating temperature of the reactor. Conversely, it need to be cooled down sometimes to a lower temperature. Sometimes there will be additional unheated make-up stream to the reactor. This flow needs to be heated or cooled down, but should not change in arrangement, which is called a stream. The liquid that is cold and needs to be heated- up is called a cold stream, whereas hot liquid which needs to be cooled down is called a hot stream. The reaction process is not a stream because it involves a change in chemical arrangement, and the make-up flow is also not a stream because it is not involved in heating and cooling [2].

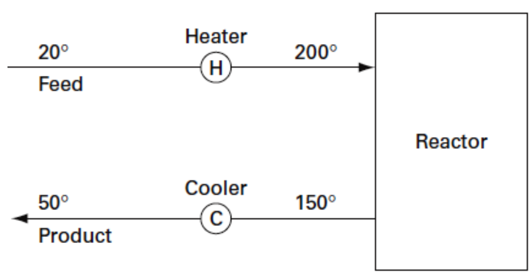

Figure 2: Process Flow sheet, [3]

The work of cooling and heating can replace each other in the flows shown in Table 1. The system needs to operate or supply -180 kW of stream cooling and +180kW stream of water heating to process.

Consumption of energy can be reduced if some of the heat can be recovered from the hot stream and used to heat the cold stream in a heat exchanger. It will use the lesser hot and cold-water stream to satisfy the remaining duties. The flow sheet in Figure 3 shows the system, which cannot recover all the energy of -18kkW in the cold and hot stream. This is because the temperature limitations must comply with the second law of Thermodynamics. Namely, hot stream at 150 ˚C cannot be used to heat a cold stream at 200˚C and the temperature condition will be on the heat exchanger [1].

Table 1: sample of two- stream data, [1]

	Hot stream	Cold stream
Heat load H(kW)	180	-180
Final target temperature Tt (˚C)	50	200
Initial supply temperature Ts(˚C)	150	20
Heat capacity flow rate CP (kW/k)	1.8	1
Specific heat capacity Cp(kJ/kgK)	4.5	4
Mass flow rate W(kg/s)	0.4	0.25

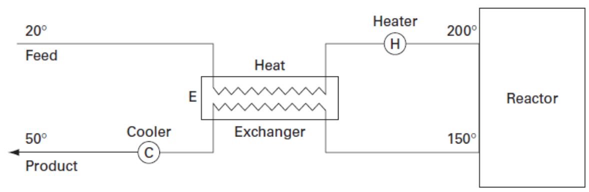

Figure 3: Heat exchange process, [1]

Optimization of the system was mostly done on a refinery which was designed a long time ago. The rules of energy saving was not applied and after the heat was transferred out, it made the system consumed more energy. Hence, the changes have to be made such as to fix the separation layer, to optimize the energy, or to save the cost in the system.

1.2 Philosophy of Optimization

The first step for system optimization network is to check the system based on the optimization process. It has to be checked well and it is essential to see how the system is working. The best way is to use the diagram for temperature based on energy (Area – Energy plot).

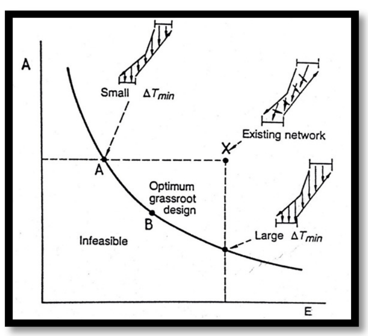

Figure 4: Minimum value of energy usage and the temperature, the area (A) and energy (E), [4]

Knowing the ΔT_{min} value for the system can make it easier for us to find out the value of temperature and energy needed for the process [4]. Therefore, if this process for system optimization is used, the ΔT_{min} value on the given system can be run and the value of temperature and energy can be found. It can be shown in Figure 4, the minimum value of energy usage and the temperature. Different ΔT_{min} for the system to be optimized has been given with the known value of the temperature and energy usage. These value in the system can locate the system stands in the optimization process and the image can show the system stands. If the X mark as shown in Figure 4 stands on the curve or stands by a 10% difference in the curve, the system is in a good condition and well designed. If the X point is far away from the curve, the system needs to be optimized [5].

