Modification of Preheating Heat Exchanger Network in Crude Distillation Unit of Arak Refinery Based on Pinch Technology

Salomeh Chegini , Reza Dargahi , Afshin Mahdavi

***Abstract* — In this work, the Hint software that is based on methods of pinch technology was applied for design, optimizing and improving the integrated heat exchanger network of crude oil preheating Process in distillation unit in Arak refinery with the aim of heat load reduction in the furnace.**

In the first step , the data gathering of hot and cold streams in preheating section of distillation unit has been done and then by using Hint software, integrated heat exchanger network was designed with assumption of ΔT = 30 k.

Improving the existing heat - exchanger network has been done with respect to operating conditions and hydraulic limitation by considering the aim of least changes in the existing arrangement of exchangers, which is led to increasing of furnace inlet temperature up to 10.5 °k and deceasing of heat duty of the distillation furnace about 9855 kw.

The most important results in this project are:

Decreasing of heat duty of distillation furnace to 9855 kw that leads to saving about 820000 US$ per year.

Increasing the inlet temperature of the furnace up to 10.5 °k.

Decreasing the temperature of furnace tubes skin to 300°k.

Decreasing the temperature of furnace flue gas to 290°k.

Decreasing the greenhouse emission to 20000 tones per year.

***Index Terms* — modification , pinch technology , heat exchanger**

I. INTRODUCTION

Highlight Over the last two decades the pinch technology has emerged as an unconventional development in process design and energy conservation. The term "Pinch Technology" was introduced by Linhoff and Vredeveld to represent a new set of thermodynamically based methods that guarantee minimum energy levels in design of heat exchanger networks [1].

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Energy conservation remains the prime concern for many process industries while oil prices continue to increase and with climbing the energy cost and environmental limitations using of this methods will grow .

Most industrial processes involve transfer of heat either from one process stream to another process stream (interchanging) or from a utility stream to a process stream . In the present energy crisis scenario in all over the world, the target in any industrial process design is to maximize the process – to- process heat recovery and to minimize the utility (energy) requirements . To meet the goal of maximum energy recovery or minimum energy requirement (MER) an appropriate heat exchanger network (HEN) is required. The design of such a network is not an easy task considering the fact that most processes involve a large number of process and utility streams. The traditional design approach has resulted in networks with high capital and utility costs. With the advent of pinch analysis concepts, the network design has become very systematic and methodical [1,2] .

It is certainly true that the industry has seen a large surge in interest from the refining industry to help define capital investment projects to improve CDU energy performance. This is from a combination of several factors: first, the increased cost of energy, combined in Europe with the desire to drive down CO2 emissions, and second, and perhaps more importantly, the availability of capital to invest outside of just safety-critical projects and stay-in-business projects such as clean fuels. So, we firmly believe that the practical implementation of pinch technology, combined with good engineering judgment, is the optimum path to improving CDU energy performance [2,3] .

In fact, CDU analysis is almost simultaneously the best and worse place to apply pinch technology within a refinery. Although the benefits are high, the skills requirements for a successful study are also high. Due to the parallel nature of the composite curves, the CDU tends to have a large pinch region where the preheat train is constrained, rather than a single pinch point. This means that some of the tools in the pinch toolbox, such as cross-pinch heat transfer, do not automatically lead the engineer to a better design. As there is normally a single cold stream (crude) and multiple hot streams (products and pump around), applying MCP rules around the pinch to meet both energy and area targets leads to excessive splitting of crude, to a degree that is not practical to implement. However, there are other tools such as temperature driving-force plots that come in into their own for CDU analysis. Often, adding new exchangers on a new crude branch is an effective way of reducing pressure drop in the existing exchangers, which are

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probably operating well above their original design flows. Leaving the main preheat train intact can also make implementation easier and faster, which is an important factor [2 , 5] .

