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Experiences with LAUNCH® MELT™ Ultra-Low Energy plant operation

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Stamicarbon 75 YEARS

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1. ABSTRACT

The Ultra-Low Energy urea plant concept (part of the LAUNCH® MELT™ series) which was launched during the Stamicarbon symposium in 2012 as 5XX design, is designed, constructed and successfully put into operation for two grass-root plants in China[1)] since the beginning of 2021. Both plants have similar name plate capacity of 2334 MTPD urea. To date, three more Ultra-Low Energy grass-root plants[2)] are licensed; two plants under construction and expected to be in operation in mid of 2023 and one plant is in engineering phase.

The Ultra-Low Energy Design for a melt plant with prilled product in operation results in the steam consumption (23 bara, 330 ºC) ≤ 567 kg steam/ton product compared to traditional Pool Reactor Designs (former Urea 2000plus®) ≤ 870 kg steam/ton product.

This paper highlights the process design aspects as well as operational experience of grass root Ultra-Low Energy urea plants in operation in China, along with the comparison of the key performance parameters incl. steam consumption and product quality. The mechanical details of special pool reactor design with dual bundle (steam and carbamate) is highlighted in the paper "mechanical aspect of the pool reactor for the Ultra-Low Energy plants".

2. INTRODUCTION AND BACKGROUND

Stamicarbon is a well-known innovative company. Several successful concepts for urea plants were developed in the past. These innovations were mainly OPEX driven without compromising the CAPEX, along with improving the process safety of the plants and reducing the emissions to the environment. These innovations finally resulted in lowering the total cost of ownership of the plants.

The Ultra-Low Energy design is the latest Stamicarbon process technology, which was launched at the Stamicarbon symposium 2012 and by now contracted for five grass-roots plants. Out of these two plants are already in operation since the beginning of 2021, two are in construction phase expected to be in operation in mid of 2023 and one is in engineering phase. The Ultra-Low Energy design is considered as a next generation Pool Condenser and Pool Reactor design (former Urea 2000 plus®, now part of the LAUNCH® MELT™ series), which utilizes major proven technological developments made by Stamicarbon as listed below and provides the benefit of a considerably lower steam consumption;

- Pool condensation in synthesis;
- Applying Safurex® stainless steels as material of construction for synthesis;
- Utilizing proven medium pressure recirculation design/operation.

The traditional urea processes were based on so called N= 2 heat integration concept, that means that the heat supplied to the urea plant in the form of extraction steam from the steam turbine is used twice. The first time this steam is used as heating agent to obtain high stripping efficiencies in the high pressure stripper.

[1)] 'Jiujiang XLX urea plant' for XLX Fertilizer Co. China, and 'Sanning urea plant' for Hubei Sanning Chemical Co. Ltd. China
[2)] 'Xinxiang XLX urea plant' for XLX Fertilizer Co. China, and 'Gemlik urea plant' for Gemlik Gubre Turkey are under construction and another confidential urea plant is in engineering phase.

Subsequently the heat is recovered by condensing the strip gas in the high pressure carbamate condenser, pool condenser or pool reactor in the synthesis section to produce low pressure steam that is used in the sections downstream the synthesis section.

The Ultra-Low Energy design utilizes an N=3 heat integration and that means that in this concept the heat supplied in the form of high pressure extraction steam is used three times in the urea plant. For that, generation of vapour by medium pressure carbamate dissociation is effected by utilizing the heat from condensing the strip gas in the pool condensation section of the synthesis, after which the heat of condensation of this medium pressure carbamate dissociation vapour is used to concentrate the urea solution in the evaporation section.

3. PROCESS DESCRIPTION OF THE ULTRA-LOW ENERGY DESIGN

The synthesis section of the Ultra-Low Energy process according the pool reactor concept is represented in figure 1.

