CHEMICAL ENGINEERING TRANSACTIONS Volume 25, 2011
Editors Jiří Jaromír Klemeš, Petar Sabev Varbanov, Hon Loong Lam
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DOI: 10.3303/CET1125014

Energy Saving for Ethylene Process by Advanced Process Integration

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Ethylene production plant is one of the most important plants in petrochemical industry. The process requires a huge amount of low temperature cooling, so highly process integrated configurations created by applying PI (Process Integration) technology to the process was included in advanced processes. The process analysis for the advanced process was likely important for creating further new process configurations on energy saving. Accordingly, how contributed PI technology to creating a new process configuration was described here. The new network was Heat Integration between De-etanizer condenser and C2 splitter side stream liquid flow from the tray at stripping section. The energy saving benefit was 102 MUS$/y, CO_2 emission reduction was 7,360 t CO_2/y, and payback time was 1.42 y.

1. Introduction

In the ethylene process which is especially a big waste heat producer as well as a big energy user, a lot of efforts for energy saving have been conducted by improving heat exchanger net work, installing a high efficient energy saving equipment through applying PI technology to the process as reviewed by Bowen (2007). The technologies were compiled over 100 separate energy improvement design studies, many of which were subsequently integrated into new plants and major expansion revamps. The latest PI technology is described by Klemeš et al. (2010). The conventional naphtha steam cracking and innovative olefin technologies in terms of energy efficiency were also reviewed by Ren et al. (2006). The pyrolysis section of a naphtha steam cracker alone consumes approximately 65 % of the total process energy. An overview of state-of-the-art naphtha cracking technologies shows that approximately 20% savings on the current average process energy use are possible by advanced coil and furnace materials. Improvements in the compression and separation sections could together lead to up to approximately 15 % savings. The exergetic analysis of the refrigeration cycles in ethylene and propylene production process was conducted by Fábrega et al. (2010) and resulted in a reduction of about 13 % of the losses of exergy for the refrigeration system of the process. However how contributed PI technology to the advanced ethylene process configuration has not been reported. Prior to installing such a high efficient energy saving equipment as AHP (Adsorption Heat Pump) described by Hirata (2010), it was promising to evaluate the advanced ethylene process by PI technology in order to get a new process configuration. In this article, a new process configuration which was very attractive for the existing process from energy saving view point and expected to

Please cite this article as: Hirata K., 2011, Energy saving for ethylene process by advanced process integration, Chemical Engineering Transactions, 25, 81-86
DOI: 10.3303/CET1125014

be applied the configuration to not only advanced ethylene processes but also traditional ethylene processes was proposed.

2. Analysis of the advanced ethylene process

2.1 Improvement of HEN (Heat Exchanger Network) by PI analysis

Propylene refrigeration system of advanced ethylene process described in Fig.1 was firstly evaluated by PI analysis. Four kinds of temperature refrigerants were utilized for cooling source or heating source of ethylene process users. PRC (Propylene Refrigeration Compressor) trip analysis with dynamic simulation was conducted by Bernard (2007). On the contrary here, a static simulation by Aspen plus (2006) was conducted except the compressor model was based on characteristic curve calculation which provides more accurate result.