2.0 METHODOLOGY

2.1 Prevailing Methods of HENs Retrofitting

The best method for optimization in the network is called random of the surface temperature on the refinery, where the constant value is random of the surface temperature on the refinery (α-constant).For this approximation, 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 5 (α-constant). 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 5). Values of both ΔA & ΔE need to be changed simultaneously to keep the target point on the curve.

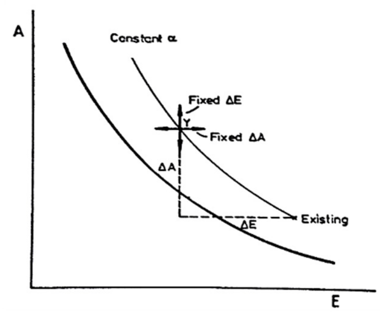

Figure 5: Two points to find ΔE and ΔA, [7]

2.2 Cross Pinch Exchanger Analysis

All designs for minimum energy requirement (MER) which have been designed cannot pass temperature from the pinch point, but in the unsuccessful designs with the temperature passing from the pinch point, it can affect the energy usage in all the heat exchangers. In optimization of the network, the work can be done by combining lines in Figure 6 to find out the value of energy that has been reduced and the energy has been saved (ΔE). Normally the value is the same value of the temperature that passes from pinch point. Figure 6 will show the temperature for optimization in the network.

After finding the value of temperature from grid representation, the exchangers at pinch point can be found, and at some point the researcher might find points that are also near to the pinch point. However, these points are in other areas which are shown in Figure 6. In this situation, each point has to be taken as one point and all exchangers are checked in that area.

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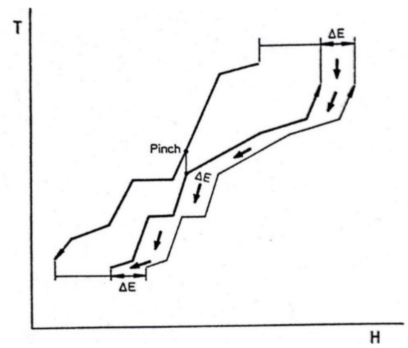

Figure 6: The passing temperature (ΔE) from pinch point, [7]

2.3 Remaining Problem Analysis

The remaining energy in the design of pinch is the beginning of design for heat exchangers. It will be from the pinch point and all other points which are close to that point, and it has to move slowly to wider areas. For this, main rules of designing have to be used [5]. Then, the match is checked by using algorithm to see if it will work with the design. In this situation, two situations may happen in which the system may need more energy or it can work with the same energy. In the first situation, the match given can transfer all the energy needed to the system, and in the second situation, a problem can occur in the energy needed. This will be explained in Figure 7. This idea can be useful to identify which exchangers are to be changed and can be used to calculate the energy usage. The existence of the temperature layer in all projects of optimization, should see which random temperature is needed and for this need to check the existence of the temperature on that layer. The full temperature knowing of that area can detect the temperatures of other areas (A_{tr}). By calculating the full area temperature and the area that is left, can find the temperature on heat exchangers to be adjusted to the match point ($\propto_{max}$).

$$\propto_{max}(\mathrm{i}) = \frac{At}{A(i) + Atr(i)} \quad (1)$$

With $\propto_{max}$ is maximum of the surface temperature on the refinery, A_t is minimum surface temperature chosen for network, $A_{tr}(i)$ is minimum surface temperature for remaining problem for exchanger i and $A(i)$ is the surface temperature of exchanger (i). Whereby $0<\propto_{max}\leq 1$ will be the ideal match and this formula shows the remaining temperature, which will be explained more in Figure 7. The remaining temperature A_{tr} will be calculated based on energy which is needed in the network, and the error of temperature area which can be made by moving the exchanger in a wrong place of energy temperature has to be guessed. The important part is to know the random temperature of the network (α) and $\propto_{max}$because α is of the full network and $\propto_{max}$is the maximum random of the area temperature in that condition. All exchangers are considered the whole network. Analysis of the remaining heat surface can help in getting back some of the energy, for example, it can be used to find which exchangers use less energy in the network ($\propto_{max}$< 1.0), and therefore, help to optimize the network which has weak surface heat. Every time $\propto_{max}$ is used for heat exchangers, main α as $\propto_{max}$ in the network should be calculated. In the optimization method, this method can be used to find how useful the exchanger for the network is.