A pinch technology study is normally split into two parts, targeting and network redesign. The methodology applied to most refinery pinch studies is to first generate an energy target based on fixed process conditions, as this is a conservative estimate and does not assume process modifications such as new pump around that can be capital intensive. The next step is then to systematically explore process changes (such as pump around and cut point changes) that further improve energy performance.

If these look attractive, they can be verified by process simulation and included in the network redesign [4 , 6] .

A significant challenge for all CDU revamp studies is that, fundamentally, you are capturing low-grade heat currently rejected to air cooling, forcing this through the length of the crude preheat train (or composite curves), to save high-grade furnace heating. Normally, adding just one heat exchanger at the cold end “bumps up” the rundown temperatures to trim coolers of the products matched in the upstream exchangers with little fuel saving. In effect, the gearing between heating at the cold end and saving at the hot end is unfavorable. It is necessary to add area both at the cold end to recover heat and through the rest of the preheat train to compensate for reduced temperature driving forces (to keep the heat in). It is possible to produce significant energy savings, but even with higher energy prices fast payout times should not be expected for major retrofits based purely on energy saving. Therefore, we always look for synergies with other benefits, such as capacity increase, yield improvement or debottle necking of rundown coolers. A traditional revamp approach quantifies savings based on a single snapshot (test run) of the unit. In reality, the economics normally change between turnarounds as the preheat train fouls, and ultimately feed rate is cut as the crude furnace becomes bottlenecked. New proprietary technology such as HX-NET permits an economic evaluation over the full cycle between turnarounds, providing a much more accurate assessment of revamp benefits.

It should never be forgotten that a project idea identified using pinch technology has to be considered and challenged in an identical way to any other idea generated from best practices or experience. Many ideas generated direct from pinch analysis have to be adapted or modified in some way to meet with plant constraints, and pinch analysis should also be always considered as a tool to guide the engineer. However, conversely, it is rare to find any energy improvement project generated from best practices (such as pump around duty and temperature changes) that cannot be explained in terms of pinch technology and temperature driving forces. Process know-how is an essential part of improving CDU energy performance, but is even more powerful when coupled with great tools, and pinch analysis is the best tool known today for revamping preheat trains[2,7] .

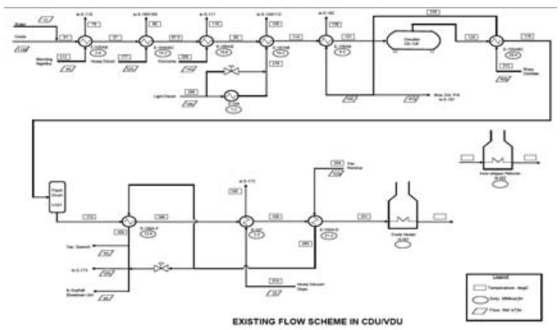

Fig 1 . Diagram of existing network in CDU / VDU

Table . 1 – The stream Table [8].

Stream	Description	Type	Heat Type	T1(k)	T2(k)	H(kw)	m.cp(kw/k)
1	BN	Hot	Sensible	485	351	-4680	28.9
2	HD	Hot	Sensible	450	353	-22630	209.4
3	KERO	Hot	Sensible	531	383	-14600	99.6
4	LD	Hot	Sensible	549	401	-20708.2	140
5	WD1	Hot	Sensible	508	409	-56925	145.8
6	WD2	Hot	Sensible	585	508	-44275	574.6
7	VR1	Hot	Sensible	538	462	-29184	244.6
8	HVS	Hot	Sensible	651	471	-3348	18.6
9	VR2	Hot	Sensible	627	538	-24090	383.6
10	crude 1	Cold	Sensible	304	620	-	730

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Table 2 . Existing Heat Exchangers Table

