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Improving Energy Efficiency of the Natural Gas Separation Plant by Pinch Analysis

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An approach based on pinch analysis is used for heat exchanger network (HEN) retrofit of the natural gas separation plant (GSP) to find the scope of energy saving and reduce the operating costs. In this research, pinch analysis can be applied to investigate the retrofit potential and generate three alternative retrofit designs of HEN by removal of utility with inappropriate placement, five heaters located in the below-pinch regions. All three retrofit designs give 27.07% and 7.46% savings on hot and cold utility usages, respectively. These can be done without adding new heat exchangers. In retrofit project, the payback periods were calculated to evaluate new extra investment. The result shows all retrofit designs give the same payback period of 0.30 year.

1. Introduction

Energy saving is playing a key role in many process industries especially in oil and gas refining plants. Unquestionably, a major concern to accomplish this aspect is to use the process heat exchangers for recovering energy from hot process streams to heat up the cold process streams, resulting in utility saving. Process integration was used for saving utility (e.g., hot oil, air and refrigerant) in GSP. This study is to analyze the retrofit potential of GSP and improve energy efficiency by retrofitted HEN.

2. Process Description and Data Extraction

Natural gas is used as a feedstock of GSP5 and firstly treated by removing mercury, acid gas, and water before it is sent to the fractionation units to produce products, methane, ethane, propane, liquified petroleum gas (LPG), and natural gasoline (NGL). After process study, the actual data like the supply and target temperatures, heat capacity, and flow rates, are required for pinch analysis. In this study, there are 32 hot

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and 20 cold process streams with the use of hot utilities (hot oil) and cold utilities (air cooler and refrigerant) as shown in Figure 1.

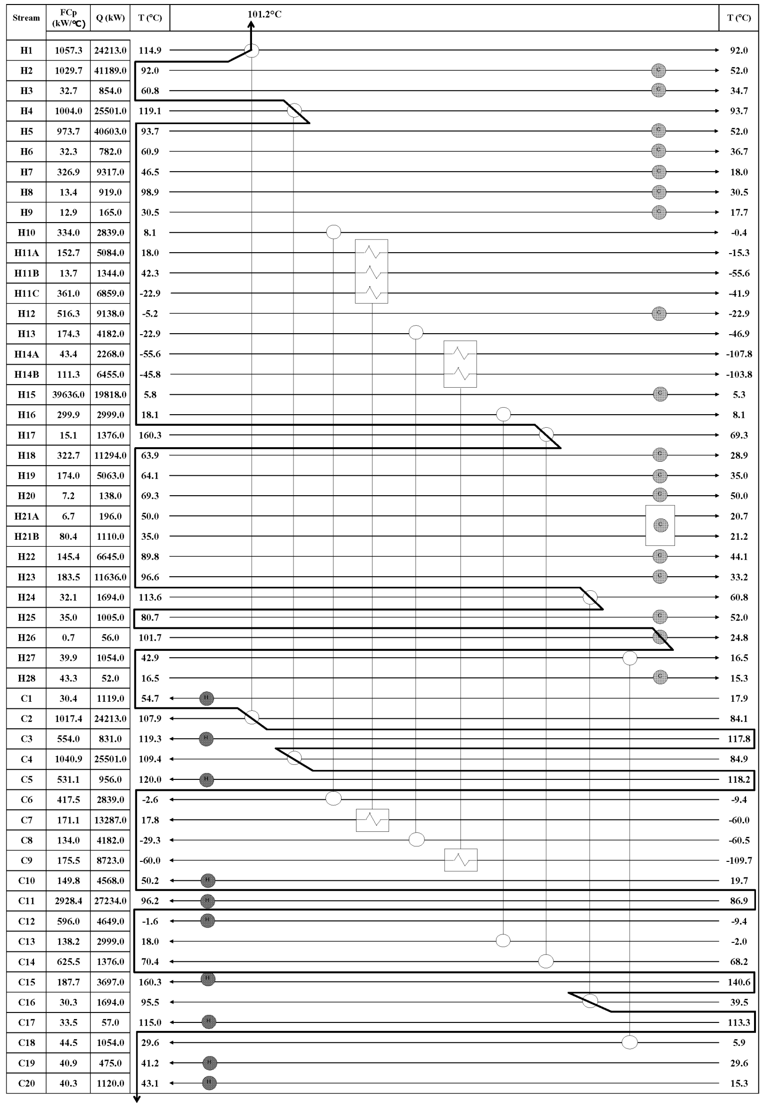

Figure 1 Grid Diagram of Existing Process.