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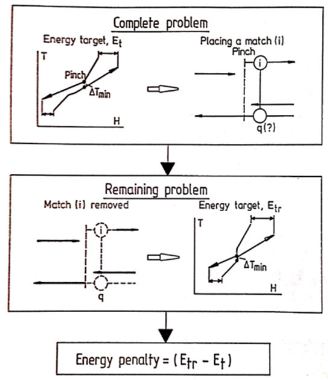

Figure 7: The remaining energy with fixed ΔT_{min}, [7]

3.0 RESULTS AND DISCUSSION

In Iraq, Dubai, USA and Iran (Isfahan) there are huge refineries, which fractionate the layer of crude oil. Refineries separate the layer of the crude oil. Table 2 shown that Iran (Abodan) is the biggest oil refinery in the world. Before the 80s, it could refine 630,000 barrels per day, which was 50% of the crude oil of this refinery and during the war in 1980, this refinery was attacked and stopped working. The need for petrol increased and the other refineries had to produce on behalf of Abodan refinery, which is shown in Table 2. Therefore, this has made other refineries work more to come up with needed oil. However, when there is an increase of production, some problems occur at these refineries.

Table 2: Capacity of existing refinery

Refinery name	Year of first production	Barrels per day (before war)	Barrels per day (after war)
Abodan(Iran)	1919	630,000	130,000
Karmanshah (Iran)	1923	2000	30,000
Tehran (Iran)	1969	200,000	270,000
Shiraz (Iran)	1974	40,000	40,000
Lavan (Iran)	1977	30,000	20,000
Tabriz (Iran)	1978	80,000	100,000
Isfahan	1980	200,000	300,000
Arak (Iran)	1984	300,000	Working on it

3.1 Problems in Refineries in Iran (Isfahan)

As can be seen in Table 2, the refinery of Isfahan had the capacity of 200,000 barrels per day in the two parallel lines. However, after the war (1980 to 1988) with Iraq had to increase the production line to 50% more. There are two issues here,

a) Can the pump boost this work?
b) Can the exchanger and the main tower handle the extra temperature?

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If the answers to both questions are positive, there will be no issue to increase the production lines, but if the answer is negative for the first question, the pumps have to be changed to stronger pumps. Whereas the answer for question two is negative, it is necessary to rearrange the exchangers. Some problems have been found in the furnace after increasing the capacity of the refinery, especially the extra temperature at atmospheric distillation H-101. The main objective of this study is to solve the optimization problem in the best way possible, and to work on the network exchanger to produce 150,000 barrels per day which is the most efficient production. The problem can to be solved in different ways. Firstly, consider the network as producing 150,000 barrels per day and then consider the network as producing 100,000 barrels per day, as production existence. The change on the exchangers at the network should consider the 100,000 barrels per day, based on:

1) The limit of product capacity increase of the refinery without having any problems and whether it is possible to increase the capacity.
2) The network can handle the capacity increase due to the fixing and changing on the network.
3) The network with the daily capacity of 150,000 barrels. If an answer is found, the answer for the daily capacity of 100,000 barrels also can be found.