H.E.	Heat Load (kW)	Hot Str	T1C (K)	T2C (K)	Cold Str	T1F (K)	T2F (K)	Area (m2)
1	86870	SG	-	-	8	501	620	1066
2	3348	6	651	471	8	466	471	70
3	29184	7	538	462	8	427	467	574
4	44275	5	585	508	8	388	449	347
5	56925	5	508	409	8	326	404	611
6	20708	4	551	401	8	359	387	230
7	14600	3	530	383	8	341	361	160
8	22630	2	461	353	8	310	341	302
9	4380	1	503	351	8	304	310	42
10	24090	7	601	538	8	471	504	298

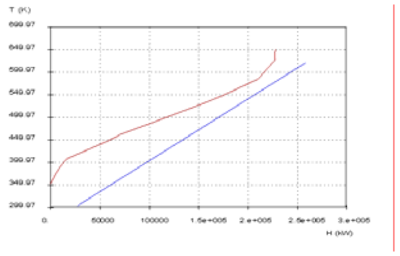

Fig 2 . Existing case composite curve

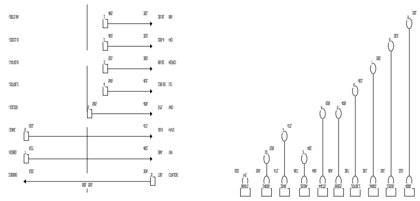

Fig 4 . Existing network grid diagram

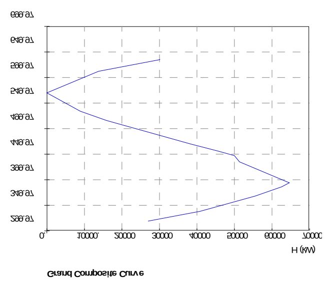

Fig 3 . Existing case Grand composite curve

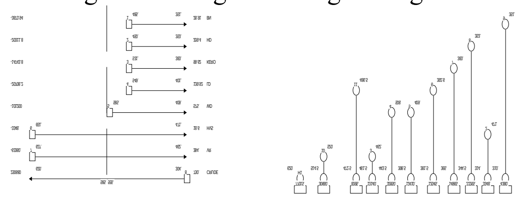

Fig 5 . Modified case – Grid Diagram

Table 3 . heat exchangers table

H.E.	Heat Load (kW)	Hot Str	T1C (K)	T2C (K)	Cold Str	T1F (K)	T2F (K)	Area (m2)	Cost ($)
1	77015	SG	-	-	8	514.5	620	999.2	514705
2	3348	6	651	471	8	309.4	314	14.0	44663.7
3	13140	7	496.2	462	8	443.5	461.5	510.0	328830
4	32850	5	565.1	508	8	398.5	443.5	284.5	225142
5	12410	5	430.6	409	8	381.5	398.5	417.4	288363
6	12045	4	487.1	392.6	8	365	381.5	207.2	184257
7	14965	3	533.2	383	8	344.5	365	170.1	163022
8	22265	2	459.3	353	8	314	344.5	317.1	241334
9	4380	1	502.5	351	8	304	310	42.4	73914.4
10	30660	7	599.8	520	8	472.5	514.5	474.7	313698
11	8395	4	546.5	486.5	8	461	472.5	184.4	171352

The project description

II. EXISTING CASE

In this case , the data is gathered related to hot and cold streams of preheated section in distillation unit . Since the most of the CDU products are usually finished products or sometimes are used for blending to produce other finished products , their final temperature is not important and it would be a relaxation opportunity [8].

The following flow diagram is the exist situation in integrated heat exchanger network in preheating section and shows that at the first the cold stream of crude oil (with the temperature 310ºK)heat exchanges with the hot stream of blending naphtha (BN) at the E-105AB heat exchanger it will continue in E-154ABC with heat exchanging with the hot stream of heavy diesel (HD) . The heat exchanging of crude will continue in E-106AB, E-107AB , E-156AB and E-155ABC after its outgoing from E-154ABC and with the streams of light diesel (LD) , Iso-feed 1 and 2 (WD1 & WD2) , respectively . At resumption after the crossing from flush drum , it will traverse its heat exchanging path , with crossing from exchanges E-159A-F, E-157 , E-158A-D ,respectively . with the streams of vacuum residue 1 (VR1) , heavy slops(HVS) and vacuum residue 2 (VR2) .