3. Construction of Composite and Grand Composite Curves

The composite and grand composite curves of the existing HEN. are shown in Figure 2 with hot and cold utilities of 44706 kW and 59980 kW, respectively. The minimum approach temperature (ΔT_{min}) is 14.3°C and Pinch temperatures are between 86.9°C and 101.2 °C, which divide the process into two regions—above and below pinch regions.

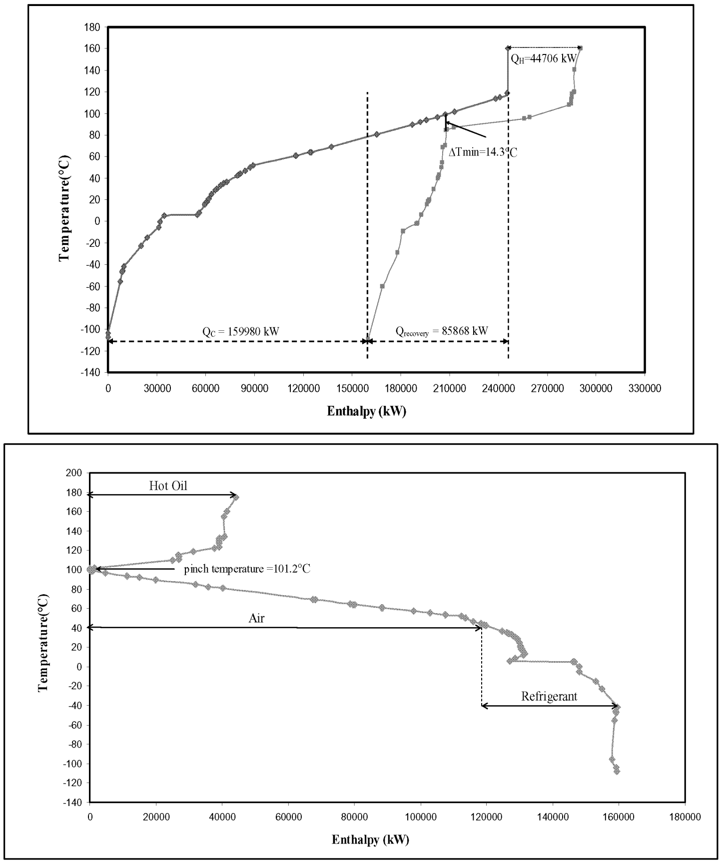

Figure 2 Composite and grand composite curves of existing process.

4. Retrofit by Elimination of Inappropriate Utility Placement

The existing network was analyzed by the violation of pinch rules—heaters must not be placed below the pinch and coolers must not be placed above the pinch to find inappropriate utility placement. The result showed five heaters for cold streams; C1, C10, C12, C19, C20, in the below-pinch region, as shown in Figure 1, needed to be eliminated. Finally, three alternative retrofit designs were proposed.

4.1 Retrofit Design option 1 (Figure 3)

This design was done by splitting a hot stream, H2, to transfer heat to five cold streams; C1, C10, C12, C19 and C20, by using five exchangers. And total increased exchanger area was 385 m^2 .

4.2 Retrofit Design option 2

This design was similar to design 1. The difference was using hot stream H7 instead of H3 to supply heat to C1, C19, C20, C10 and C12. An increased exchanger area was 376.6 m^2

4.3 Retrofit Design option 3 (Figure 3a)

This design was done by using four different exchanger matches between four hot streams; H2, H18, H22 and H25 and process cold streams. Hot stream, H2, was matched with cold stream C1. Also hot stream H18 was matched with cold streams; C10 and C12. Moreover, hot streams; H25 and H22, were matched with C19 and C20, respectively. The additional exchanger area was 901.1 m^2.