3.2 Fixing the Temperature in the Network by Capacity of 150,000 Barrels

The first step in optimizing the network is to study the existing network. This information will be the power of the flow, heat capacity, entering and exiting temperature, and it will include all the inputs and outputs of the temperature on the exchangers. It can also be collected directly from the unit. In the base capacity, all the information is available or can be calculated, but when the capacity is increased in the refinery, all this information is not available and it has to be calculated in two ways which have been described previously. Both solutions cannot give a direct answer. The information from the unit is not very accurate because the information is normally related to the network in operation and can change based on other conditions of the refinery. The measuring devices might not be very accurate and cannot give exact information. Therefore, the two ways that were given before will never give exact solutions. Due to this fact, the best way to get the information is still to use these two ways to get the answer and at the same time, obtain other information from the unit. After comparing exchangers, the best result closer to both types of information will be achieved. In this study, the only way is to use the information from the process even if it might bring about some errors because of changes in the process. Hence, all the information that has been collected and will be compared with the information from the refinery. Therefore, the information from Figure 8 will be used to optimize this refinery network. Information from the refinery is shown in Table 3. 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 [6]. 25 hot lines and 11 cold lines are apparent in this table. This will also be shown in Figure 8.

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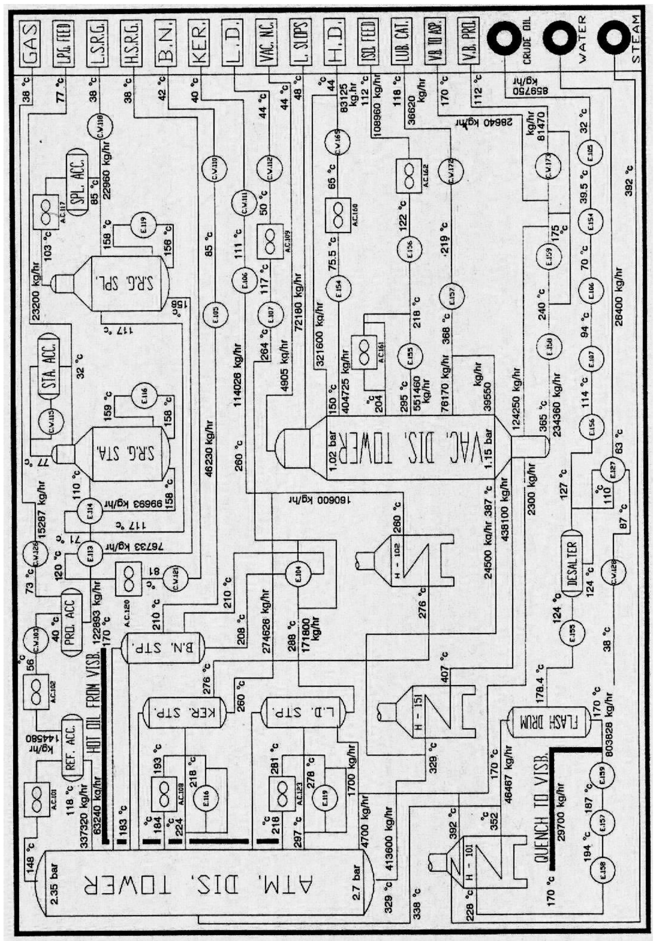

Figure 8: Flow diagram for the capacity of 150,000 barrels per day, Isfahan refinery

Based on the result at HEXTRAN software, it shows the same results [7]. Table 4 illustrates some of these results.

Table 3: 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)
10	84.05	73.45	23293	150	139.7
20	89.48	80.26	16659	280.1	260
30	98.05	88.84	11483	288	257.1
40	104.95	95.74	9119	288	247.3
50	111.97	102.76	7428	218.5	168
60	121.11	111.89	5935	228.1	168
70	130.33	121.12	4807	239	168
80	138.9	129.69	4025	249	168
90	147.47	138.26	3393	259	168
100	156.21	147	2878	269	168

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Table 4: 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/°C)	T_{in} (°C)	T_{out} (°C)	St. No	CP (KW/°C)	T_{in} (°C)	T_{out} (°C)	Q (KW)	ΔT_{LM} °C	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

The information in Table 5 is plotted as A-E diagram. This Figure13 shows the minimum value of temperature and shows the outside different services of ΔT_{min} . Therefore, knowing the surface temperature and knowing the temperature at heat exchangers in the network allow to know where the network stands in the figure and to see how far it can stand to take the action. It should be noted that to determine the network, only the information from the surface temperature of the process-to-process, and not surface temperature of the cooling system, is needed. In this calculation, surface temperature of the cooling system will not be used in the optimization process. The goal is to optimize the system and reduce the energy waste for the new investor, and this means by increasing the temperature surface of the process-to-process, the temperature on the exchangers can be reduced.

