High Pressure Stripper Efficiency Problems

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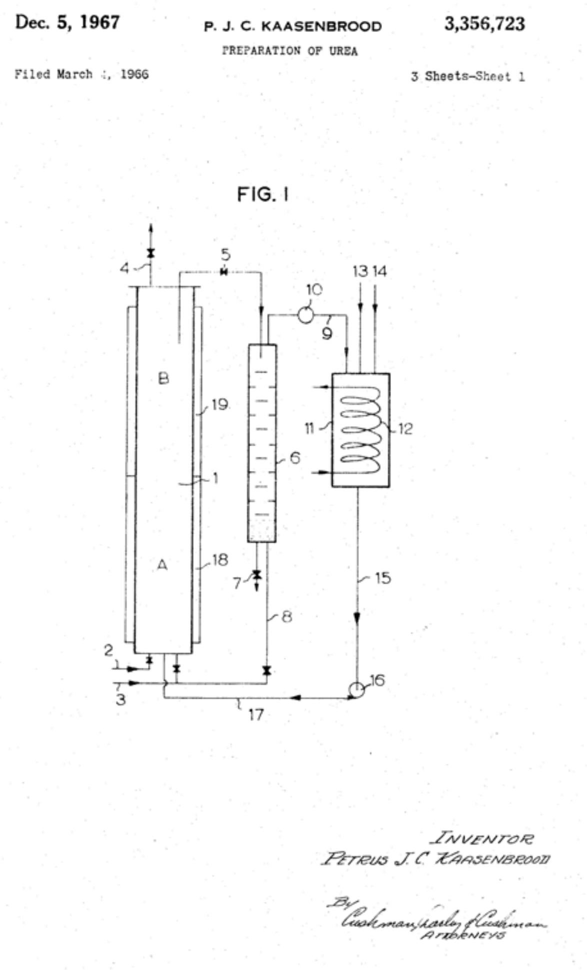
1. Introduction

In 1967 Stamicarbon revolutionized the urea process by the invention of the HP CO_2 Stripper by Mr. Petrus JC Kaasenbrood. US patent 3,356,723 describes the invention of the HP CO_2 stripper.



"In a continuous process for the preparation of urea wherein NH_3 and CO_2 are reacted at elevated temperature and pressure to continuously provide an ammonium carbamate melt, thereafter in an autoclave, said melt being converted into a urea solution containing ammonium carbamate and the carbamate being stripped from said solution by decomposing said carbamate into NH_3 and CO_2 by heat and expelling NH_3, CO_2 and H_2O from said solution, the improvement which comprises continuously stripping the urea solution with CO_2 in a stripping zone outside said autoclave and at a pressure of at least 50 atmospheres up to urea synthesis pressure wherein the urea solution flows downwardly along the inside of externally steam heated tubes in the stripping zone and CO_2 stripping gas passes upwardly in said tubes in contact with said urea solution, the pressure of the heating steam being in the range of 15-30 atm., whereby NH_3 and CO_2 are expelled from said solution, condensing the resulting mixture of CO_2 gas and gases expelled from said urea solution after addition of further NH_3 and at a pressure of at least 50 atmospheres up to urea synthesis pressure to form a carbamate solution and returning the thus formed carbamate solution to said autoclave for further urea synthesis."

In the HP CO_2 stripper urea reactor effluent is thus treated counter currently with carbon dioxide in a stripper at high pressure in order to dissociate carbamate and at the same time enable easy condensation of the carbamate gasses without the addition of water. Preferably this is done at the same pressure as the reactor is operating. The condensation of strip gasses will produce steam leading to significant reduction in steam consumption to produce urea.
This patent from 1967 has revolutionized urea technology and nowadays all modern urea processes operate a HP stripper.

A HP CO_2 stripper did lead to three main benefits:

1. the carbamate could be recycled at synthesis pressure so now extra water needed to be added to recycle the carbamate;
2. no medium pressure recirculation section was needed anymore and
3. with the condensation of strip gasses in the high pressure carbamate condenser low pressure steam could be produced, which could be used in the downstream sections leading to a reduction of the steam consumption of a urea plant of about a factor two.

This originally Chinese Technical Paper provides an overview of the causes why the efficiency of a CO_2 stripper reduces and at the same time it provides practical solutions to recover the efficiency again.

