NEW DESIGN FOR ULE POOL REACTOR / CONDENSER

STAMICARBON

NEXTCHEM
MAIRE Sustainable Technology Solutions

Conference name	Stamicarbon Symposium
Conference date	May 18 – 21, 2026
Author(s)	Alex Scheerder, Mark Wagemans and Kedar Lakhe
Classification	PUBLIC

CONTENT

1 ABSTRACT

The NX STAMI™ Urea Ultra-Low Energy (ULE) plant concept was launched during the Stamicarbon symposium in 2012 as 5XX design. Since 2021, six grassroot ULE plants have been designed, constructed and successfully put into operation, with four more plants under construction or in engineering phase. The first licensed ULE plants have a capacity of 2350 MTPD, while the capacity of the plants under construction reaches up to 3850 MTPD. For these bigger plant capacities, a second-generation ULE Pool Condenser Design is introduced.

The ULE Design for a melt plant with prilled product lowers steam consumption (23 bara, 330 ºC) to less than 560 kg steam/ton of product compared to the traditional NX STAMI™ Urea Pool Reactor Design (formerly known as Urea 2000plus®) with a steam consumption less than 870 kg steam/ton of product.

This paper highlights the mechanical design aspects of the first and second generations of ULE pool reactor and ULE pool condenser as well as operational experiences of the first-generation pool reactor and pool condenser with dual bundle (steam and carbamate) for the ULE plant.

2 INTRODUCTION

Stamicarbon, the nitrogen technology licensor of NEXTCHEM (MAIRE Group), has built a strong reputation for innovation, having developed several successful concepts for urea plants over the years. These innovations were mainly aimed at reducing operational expenses (OPEX) while maintaining capital expenditure (CAPEX) and enhancing plant safety, resulting in a lower total cost of ownership of the plants.

The NX STAMI™ Urea Ultra-Low Energy (ULE) Design is one of Stamicarbon's latest process technologies. It was launched at the Stamicarbon symposium in 2012 and by now contracted for ten grassroot plants. ULE is considered the latest generation of NX STAMI™ Urea Pool Condenser and Pool Reactor Designs –formerly known as Urea 2000plus®. It offers significantly reduced steam consumption and incorporates major proven technological advancements developed by Stamicarbon, including:

- The use of pool condensation in the synthesis,
- The application of Stamicarbon's E-type steel (formerly known as Safurex®) as material of construction for the synthesis, and
- The implementation of a proven medium-pressure (MP) recirculation design and operation.

This paper will discuss the mechanical aspects of the first-generation ULE pool reactor for smaller capacities and the second-generation ULE pool condenser for larger-capacity ULE plants. Furthermore, operational experiences with the first-generation ULE pool reactors from a mechanical point of view will be covered.

3 PROCESS DESCRIPTION OF ULE DESIGN

Traditional urea processes are based on the so-called N=2 heat integration concept, in which the heat supplied to the urea plant as extraction steam from the steam turbine is used twice. Firstly, this steam is used as a heating agent to obtain high stripping efficiency in the high-pressure (HP) stripper. Subsequently, the heat is recovered by condensing the strip gas in the HP carbamate condenser, pool condenser or pool reactor in the synthesis section to produce low-pressure (LP) steam used in downstream sections.

The ULE Design utilizes N=3 heat integration, in which the heat supplied in the form of HP extraction steam is used three times in the urea plant. To achieve this, MP carbamate dissociation generates vapor by utilizing the heat from condensing the strip gas in the pool condensation section of the synthesis. The condensation heat from this MP carbamate dissociation vapor is then used to concentrate the urea solution in the evaporation section.

The synthesis section of the ULE process according to the Pool Reactor concept is represented in Figure 1.

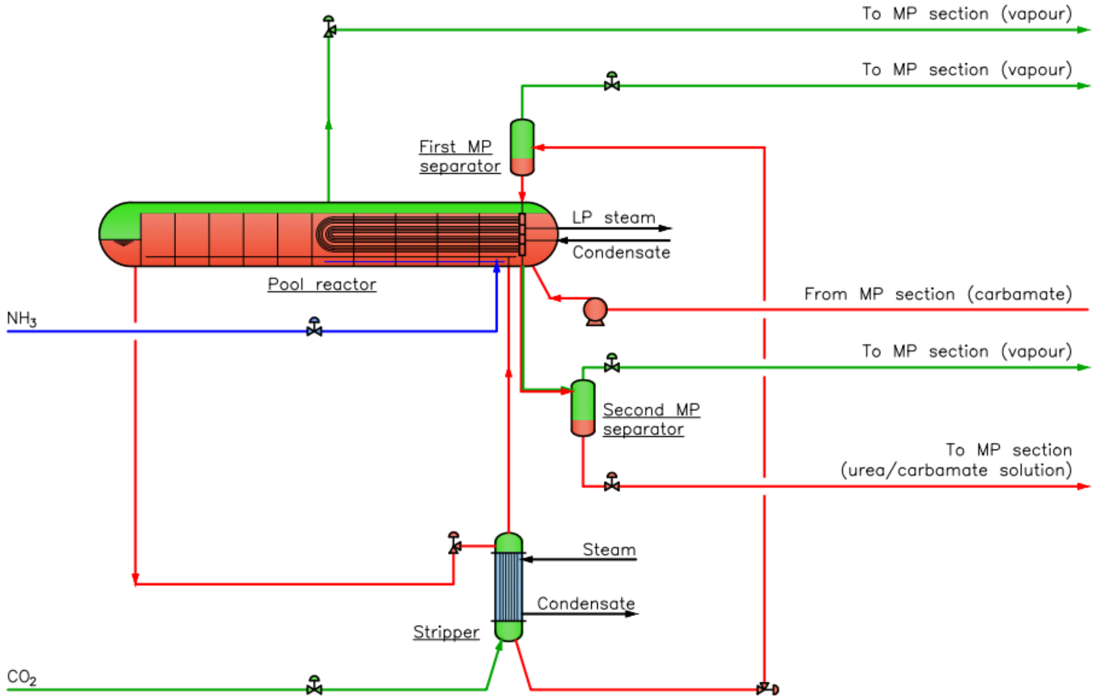

Figure 1: The synthesis section and connected MP equipment of the ULE Design.