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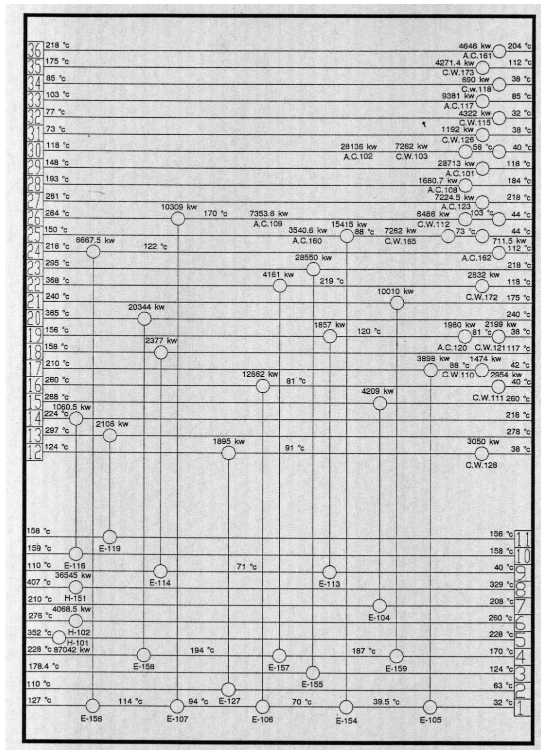

Figure 9: Exchanger view window for the capacity of 150,000, Isfahan refinery

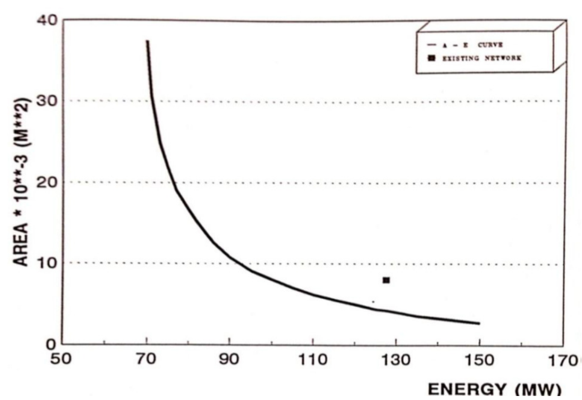

Figure 10: Curve A-E for the process information of 150,000 barrels per day, Isfahan refinery

In this study, the main goal is to reduce the temperature at the tower (H-101) and to reduce the temperature at the cooling system. It will then reduce the temperature at the heat exchangers [8]. Therefore, in the A-E diagram, the surface temperature of the process-to-process with the ratio of the loads at heat exchangers and the temperature at cooling system will not give, so the information has to be taken out from the tables which have been given. Table 3 shows that the temperature at the exchangers of process-to-process is 8016M^2 and temperature at the heat exchangers is 127/65MW. Therefore, the place is found as depicted in Table 3. This point will be the minimum of surface temperature that is the good point of energy usage at the network 4240M^2. The formula for the existing network will be:

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$$\alpha = \left(\frac{A_{tx}}{A_x}\right) E_x = \left(\frac{4240}{8016}\right) = 0.53 \quad (7)$$

Knowing α value can lead to the design of α-constant. The information of this figure will be in Figure 9. As can be seen, α is lesser than (0.9); therefore, the use of the α-constant is not good and the (α-incremental) has to be used instead. To use this figure, two rules should be;

1) The use of α-constant is only when α > 0.9.The figure is not in a good shape so it is better to use figure (α-incremental) [9].

$$\Delta\alpha = \left(\frac{\Delta A_{min}}{\Delta A}\right) \Delta E \quad (8)$$

