

Energy Saving for Ethylene Process by AHP

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Recently an AHP (Adsorption Heat Pump) for ethylene process in which cold water could be produced by using low temperature heat source for desorption of adsorbent has been developed so that partial replacing of propylene refrigerant by the cold water was considered in ethylene process. The feasibility study which includes potential benefit, investment cost and pay back time resulted in that the required power for PRC (Propylene Refrigeration Compressor) got down 10 % by using the cold water from AHP for both depropanizer condenser and CGC (Charge Gas Compressor) 5th stage chiller.

1. Introduction

In Japanese industries 240 Mkl/y oil is imported and a lot of waste heat corresponding to 30 Mkl oil has been disposed. This urges the industries to develop some advanced technologies for heat recovery in low temperature part as heat source because of occupying a big part of waste heat described in Figure.1 for MCC (Mitsubishi Chemical Corporation). Recently AHP as described in Figure.2, which is able to cool a water flow by a sensible heat of the water flow inside AHP under evacuated condition circulated after cooling the water vapor flow through two fixed beds for switched operation with the adsorbent in AHP, was developed by MPI (Mitsubishi Plastics, Inc, 2009). After adsorption of the water vapor flow to the adsorbent for a cycle time, desorption of the water vapor flow from the adsorbent starts and continues

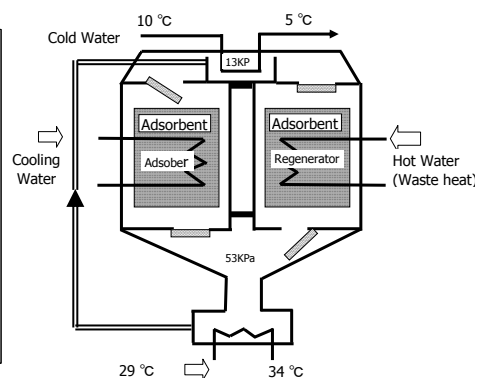
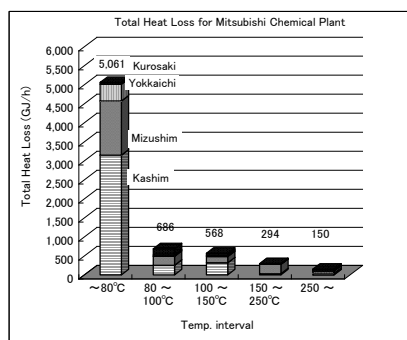


Figure 1: Total heat loss for MCC

Figure 2: AHP (Adsorption Heat Pump)

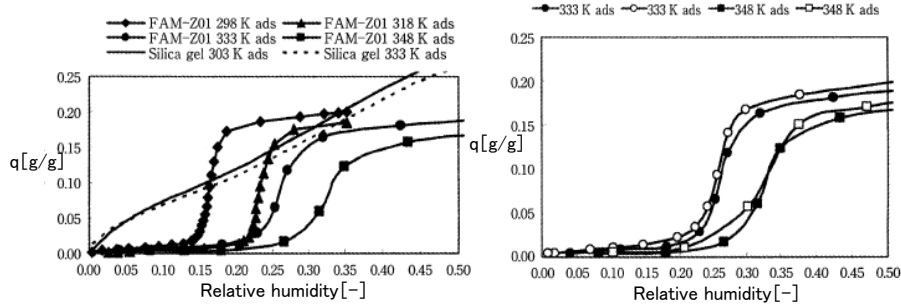


Figure 3: (a) Adsorption isotherm, FAM, Silica gel (b) FAM hysteresis characteristics

Table 1: Comparison of the state of the art for cold water producing

Evaluated factor	Unit	Adsorption refrigerator	Turbo refrigerator	Air-cooled chiller	Absorption refrigerator
Driving utility source		Hot water	Electricity	Electricity	Steam
Refrigerant		H ₂ O	HFC(R134a)	HFC(R407c)	H ₂ O
Capacity	kW	350 (at 9°C)	387 (at 7°C)	355 (at 9°C)	352 (at 7°C)
Required power	kW	38.1	92.4	75	16.2
Steam	kg/h	–	–	–	390
CO ₂ emission	t/yr	126.87	307.7	249.7	467.6
COP	–	9.2	4.2	4.7	1.1

