Urea Evaporator Entrainment Separator

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Abstract

This paper presents the application of mist eliminators to urea evaporators overhead where liquid entrainment consists of concentrated urea droplets that could solidify in the filters. The selected mist eliminators are vertical units with a perpendicular water spray to physically remove the urea liquid from the overhead stream and reduce urea product solidification. The operating conditions are an absolute pressure of 41.3 KPA (310 MM Hg) and a saturation temperature of 77°C (170°F). The result of this analysis shows a recovery of 99% by weight of the entrained urea with an overhead carryover that fluctuates from 1.54 to 10.66 K/hr (23.5 lbs/hr). The units have complied with their guarantee and their urea recovery is approximately 8 tons/day above that of the vane separators. Average savings since its installation are in the range of $85,000 (U.S.) based on the quantity of urea recovered.
Included are analysis of the turbulence of the evaporator, the problems and performance of previous systems and results of the urea recovery.
Introduction:

The production of granulated urea involves the evaporation of water from the urea water solution until the desired concentration is achieved. This involves a significant heat exchange at the correct temperature and pressure conditions based on chemical equilibrium to minimize the formation of biuret, an undesirable product of urea production.

At the Blytheville plant this evaporation process is performed in two stages, with the first evaporator removing the largest quantity of water. The excessive urea in the overhead vapors of the first evaporator has always been an undesirable operating condition.

To reduce this carryover, in the summer of 1975 a system of vane separators was installed in the separator portion of the first and second evaporator. Although the use of similar type units to reduce the entrainment has apparently been successful in other plants, plugging these units with urea droplets was always a problem.
While in operation, the urea content of the overhead stream fluctuated from 1 to 3% by weight, which made attractive the pursuit of a system with a higher recovery efficiency.

In June 1980 a mist elimination system designed by Monsanto Enviro Chem was installed in the evaporation separation vessel. The overhead gas flows vertically and changes to horizontal direction when it goes across the filters. The concept of the system as developed by Monsanto consists of a perpendicular water spray to the filters concurrent with the gas flow to keep them clean of entrained particles. The filters have been in operation since then.

This report includes a turbulence analysis in the evaporator overhead and carryover, the vane separator problems and performance, the mist eliminator configuration, their performance and the economic evaluation of product
recovery. Also included are the operating conditions and conclusions of their one year of operation.
Process Information

Evaporator Analysis

The evaporation of water from a urea water solution is conducted in the Blytheville plant in two evaporation units that expose the solution to heat at controlled temperature and pressure. The evaporation system consists of two vertical shell and tube heat exchanger units connected in series with steam in the shell side in each case. Product solution of 95% concentration urea is found in the outlet of the first evaporator and 99.8% urea is the outlet of the second. Both of these heat exchangers are operated under vacuum conditions and each of these evaporators has a dome separator at the top. The configuration of the original installation is shown on figure 1. The overhead vapors from these two units is essentially steam contaminated with ammonia and urea. It is recovered in two different condenser systems. The condensate is then returned to a recovery system where the
FIGURE I EVAPORATOR CONFIGURATION
urea is decomposed into carbamate and the ammonia-
carbamate solution is then returned to the synthesis 
section.

Historically, and by design, the first of these 
evaporators has the highest heat exchange; and therefore; 
the highest vapor volume. The fact that it is a forced 
circulating evaporator with a high temperature rise 
through the heating element helped produce product losses 
due to entrainment. The gas flow out of the tubes of 
the evaporators was correlated to turbulence. The velocity 
profile at the evaporator outlet, the dome separator and 
the gas outlet to the exchanger is shown on figure II.