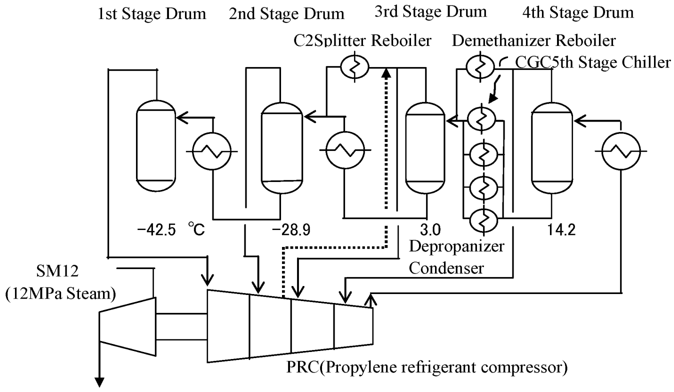

Fig. 1: Propylene refrigeration system

PI analysis for the propylene refrigeration system was conducted by applying SPRINT 2.4 (2009) to the system for creating a new process configuration. The new configuration was the heat integration between de-ethanizer condenser and C2 splitter side stream from the GCC (Grand Composite Curve) in Fig. 3. The grid diagram for heat exchanges in existing propylene refrigeration system was described in Fig. 4. Ethylene refrigerant was cooled by C2 splitter side stream as described by solid line however the heat exchange partially caused cross-pinch heat transfer. The cooling source was to be utilized for de-ethanizer condenser from PI analysis viewpoint as described by dotted line. The new process configuration was described in Fig. 2(a),(b) by dotted line compared with the existing process flow. The targeting approach by GCC and the grid diagram was basically for a new design however to be utilized for a retrofit by evaluating the configuration through such a process simulation as Aspen plus.

