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Heat Integration of ammonia cooling unit into the purification process of fats and oils

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Abstract

The majority of the enterprises of the food processing industry in Ukraine use the technological processes with refrigerating cycles. Basically it is ammonia refrigeration units. In most of such refrigeration units energy of the ammonia overheat after compression is not used and discharged to the environment through cooling system. After some modernization this energy can be utilized for heating of technological streams. It can be achieved by detailed inspection of technological streams system and heat integration of the ammonia unit into a heating system of the enterprise.

In this work inspection of fining and deodorization process of vegetable oils has been conducted and the opportunity of heat integration of an existing ammonia refrigeration unit into technological process is considered. There are two options for using of heat from cooling and condensation of ammonia:

- without additional compression of ammonia;
- with additional compression of ammonia stream.

In this paper both options are considered and comparison is given.

Keywords: compressor unit, heat integration, pinch, retrofit, payback period.

1. Introduction

Refrigerating units are widely used in the food industry, in particular, in manufacture of milk, cheese, beer, ice cream, baking yeast, wine processing and also on meat packing plants. Ammonia is one of refrigerants which are not rendering harmful influence on an ozone layer and it mostly used in Ukrainian food industry. At the same time, heat of ammonia condensation in the refrigerating unit practically not utilized. To estimate the possibilities of ammonia heat utilization the inspection of existing condensation part of the fats and oils factory refrigerating unit has been performed.

A brief description of technological streams and equipment in the inspected process is given below.

2. Existing ammonia unit

The ammonia gas with temperature -3°C and pressure 1 bar goes to compressor unit which consist of 12 compressors. Usually in winter 3 or 4 compressors are working and in summer 5 or 6 compressors, others are used as reserve. In compressor unit there is a compression of gaseous refrigerant to 12-15 bar.

From compressor unit ammonia with temperature 125-140ºC and pressure of 12-15 bar goes through an oil trap to the block of condensers where there is a cooling and condensation of ammonia. The block of condensers consists of 5 shell and tube condensers and 6 evaporating condensers. Cooling and condensation of gaseous ammonia in the evaporating condensers is carried out by air and by water in shell and tube heat exchangers. During the winter period condensation of ammonia basically occurs due to water cooling and the consumption of the electric power for air fans decreases.

Liquid ammonia after condensation with temperature 23-40ºC and pressure of 12-15 bar goes to a linear receiver. In pipelines and a linear receiver there is a cooling of ammonia condensate on 2-3 ºC. Further the liquid refrigerant comes through the regulating valves where occurs throttling of ammonia from pressure of condensation to evaporation pressure, than proceeds to circulating receiver. From the receiver ammonia with temperature -19 ºC and pressure 1-2 bars comes to votators of margarine plant, pre cooling chamber of margarine plant and to storage chambers for finished product. Ammonia evaporates taking heat of evaporation and supplying cold streams to users.

The ammonia gas which has formed in evaporation system goes through the circulating receivers to compressor station of the enterprise refrigeration unit.

3. Heat integration of ammonia technological streams into heat supply system of the enterprise

The analysis of composite curves shows an opportunity of heat integration of boiler house streams, in particular the stream of water from the well for water make up. Heat energy necessary for this stream can be received from ammonia cooling and condensation (fig. 1), but composite curves show also big amount of low potential heat which now is took off from the system by cooling water. This heat can be used for heat integration and for combined heating of make up water and also for the stream of enterprise hot water supply system.

Table 1. Stream data for the integrated flowsheet without an additional compression.