The use of a separator in the overhead of the heat 
exchanger was intended to reduce the amount of the urea 
droplets carried over in the vapor steam. The sudden 
increase in volume in the separator decreased the 
velocity of the gas leaving the evaporator. This produces 
a reduction of the liquid entrainment. Urea entrainment
Stage 1: Leaving evaporator
Stage 2: At separator
Stage 3: At separator nozzle
was analyzed by sampling the condensate of the evaporators overhead. Figure III shows the urea concentration per pound of steam found in the overhead versus the total flow of urea solution to the evaporators. The samples contained from .5 to 7.2% urea.
FIGURE III UREA CARRYOVER IN EVAPORATOR SEPARATOR

Urea Melt Flow to Evaporator

$\text{m}^3/\text{sec} \times 10^2$
The vane separator's installation on these evaporators is shown on figure IV. It consists of vertical hollow vane units manifolded with steam inside the vanes to keep a high temperature in the unit so the urea would not solidify during start up. At the evaporator outlet the vapors change direction in a deflector shaped as a "Chinese hat". From here they go to the vane separators. These separators force the overhead vapors to experience many changes in directions in short periods of time. Since the urea liquid droplets move slower than the gas, it tends to impinge and move along the vanes. When the liquid reaches the next direction change in the vanes, it contacts a hook type arrangement where the flow is stopped and the direction is changed downwards. There, the urea is recovered in a channel where it returns to the synthesis section.

The operation of these filters allowed an overhead urea flow in the range of 3 to 1% as is shown on figure V.
FIGURE IV  VANE SEPARATOR CONFIGURATION
FIGURE V  UREA CARRYOVER USING VANE SEPARATORS

Urea Melt Flow to the Evaporator  M3/Sec x10^2
During plant shutdowns solids deposits were found on these vanes that seemed insoluble in water. The substance was suspected to be the product of urea degradation to biuret; from biuret to an intermediate compound called triuret and from it, it degraded into cyanuric acid. This substance is essentially insoluble in water and it represented the bigger obstacle for the use of regular mesh separators to recover the entrained urea.
Mist Eliminators' Configuration

The Monsanto Mist Eliminators were designed to fit the separator vessel. They consist of twenty three vertical elements with 316 SS polygon frame and a special Teflon fiber bed weighing approximately 17.69 kilos (39 pounds) each. These filters are installed perpendicular to the dome separator head. The elements are continuously sprayed with a 3% ammonia solution to prevent urea crystallization in the mist eliminator fiber using two spray nozzles per element. The sprayed solution pressure is controlled in the range of 239.25 to 446.09 KPA (20 to 50 psig) and its flow ranges from 1.61 to 2.22 Kilos/hr (13,000 to 19,000 lbs/hr). As the water passes through the filters it is collected in a metal cone that eventually returns it to our product tanks. The filters configuration is shown on Figure VI. An indication of the pressure differential across the filters is required to monitor their operation.
FIGURE VI
MIST ELIMINATOR CONFIGURATION
Operating Parameters

The first evaporator operates at an average absolute pressure of 41.3 KPA (310 MM Hg) with an average flow rate of 44,500 ACFM. Data was taken while the mist eliminators were exposed to different conditions and part of the data is shown on Table I.

The pressure differential across the filters is monitored continuously during the start up to determine the adequacy of the water spray. Once the unit is on line the pressure drop stabilizes and sampling of the overhead takes place. An increase in pressure drop is a sign that the fibers are becoming blinded or plugged. Such condition can be the result of entrainment of the droplets due to improper water spray or to entrainment of any other foreign material.