2. Design and Working Principle of the High Pressure CO2 Stripper

Firstly, let me give a brief introduction to the design of the High Pressure Stripper in urea plants adopting 18.30 CO_2 stripping process. The Stripper is actually a falling-film tubular heat exchanger with fixed tube-sheets. The high pressure section of the stripper is composed of an access hole cover, nipple jointed spherical head with channel sub, riser, liquid distributor, tube-sheet, stripper tubes and so on, while the low pressure section consists of low pressure shell, expansion joint, explosion-proof disk and so forth. The design of the stripper is generally divided into three parts. The upper part is for gas-liquid separation between the synthesis fluid from the urea reactor and the stripping gas, where the main components are liquid distributors. Corresponding liquid distributors are arranged at the upper tube ends of each stripper tube. The purpose of the liquid distributor design is to ensure that synthesis fluid can flow into all stripper tubes and prevent them from overheating due to a "Dry tube", avoiding severe corrosion and damage of the stripper tubes. The middle part consists of the stripper tubes. The lower part is for gas-liquid separation between stripped solution and CO_2, where the main component is the CO_2 distributor.
As the level of urea solution has to be controlled during production, a level gauge using cobalt 60 as radiation source is installed in the bottom of the stripper for level measurement purpose. Meanwhile, in order to reduce heat loss and prevent corrosion in equipment or tubes due to potential partial crystallization or partial condensation, the whole equipment, inlet and outlet tubes must be insulated using thermal insulation cotton. The whole weight of the stripper is carried by asupport welded on the shell above expansion joints.

Secondly, the working principle of the CO_2 stripper is as follows: reactor solution from urea reactor passes through the discharge control valve HV201 of the reactor and flows to the upper part of the stripper by means of level difference, then passes through liquid distributors and flows downwards along the inner wall of stripper tubes in film form. The liquid flowing downwards meets CO_2 gas coming from the lower part, thus free ammonia is expelled first followed by carbamate decomposition. As saturated steam of 2.0 MPa and 230 ^oC (approx.) heats the outside surface of the tubes, the carbamate decomposition reaction can proceed instantly. Urea and carbamate are decomposed into ammonia and CO_2 under the combined action of heating and stripping. Ammonia and CO_2 flow into HP carbamate condenser from the hole at the top of the riser which is located at the upper part of liquid distributors. Urea solution from the bottom is sent into the downstream section for further depressurization, thus decomposing carbamate contained therein.

3. Analysis on the Causes Resulting in Stripping Efficiency Decrease of the Stripper

In a company I've ever worked, the outlet fluid temperature of the stripper exceeded 175 °C, the stripping efficiency reduced from original 85% down to 77%, ammonia consumption per ton of urea production increased and the load on the low pressure recirculation obviously rose under the circumstance that other operating conditions were kept constant after three years of operation.
I think there were two main reasons for the stripper efficiency reduction after having analyzed factors affecting stripping efficiency of the stripper, such as low steam pressure of HP steam drum, deviation of N/C ratio in the system, high level in the bottom of the stripper, low conversion rate of urea reactor, high water content in the system, excessive accumulation of inert gases or condensate at the shell side of the stripper, high system pressure, too high level in HP steam drum, improper control of the outlet fluid valve of the urea reactor, higher vapor-liquid ratio of a single stripper tube caused due to intensified corrosion of liquid distribution holes, uneven gas distribution in stripping tubes due to damage of the gas distributor, and vapor-liquid ratio imbalance due to CO_2 leakage from PPV2204 (Translators note: blow off vlave at discharge CO2 compressor ?), etc.

3.1 Part of the liquid distributor holes are clogged by impurities

Fine particles resulted from packing wear and tear of the High Pressure ammonia pumps and carbamate pumps are brought into liquid ammonia and carbamate solution by the reciprocating movement of pump plungers and finally they are entrapped in the small holes of distributors of the stripper, thus clogging such small holes. As the liquid flow of stripper tubes is small when the small holes of distributors are clogged, partial longitudinal area at the upper layer of stripper tubes may have no liquid film formed or only have very thin liquid film, resulting in smaller resistance to gas and therefore a larger gas throughput. When the liquid flow in the stripper tubes is higher, the liquid film becomes thicker, the area for gas passage reduces and the resistance becomes higher. When the gas flow resistance increases, the gas throughput decreases, the gas-liquid ratio becomes smaller, the carbamate decomposition rate reduces and the outlet fluid temperature of the stripper becomes higher, thus the stripping efficiency decreases. Therefore, gas flow and liquid flow in the stripper tubes interact with each other, which is one of the most important factors affecting stripping efficiency. The higher the vapor-liquid ratio is, the higher the stripping efficiency and vice versa. When the stripper efficiency decreases, the ammonia content in the outlet fluid increases, heat absorption for carbamate decomposition reduces and the outlet fluid temperature rises certainly under same heating conditions.

