Troubleshooting Case:

Failure to raise the 1st stage evaporator outlet temperature

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Introduction

The urea plant in our company is a large-scale Stamicarbon CO_2 stripping urea plant introduced from Netherlands in the early 1970s with the daily and annual production of 1620 mt and 480 kt respectively. Since its commissioning in 1977, the evaporation system has undergone a number of revamps which are mainly focused on the second evaporator section such as adding louvers, adding flushing points, and using a larger booster (702L) etc. In recent years, there is a frequent problem in the first evaporator in that the outlet temperature of urea solution is hard to increase especially at high plant load conditions. So an analysis of this problem is presented here in this paper.

Based on the particular crystallization properties of urea, nowadays a two-stage evaporation and two-stage separation process is adopted in our company. The flowchart is shown in Figure 1.

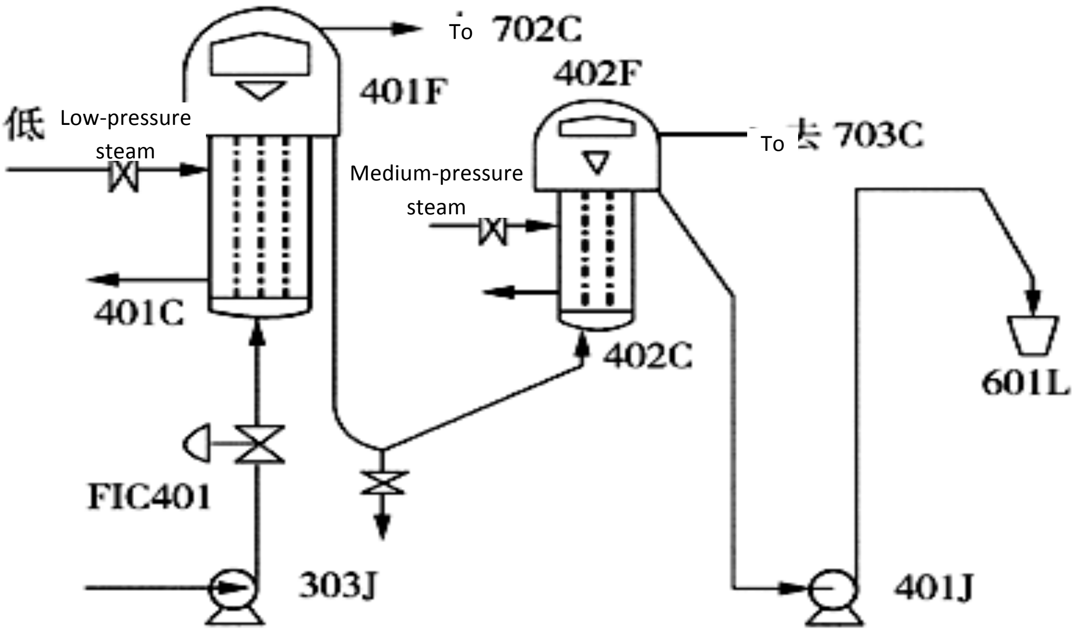

Figure 1: Flow scheme of the evaporation system

Urea solution enters the first stage evaporator (401C) via the pump 303J, with its flow controlled by FIC401. This evaporator is a vertical shell-and-tube heater, in which the urea solution flows upwards along the tube wall in a membranous form and the stem produced by the high-pressure carbamate condenser (202C) - 0.3MPa steam - is used as the heating source.
The liquid-gas mixture from the evaporator is separated in the separator (401F), and the water vapor is condensed in the first stage evaporator condenser (702C). The ejector (701L) of the first stage evaporator is employed to maintain a vacuum condition with the pressure controlled to 27kPa. The urea solution concentrated from the first stage separator is passing through a U-shaped pipe to enter the second stage evaporator heater (402C), where the pressure is changed to 3.2kPa. The solution is then heated by 0.8MPa steam and concentrated to 99.7 wt%. The liquid and vapor from the second stage evaporator are separated in the second stage evaporator separator (402F). The 99.7 wt% urea solution is sent to the urea melt pump (401J) from the bottom of the second stage evaporator separator and then to the prilling bucket (601L) at the top of the prilling tower, where the urea melt is thrown out via the rotating priling bucket. The falling urea melt droplets are cooled by the air supplied from the bottom of the tower, which are finally turned into prills and sent to the finished product workshop.

