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Redesigning and Optimizing a Heat Exchanger Network using PINCH Method

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Abstract

The atmospheric and vacuum distillation unit (AVDU) is one of the largest energy consumers in a refinery. Crude oil is preheated in a heat exchanger network with the liquid petroleum fractions that result from the fractionation columns of the installation. Thus, the fuel consumption for heating the oil until reaching the required temperature is reduced. Following the analysis of heat exchange in the current scheme, it is studied the possibility of redesigning and optimizing the network of heat exchangers using the PINCH method, using simulation program ASPEN ENERGY ANALYZE.

Key words: *optimization, heat exchanger, simulation, PINCH method*

Introduction

The application of simulation in existing oil processing facilities is widely developed today. Simulation efficiency in decision-making regarding modernizing and improving the functioning of existing installations has demonstrated its usefulness and the present work aims to improve the heat exchange in an installation of atmospheric and vacuum distillation. There are several concerns about the proper functioning of this installation in terms of economical and performance aspects [5, 6]. Starting from the current scheme of heat exchange, the work studies the possibility of redesigning and optimizing the network of heat exchanger using the simulation program ASPEN ENERGY ANALYZER. The current tendency of heat exchanges takes into account the efficiency of available at one point (raw materials, energy, production capacity, personnel) in order to obtain specific products in quality conditions and imposed restrictions. A PINCH analysis starts with the heat and material balance for the process. Using PINCH method, it is possible to identify appropriate changes in the core process conditions that can have an impact on energy savings [1-3, 7]. There was also studied and presented the version when the cold flow is made of raw materials and a new heat exchanger network was redesigned.

Calculation Algorithm

The current scheme for AVDU facility that was done in this study comprises 53 heat exchangers, totaling an area of heat transfer totaling 12551 m^2. Optimizing and redesigning the heat exchange is setting the objective function realization train heat exchangers with fewer devices and reduced heat transfer area. Pinch methodology for application of the system were identified AVDU cold and hot flows. These data are presented in Tables 1-2. Based on actual data from the plant they were able to trace the curves composed of fluids. This representation is shown in Figure 1.

Table 1. Cold fluids and their characteristics

Cold fluids		Weight rate, kg/h	t_i °C	t_f °C	t_m °C	c_p, J/kg °C	C, W °C
R1	TB	300000	30	110	70	2107.1	175591.7
R2	TD	296700	100	220	160	2480.1	204402.0
R3	BU	10937	35	200	117.5	2483.4	7544.7

Table 2. Hot fluids and their characteristics

Hot fluids		Wight rate, kg/h	t_i °C	t_f °C	t_m °C	c_p, J/kg.°C	C, W °C
C1	BR	250000	150	90	120	2488.5	172812.5
C2	P1	36000	197	45	121	2439.7	24397.0
C3	P2	25375	215	45	130	2401.04	16924.0
C4	PR	150000	250	135	192,5	2625.1	109379.2
C5	M1	38800	290	75	182,5	2573.0	27731.2
C6	M2	19350	315	75	195	2557.4	13746.0
C7	DV	94061	250	220	235	2661.4	69537.2
C8	DVR	178192	285	210	247,5	2653.0	131317.6
C9	RV	65000	324	150	237	2507.4	45272.5
C10	BS	8750	220	40	130	2489.2	6050.1

