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Retrofit for a Gas Separation Plant by Pinch Technology

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This study focuses on retrofit of the PTT gas separation plant applying pinch technology. The prime objective is to maximize the energy recovery of the process via several tools including Problem Table Algorithm (PTA), Grand Composite Curve (GCC), Grid Diagram, and Column Grand Composite Curve (CGCC). The entire process consists of three main parts, distillation columns, heat exchanger networks, and the refrigeration system. There are thirteen hot and six cold streams with fourteen heat exchangers. Existing network is an unpinch process with ΔT_{min} lower than the threshold ΔT_{min} of 21^{O}C and the minimum temperature approach (ΔTmin) is observed around 1.06^{O}C. The column grand composite curve (CGCC) of Deethanizer and Depropanizer reveal the scope of energy recovery via side reboiling and feed preheating. The maximum energy saving can be obtained approximately 13.32% by integrating with heat exchanger network of background process. This reduces the annual energy cost about 6125989.118 US$/yr. In order to achieve it, the capital investment is necessary but the annual cost saving will be enough to recover the cost in less than one year.

Keywords

Pinch analysis, Energy recovery, Process heat integration, Heat exchanger network

1. Introduction

One of the most important roles in many industrial processes is reducing energy consumption. A gas separation plant is a capital intensive industry consuming much energy. Energy cost contributes significantly to the total cost and the budget of energy cost rises sharply due to high oil price recently. Hence, saving and optimizing the energy usage is a promise to meet the goal of an optimum energy cost and to gain more profitability.

Pinch technology is one of process integration methods, representing a simple powerful methodology for energy-saving based on thermodynamic principles. This methodology, using a graphical diagram, can provide the optimum energy needs for any processes.

The purpose of this research is to apply the effectiveness of the pinch technology for optimizing energy consumption toward the gas separation plant 5 of PTT Public Company Limited. This research is divided into three main parts; the retrofit of HENs, the distillation column targeting, and the shaft work targeting respectively.

2. Materials And Methods

Gas separation unit 5 (GSP5) under study has production capacity around 530 MMSCFD. It produces many kinds of products of Methane, Ethane, Propane, and LPG (Liquefied Petroleum Gas). The plant consists of three main parts; distillation column, heat exchanger networks (HENs) and the refrigeration system. In the distillation columns part, there are three distillation columns including Demethanizer, Deethanizer, and Depropanizer. Furthermore, a numbers of hot and cold streams are thirteen and six with fourteen heat exchangers in the HENs part. To apply pinch analysis, the first step is to perform data extraction and plant simulation. The commercial simulation software, Pro/II with the SRK thermodynamic method is used to simulate heat exchanger network and the distillation columns. To satisfy the actual data, Table 1 shows the accuracy of process simulation to guarantee that the data from simulation is very close to the actual values.

Table 1. Accuracy of process simulation by ProII compared to actual data

Parameters	Simulation Error Value
Flow rate (KGMOL/HR)	+/- 10 %
Temperature (°C)	+/- 3
Pressure (BAR_G)	+/- 4
Composition	+/- 0.05

After doing the simulation, pinch design method (Linnhoff and Hindmarsh, 1983), and distillation column targeting (Dhole and Linnhoff, 1983) are used to generate the Grand Composite Curve (GCC) and Column Grand Composite Curve (CGCC). Subsequently, the stand–alone column modifications and process heat integration were done to find the possibility and scope of energy recovery. The shaftwork targeting is the final step to reduce the energy consumption.

3. Result And Discussion

3.1 Heat Exchanger Networks of Background Process

The GSP5 is the low temperature process having fourteen heat exchange units between hot and cold process streams. After applying pinch analysis to figure out the minimum approach temperature (ΔT_{min}) of the process. Problem Table Algorithm (PTA) is used to obtain utility requirements for various ΔT_{min} and a trial-and-error procedure to ascertain the ΔT_{min} for existing utility level.

The GSP5 is an unpinch process with ΔT_{min} =1.06^{O}C lower than the threshold ΔT_{min} = 21°C. The cold utilities are air and refrigerant-propane with total cold duties about 0.0377 MM KW. From the literature survey, Querzoli and Hoadley (2002) apply utility pinch to find the ΔT_{min} for unpinch problem. In this case, air coolers are applied to match energy consumption as summarized in Table 2. The reason for not using refrigerant-propane due to phase change problem The GSP5 has ΔT_{min} around 1.06°C. Figure 1 and 2 present the GCC and the grid diagram of current process.