The reasons for failure to raise first stage evaporator outlet temperature are analyzed as follows:

1. Process aspects

(1) High load

The quantity of urea solution generated increases with the raise of CO_2 load. When the CO_2 load (FL0001) is 110%, the maximum evaporation flow (FIC401) reaches 120 m^3/h, while the heating source used in first stage evaporator is the steam produced by the high pressure carbamate condenser 202C. The increase of CO_2 load will certainly reduce the pressure of PIC206, i.e. the pressure of the 0.3MPa steam of 202C will decrease. That is to say, the flow of first stage evaporator is increased, while the pressure of the heating source, 0.3MPa steam, is lowered, causing a certain conflict between supply and demand. When the CO_2 load at FL0001 is 110% and the flow at FIC401 is 120m^3/h, the first stage evaporator outlet temperature is reduced to around 120 ^oC, which is lower than the design value (128-132 ^oC) and closer to the crystallization temperature (116 ~ 118 ^oC), making the operation more challenging.
This situation is difficult to deal with. As the CO_2 load cannot be lowered, the pressure of PIC206 cannot be raised and the quantity of urea solution generated in the high-pressure system or the flow of urea solution passing FIC401 can not be reduced. With the addition of H_2O_2, which is added in the high-pressure system to replace a part of air for corrosion protection, the pressure of PIC206 is increased to a certain extent, but the effect is not significant. Therefore, other solutions had to be found.

(2) The pressure of the low-pressure recirculation system being a little too high

The pressure of the low-pressure recirculation system (PIC304) will be slightly on the high side due to the low CO_2 conversion rate or reduced stripping efficiency in the high-pressure synthesis system, which will directly affect the evaporation system. The first stage evaporator outlet temperature will also be affected if the pressure of PIO309 is too high as a result of improper control of flash tank (302F) pressure, leading to the increase of free NH_3 at the inlet of the urea solution pump and reduction of urea solution concentration. Analysis has shown that the pressure of PIO309 is often at 70-80kPa, and the concentration of urea solution and the amount of free NH_3 before 303J are in the normal range.

(3) Pressure of steam saturator 904F

After the 0.3MPa steam has done work in the first stage evaporator heater 401C, the steam condensate is discharged into 904F. It seems that the 0.3MPa steam could be fully used if the pressure of 904F gets reduced. But it is impossible. Reasons are as follows: The pressure of 904F can not be too low as it is subject to the limitation of design requirement (the design pressure being 0.07MPa); The pressure of 904F can not be lowered because the 904F's steam condensate is used as the heat source for the ammonia preheater (101C) and liquid ammonia heater (102C), such that the significant reduction of its pressure will affect the heating of liquid ammonia, and then affect the high-pressure system.

Further other possible failures have also been analyzed, such as open/close not in place of the instrument heating valve PV401 (= steam heating valve for the first evaporator heater 401C), the falling off of the bottom of the liquid distributor, tube array leakage, and the falling off or deformation of the 4 baffles on the steam side. However, final inspection and tests have denied these suspicions.

To sum up, it is not something of the process that causes the failure to raise the first evaporator outlet temperature. Therefore, we turned to seeking for causes from the equipment.

2 Equipment aspects

(1) Problem with baffle on steam side

It can be seen from Figure 2 that steam enters via nozzle N2 and heats evenly through 4 baffles, increasing the temperature of urea solution in tubes. If any baffle has come off or has been deformed, steam distribution in 401C will be affected. During the overhaul in 2007, a baffle in the middle was unripped for a check and found that it was intact. But we could not unrip the entire equipment for all the 4 baffles, so other baffles remained unchecked.