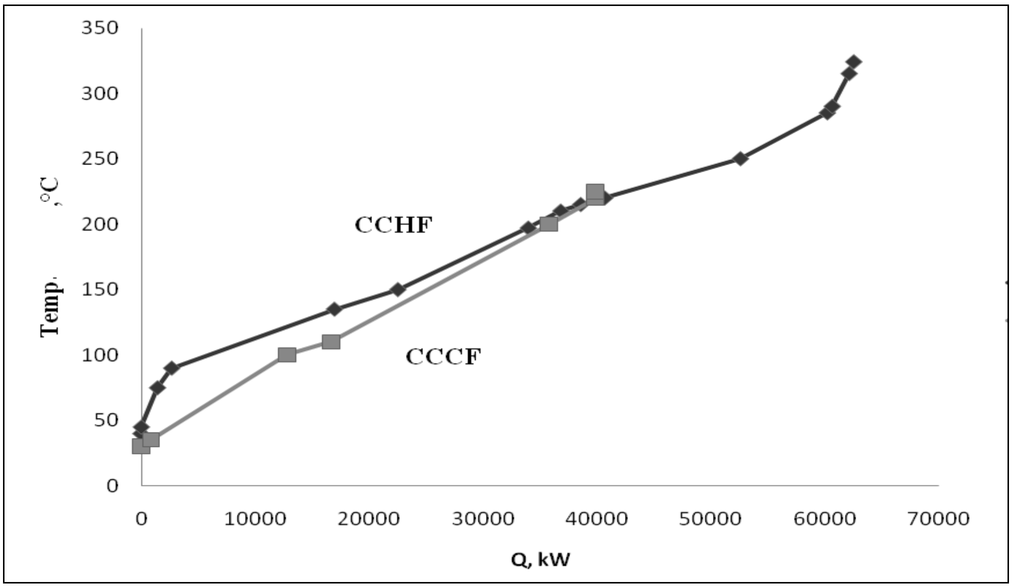

Fig.1. Composite curves of hot and cold fluids

Because CCCF is partly situated above the curve CCHF, this will translate to establish pinch site (Δt_{min} = 10 ^{0}C). The new curve position CCCF is presented in Figure 2.

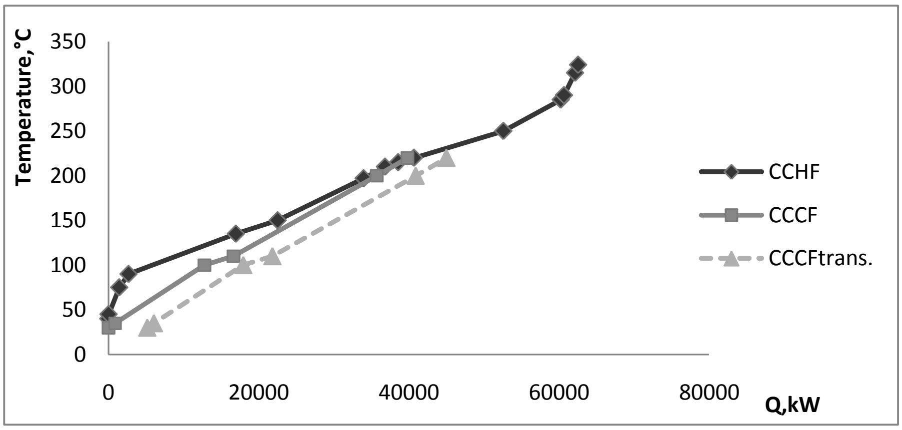

Fig. 2. Composite curves after translation

Results and Discussions

Generating the network of heat exchangers for the version of cooling the flows with water

Next, for redesigning and optimizing the heat exchanger network for the version of cooling the flows with water is presented a general diagram when ASPEN HX-NET works and its optimised version.

Table 3. Results of development of ASPEN HX-NET program for design 28

Apparatus	Flows	Area, m^2	Heat flow, 10^{-6} kJ/h	Global coefficient of heat transfer, $kJ/hm^{2o}C$	Temperature difference, ^0C
E111	R2-C8	2565.3	54.72	328.5	81
E106	R1-C3	109.9	4.87	472.3	105
E115	R3-C6	84.6	4.48	930	71
E121	Apa-C10	39.3	3.92	1281	78
E119	Apa-C5	51.7	9.4	2259	81
E107	R1-C2	149.7	5.57	472.3	91
E105	R1-C4	200	13.51	472.3	149
E109	R1-C1	1445.2	29.95	525.6	49
E112	R2-C7	252	4.39	328.5	61
E114	R2-C9	2895	35.67	230	66
E116	Apa-C1	77	9.11	1281	93
E118	Apa-C2	115	6.11	1005	54
E120	R2-C4	475	11.55	472.3	53
E110	R1-C9	403	13.59	230	163
E108	R1-C6	109	6.26	639.2	105.5
E113	R2-C5	961	22.45	639.2	46
E117	Apa-C3	97	5.48	1005	57
Total area, m^2 10030.4, Total number of units 17, Total number of apparatus 37, Wight rate of cold water 452 kg/s					