Table 2. The cold utility for ΔT_{min} in the range of 1 to 15°C

ΔT_{min} (°C)	Cold Utility (MM KW)	
	Air cooler	Refrigerant-C3 cooler
1	0.02595	0.01176
2	0.02530	0.01241
5	0.02310	0.01461
10	0.02010	0.01761
15	0.01760	0.02011
1.06°C	**0.02591**	**0.01180**

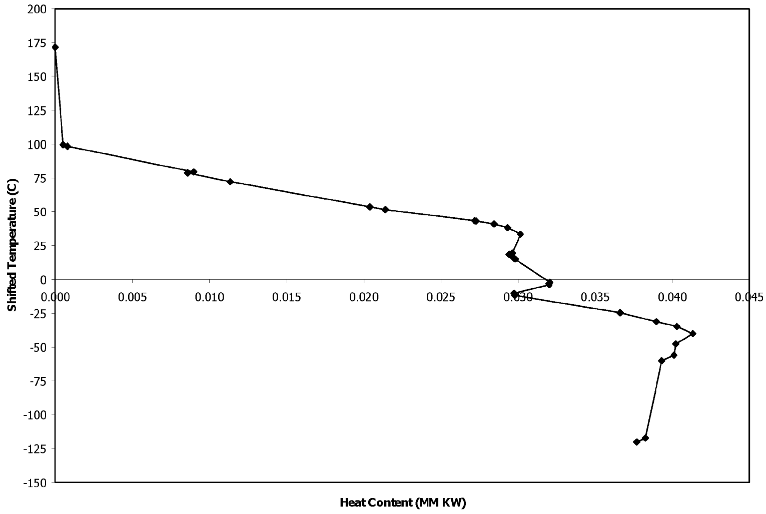
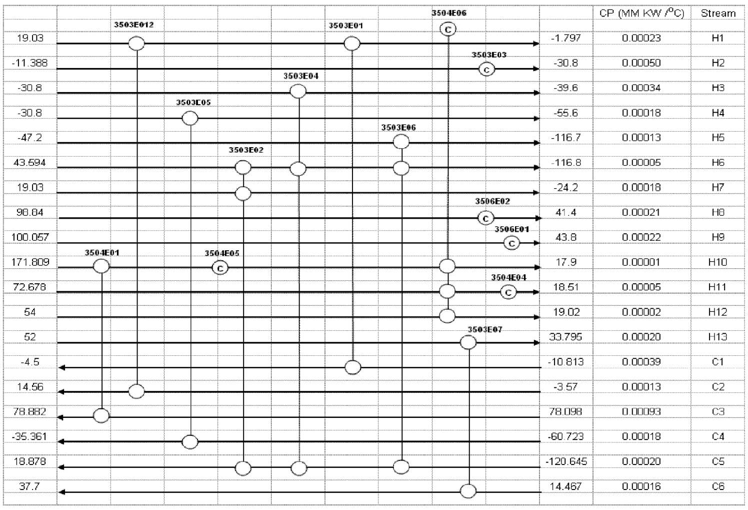


Figure 1. Grand Composite Curve



		CP (MM KW /°C)	Stream
19.03	-1.797	0.00023	H1
-11.388	-30.8	0.00050	H2
-30.8	-39.6	0.00034	H3
-30.8	-55.6	0.00018	H4
-47.2	-116.7	0.00013	H5
43.594	-116.8	0.00005	H6
19.03	-24.2	0.00018	H7
98.84	41.4	0.00021	H8
100.057	43.8	0.00022	H9
171.809	17.9	0.00001	H10
72.678	18.51	0.00005	H11
54	19.02	0.00002	H12
52	33.795	0.00020	H13
-4.5	-10.813	0.00039	C1
14.56	-3.57	0.00013	C2
78.882	78.098	0.00093	C3
-35.361	-60.723	0.00018	C4
18.878	-120.645	0.00020	C5
37.7	14.467	0.00016	C6

Figure 2. Grid diagram of current heat exchanger network

3.2 Distillation Column Targeting

In this section, it starts with generating Column Grand Composite Curve (CGCC) of each distillation column separately by using a converged simulation of each column based on Top-Down and Bottom-Up procedures. The selection of key components is the important thing for column targeting. In this work, the key component is selected based on their boiling point and the column composition profile on a stage-by-stage basis.

3.2.1 Stand-Alone Column Modification and Process Heat Integration

For optimum performance, modifications of reflux ratio, feed conditioning (feed preheating/cooling), and side condensing/reboiling may be necessary. Moreover, side condensing/reboiling can be modified with Process Heat Integration.

Feed Preheating

There were two modification options for feed preheating; option A and B. By inspection, the option A is using a hot process stream 100.054°C to preheat feed of Depropanizer to 90°C. Furthermore, this option also resulted in decreasing 3506E01 duty (Air cooler) that means lowering cold utility of process vice versa this modification had to introduce a new heat exchanger; therefore, the cost of new heat exchanger and energy saving should be compromised. While, option B is using a hot process stream 98.84°C to increase Depropanizer feed to 88°C and also decreased 3506E02 duty. Table 4.3 summarizes the benefit of feed preheating on utility saving.