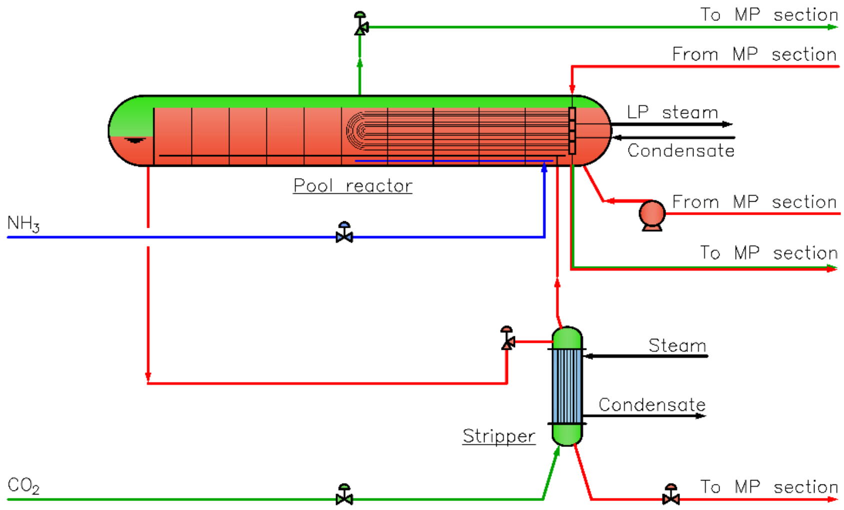

Figure 1: The synthesis section of the Ultra-Low Energy design' as implemented in two grass-root plants in China (plant capacities 2334 MTPD).

As illustrated in figure 1, the synthesis for the Ultra-Low Energy process as implemented in two grass-root pool reactor plants in operation includes only two-high pressure pieces of equipment. Essentially it is similar as the synthesis of Flash design consisting of a high pressure stripper, and a high pressure pool reactor in the absence of a high pressure scrubber. The high pressure scrubber is not required in Ultra-Low Energy design either. However, a closer look at the pool reactor reveals that now the U-tube bundle has two separate sections, and is handling two different fluid mediums (steam and carbamate), which have been incorporated in the shell side of the pool reactor. The inner part of the bundle is called the 'steam bundle', which is used for generating low pressure steam as is commonly found in Stamicarbon pool condenser and pool reactor plants and is used in the Ultra -Low Energy design to generate only the amount of low pressure steam needed in the urea plant itself, without excess of (export) low pressure steam. [3)]

The outer part of the bundle, which is called the 'carbamate bundle' however, is used for the heat integration with the medium pressure recirculation section. On the shell side of this bundle, condensation of CO_2 and NH_3 vapour releases heat (at about 144 bara and 175 °C), which is used to decompose carbamate into CO_2 and NH_3 on the tube side. Consequently the tube side of this tube bundle in the pool reactor functions as a medium pressure rectifying heater. By integration of these two functions, without any intermediate heat transfer medium, the available temperature difference between both process sides enables the bundle to be relatively small. The further details of the pool reactor design with dual bundle is elaborated in the paper "mechanical aspect of the pool reactor for the Ultra-Low Energy plants".

The medium pressure recirculation section of the Ultra-Low Energy design process is represented in figure 2.

