

Section wise description of Process Flow Diagram

The PFD of the process has been divided into 4 sections. At the end of 4th section, after going through an extensive network of recycle streams and purification units, we finally successfully obtain 99.6% pure urea as our product stream. Below is a section wise description of the PFD.

1. High Pressure Section

In this section, urea is synthesised from ammonia and carbon dioxide at a temperature of 188°C and 150 bar pressure. These conditions are appropriate as they allow us to achieve decent conversions for both the reactions as explained in Section 3.1.

- A. The CO₂ feed (10) along with 0.25 % v/v passivation air is compressed to 150 bar pressure by a multistage compressor (K1101) and fed to the reactor (R1101).
- B. The ammonia feed (3C) as "*obtained from the medium pressure section*" post purification is pumped to 150 bar in the high pressure ammonia pump (P1101), mixed with recycle stream (17) consisting of ammonium carbamate solution coming from high pressure carbamate separator (V1101) and ejected via an ejector (EJ1101) to reactor (R1101).
- C. The reactor performs the reactions with conversions (Ammonium Carbamate Formation-90% w.r.t. CO₂ and Urea Formation-75% w.r.t. Carbamate) to produce urea stream (11) comprising of ammonium carbamate, ammonia and water.
- D. This stream (11) is then passed through the stripper (E1102) which is a falling film heat exchanger. Here, the solution is heated using MP steam and ammonium carbamate is decomposed (~41%) to ammonia and CO₂. The gases produced here strip the additional ammonia from liquid thus producing off gases (12) consisting of ammonia and CO₂.
- E. The off gases produced are sent to the high pressure carbamate receiver (E1101). Here, they condense to produce ammonium carbamate (~98%) (15) which is further fed to carbamate separator (V1101).
- F. The urea solution formed in E1102 (13) is "*fed to the medium pressure section*".

2. Medium Pressure Section

This section comprises of purification unit for fresh ammonia feed for the plant and one unit for purification of the urea solution.

- A. The medium pressure section receives the fresh ammonia feed into ammonia receiver (V1201) wherein it is flashed to separate the impurities like methane (4).
- B. Adding to the point B of section 4.2.1, the ammonia feed is obtained from ammonia receiver (V1201) (3) via ammonia booster pump (P1203) which increases the pressure of the stream from 18 bar to 22 bar.
- C. The gases flashed off from ammonia receiver (4) are further sent to the scrubber (C1203) where pure liquid ammonia (5) is recovered and recycled back to ammonia carbamate separation column (C1202) (5A).
- D. Adding to the point F of the section 4.2.1, the urea solution (13) coming from (E1102) is fed to the medium pressure decomposer (C1201). Here ammonium carbamate is decomposed (~85%) to ammonia and CO₂. The purified urea is "*fed to low pressure section*" to further decomposer. The off gases are also "*fed to low pressure section*".
- E. The carbamate solution (26A) as "*obtained from the low pressure section*" is fed to the Ammonia carbamate separation column (C1202). This column separates ammonia and CO₂ by converting CO₂ (100%) to carbamate.
- F. Ammonia along with other inert gases (2A) as obtained from separation column is cooled and recycled back to ammonia receiver (V1201).
- G. The carbamate solution (21) obtained from the same separation column is recycled back to the high pressure carbamate receiver (E1101).

3. Low Pressure Section

The low pressure section consists of further purification units for concentrating urea solution.

- A. Adding to the point D of section 4.2.2, the purified urea from medium pressure carbamate decomposer (C1201) (18) is fed to the low pressure carbamate decomposer (C1301) where again decomposition of ammonium carbamate takes place at a lower pressure of 5 bar.
- B. Hence, the purified urea solution (20) obtained from above is further sent to the tube side of preheater (C1302), where its purity is further raised by removing water vapour from the solution. The purified urea solution (27) is further "*fed to the vacuum evaporator section*".
- C. The off gasses (19) from LP decomposer (C1301) along with recycle stream obtained from water treatment plane are cooled by heat exchanger (E1301), receiver and flashed off in carbamate receiver (V1301) and added to shell side of preheater (C1302).
- D. Adding to the point D of section 4.2.2, the off gasses (17) from medium pressure carbamate decomposer (C1201) are further sent to the shell side of preheater (C1302), where they react to produce ammonium carbamate to release heat which in turn heats up the endothermic reaction occurring in the tube side.

4. Vacuum Evaporator Section

This section evaporates remaining water in the urea solution to concentrate it to the required purity levels.

- A. Adding to the point B of section 4.2.3, the purified urea solution (27B) is fed to the first vacuum evaporator (V1401) through a heat exchanger (E1401). A pressure of 0.3 bar is maintained in this unit.
- B. The purified solution (29) from above unit is again fed to similar second vacuum evaporator (V1402) through another heat exchanger (E1402). Even lower pressure of 0.03 bar is maintained in this unit to ensure evaporation of last traces of water.
- C. Finally, the product stream (30) comprising of 99.6 wt. % pure urea is obtained from the above unit. The water vapor (28) released from the vacuum evaporators is further fed to the wastewater treatment plant.

Difficulties in Simulation of Urea Production Flowsheet:

Thermodynamic properties of Ammonium Carbamate (AC) and Urea are not available in any chemical database. AC is a solid at room temperature and sublimates at 60° F. Therefore, theoretically and practically no vapor-liquid equilibrium data is available for it. Also, theoretically Urea doesn't exist in vapor form as it decomposes at high temperatures and hence boiling point is not defined. Therefore, no vapor-liquid equilibrium data is available for Urea as well. Secondly, no property package can handle ammonium carbamate properly due to absence of interaction parameters with other molecules and compounds. Therefore, in order to perform simulation we forced the physical state of Ammonium Carbamate and Urea to be liquid in our domain of temperature by manually increasing their boiling points. This forced them to stay in the liquid as they would be in reality, therefore the simulations remains in accordance with actual chemistry of reality.