Resultant of this heat exchanging complex is temperature increasing of cold stream of crude oil until 504 ºK that after crossing from the furnace of distillation unit (H-101) , its temperature will increase to 620 ºK and it will be ready for going to the distillation tower .

In applying Hint software the streams WD1& WD2 and VR1 & VR2 are considered as single streams named WD and VR , respectively [8].

III. MODIFIED CASE

Hot and cold streams data are introduced to Hint software according to stream table data and the integrated heat exchanger network was designed with assumption of $\Delta T = 30$ k . Obviously the existing network grid diagram shows the violation of ΔT_{min} in heat exchangers No.2 , 3 and 5 with the amounts of 4 , 13 and 22 k , respectively . In this situation the requirement hot utility for furnace H-101 is 86870 kw that partial of it is cross the pinch .

For improving the existing heat exchanger network with considering operation and hydraulic limitation , the least modifications in the existing arrangement of heat exchangers, has been considered which are as :

– Replacing of heat exchanger No.2

– Installation of a new exchanger , No.11 between crude oil stream and hot stream of light gas oil .

- Decreasing of heat duty of exchanger No.6

- Increasing of heat duty of exchanger No.10 with changing in hydraulic of exchanger

after above modifications and input the new informations into hint software, as result , we can consider the decreasing of heat duty of the distillation furnace H-101 about 9855 kw that it was because of increasing the temperature of inner cold stream of crude oil to the furnace up to 10.5 k .

Table 4. Remaining Problem Analysis -modified case

	Minimum	Installed	Remaining	Total
Number of H.E.	11	11	0	19
Area (m2)	4287.26	3621.16	-1.#IND	-1.#IND
Capital Cost ($/annual)	3.03E+06	2.55E+06	980282	3.53E+06
Heating (kW)	30094.4	77015	0	77015
Cooling (kW)	26960.1	0	161213	161213

IV. REMAINING PROBLEM ANALYSIS - MODIFIED CASE

In the table 4 , the results of a Remaining Problem Analysis are summarized .

V. ΔT_{MIN} ANALYSIS - MODIFIED CASE

You can see the ΔT_{min} analysis in modified case in the figures No.6 to No.9. According to the curves , reduction of ΔT_{min} can be lead to to reduction of energy consumption but we will need more heat exchanger area . The optimum ΔT_{min} is calculated about 30k and the pinch temperature is equal to 570k.

VI. CONCLUSION

The most important results of this project performance can be express as below:

1) Operating conditions before and after pinch project have been shown at table 3 . The heat duty reduction of furnace H-101 causes reduction of fuel consumption in the furnace and leads to saving about 820000 US$ per year for the refinery.

2) Skin temperature reduction of furnace tubes about 300 k.

3) Temperature reduction of furnace flue gas about 290 k.

4) Emission reduction of NOX, SOX and CO2 about 20000 tones per year.