Table 4. Results of development of ASPEN HX-NET program for design 28 optimization

Apparatus	Flows	Area, m^2	Heat flow, 10^{-6} kJ/h	Global coefficient of heat transfer, kJ/hm$^{2\circ}$C	Temperature difference, ^{0}C
E111	R2-C8	2697.6	54.72	328.5	77
E106	R1-C3	158.1	5.9	472.3	95
E115	R3-C6	84.6	4.48	930	71
E121	Apa-C10	39.3	3.92	1281	78
E119	Apa-C5	55.5	10.41	2259	83
E107	R1-C2	154	5.57	472.3	89
E105	R1-C4	178.1	10.1	472.3	128
E109	R1-C1	1057.7	29.95	525.6	63
E112	R2-C7	191,5	4,39	328,5	76
E114	R2-C9	2322	33,2	230	77
E116	Apa-C1	107,8	9,11	1281	66,5
E118	Apa-C2	115	6,11	1005	54
E120	R2-C4	575,2	15	472,3	58
E110	R1-C9	718,1	16	230	118
E108	R1-C6	137,5	6,26	639,2	88
E113	R2-C5	869,2	21,4	639,2	48
E117	Apa-C3	86,5	4,46	1005	52
Total area, m^2 9547, Total number of units 17, Total number of apparatus 38, Wight rate of cold water 452 kg/s					

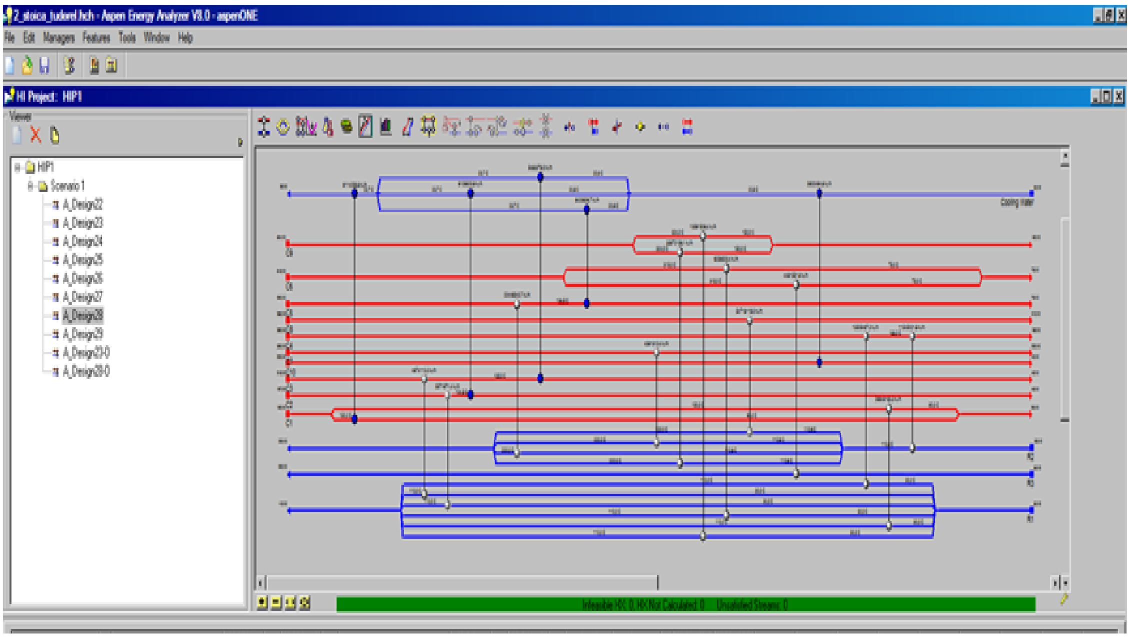

Fig. 4. Scheme development – design 28

Generating heat exchangers for the steam version

Next, for redesigning and optimizing the network of heat exchangers for the steam version, it is presented a diagram that appears when ASPEN-HX NET works and its optimized version.