a. Liquid distributors or stripping tubes of the stripper are polluted by oil

When the plant is operated for a long period even for several months without shutdown , oil brought by liquid ammonia and CO_2 compressors accumulates at the upper layer of the urea reactor as the specific weight of oil is lighter than that of urea and carbamate solution. The longer the operation cycle is, the thicker the oil layer. If the level in the urea reactor is reduced too low during operation, oil stain will enter into the stripper and clog the small holes of distributors, or enter into the stripping tubes and decrease their heat transfer efficiency, thus reducing the stripping efficiency. Another situation is that during the discharge prior to a long-time shutdown, oil layer at the upper part of the urea reactor flows into the downcomer as the level in the reactor decreases. In case the pressure of the stripper decreases or the outlet fluid valve HV-201 of the urea reactor has minor leakage during the discharge, oil stain will enter into the stripper, polluting the liquid distributors or stripping tubes of the stripper, thus decreasing the stripping efficiency. Consequently, the stripping efficiency is always poor during every restart after a long-time shutdown. However, this does not happen during short-time shutdown, for which the reason is that steam with a certain pressure is fed into the stripper and the shell side of the HP carbamate condenser during short-time shutdown, this helps prevent ammonia and CO_2 condensation in the stripper and HP carbamate condenser, thus urea solution in the urea reactor and downcomer will not flow into the stripper. Alternatively, HP washing water can be added to the downcomer of the urea reactor at intervals during short-time shutdown so as to force urea, carbamate solution and oil stain in the downcomer to come back to the urea reactor.

4. Solutions to solve clogging of liquid holes in liquid distributor

4.1 After a long-time plant shutdown

Upon the completion of heating & passivation and prior to CO_2 pressure boosting, add High Pressure flush water into the HP stripper until full level has been reached. Start the CO_2 compressor, control PRC-204 (translator's note PRC-204 is the CO_2 compressor discharge pressure) pressure in the range of 2-3.0 MPa, meanwhile continuously add flush water into the High Pressure stripper through the CO_2 pipeline, fully open the 3" vent valve on the gas phase pipeline and the reactor outlet fluid valve HV-201 of the urea reactor, then quickly open the CO_2 quick on-off valve at the inlet of the stripper, allowing a large amount of CO_2 gas entrained with washing water to quickly flow into the stripper for back blowing the small holes of liquid distributors of the stripper, then let the CO_2 stream be discharged out of the system through the gas-phase vent valve of the urea reactor, and repeat the said process for 3-4 times in the same way.

4.2 After a short-time plant shutdown

During the restart after a short-time plant shutdown, CO_2 is introduced first, the outlet fluid valve HV-201 of the urea reactor is not open yet at this moment, the liquid distributors have no liquid level, part of the CO_2 gas directly passes first through the small liquid distribution holes of the stripper and then through the balancing holes in the fixing plate of the risers of the liquid distributors before it flows out of the stripper, and this is actually a process of back blowing. Consequently, the stripper efficiency is very well during the restart after a short-time shutdown. However, as there is only 70% load during startup and feeding, a major part of CO_2 passes through the top of the risers of the liquid distributors and only a minor part passes through the small liquid holes of the liquid distributors. Therefore, the pressure of the High Pressure synthesis has to be reduced down to 8 MPa and the gas-phase control valve of Low Pressure absorber should be fully open to prevent overpressure; when the CO_2 flow reaches up to 100% load, the pressure of PRC-204 of CO_2 entering into the stripper should be controlled at 2.0MPa (or above) higher than that of the whole system. Then quickly open the CO_2 quick on-off valve at the inlet of the stripper and open the outlet fluid valve HV2201 of the urea reactor stepwise by 30%, 60% and 100%, allowing a large amount of CO_2 to pass through the small liquid holes of the distributors, thus flowing back the impurities clogging the small liquid holes of the liquid distributors. The gas-phase vent valve of the urea reactor should be opened according to pressure increase during back blowing; control the pressure of the LP steam drum at the upper limit (0.55 MPa) which is set for the blocked shutdown of the urea reactor, and increase the resistance of the gas phase to be sent to the High Pressure Carbamate Condenser, and repeat the said process for 3-4 times in the same way.