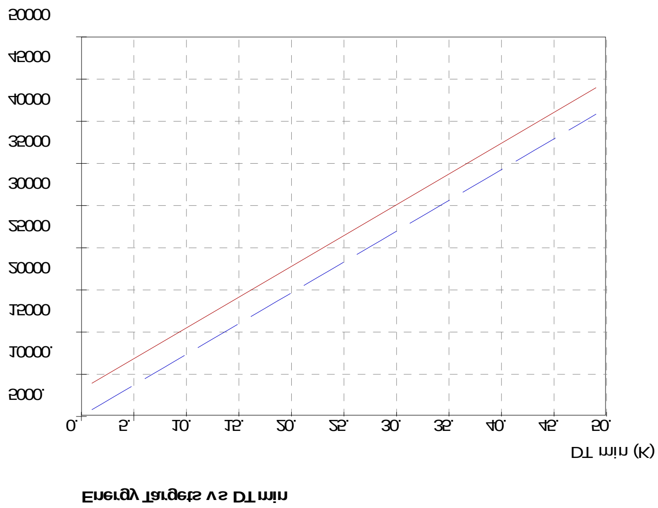

FIG 6 . DIAGRAM OF ENERGY TARGETS VS ΔT_{MIN}

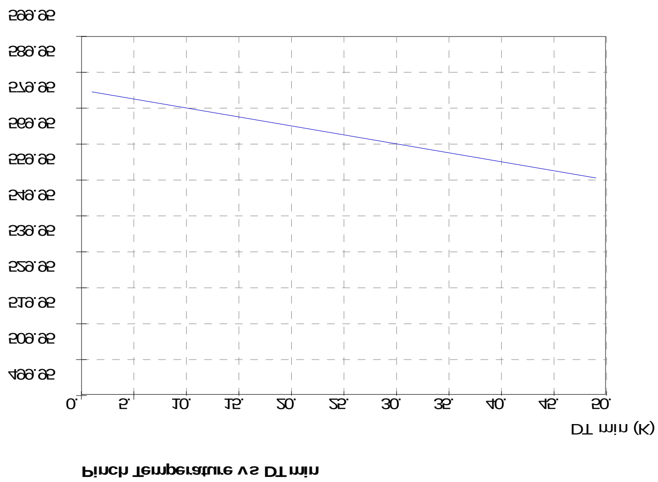

FIG 7 . DIAGRAM OF PINCH TEMPRATURE VS ΔT_{MIN}

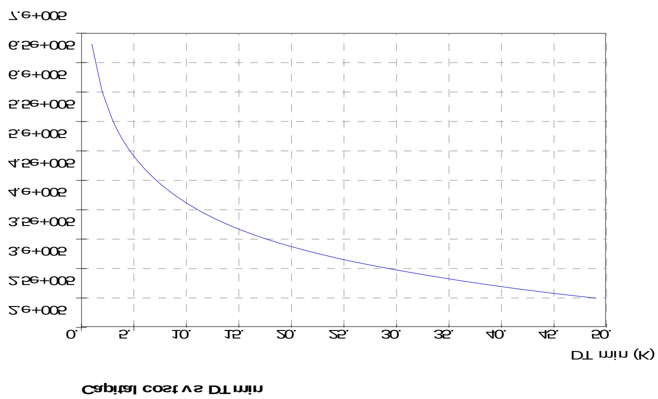

Fig 8 . Diagram of capital cost vs ΔT_{min}

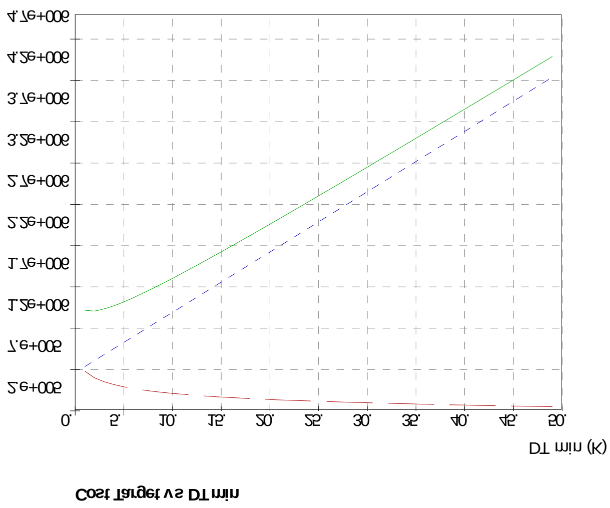

Fig 9 . Diagram of cost target vs ΔT_{min}

Table 5.Operating conditions before and after pinch project

	Before pinch project	After pinch project	Improvement
Duty of H-101 (KW)	86870	77015	Decrease duty: 9855
Intel Temp to H-101 (K)	504	514.5	Increase temp: 10.5

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