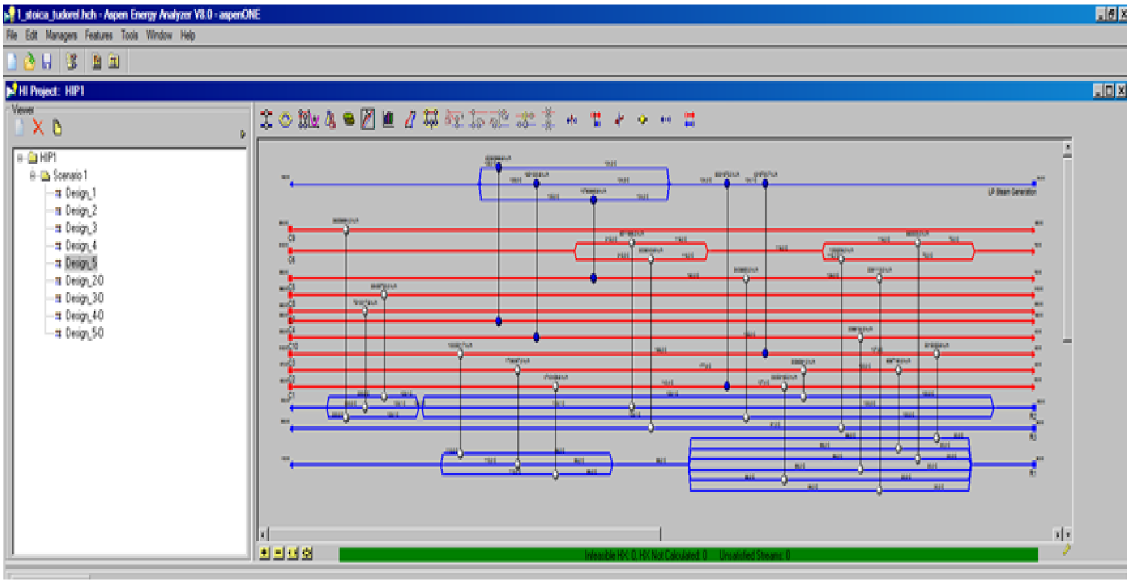

Fig. 5. Scheme development – design 5

Table 5. Results of development of ASPEN HX-NET program for design 5

Apparatus	Flows	Area, m^2	Heat flow, 10^{-6} kJ/h	Global coefficient of heat transfer, kJ/hm$^{2\,0}$C	Temperature difference, ^{0}C
E105	R1-C3	16.29	1.023	614.3	102.5
E124	R1-C1	944.2	2.325	707.6	42.76
E112	R2-C8	1504	3.546	391.4	75.43
E116	R2-C2	286.3	5.057	614.3	34.42
E108	Abur-C4	944.3	4.518	1034	46.65
E106	R1-C2	33.6	1.706	614,3	83.14
E126	R3-C6	44.05	1.254	930	38.5
E123	R1-C10	177.05	2.069	707.6	20.58
E125	R1-C5	193.2	5.291	930	36.89
E121	R1-C2	741.2	6.587	614.3	18.2
E109	Abur-C10	36.25	1.851	1328	38.74
E111	Abur-C1	808.1	9.332	1328	8.74
E107	R1-C1	160.7	4.742	707.6	42.06
E114	R2-C9	2360	2.836	251.1	57.04
E118	R2-C5	162.3	5.409	930	41.69
E122	R1-C6	38.22	8.833	930	30.83
E120	R1-C3	481.4	5.015	614.3	21.29
E110	Abur-C5	43.7	1.076	2410	102.3
E113	R2-C7	393	7.510	391.4	57.07
E115	Abur-C3	183.4	4.320	1034	22.8
E117	R2-C6	102.5	6.512	930	73.72
E119	R3-C6	62.4	3.228	930	68.8
Total area, m^2 9718, Total number of units 22, Total number of apparatus 52, Wight rate of steam 32575.95 kg/h					