Stream	FCp (kW/°C)	Q (kW)	T (°C)	T (°C)
H1	1057.3	24213.0	114.9	92.0
H2	1029.7	41189.0	92.0	52.0
H3	32.7	854.0	60.8	34.7
H4	1004.0	25501.0	119.1	93.7
H5	973.7	40603.0	93.7	52.0
H6	32.3	782.0	60.9	36.7
H7	326.9	9317.0	46.5	18.0
H8	13.4	919.0	98.9	30.5
H9	12.9	165.0	30.5	17.7
H10	334.0	2839.0	8.1	-0.4
H11A	152.7	5084.0	18.0	-15.3
H11B	13.7	1344.0	42.3	-55.6
H11C	361.0	6859.0	-22.9	-41.9
H12	516.3	9138.0	-5.2	-22.9
H13	174.3	4182.0	-22.9	-46.9
H14A	43.4	2268.0	-55.6	-107.8
H14B	111.3	6455.0	-45.8	-103.8
H15	39636.0	19818.0	5.8	5.3
H16	299.9	2999.0	18.1	8.1
H17	15.1	1376.0	160.3	69.3
H18	322.7	11294.0	63.9	28.9
H19	174.0	5063.0	64.1	35.0
H20	7.2	138.0	69.3	50.0
H21A	6.7	196.0	50.0	20.7
H21B	80.4	1110.0	35.0	21.2
H22	145.4	6645.0	89.8	44.1
H23	183.5	11636.0	96.6	33.2
H24	32.1	1694.0	113.6	60.8
H25	35.0	1005.0	80.7	52.0
H26	0.7	56.0	101.7	24.8
H27	39.9	1054.0	42.9	16.5
H28	43.3	52.0	16.5	15.3
C1	30.4	1119.0	54.7	17.9
C2	1017.4	24213.0	107.9	84.1
C3	554.0	831.0	119.3	117.8
C4	1040.9	25501.0	109.4	84.9
C5	531.1	956.0	120.0	118.2
C6	417.5	2839.0	-2.6	-9.4
C7	168.8	13287.0	18.7	-60.0
C8	134.0	4182.0	-29.3	-60.5
C9	175.5	8723.0	-60.0	-109.7
C10	149.8	4568.0	50.2	19.7
C11	2928.4	27234.0	96.2	86.9
C12	596.0	4649.0	-1.6	-9.4
C13	138.2	2999.0	18.0	-2.0
C14	625.5	1376.0	70.4	68.2
C15	187.7	3697.0	160.3	140.6
C16	30.3	1694.0	95.5	39.5
C17	33.5	57.0	115.0	113.3
C18	44.5	1054.0	29.6	5.9
C19	40.9	475.0	41.2	29.6
C20	40.3	1120.0	43.1	15.3

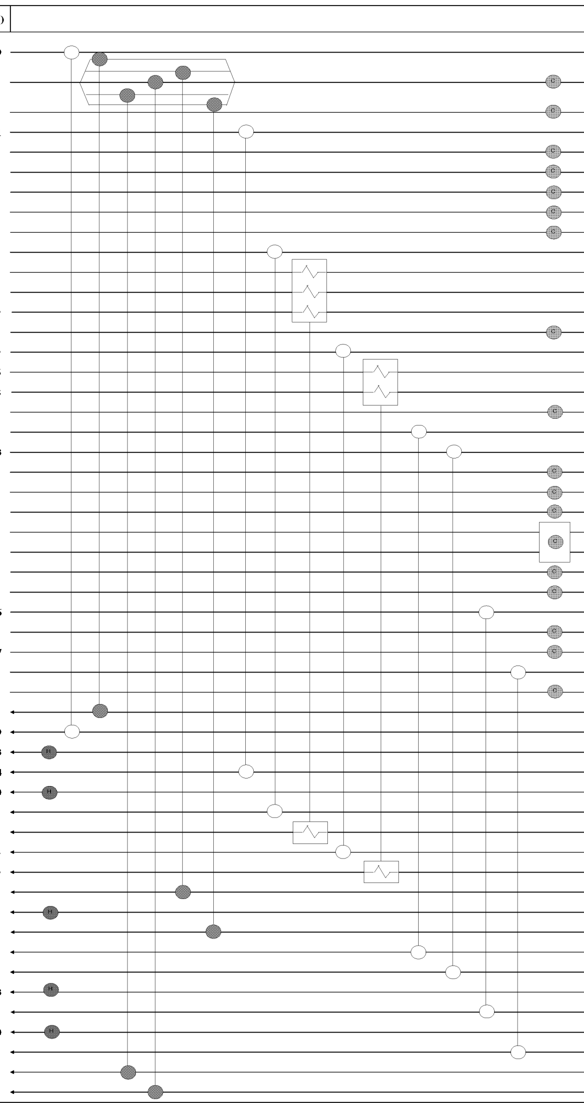

Figure 3 Retrofit design option 1.