for a cycle time in AHP by heating the adsorbent through other waste heat. Finally the water vapor flow was collected in the tank, cooled by a cooling water, and circulated to the evacuated vessel. Silica gel has been firstly used as adsorbent, recently a functional material based on zeolite called AQSOA was developed and used as adsorbent in AHP because of efficient adsorption and desorption ability as described in Figure 3(a),(b) as FAM. Hidaka et al. (2008) has reported AQSOA has a significant bigger desorption and adsorption ability than Silica gels with optimum particle diameter. MPI (2009) also describes the state of the art for cold water producing, in which the AHP had the best COP (Coefficient Of Performance) among other technologies as described in Table 1. On the contrary, in the chemical industries various kinds of energy saving efforts have been conducted since first oil crisis on 1973. This is not only for energy saving and cost reduction, but also recently for reducing the CO₂ gas emissions. 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 works, installing high efficient energy saving equipments through applying pinch technology to the process. The traditional energy saving technologies have been applied to the process as reviewed by Bowen (2007), so an appearing of new technology has been desired. In this article the feasibility study results for applying cold water from AHP to the cooler refrigerant as cooling source by partially replacing propylene refrigerant at the propylene refrigeration system in the ethylene process was described.

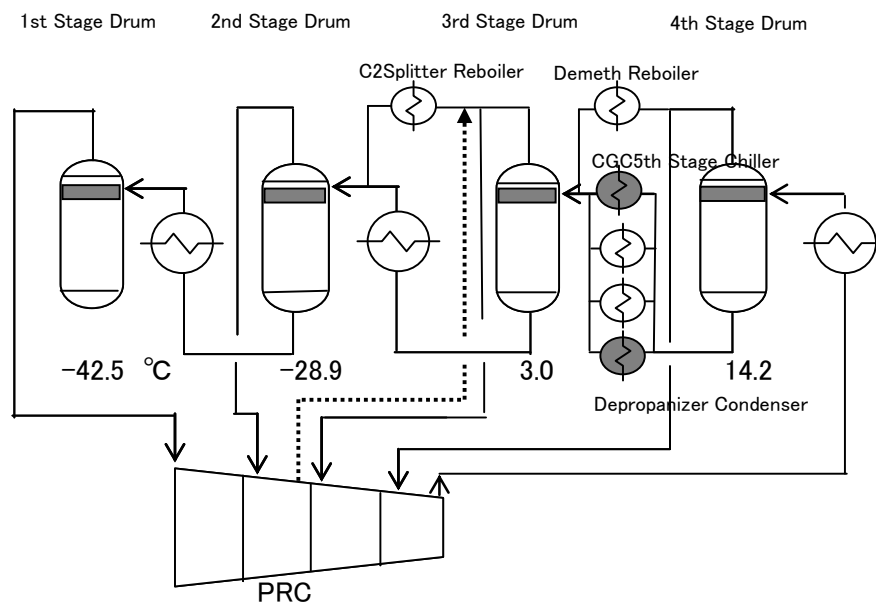


Figure 4: Propylene refrigeration system

2. Feasibility study results on application of AHP to ethylene process

2.1 Pinch analysis

Pinch analysis for the propylene refrigeration system described in Figure 4 was conducted by applying SPRINT 2.4 (2009) to clarify which cooler to be selected for AHP user. The data for the analysis was evaluated by Aspen plus 2006. The grid diagram for heat exchange was described in Table 3, in which the approach temperature difference of the system for the analysis was 3 degree. The 3C3 (3 ° C-propylene refrigerant) was used as cooling source in the existing system however the heat exchanges cause 'cross-pinch heat transfer' as described in Table 3 so that the proposed cold water from AHP described in Table 3 as ChW was more suitable cooling source from Pinch analysis viewpoint. Consequently the cold water user was fixed to be depropanizer condenser and 5th stage chiller of cracking gas from CGC in the ethylene process.

2.2 Benefit for installing AHP to ethylene process

The benefit for installing AHP to ethylene process was evaluated by SM120 (Steam, 12 MPaG) consumption rate at the driver turbine based on the required power of PRC. In case of applying the cold water as cooling source to the above heat exchangers, the vapor flow for C2 Splitter reboiler heat source from the 3rd stage drum was deficit so that 2nd stage extraction vapor flow from PRC was partially extracted to the vapor flow from 3rd stage drum as described by dotted line in Figure 4. The evaluation results were summarized in Table 3 and 12 % reduction of required power of PRC was expected by removing the target heat exchangers from propylene refrigeration system.