In this formula, ΔE is added to the new temperature surface and the network for less usage of energy at the value of ΔE A_{min} needs the minimum of a new surface temperature to reduce the energy until it reaches ΔE value. In any situation, Δα can be the same value as ΔA in the figure of A-E because in the figure of optimization, α has the same value as Δα. The value of the surface temperature will increase by doing optimization at the network, therefore, $\Delta\alpha > \propto_{existing}$ can give a better value. Testing this on the network which has a value of $\propto_{existing}<0.9$, Δα = 1 can be a very good way to do optimization at that network [7].In this study, because existing is α = 0.53 (lesser than 0.9), the figure of α-constant cannot be used, and it is better to use the figure of α-incremental by taking Δα = 1

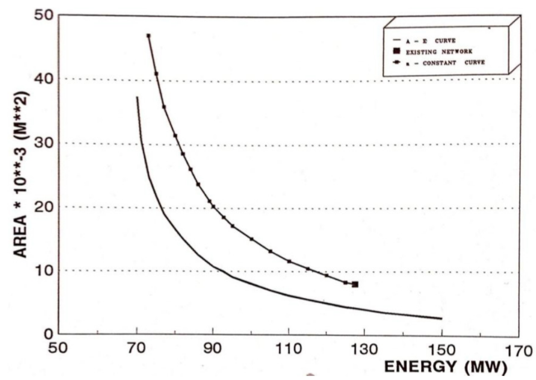

Figure 11: Figure of α-constant with the curve of A-E for the network of Isfahan refinery

In every optimization, the new value of the temperature has to be added to the network, and this will be done in two ways:

1) In a series that has to be connected to the existing network. In this case, extra pumps need to be added in the network because of the increase in falling pressure.
2) Or to connect in a parallel way to the network. In this situation, because of the divided flow and decreased Reynolds number, power of transfer temperature will go down and make the surface temperature increase in both conditions, due to the value of the new pumps or the value of extra surface temperature. The investment is the plan that has been done before and is going to be used in these conditions in the next steps.

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Table 5: Information about α-incremental and α-constant for the network exchangers

Energy (MW)	$A_{target}(m^2)$	$A_{\alpha-constant}(m^2)$	$A_{\alpha-incremental}(m^2)$
70.54	37432	70626	------
80.26	16659	31432	------
91.95	10427	19673	------
95.74	9119	17205	12820
101.36	7747	14617	11400
102.76	7458	14071	11200
110.2	6160	11622	10040
121.12	4807	9070	8700
127.97	4240	8016	8016

The base of investing in retrofit designs will explain the base of the extra temperature in the network. In the year 1990, Jegede, with the use of pressure drop at the pipes, heat transfer coefficient and the Nusselt number, came up with a formula;

$$\Delta P = K * A * h_i^{3.5} \quad (9)$$

With this formula, the extra heat on the surface due the pressure drop can be calculated. After finding this temperature and the extra temperature of the network, the change of network can be seen (point X) and the efficiency of the heat surface can be found. Therefore, the effect of the dropped pressure will be drawn in the figure of targeting based on the point X [9]. After Polley, 1990, with the use of fluid inside the pipe and correction of the fluid inside the skin, came up with the new explanation for the pressure drop. Therefore, with this explanation they have changed the point at the curve A-E and they could apply the side effect of the pressure drop on the figure of targeting. With these steps, the study can find the exchanger, which is not good at pressure drop, and make a move to fix exchangers or change exchangers. This work is beneficial and research on some retrofit shows that if pressure drops, the refinery can reduce the cost of investment up to 10%. The Figure 12 shown the outside services prices from Iran (Isfahan refinery) in the year 2013.