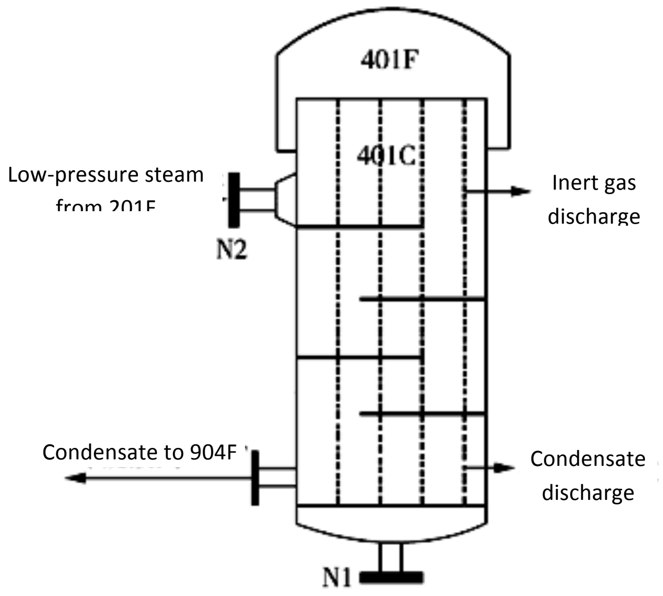

Figure 2: Scheme of the evaporation separator

(2) The steam trap not working well

After the steam has done work in 401C, it turns into steam condensate and is discharged into the steam condensate flash tank (904F). Originally, a bypass valve and two steam traps are designed on the main pipeline of Φ108mm for condensate discharge. At high load conditions, both steam traps are opened fully and the bypass valve is opened slightly. In order to prevent the steam having done no work from going into 904F at a great amount, the bypass valve cannot be widely opened. Considering that it is unable to discharge the condensate at the bottom of 401C, a pipe of Φ57mm with a steam trap was added to the bottom during the overhaul in May 2008, with the purpose of enhancing condensate discharge from 401C. However, this revamp did not show a significant effect.

(3) Tube scaling

The urea solution enters the liquid distributor via N1 and then enters the tube bundle with an even distribution, forming a membrane in the tubes and flowing upwards at a flow rate of 70 m/s. Sludge and welding slag are inevitable inside the equipment and may stick to the wall. On August 7, 2008, the synthesis unit was shutdown for repairing a one-way valve. Taking this chance the lower liquid seal head of 401C was removed to check and wash the 1300 tubes in 401C, through which a great deal of sludge (determined to be Fe_3O_4 by chemical analysis) was cleaned out. After that, the first evaporator outlet temperature improved a lot in later operation, which can be seen from Table 1.

Table 1 Operating parameters of first evaporation after washing

Date	FL0001 (Load) /%	FIC401/m³/h	TIC403/℃	PI0402/kPa	PIC206/MPa
2008. 5. 10	99	105	122	34	0. 32
2008. 8. 5	100	106	123	32	0. 32
2008. 8. 17	105	110	126	32	0. 30
2008. 9. 20	110	120	122	32	0. 30
2008. 10. 3	110	120	121	33	0. 30

From above cause analysis and treatment, it can be concluded that the main reason lies in the serious scaling inside 401C, which affects heat transfer. At the same time, Table 1 reveals another problem that with the increase of CO_2 load (particularly, the current load has exceeded the originally designed capacity), the production rate is raised from the original 1620 mtpd to 1800 mtpd, posing a severe challenge to the capacity of the first stage evaporator heater.

3 Recommendations

(1) Adding a urea solution preheater before the first stage evaporator to reduce the load on the first stage evaporator heater.

(2) Replacing 401C with a larger one to accommodate the current high-load production.

Note UreaKnowHow.com:

Another recommendation to increase the first stage evaporator outlet temperature is installing orifice plugs in the bottom tube sheet in order that more turbulence exists inside the tubes leading to a higher heat transfer coefficient and less risks for fouling. More info at:
http://www.ureaknowhow.com/urea_j/images/stories/pdf/how_to_increase_the_performance_of_vop_heat_exchangers_v5.pdf
In case plant loads increase further a pre-evaporator section seems a good debottlenecking tool to unload the existing first and second evaporator stages.