Table 2 Grid diagram for heat exchange in propylene refrigeration system

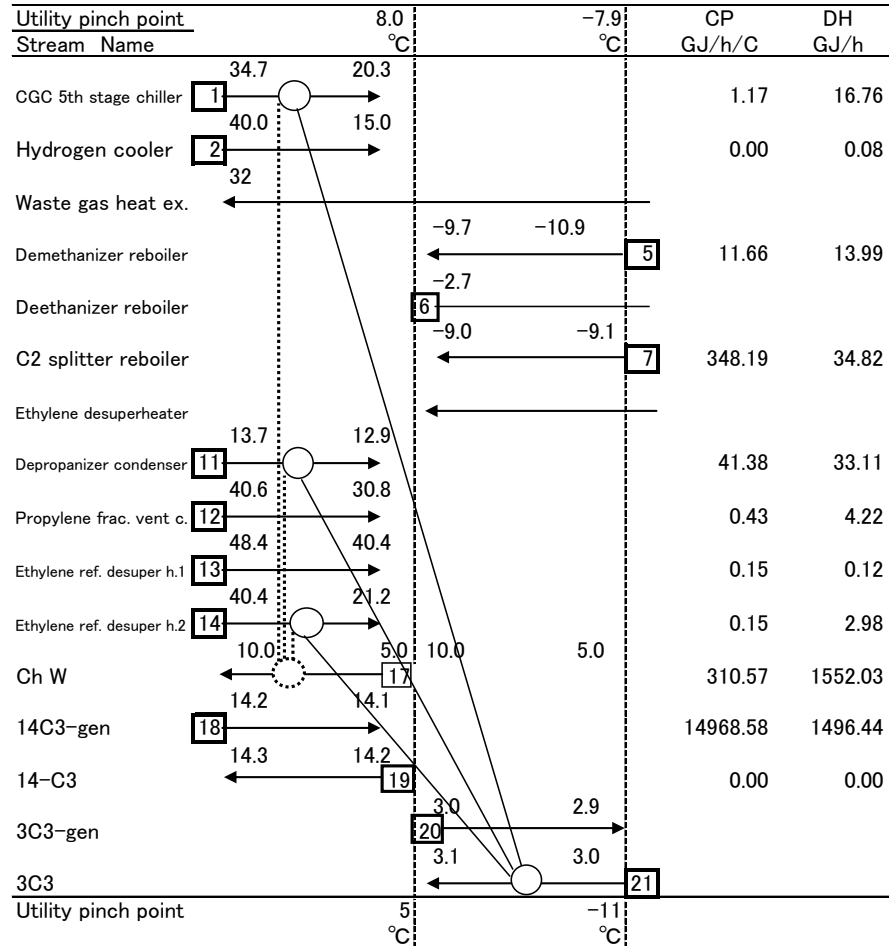


Table 3 Benefit for removing the heat exchangers from propylene refrigeration system

Heat exchanger removed		CGC 5th chiller	Depro. cond.	Both heat ex.
Duty reduction	GJ/h	7.177	32.45	39.627
SM120 reduction for Turbine	t/h	1.63	7.21	8.84
Running Cost Benefit	US\$/yr	314,444	1,394,444	1,670,000
Full Cost Benefit	US\$/yr	427,778	1,895,556	2,271,111
Required Power Reduction	KW	1,087	3,951	4,914
Ratio to Total Required Power	%	2.6	10	12

The operating condition of PRC for applying cold water to the heat exchangers was described in Table 4 compared with the existing case, so that the flow rate at 3rd stage of PRC was significantly small for proposed case.

2.3 Retrofit plan for installing AHP to ethylene process

The retrofit plan proceeded with investigating for both waste heat source for

Table 4 Operating condition of PRC for applying cold water to the heat exchangers

Case		Summer Time (4 Months)				Winter Time (8 Months)			
CGC 5th chiller Duty (GJ/h)		13.5				4.1			
Compressor	Case	Base		Removal of both H.EX.		Base		Removal of both H.EX.	
		Suction	Discharge	Suction	Discharge	Suction	Discharge	Suction	Discharge
Temp (°C)	PRC -1	-42.8	-19.0	-42.8	-19.7	-42.8	-19.9	-42.8	-20.8
	" -2	-22.5	24.7	-23.1	21.4	-23.2	21.0	-23.9	17.0
	" -3	20.5	43.8	21.4	47.6	18.2	39.6	17.0	40.6
	" -4	43.4	81.7	47.3	86.9	38.6	73.1	40.1	76.3
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	0.43	0.11	0.43	0.10	0.38
	" -3	0.48	0.79	0.43	0.78	0.43	0.67	0.38	0.66
	" -4	0.79	1.70	0.76	1.65*	0.67	1.40	0.66	1.40
Flow rate (T/H)	PRC -1	275.73		275.05		274.93		274.06	
	" -2	445.71		441.99		440.20		433.97	
	" -3	539.10		405.96		499.37		397.92	
	" -4	546.58		406.09		517.38		405.10	
Power (kW)	PRC -1	2243.97		2165.53		2151.40		2052.85	
	" -2	7499.55		7012.06		6932.11		6343.98	
	" -3	4601.96		3943.95		3979.90		3480.73	
	" -4	7366.05		5913.34		6395.44		5343.54	
	Total	21711.53		19034.88		19458.85		17221.10	
	Saving	/		2676.65		/		2237.75	
Shaft Speed (rpm)	All Stages	4108.0		4064.0		4054.4		3987.1	
	Cost for Pumping (US\$/yr)	/		130,555		/		8.11	
SM120 Reduction (t/h)	/		9.70		/		8.11		
Running Benefit (US\$/yr)	/		1,669,667		/		/		

desorption and cooling source for adsorption in AHP so that quench water was selected. for the above both sources as described in Figure 5 in which thin line shows existing one.