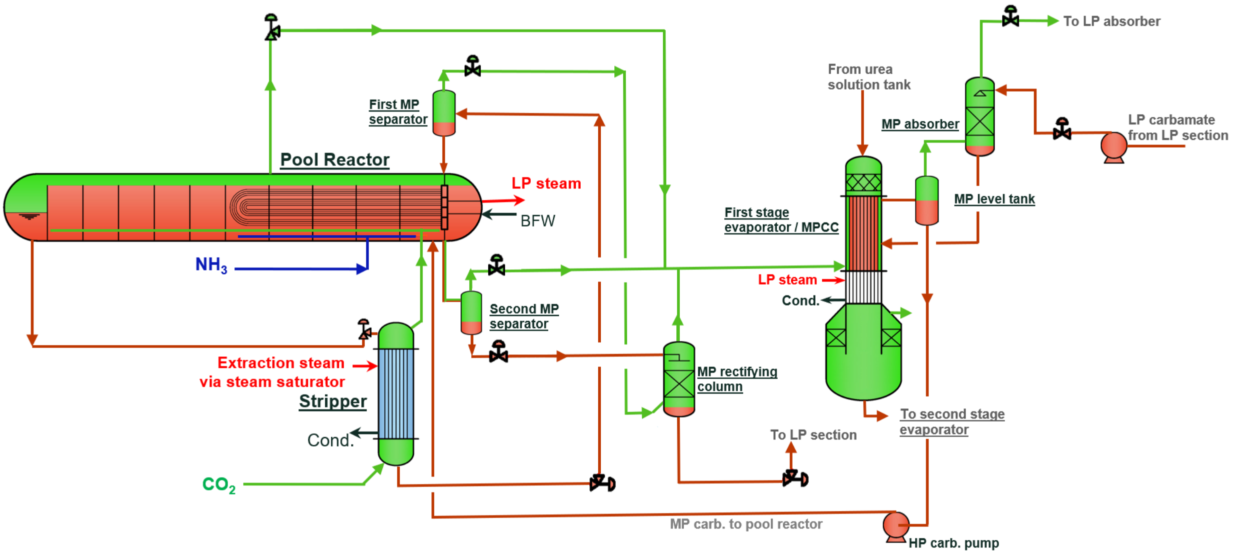

Figure 2: The synthesis including the medium pressure (MP) recirculation section of the 'LAUNCH MELT™ Ultra-Low Energy design' as implemented in two grass-root plants in China (plant capacities 2334 MTPD).

After leaving the stripper the urea/carbamate solution is adiabatically flashed at medium pressure in the first medium pressure separator resulting in CO_2 rich vapor and urea solution/carbamate liquid. The first medium pressure separator is located at higher elevation than the pool reactor. The urea solution/carbamate flows on gravity from the first medium pressure separator to the outer part of the pool reactor bundle (carbamate bundle) where it is heated by condensing strip-gas on the shell side and a part of the carbamate decomposes to NH_3 and CO_2 vapor. This vapor/liquid mixture is sent to the second medium pressure separator, where vapor and liquid get separated. The urea solution/carbamate leaving the second medium pressure separator has a higher NH_3/CO_2 ratio. The liquid from the second medium pressure separator is

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[3)] In figure 2, the carbamate bundle is located as outer part of the bundle. The relative position of the bundles to each other is an arbitrary selection. Alternatively the tube bundles could be placed next to each other or one above the other. When the carbamate bundle is located as outer part, it facilitates easier cleaning of the carbamate bundle in case of fouling, due to larger bend radius.

discharged to the medium pressure rectifying column, where the CO_2 rich vapor from the first medium pressure separator is used to decrease the NH_3/CO_2 ratio of the liquid from the medium pressure separator, before discharging this liquid to the low pressure recirculation section, which again is standard in Stamicarbon designs.

The vapor generated in the medium pressure recirculation section along with the off-gas from the synthesis are condensed on the shell side of the first stage evaporator/medium pressure carbamate condenser (MPCC) to form medium pressure carbamate. The released condensation heat is used to concentrate the urea solution in the first stage evaporation. The first stage evaporation is based on falling film evaporation. So that makes it possible in the Ultra-Low Energy design to utilize the heat, which is supplied to the urea plant in the form of steam, three times (N=3).

1. At first for dissociating the carbamate at synthesis pressure in the stripper,
2. secondly for dissociating the carbamate under medium pressure conditions in the carbamate bundle of the pool reactor,
3. and finally for concentrating the urea solution on the tube side of the first stage evaporator/MPCC under sub-atmospheric pressure conditions.

The Ultra-Low Energy design is optimized from CAPEX and OPEX point of view in such a way that the introduction of the new medium pressure recirculation section along with elimination of the high pressure scrubber is well balanced out in terms of CAPEX of the plant compared to the Pool Condenser and Pool Reactor designs (former Urea 2000plus®) process, while the steam consumption is radically reduced. The earlier operational benefits of the traditional Pool Condenser and Pool Reactor designs related to CO_2 stripping, pool condensation and proven medium and low pressure recirculation operation remain intact in the Ultra-Low Energy design.

4. PLANT LAYOUT OF ULTRA-LOW ENERGY PLANT

In the Ultra-Low Energy pool reactor design the total height of the high pressure equipment structure is limited to about 20 meters, where the heaviest piece of equipment (pool reactor) is located. The stripper is located close to ground level. The high pressure scrubber is not part of the design which results in the lower height of the structure.

The vessel at the highest elevation in the plant is the first medium pressure separator. A typical Ultra-Low Energy plant-layout is shown below in the figure 4.