In order to reduce the possibility of filter failure due to the improper water spray, these jets are removable
and they can be cleaned while the unit is on line. A
daily inspection is performed for each one of these jets.
<table>
<thead>
<tr>
<th>Case</th>
<th>Urea Plant Production Tons/Day</th>
<th>D-106 Vacuum Pressure</th>
<th>Saturation Temperature in Vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metric</td>
<td>Short</td>
<td>KPA (MM)</td>
</tr>
<tr>
<td>Case I</td>
<td>929</td>
<td>1024</td>
<td>39.97 (300)</td>
</tr>
<tr>
<td>Case II</td>
<td>945</td>
<td>1042</td>
<td>49.96 (375)</td>
</tr>
<tr>
<td>Case III</td>
<td>786</td>
<td>867</td>
<td>30.91 (232)</td>
</tr>
<tr>
<td>Case IV</td>
<td>974</td>
<td>1074</td>
<td>38.64 (290)</td>
</tr>
<tr>
<td>Case V</td>
<td>1001</td>
<td>1103</td>
<td>58.62 (440)</td>
</tr>
<tr>
<td>Case VI</td>
<td>980</td>
<td>1080</td>
<td>43.30 (325)</td>
</tr>
<tr>
<td>Case VII</td>
<td>986</td>
<td>1087</td>
<td>42.23 (317)</td>
</tr>
</tbody>
</table>
Mist Eliminators Performance

The operation of the mist eliminators has run continuously and without upsets to the system since the installation. Samples of the overhead stream of the first evaporator have been taken on a continuous basis and sampled for the urea content. Figure VII shows the mist eliminator carryover from the overhead. Material balances show the kilos of urea leaving the vessel overhead to be in the range of 1.54 to 10.66 kilo/hr. Table II shows representative urea carryover in the unit versus the maximum allowable quantity guaranteed for a flow of 33,375 ACFM or above. Lower flows decrease the efficiency as is shown on Case V.

Pressure drop through the filters is monitored on a daily basis to determine the conditions of the filters and to show where any pluggage occurs. The operation of the forty six jet nozzles is also closely followed for pluggage. To this date there have been no operation problems with any of the filters.
Figure VII: Mist Eliminator Carryover

Graph showing the relationship between Urea Melt Flow to Evaporator (M3/Sec x 10^2) and Overhead Urea ppm.

Key points:
- Linear trend line indicating an increase in Overhead Urea ppm with increasing Urea Melt Flow to Evaporator.
- Data points plotted with a scatter diagram.

Axes:
- Y-axis: Overhead Urea ppm
- X-axis: Urea Melt Flow to Evaporator (M3/Sec x 10^2)
<table>
<thead>
<tr>
<th></th>
<th>Milligrams/ACM</th>
<th>Urea Carryover (Milligrams/ACF)</th>
<th>ACM/Sec</th>
<th>Gas Flow ACF/Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case I</td>
<td>.2265</td>
<td>.0110</td>
<td>.39</td>
<td>16.14 (34,200)</td>
</tr>
<tr>
<td>Case II</td>
<td>.0125</td>
<td>.0125</td>
<td>.44</td>
<td>14.30 (30,307)</td>
</tr>
<tr>
<td>Case III</td>
<td>.0535</td>
<td>.0535</td>
<td>1.89</td>
<td>43.84 (92,885)</td>
</tr>
<tr>
<td>Case IV</td>
<td>.0221</td>
<td>.0221</td>
<td>.78</td>
<td>17.40 (36,882)</td>
</tr>
<tr>
<td>Case V</td>
<td>.0801</td>
<td>.0801</td>
<td>2.83</td>
<td>11.80 (25,009)</td>
</tr>
<tr>
<td>Case VI</td>
<td>.0246</td>
<td>.0246</td>
<td>.87</td>
<td>13.78 (29,197)</td>
</tr>
<tr>
<td>Case VII</td>
<td>.0626</td>
<td>.0626</td>
<td>2.21</td>
<td>29.10 (61,676)</td>
</tr>
</tbody>
</table>
Economic Evaluation of Product Recovery

Several benefits are evident with the recovery of urea as urea product. Among them

1. Increase in available product

2. Decrease in costs of chemical recovery

A comparison from the estimated carryover from the balances shows a recovery of approximately 99% of the entrained urea by the mist eliminators.

An average production of 1100 tons per day produced an estimated recovery of 8.00 tons per day above those of vane separators. This daily savings can be translated to an extra recovery of $108,000 worth of product per year.
Conclusion:

This report concludes that the mist eliminators have shown to be an efficient method of recovering the urea product of the carryover from the evaporators.
Bibliography