* *Fuel Oil = 58000 $ / MW.Yr*

* *Fuel Gas = 15000 $ / MW.Yr*

* *Cooling (Water & Air) = 3000 $ / MW.Yr*

* *Ex.C. = 37100 + 950 * (A)* $^{0.81}$ *$*

Figure 12: The outside services prices, 2013

Table 6: The information about figure S-I

ΔA (M^2)	ΔE (MW)	Investment (MM$)	Saving (MM$/Yr)
400	4.72	0.153	
1200	13.43	0.459	0.779
2000	19.07	0.765	1.106
2800	23.66	1.0714	1.372
3600	28.17	1.378	1.634
4400	32.43	1.684	1.881
5200	35.38	1.99	2.052
6000	38	2.296	2.204
6800	40.62	2.602	2.356
7600	41.93	2.908	2.432

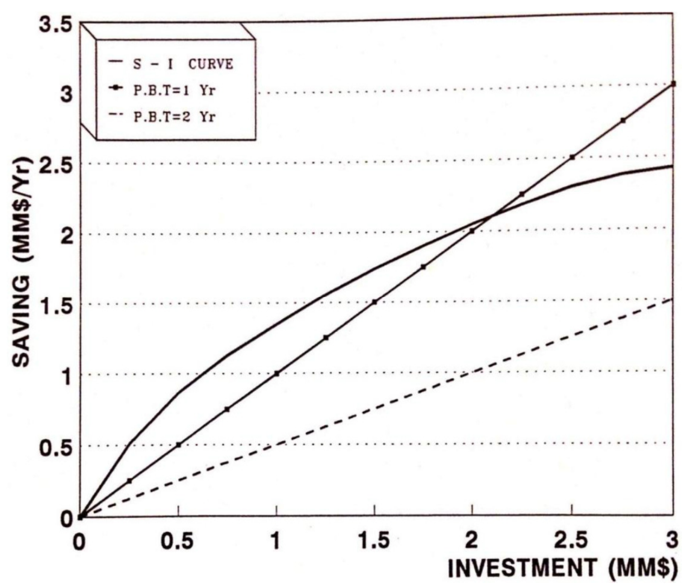

Figure 13: Figure for S-I for the refinery exchangers, [9]

Table 7: Study the different cases of optimization in the refinery

Saving (MW)	Investment (MM$)	Payback Time (month)	ΔT_{min} (^oC)
6.55	0.157	5	70
22.6	0.96	8.8	52.5
22	0.95	8.9	52

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Table 8: A summary of the result of the rest of the exchangers

Ex. No	EX. Name	A (M^2)	$A_{tr}(M^2)$	$\propto_{max}$	ΔT_{min}r(°C)
2	E-105	102	6185	0.99	52
3	E-106	365.2	6160	0.95	51
4	E-107	380	6274	0.93	50
10	E-154	737	5747	0.96	52
11	E-155	1546.8	2706	1	26
12	E-156	954.8	5484	0.96	52
13	E-157	161	5766	1	48
14	E-158	684	3704	1	27
15	E-159	1982	5464	0.83	52

* ΔT_{min}=52°C

*$\propto_{max}$ (127,104,113,114,116,119) = 7157/[6204+(1103.7)] = 0.98

*ΔT_{min}r(127,104,113,114,116,119)= 50°C

Table 9: Summary of the heat temperature on new exchangers

Ex.No.	Ex. Name	Q (KW)	ΔT_{LM}(°C)	U (KW/M^2 °C)	A (M^2)	No.Of.Sh.	Cost of Ex.(MM$)
11	N.E-155	24994	45	0.25	2220-1550=670	2	0.275
14	N.E-158	16385	59	0.4	694-1550=10	0	0
41	N.E-1	3558	57	0.2	315	1	0.133
42	N.E-2	7224	92	0.65	120	1	0.081
43	N.E-3	4646	84	0.36	154	1	0.091
44	N.E-4	1680	50	0.7	48	1	0.058
45	N.E-5	1260	59	0.72	30	1	0.051
46	N.E-6	5563	16	0.5	695	2	0.281
47	N.E-7	3958	78	0.35	145	1	0.0881

Average Size of Ex. Per Sh. = 308 M^2

As can be seen in the table 7, to reduce the cost of energy at a value of 6.55MW, the investor needs $157,000 and the time of pay back is 5 months. In this situation, optimization of 70°C is needed. After fixing the refinery, the temperature of the main tower will be stable, but if the energy usage is no lesser than 22.6MW, the investment cost will be $960,000 and payback will be 8.8 months and the needed for the network is 52.5°C. The temperature at the main tower will be normal. As can be seen, in both conditions the value of is high and there is a big difference with the existing network. In this condition, the difference between both should be reduced to do the optimization in this network. The optimization conditions in the refinery should be happened that the investment and energy saving is increased, but it has to be less in investment, whereas energy saving should not be more than 22MW.