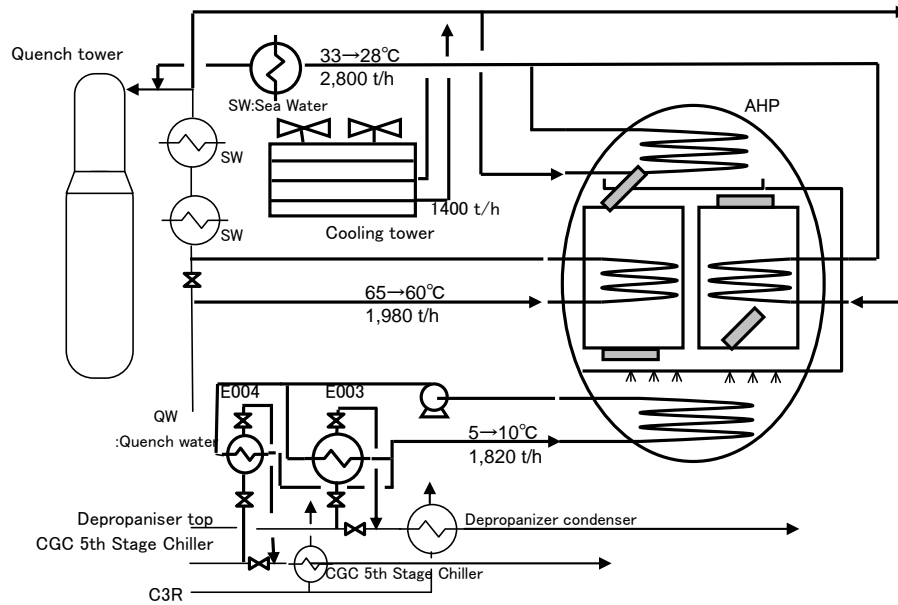


Figure 5: Process flow diagram between AHP , cold water user and Quench tower

Table 5 Investment cost for installing AHP to the existing ethylene process

Items	Purchas	US\$	Const	US\$	Items	Purchas	US\$	Const	US\$
Civil engineering	Evaluation of piping	11.1	Pipe	166.6	Electricity	Labor	203.1		
			Equip	4.978		Adjusting	53.0		
			Adjustm	2.67	total	0	total	203.1	
			total	11.1	Instrument	Labor	650.6		
Equipment			Material			Adjusting	0.4		
AHP	2.00	0.50	0.00	0.00	total	0	total	651.0	
			SW pipe	720					
			Heat ex	7.7728	Total	3,007	Total	4,417	
			Pump	88.8	Piping	285.756			
			Cooling	8.0	Installing				
					Insulation		Total US\$	7,425	
					Painting		Subsidy US\$	4,950	
					Adjustm	2.7	Running US\$/yr	1,666	
					total	2.99	total	2,890	Pay back time
									3.0

The number of AHP unit which has a capacity of 500 USRT was 6 for supplying cold water to the users so that quench water flow rate was deficit as cooling source, thus new cooling tower was needed. The piping length between AHP and the users was around 500 m, so that it caused the expensive retrofit cost as described in Table 5.

The total investment cost was 7.4 million US\$ however expected 4.95 including subsidy by Japanese government. The practical pay back time was proposed.

2.4 Potential impact of AHP on energy reduction of ethylene process

CO₂ reduction contribution on required power reduction of PRC was 4.6 million t-CO₂ per annum by applying AHP to all ethylene processes in the world for removing only depropanizer condenser from the propylene refrigeration system as described in Table 6.

Table 6 AHP impact on energy reduction of ethylene process

Items		Local	MCC	Japan	World
Ethylene production	1,000 t/yr	500	1,500	7,400	132,000
Energy reduction	GJ/h	32.4	97.3	480.1	8,563
Power reduction	KW	3,951	11,853	58,475	1,043,064
CO ₂ reduction	t-CO ₂ /yr	17,542	52,627	259,628	4,631,204
Potential benefit	1,000US\$/yr	1,516	4,547	22,430	400,107
Retrofit cost	1,000US\$/yr	6,667	20,000	98,667	1,760,000

3. Conclusion

Applying AHP to ethylene process had a significant impact on energy reduction of the process because of recovering a lot of low temperature waste heat to sea water however the scale up technology was on the way so early establishment of AHP expected.

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