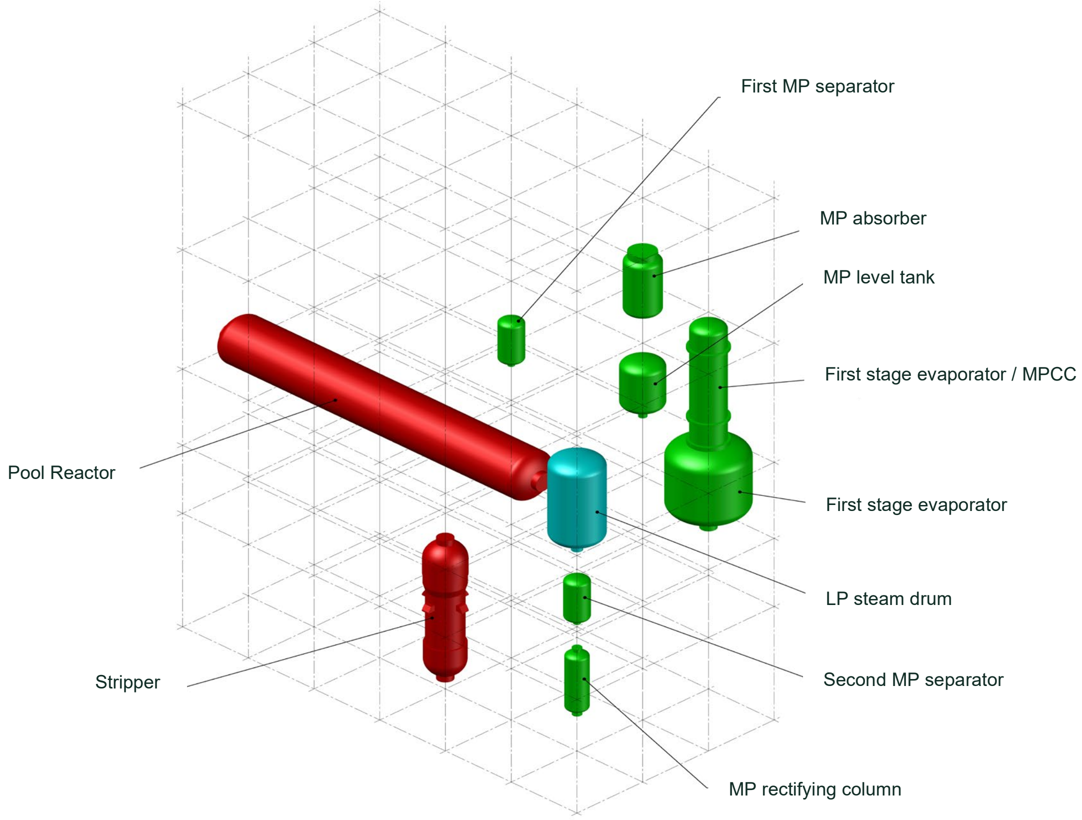

Figure 3: The layout of synthesis and medium pressure (MP) recirculation section of the Ultra-Low Energy design' [4)]

5. SIMULATION OF OPERATIONAL WINDOW AND START-UP PROCEDURES

The start-up and operational conditions of the as-built urea plant for Jiujiang XLX were dynamically simulated together with the Stami Digital department (former Protomation), to get a deeper understanding of the dynamics in the high pressure section and the medium and low pressure recirculation sections and to train the operators for the Ultra-Low Energy design. In this specific case, the application was made available in a cloud environment to create the possibility to train operators, despite COVID related travelling restrictions. The Stami Digital OTS based on the Ultra-Low Energy design is represented in figure 4.

[4)] This is a layout from the design phase, the final contractor/client plant layout is not shown due to confidentiality.

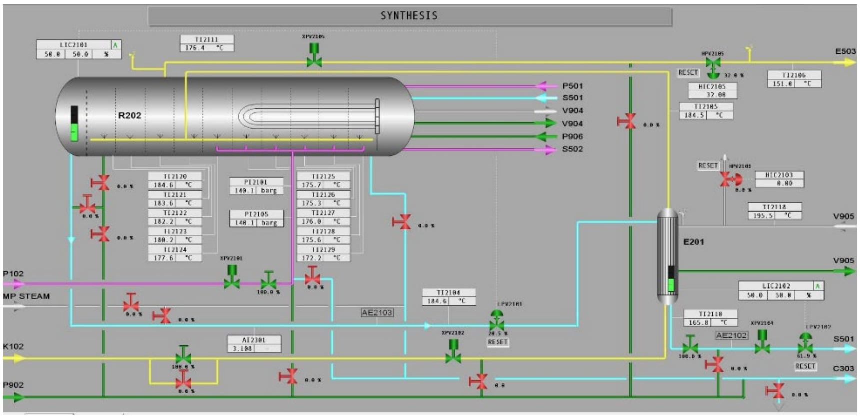

Figure 4: The synthesis and medium pressure recirculation section of theUltra-Low Energy design' as built in the simulator. Screenshots from Operator Training Simulator (OTS) © Stamicarbon