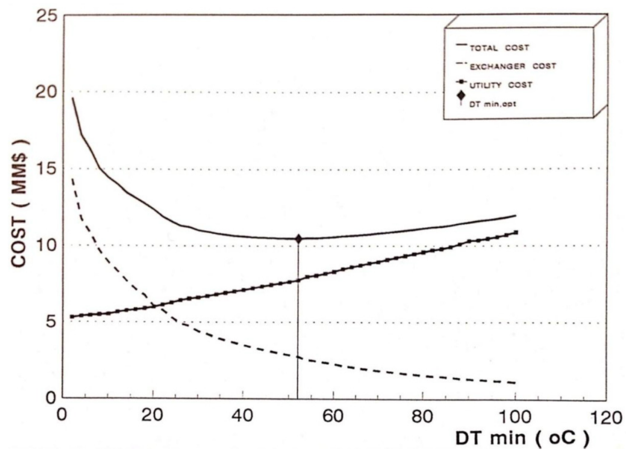

Figure 14: network refinery, ΔTmin, opt [14]

Figure 14 shows that, $\Delta T_{min,\ opt}$ of the network is 52 °C, but in optimization at network refinery, if ΔT_{min} =52°C makes the outside services temperature change, all the limits in optimization network will be observed and the investment will be reduced. Therefore, the ΔTmin for optimization in the refinery will be chosen as $\Delta T_{min,opt}$. In this condition, the cost of investment will be $950,000, the payback time will be from 8 to 9 months and the energy which will be saved is 22MW. The payback time may be longer, but the temperature of the main tower will be stable and the can be chosen as ΔT_{min}, opt for the refinery network. In the other sections, the design will be done based on the ΔT_{min}.

4.0 CONCLUSSION

The investment that has been done, if there is no other major problem in the network, the network can produce 13% and in the condition of the base production to 15% with a maximum of 35%. However, in these conditions, the temperature of the main tower will reach the maximum. $\Delta T_{min,opt}$ of the network has not gave significant change. ($\Delta T_{min,opt}$ of the network in production of 150,000 barrels per day 52°C and for the base production of 100,000 barrels per day will be 55°C).The payback time of investment is 9 months.

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REFERENCES

[1] R. Smith, Chemical Process Design and Integration, first ed., John Wiley & Sons Ltd, West Sussex, 2005.

[2] P. Heggs, Minimum temperature difference approach concept in heat exchanger networks, Heat Recovery Systems and CHP (1989) 367–375.

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[3] B. Linnhoff, J.R. Flower, Synthesis of heat exchanger networks, AIchE Journal 24 (4) (1978) 633–642.

[4] S. Ahmed, B. Linnhoff. Overall cost targets for heat exchanger networks, IChemE 11th Annual Res. Meeting, April, Bath, U.K., 1984.

[5] III. Kleinschrodt, F. Hammer, A. Gary, Heat transfer: exchanger network for crude units powerful computer programs now make it possible to simultaneously evaluate fractionator efficiency, flexibility and energy usage, Chemical Engineering Progress 79 (1983) 33-38.

[6] B. Linnhoff, T.N. Tjoe, Pinch technology retrofit: setting targets for existing plant, AIChe National Meeting, Houston, March 24-28, 1985.

[7] S. Ahmad, B. Linnhoff, R. Smith, Cost optimum heat exchanger networks-2 targets and design for detailed capital cost models, Computers and Chemical Engineering 14 (1990) 751-767.