№	Name of stream	Type	TS, °C	TT, °C	G, t/h	C, kJ/(kg·K)	r, kJ/kg	CP, kW/K	ΔH, kW
1.1	Ammonia cooling	hot	125	23	1,95	2,608		1,413	144,08
1.2	Ammonia condensation	hot	23	23	1,95		1168		632,7
2	Water from well	cold	12	22	66,70	4,190		77,631	776,31

For integration of heat exchange system it is chosen ΔT_{min} equal 2°C. Such small temperature difference between streams possible to achieve in

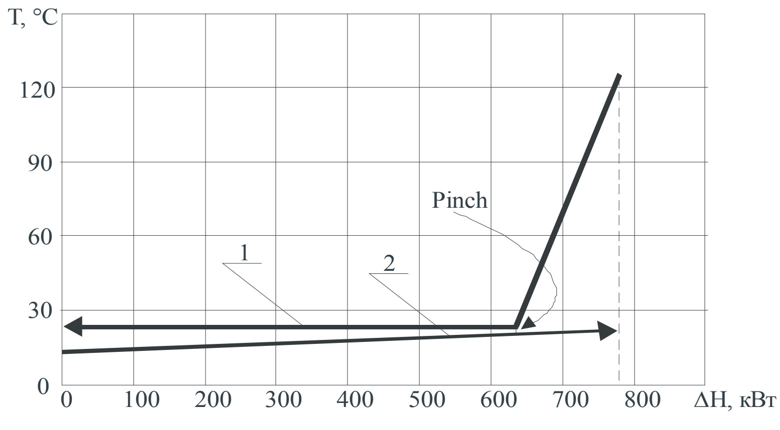

Fig. 1. Composite curves of ammonia compression unit after integration without additional compression. 1 – hot composite curve; 2 – cold composite curve; ΔT_{min} = 2°C

modern highly effective plate heat exchangers.

The composite curves that were plotted using our own software, specially developed for problems of such kind, are shown on Figure 1. The streams data are presented in table 1. With ΔTmin=2°C it is exists an opportunity of full exception of cold utilities from considered system and an additional heating of network water with flow rate 66,7 m^3/h from temperature 12°C up to temperature 22°C. Heat energy of recuperation in considered system for chosen ΔT_{min} is about 776,8 kW.

The annual economy in money terms will make ~101000 US dollar, at cost of hot utilities 130 USD/(kW·year). To achieve this energy targets one recuperative heat exchanger is required. Cost of the plate condenser for this position with installation is about 22000 US dollars. The pay back period of the offered retrofit project will be equal 2.6 months.

Carrying out the additional analysis of composite curves for offered heat exchange system, we see that localization of pinch point on hot temperature 23°C (Fig. 1), temperature of ammonia condensation, limits the flow rate and temperature of the heat transfer agent which could be used for heating, hot water supply and other needs. If we will manage to increase condensation temperature of the ammonia stream it would be possible to increase temperature of the heat transfer agent for needs of the enterprise.

To increase the temperature of ammonia condensation is possible by increasing equilibrium temperature of gaseous ammonia by additional compression.

It was found that for heating of water with flow rate ~ 12,85 t/h up to 64°C the additional compression of ammonia up to 26 bar is required, which gives temperature of condensation about 60°C. Results of research are presented in table 2.

Table 2. Data for the integrated flowsheet with an additional compression

№	Name of stream	Type	TS, °C	TT, °C	G, t/h	C, kJ/(kg·K)	r, kJ/kg	CP, kW/K	ΔH, kW
1	Cooling of ammonia gas 12 bar	hot	125	23	1,95	2,608		1,413	144,09
2.1	Ammonia condensation 26 bar	hot	60	60	1,95		986,2		534,19
2.2	Cooling of liquid ammonia 26 bar	hot	60	23	1,95	4,957		2,685	99,35
3	Water from well	cold	12	64	12,85	4,190		14,956	777,71

The composite curves constructed for stream data from table 2 for already chosen ΔTmin=2°C are shown on fig. 2.

Composite curves also show, that in system with additional compression of ammonia the recuperation is about 778 kW, but with higher potential of the heat transfer agent, than in system without additional compression (fig. 1).