The result reveals 11931 kW of both hot and cold utility usages (27.07% and 7.46%, respectively) can be saved. Utility savings was classified and payback period can be calculated as shown in Table 1 and 2, respectively.

Table 1 Utility cost saving of each retrofit design

Utility Type	Utility Cost (US$/kW-yr)	Utility Saving (kW)	Cost Saving (US$/yr)
		Design1, 2 and 3	Design1, 2 and 3
Hot Oil	203.59	7363	1499033.2
Refrigerant	90.4	4568	412947.2
Air cooler motor	212.94	11931	2540587.1

Table 2 Payback period of each retrofit design

Design option	Operating cost saving ($/yr)	Heat exchanger cost ($)	Payback period (yr)
1	4452567.5	1367882.751	0.31
2	4452567.5	1351136.701	0.30
3	4452567.5	1337633.411	0.30

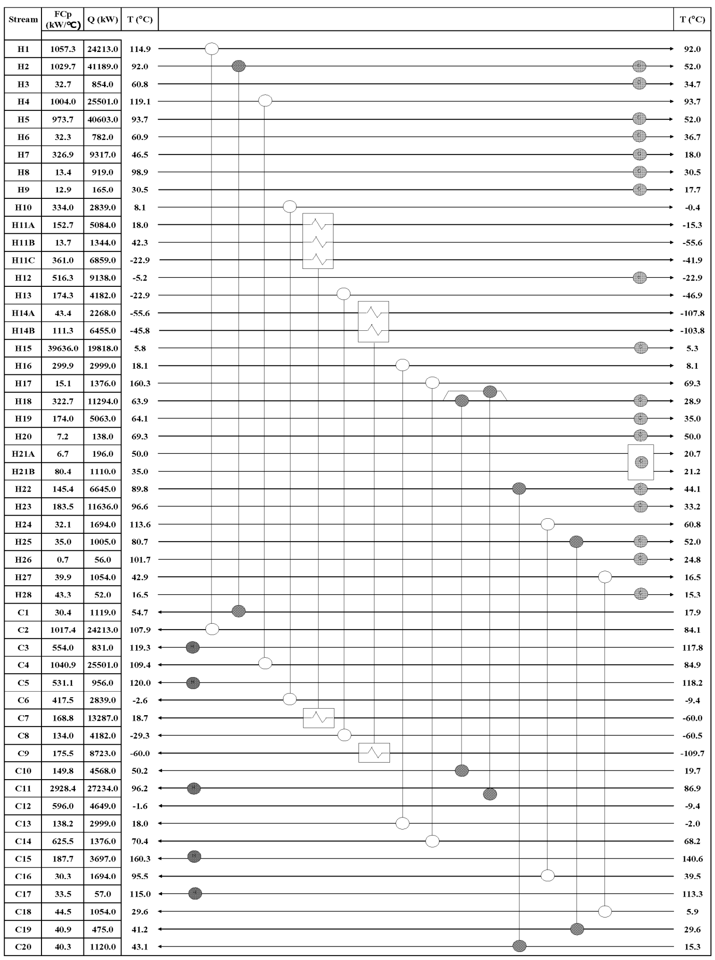

Figure 3a Retrofit design option 3

Design option 1 and 2 can be modified without any problems. Practically, design option 3 will be difficult to control the overhead temperature of depropanizer. In addition, power of gas compressor will be increased since pressure drop increases when sales gas is used to heat the ethane. Therefore, design option 1 and 2 are practical.

Conclusions

According to actual data, pinch analysis was taken for retrofit work. The network reveals the minimum approach temperature between 86.9-101.2 °C. Three alternative design options were carried out from determining inappropriate utility placement of heaters and coolers, giving the same energy saving of 11931 kW for both hot and cold utilities (27.07% and 7.46%, respectively). The design 1 and 2 were practical however design 3 can cause increasing of compressor work. For design 1 and 2, five new exchangers were added with additional exchanger area about 380 m^2. All retrofit designs gave the same payback period of 0.30 year.

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