The dynamic simulations also revealed that for the Ultra-Low Energy design the plant start-up/shut-down/block-in is relatively similar to the Pool Condenser and Pool Reactor designs along with some new steps required for the medium pressure recirculation section. It was also found in the dynamic simulations that the presence of the medium pressure recirculation section actually reduced disturbances in the low pressure recirculation section, which are sometimes observed in a traditional Pool Condenser and Pool Reactor designs, originating from stripper operation, due to fluctuation in liquid flow from the stripper or CO_2 slippage from the stripper. In the Ultra-Low Energy design due to the presence of the medium pressure recirculation section these fluctuations are dampened in the medium pressure section. The similar performance improvement in the low pressure section is also proven in running plants of the Flash design.

6. OPERATION EXPERIENCES AND KEY PERFORMANCE PARAMETERS

The first Ultra-low energy plant, XLX Jiujiang, was successfully brought in operation in February 2021. Prior to startup of the plant the operational team of the plant were thoroughly trained on the Operator Training Simulator (OTS) by Stamicarbon to get good understanding on expected ultra-low energy plant behavior. The startup of the plant went very smooth without any issues in the very first attempt. Initially the plant was operated with turndown capacity operation. After the feedstocks were assured the capacity of the plant was increased to above 100% within the first week of operation.

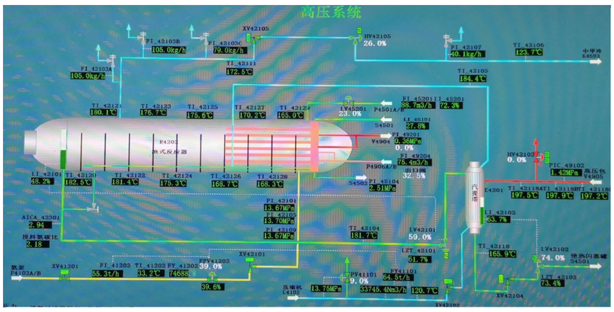

Figure 5: The DCS screen shots XLX Jiujiang from above 100% operation for synthesis and medium pressure section

The XLX Jiujiang urea plant has been in operation since February 2021 successfully, the actual DCS screens from operation are indicated in the Figure 5. The energy consumption of the Ultra-low energy plant is considered to be a benchmark performance worldwide. Apart from energy benefit also the easiness to operate the Ultra-low energy plant incl. pool reactor with dual bundle design, is considered to be another important benefit by XLX Jiujiang operations compared to traditional plants. The presence of the medium pressure recirculation section incl. the presence of the carbamate bundle dampen disturbances, which were found in traditional stripping plants, originating from discharging liquid directly from the stripper operation to the low pressure section. Also the lower biuret in the final urea product compared to traditional processes is considered to be a major enhancement in the final product quality – see table 1.

In the Ultra-Low Energy plant, the shell side steam temperature in the CO_2 stripper shell is only about 196 to 198 ^{0}C, which are much milder conditions than for a traditional CO_2 stripper, where the required shell side steam temperature is about 210 to 215 ^{0}C. This reduces the biuret formation in the stripper and also positively influences the life time of the CO_2 stripper in the Ultra-low energy design.

Considering the benefit of the first Ultra-Low Energy plant at Jiujiang, XLX also contracted a second Ultra-Low Energy design urea plant for the Xinxiang location in China, which is under construction. The actual plant operation information from XLX Jiujiang is indicated in table 1.

Key performance parameters		**Units**	**Expected values during design phase**	**Actual plant performance during the performance test. (average 5 days)**
Production capacity		tons/day	**2334**	**2387**
Cooling water [5)]		tons/ton_{urea}	61 (ΔT = 10 °C)	61 (ΔT = < 10 °C)
High pressure Steam [6)]	Extraction steam 23 bara, 330 °C [equivalent extraction steam quantities for comparison]	kg/ton_{urea}	**577**	**567**
Product quality	Total nitrogen	wt%	46.5	46.6
	Biuret	wt%	0.85	< 0.80

Table 1: Ultra-Low Energy plant performance parameters are listed as follows 'actual plant performance' comparing with 'performance guarantee values' from XLX Jiujiang plant performance test. All figures indicated as tons are in metric tons.