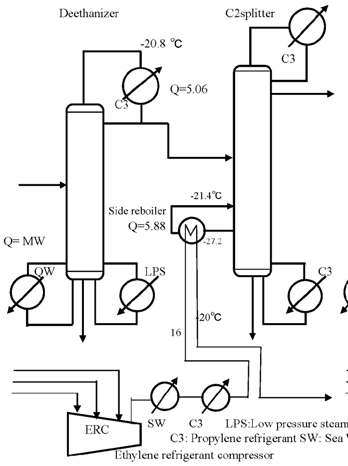

Fig. 2(a): Existing process flow

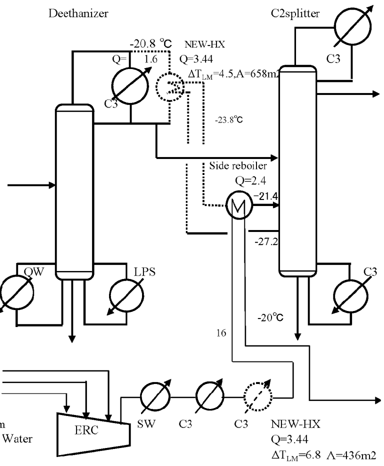

Fig. 2(b): New process configuration

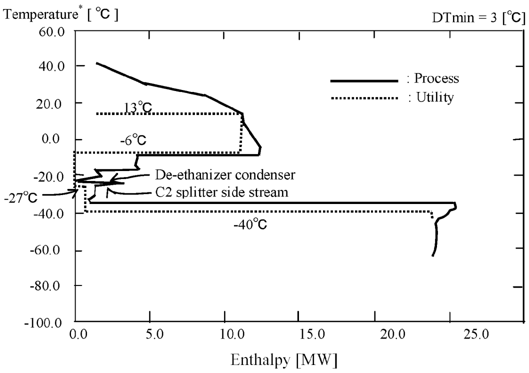

Fig.3: GCC for Propylene refrigeration system

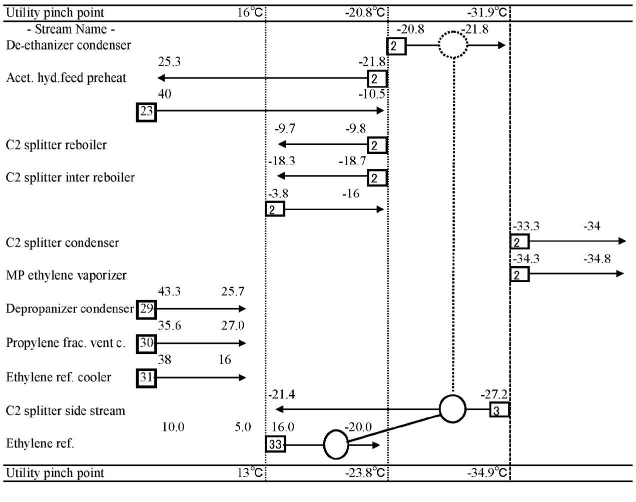

Fig. 4: Grid diagram for heat exchange in propylene refrigeration system

2.2 Application of new process configuration to traditional ethylene process

PI analysis for the propylene refrigeration system on the traditional ethylene process resulted in no above new process configuration except other traditional heat recovery opportunities from GCC as described in Fig.5. This was due to lack of C2 splitter side stream as cooling source for de-ethanizer condenser on the traditional ethylene process. So it was likely considered beneficial to include the new process configuration in the traditional ethylene process.

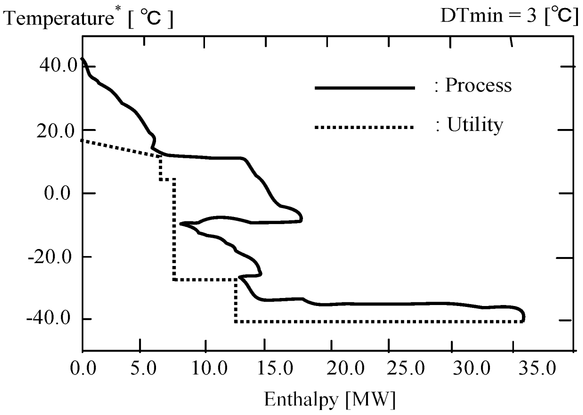

Fig.5: GCC for Propylene refrigeration system

The process flow for applying the new process configuration was described in Fig.6. The operating condition was a little bit different from the advanced process, so one more side stream drawing from C2 splitter stripping section was necessary for cooling source on de-ethanizer condenser. Heat exchanger duty was finally decided to keep ethylene product purity specification 99.15 wt% as described in Table 1 and Fig. 7.

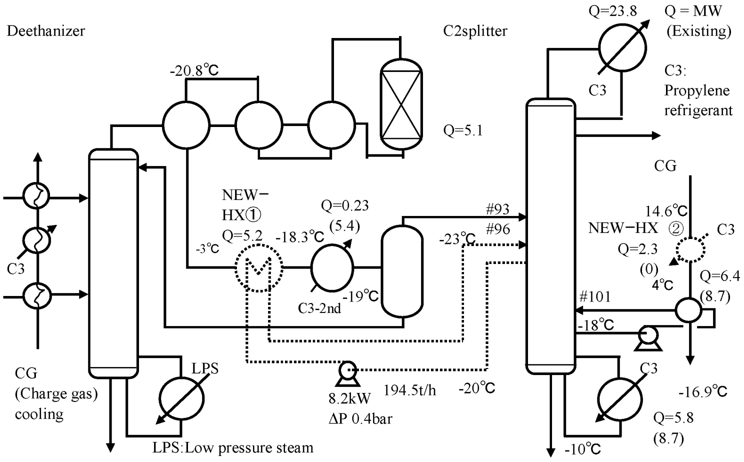

Fig.6: Applying new configuration to traditional process

Table 1: Evaluation for heat exchanger duty on energy saving

Heat exchanger	Source	Duty MW Proposed	Duty MW Existing	result
De-ethanizer condenser	C3-2nd	0.23	5.4	benefit
NEW-HX①	C2splitter side stream 2	5.2		
CG cooler	C2splitter side stream 1	6.4	8.7	penalty
NEW-HX②	C3-3rd	2.3		
C2splitter reboiler	C3-3rd	5.8	8.7	penalty

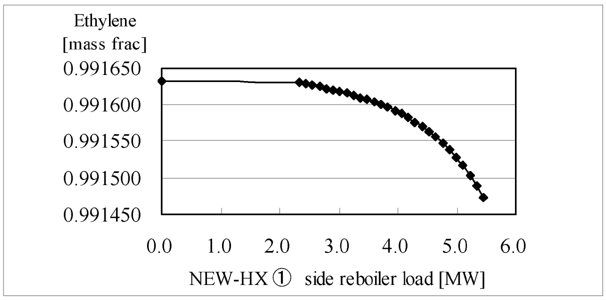

Fig.7: Evaluation for product ethylene purity

The operating condition of PRC for proposed case was evaluated by including the above required duty in the propylene refrigeration system as described in Table 2.