Table 6. Results of development of ASPEN HX-NET program for design 5 optimization

Apparatus	Flows	Area, m^2	Heat flow, 10^{-6} kJ/h	Global coefficient of heat transfer, kJ/hm^{2o}C	Temperature difference, ^{0}C
E105	R1-C3	0.1667	1.074	614.3	104.9
E124	R1-C1	1338	2.766	707.6	35.78
E112	R2-C8	1608	3.546	391.4	70.31
E116	R2-C2	165.5	5.238	614.3	55.24
E108	Abur-C4	944.4	4.528	1034	46.64
E106	R1-C2	0	0	614.3	87.02
E126	R3-C6	53.7	1.361	930	34.21
E123	R1-C10	178.2	2.269	707.6	22.44
E125	R1-C5	248	5.730	930	31
E121	R1-C2	683	8.112	614.3	24.21
E109	Abur-C10	25.93	1.651	1328	48.16
E111	Abur-C1	429.6	9.662	1328	16.96
E107	R1-C1	59.70	1.690	707.6	40
E114	R2-C9	2272	2.836	251.1	59
E118	R2-C5	125.4	4.970	930	46.26
E122	R1-C6	29.36	6.257	930	28.11
E120	R1-C3	478.8	6.157	614.3	26.17
E110	Abur-C5	43.7	1.076	2410	102.3
E113	R2-C7	322.6	7.510	391.4	66.58
E115	Abur-C3	83.51	4.190	1034	48.56
E117	R2-C6	115.9	6.769	930	69.81
E119	R3-C6	70.8	3.120	930	58.31
Total area, m² *9216*, Total number of units 22, Total number of apparatus 50 Wight rate of steam 32575.95 kg/h					

Conclusions

The liquid fractions, resulted in atmospheric and vacuum distillation unit, have a high thermic potential due to big flow rates and high temperature. Heat regeneration of these liquid fractions is done by preheating the oil that feeds the plant, the positive effects of these regeneration coming from two directions: one is the reduction in fuel required in furnace for atmospheric distillation unit, and the second is the reducing consumption of coolant (water recirculated, air) needed for cooling warm fractions up to the temperature required for storage.

Heat exchanger network scheme must provide flexible operating conditions allowing flow changes, changes in the oil and products quality and the point of optimum functioning to become less sensitive to price changes in time. In the present study it was aimed to achieve a total heat exchange area reduced by comparing the obtained value to the current scheme of heat exchange.

In alternative cooling with water method, it was obtained a total of 37 heat exchangers, and through optimization, the area of heat transfer was reduced from 10030.4 m^2 to 9547 m^2 (compared to 12 551 m^2 in the current scheme, to 53 devices).

In the version with steam, it was obtained a total of peculiar 52 and through optimization, the area of heat transfer was reduced from 9718 m^2 to 9216 m^2 (compared with 12 551 m^2 in the current scheme, with 53 devices).

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Reproiectarea şi optimizarea unei reţele de schimbătoare de căldură prin aplicarea metodei PINCH

Rezumat

Instalaţia de distilare atmosferică şi în vacuum (DAV) este una dintre cele mai mari consumatoare de energie din cadrul unei rafinării. Ţiţeiul este preîncălzit într-o reţea de schimbătoare de căldură cu fracţiunile petroliere lichide care rezultă din coloanele de fracţionare ale instalaţiei. Valorificarea energiei termice din fracţiunile petroliere lichide în această variantă se numeşte regenerare de căldură. Astfel, consumul de combustibil pentru încălzirea ţiţeiului până la temperatura necesară în coloana de distilare atmosferică se reduce. În urma analizei schimbului de căldură în schema actuală, se tratează posibilitatea reproiectării şi optimizării reţelei de schimbătoare folosind metoda PINCH, cu ajutorul programului de simulare ASPEN ENERGY ANALYZER. Reţeaua optimă de schimbătoare de căldură permite recuperarea maximă de căldură din fluxurile calde, fără consum de utilităţi sau cu un consum minim de utilităţi.