Table 4.14 The benefit of feed preheating on Depropanizer

Modification Option	Utility Saving (KW)			Utility Saving (%)		
	Depropanizer	3506E01	3506E02	Depropanizer	3506E01	3506E02
A	4000	4314	▨	21.2	35.36	▨
B	3180	▨	3699	16.85	▨	31.01

Side Reboiling

Figure 3 reveals the maximum heat recovery can be obtained from integration between Deethanizer and a hot process stream with temperature above 63°C, using a new side reboiler on Deethanizer around tray temperature 33.9-93.9°C. After investigation, two hot process streams of temperature 100.054°C and 98.84°C, from air cooler unit 3506E01 and 3506E02, respectively were selected to side-reboil the Deethanizer. Option C is integrating hot stream 100.054°C with a new side reboiler of Deethanizer on tray number 39 and side-draw at this stage 755 kgmol/hr. This option results in hot utility and cold utility savings at main reboiler of Deethnaizer and air cooler unit 3506E01, respectively. Whereas, option D is using hot stream 98.84°C with side-draw from Deethanizer 597 kgmol/hr and can save duty in both main reboiler of Deethnaizer and air cooler unit 3506E02. The results of two options after adding side reboiler on Deethanizer are summarized in Table 4.15 and 4.16.

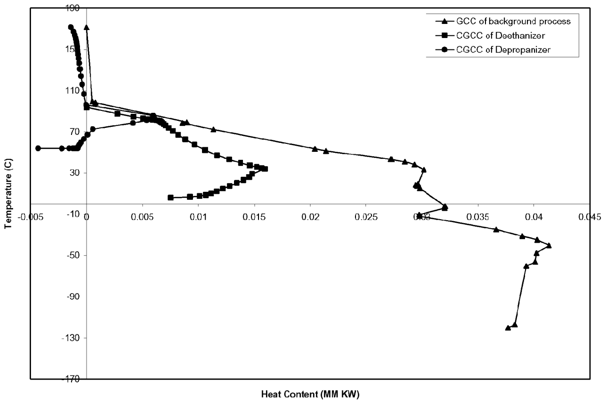


Figure 3. Process heat integration

Table 4.4 Energy-saving after adding side reboiler on Deethanizer (Option D)

Modification Option	Utility Saving (KW)		Utility Saving (%)	
	Deethanizer	3506E01	Deethanizer	3506E01
C	2313	2326	8.76	19.07

Table 4.5 Energy-saving after adding side reboiler on Deethanizer (Option E)

Modification Option	Utility Saving (KW)		Utility Saving (%)	
	Deethanizer	3506E02	Deethanizer	3506E02
D	1813	1838	6.88	15.41

3.3 Summary of Retrofit Design of GSP5

The retrofit design of GSP5 can be option A, B, C, or D. Furthermore, the alternative retrofit designs; Option E and F, which can obtained by combining option A and D and option B and C respectively, as represented in Figure 4. Eventually, Table 4.6 and 4.7 summarizes the energy saving and the economics evaluation for various modification options, respectively.

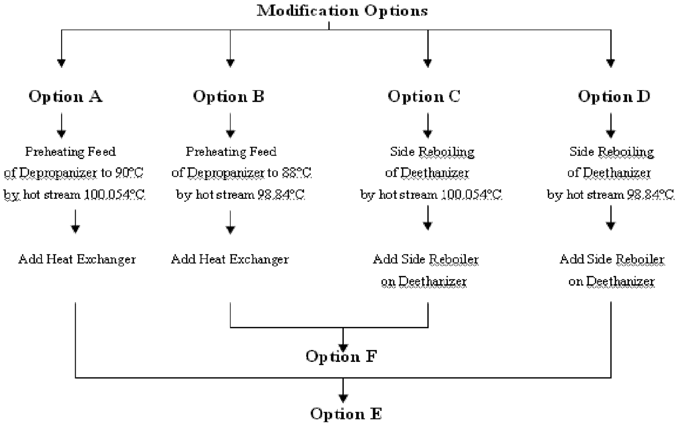


Figure 4. The summary of alternative options

Table 4.6 Utility saving for various modification options

Modification Option	Overall Process Utility Saving	
	KW	%
A	8314	9.47
B	6871.1	7.83
C	4648	5.29
D	3660	4.17
E	11345.50	12.92
F	11694.10	13.32

Table 4.7 The economics evaluation for various modification options

Modification Option	Utility Cost Saving (US$/yr)	New Investment Cost (US$)	Payback Period (yr)
A	4339327.914	1444941.908	0.33
B	3650661.572	1112197.685	0.30
C	2388736.105	1921670.187	0.80
D	1888047.061	1920844.707	1.00
E	6086129.448	3347655.547	0.55
F	6125989.118	3058629.476	0.50

4. Conclusion

This research aims to apply pinch analysis in the chemical engineering industry. Both distillation column targeting and process heat integration techniques between heat exchanger network and distillation column are very useful to recover heat in the process. Six modification options (A,B,C,D,E, and F) for gas separation unit were offered to reduce the energy consumption. Option F offers the highest energy saving about 13.32% (6125989.118 US$/yr) with a payback period of 0.5 year; whereas, option D is the lowest which can save energy about 4.17% (1888047.061 US$/yr) with a payback period of 1.0 year.

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6. References

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