Table 2: Operating condition of PRC for proposed PI case

		Summer Time (4 Months)				Winter Time (8 Months)			
Case		Base		Proposed		Base		Proposed	
Compressor		Suction	Discharge	Suction	Discharge	Suction	Discharge	Suction	Discharge
Temp (°C)	PRC -1	-42.8	-19.0	-42.8	-20.0	-42.8	-19.9	-42.8	-21.0
	" -2	-22.5	24.7	-22.7	26.1	-23.2	21.0	-23.5	22.2
	" -3	20.5	43.8	19.5	42.5	18.2	39.6	17.0	37.9
	" -4	43.4	81.7	42.2	79.6	38.6	73.1	37.1	70.4
Pres (MPaG)	PRC -1	0.02	0.11	0.02	0.11	0.02	0.11	0.02	0.10
	" -2	0.11	0.48	0.11	0.49	0.11	0.43	0.10	0.44
	" -3	0.48	0.79	0.49	0.80	0.43	0.67	0.44	0.70
	" -4	0.79	1.70	0.80	1.70	0.67	1.40	0.70	1.40
Flow rate (t/h)	PRC -1	275.73		274.78		274.93		273.88	
	" -2	445.71		395.33		440.20		390.68	
	" -3	539.10		536.60		499.37		498.09	
	" -4	546.58		541.95		517.38		513.13	
Power (kW)	PRC -1	2243.97		2134.66		2151.40		2032.27	
	" -2	7499.55		6883.49		6932.11		6353.19	
	" -3	4601.96		4464.77		3979.90		3796.70	
	" -4	7366.05		7065.90		6395.44		6030.04	
	Total	21711.53		20548.81		19458.85		18212.20	
	Saving	/		1162.72		/		1246.65	
Shaft Speed (rpm)	All Stages	4108.0		4043.0		4054.4		3973.0	
Cost for Pumping (US$/y)		10,000							
SM12^1 Reduction (t/h)		/		4.20		/		4.5	
Running Benefit (US$/y)		1,020,700							

^{1}: 12 MpaG Steam

The benefit was evaluated by SM12 (Steam 12 MPaG) consumption rate at the driver turbine based on the required power of PRC. SM12 reduction was 4.4 t/h and CO_2 emission reduction was 7,360 t CO_2/y. The investment cost resulted in 1.45 M$ as described in Table 3 and contributed to practical payback time 1.45 y.

Table 3: Investment cost for proposed configuration

Items	Unit	NEW-HX⍰	NEW-HX⍰
Heat duty	MW	5.2	2.3
ΔT_{LM}	°C	10.2	6.7
U	$kW/m^2/°C$	850	598
Area	m^2	603	580
Equipment cost	US$	306,000	275,000
Total investment cost	US$	1,452,500	

3. Conclusion

PI analysis for the advanced process could lead to create the new practical process configuration which could be applied to the traditional process as well as the advanced process and contribute to energy saving and CO_2 emission reduction. A series of the approach was called Advanced Process Integration. The effect of the new process configuration on the existing process resulted in 1.02 M$/y saving, 1.42 y payback time and 7,360 t CO_2/y reduction. Extracting an interesting stream flow from the tray at the column in the stream extraction step was very important to create a new energy saving opportunity. New energy saving opportunity could be created and implemented by proceeding with PI analysis for both an advanced heat exchanger network and a traditional one prior to applying new technology.

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