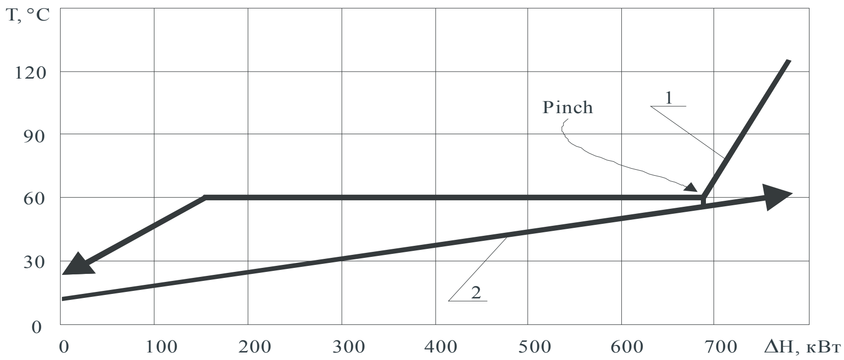

Fig. 2. Composite curves of ammonia unit after heat integration with additional compression of ammonia stream. 1 – hot composite curves; 2 – cold composite curves; $\Delta T_{min} = 2°C$

The heat that should be utilized from the system of hot streams in this case is equal 778 kw. To synthesize the grid diagram of heat exchange system which will satisfy to composite curves in Figure 2, we shall represent the plurality of process streams according to data of table 2.

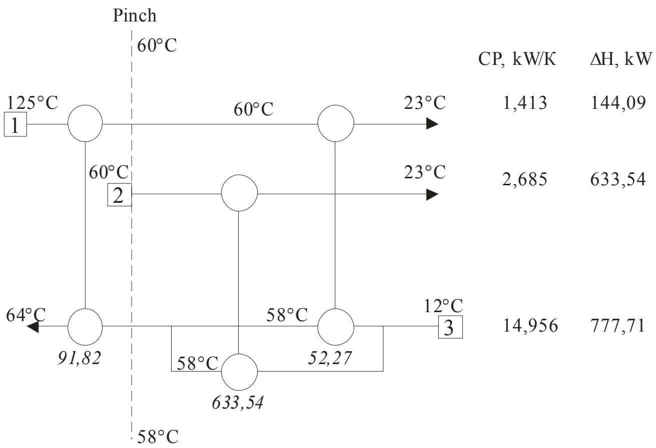

Fig. 3. Grid diagram of integrated process of ammonia unit satisfied composite curves on Fig. 2.

As a result we receive the grid diagram of the heat exchange network, presented on figure 3. Here we can notice 1 loop, but to break off it with the purpose of system simplification it seems unpractical technically and economically.

There are 3 recuperative heat exchangers in given system. The estimated cost of heat exchangers included the installation is about 32000 US dollars. For compression of ammonia stream up to 26 bar the compressor is necessary. The estimated cost of such compressor is about 42500 US dollars. The total cost of the equipment is 74500 US dollars. The equipment selected so that the unit could work in the summer mode (with the increased loading).

Consumed electric power of the compressor is 60-100 kW. Annual cost of the electric power is 34693 US dollars. The economy of energy due to recuperation is 778 kW and in money terms 101102 US dollars per year. Total the annual economy will make 66409 US dollars.

The existing ammonia cooling cycle and offered retrofit project were simulated using software UniSim Design®.

4. Conclusions

With modernization of existing in food industry ammonia refrigeration units using process integration technique it is possible to achieve significant savings in energy and money terms. The payback period of the retrofit with additional compression will be about 13.5 months. This payback period expects that the ammonia unit is working with loading in winter mode. During the summer period loading increases approximately in 2 times so, recuperation also will increase in 2 times, i.e. it will be possible to heat up ~25 m3/h of the water to temperature 64°C and accordingly the payback period of the offered project of reconstruction will decrease. The payback period without additional compression is about three months, but annual economy is lower.

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