4.3 In operation without shut down

The stripper efficiency gradually decreases and consumption figures increase progressively with the urea production period. It will bring some economic loss if the plant is shut down specially for back blowing or dismantling and cleaning the liquid distributors of the High Pressure Stripper due to stripper efficiency reduction. The method for back blowing the liquid distributors of the stripper in operation without shut down is proposed according to successful experience of back blowing after long-time and short-time shutdowns. Firstly, increase the load of the CO_2 compressor up to approximately 120%, control the level in the urea reactor at 30% (low limit), fully open the gas-phase valve HV2202 of the High Pressure Scrubber, open the High Pressure steam drum to vent, control steam pressure of PIC2904 at approximately 1.2 MPa. Manually control the stripper fluid outlet valve at 88% (high limit) and close the stripper outlet fluid valve LV2202, then quickly close the outlet fluid valve HV-201 of the urea reactor, allowing a large amount of CO_2 gas to pass through the small liquid holes of liquid distributors of the stripper for 1-2 minutes only, and finally maintain the gas flow at original load. During the treatment, the vent valve of the urea reactor can be opened for avoiding overpressure of the High Pressure section. Pay attention to the control of the Low Pressure system to prevent the High Pressure carbamate pump from fluctuating. The level in the urea solution tank should be increased prior to back blowing and evaporation and prilling system should be ready for shutdown and circulating operation.

5. Oil fouling of Liquid Distributors or Stripper tubes of the Stripper

With regard to oil fouling of the liquid distributors or stripper tubes of the stripper, we adopt the process of blowing and boiling the CO_2 stripper after the blocked shutdown (preferably drained shutdown) of the urea reactor system and prior to restart of the system. Reduce the pressure of the HP section down to 5 Mpa, control the CO_2 flow at 60% load, charge condensate into the stripper from the CO_2 inlet pipeline up to the top of the stripper, control the pressure of HP steam drum at 1.0 Mpa, simultaneously open the outlet fluid valve HV2201 of the urea reactor and the low point drain valve of the U-shaped outlet fluid pipe as wide as possible; close the condensate valve, open the CO_2 quick on-off valve at the inlet of the stripper, blow gas into the stripper for one minute and then close the CO_2 quick on-off valve; again blow gas for boiling after a stoppage of 2 minutes and repeat the process for 5 times in total. Stop the supply of condensate upon the completion of blowing and boiling; open the gas-phase vent valve of the urea reactor for venting again after the level in LR2202 of the stripper is discharged down to 60%, then fully open the outlet fluid valve HV201 of the urea reactor and apply CO_2 for back blowing for 20 minutes (approx.), afterwards stop CO_2 supply and apply liquid seal, start to increase the pressure and be ready for startup.
Of course, professional chemical cleaning for the stripper is preferred after long-time shutdown of the system.

6. How to Prevent Liquid Distributors and Stripper Tubes from being Clogged by impurities or polluted by oil during normal operation

It is known from the above analysis that importance should be attached mainly to the following nine aspects:

1) Regularly clean the outlet strainers of HP ammonia pump and carbamate pump to prevent scraps of the plunger packing material of the pumps from entering into the stripper

2) Prevent liquid ammonia sent to the urea plant from carrying oil and catalyst particles, ensure the liquid ammonia filter for liquid ammonia entering into the urea plant battery limit to be put into operation and clean filter cloth on the occasion of overhaul

3) Enhance the blow-down of the compressor, control oil charged into each stage of the compressor cylinder at low limit and prevent oil from entering into the system, forming carbide under high temperature and high pressure

4) Control the level in the urea reactor at above 40% in normal production

5) Strictly prohibit adjusting the HV2201 in a wide range in normal production to prevent oil stain and dirt on the surface of the synthesis fluid from being instantaneously pumped into the stripper along with liquid

6) Timely close the outlet fluid valve of the urea reactor when the level of the urea reactor drops down to 20% during short-time enclosed shutdown

7) Control the pressure of the HP and LP steam drums in strict accordance with relevant regulations during blocked shutdown to prevent liquid backflow from HP system into the stripper

8) During the discharge of the urea reactor for a long-time shutdown of the system, liquid in the overflow pipe of the reactor should be drained at last

9) Thoroughly purge and clean a new plant before startup to prevent impurities being remained in the system.

7. Summary

The above-mentioned proposed measures can only solve such problems as clogging and oil fouling of the stripper tubes and small liquid holes of liquid distributors of the stripper for a short period. However, such impurities as crushed packing materials, oil stain and so on have not been removed completely out of the system. In order to solve the problems thoroughly, regular overhaul and inspection of such HP equipment as stripper, etc. should be carried out in addition to the nine routine maintenance measures as mentioned in Chapter 5, in order ensure the stable operation of the stripper on a long-term basis.

Translator notes:
This is a Technical Paper originating from our Chinese partner: www.Ureanet.cn. The paper was original in Chinese language and it is translated and interpreted into English with care and as much as reasonable possible accuracy, all to the best of our abilities. The Introduction chapter is added by the UreaKnowHow.com.