The performance parameters indicated above with respect to steam consumption and biuret in the final product from the actual plant operation of the Ultra-Low Energy plant, demonstrate the Ultra-Low Energy

5) The cooling water consumption figure is indicated equivalent to ΔT_{cw} = 10 °C.
6) In XLX Jiujiang only saturated steam is supplied to the urea plant, above steam consumption figure is indicated based on the steam quality equivalent to standard extraction steam quality (23 bara, 330 °C) for right comparison. The actual saturated steam (26 bara, 226 °C) consumption during operation is 635 kg/ton_{urea}.

plant performance to be a major advancement in the urea technology. Key performance parameters are further elaborated below at average plant operation capacity of 102 %. The performance of the Sanning plant is also comparable to XLX Jiujiang, although there is less information available.

6.1. STEAM CONSUMPTION [5)]

The actual high pressure steam (23 bara, 330 °C) consumption at XLX-Jiujiang is 567 kg/ton urea, which is lower than initial expected value, during design. These figures are expected to be further reduced by about 20 to 25 kg/ton urea, by optimization of the process conditions of the ammonia feed temperature to the synthesis.

6.2. COOLING WATER CONSUMPTION [4)]

The actual cooling water heat duty observed during performance test is close to expected value during design. The cooling water flow required considering equivalent ΔT_{cw} = 10 °C is 61 tons/ton urea.

6.3. PRODUCT QUALITY:

In the Ultra-Low Energy plant apart from energy benefit also a significant product quality improvement was achieved with respect to the reduction in biuret concentration in the final product by > 0.05 wt%, compared to a traditional stripping process. This is due to the process specifics of the Ultra-low energy design; milder process temperatures in the stripper and process-process heat exchange at the first stage evaporator part.

7. CONCLUSIONS

To date the Ultra-Low Energy plant concept is already licensed five times. Two grass-root plants in China are successfully in operation since the beginning of 2021: Jiujiang XLX and Sanning, both designed for a production capacity of 2334 MTPD. The design is fully optimized and requires only two pieces of synthesis equipment (pool reactor and stripper). The plants are running stable and the targeted energy savings are achieved. Two other grass-root plants are currently in the construction phase: Xinxiang XLX in China, and Gemlik Gubre in Turkey, and one confidential grass-root plant in engineering phase.

Process Concept	Steam consumption (23 bara, 330 °C)	Cooling water consumption (ΔT_{cw} as 10 °C)	Expected Biuret in final product
Ultra-Low Energy plant in operation	567 kg_{steam} / ton_{urea}	61 ton_{CW} / ton_{urea}	< 0.8 wt%
Pool Reactor designs (former Urea 2000plus®)	870 kg_{steam} / ton_{urea}	73 ton_{CW} / ton_{urea}	0.85 wt%
Improvement	**35%**	**16%**	**> 6%**

Table 2: Consumption figures for LAUNCH® MELT Ultra-Low Energy™ design in operation from performance test XLX-Jiujiang and a LAUNCH MELT™ Pool Condenser Pool Reactor designs (former Urea 2000plus®)

The steam consumption for the Ultra-Low Energy design as proven in operation at two plants in China, is reduced by about 35 % and cooling water consumption is reduced by about 16 % compared to the traditional Pool Condenser and Pool Reactor designs. The CAPEX of the Ultra-Low Energy design is comparable to the

Pool Condenser and Pool Reactor designs. The 'N=3' heat integration is accomplished by heat integration between the pool reactor (condensation strip gas) and the medium pressure carbamate dissociation heater (urea solution liquid/NH_3/CO_2 vapour from carbamate), also called carbamate bundle followed by a heat integration between the medium pressure carbamate condenser (NH_3/CO_2 vapour from carbamate) and the first stage evaporator heater (water evaporated from urea solution from urea storage tank). The heat integration between pool reactor and medium pressure recirculation section is achieved via a patented unique pool reactor design with internal tube sheet along with dual bundles allowing heat exchange with process fluids on both shell and tube side, thereby avoiding the use of an intermediate heat exchange fluid (e.g. steam).

In the Ultra-Low Energy plant, apart from energy benefit also a significant product quality improvement was achieved with respect to the reduction in biuret concentration in the final product by about 0.05 wt%, compared to a traditional stripping process. This is due to the process specifics of the Ultra-Low Energy design; milder process temperatures in the stripper and process-process heat exchange at the first stage evaporator part.

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