As illustrated in Figure 1, the synthesis of the ULE process for plant capacities up to 2350 MTPD includes only two HP equipment items: an HP stripper and a ULE pool reactor. For larger plant capacities, the synthesis section includes an HP stripper, a ULE pool condenser, and a urea reactor. The MP separators and the HP carbamate pump are part of the MP section.

Essentially, it is like the synthesis of NX STAMI™ Urea Adiabatic Flash Design, consisting of an HP stripper and a ULE pool reactor (or a ULE pool condenser combined with a urea reactor) without an HP scrubber. The HP scrubber is not required in the ULE Design. A closer look at the ULE pool reactor or ULE pool condenser shows that its U-tube bundle consists of two separate sections, each handling a different medium (steam/condensate in one section and MP carbamate solution in the second section). On the shell side, HP carbamate is present. The inner bundle is called the "steam bundle," which is used to generate LP steam as is commonly found in Stamicarbon's conventional Pool Condenser and Pool Reactor plants.

The outer part of the bundle, called the "carbamate bundle," is used for heat integration with the MP recirculation section. On the shell side of this bundle, condensation of strip gas releases heat (at about 144 bara and 175 ºC), which is used to decompose MP carbamate into ammonia and carbon dioxide on the tube side. Consequently, the tube side of this bundle in the ULE pool reactor or ULE pool condenser functions as an MP rectifying heater. By integrating these two functions, without any intermediate heat transfer medium, the available temperature difference between both process sides enables the bundle to be relatively small.

4 CONSIDERATIONS FOR EQUIPMENT DESIGN

To establish the N=3 concept – without compromising CAPEX – a dual bundle has been integrated into the ULE pool reactor or ULE pool condenser utilizing superior corrosion-resistant properties of Stamicarbon's E-type steel. The proprietary design is patent protected. This chapter describes mechanical design considerations for the first and second generations of the ULE pool reactor and ULE pool condenser.

4.1 Mechanical design: First generation

One of the main challenges of designing a ULE pool reactor that allows corrosive media on the shell side and the tube side was solved by designing an internal tube sheet fully made from E-type steel. Unlike in the conventional type of pool reactor or pool condenser, in ULE equipment, the tube sheet and its distribution channels are placed inside the pressure vessel. The thickness of the tube sheet for a conventional pool reactor is typically about 500 mm, while installing the tube sheet inside the vessel allows the tube sheet to reduce thickness significantly. Figure 2 represents the differences between the tube sheet configuration of a conventional pool reactor and a ULE pool reactor.

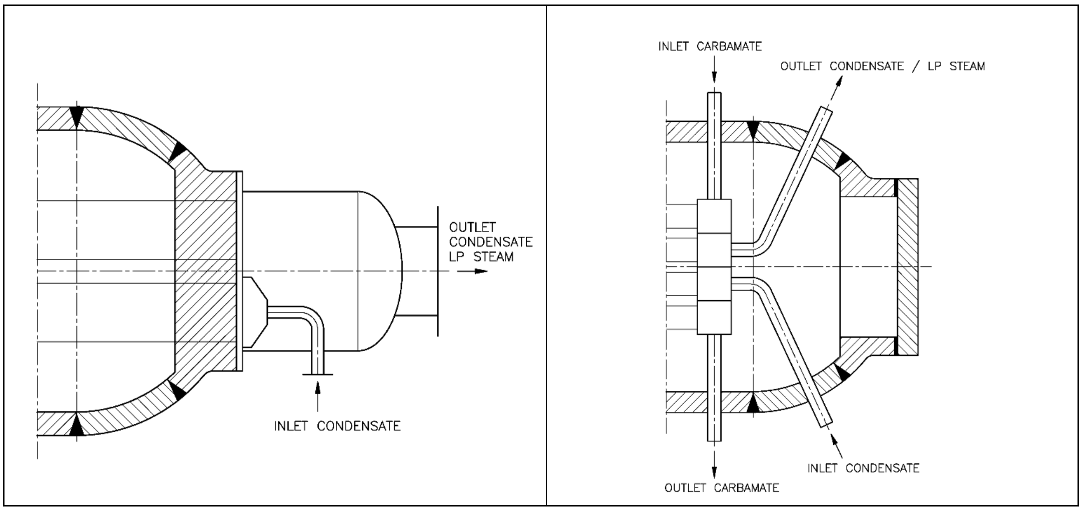

Figure 2: The difference between the tube sheet configuration of the conventional pool reactor or pool condenser and the pool reactor for the ULE Design.

All process fluids at the tube side are collected in a distribution box and connected to external equipment nozzles via HP piping. This enables the construction of the tube sheet and distribution channels entirely from a lower-thickness E-type steel plate, avoiding the thick weld overlayed carbon steel tube sheet. A carbon steel tube sheet is not needed in this ULE concept.

The conceptual layout of the pool reactor with a dual bundle is shown in Figure 3.

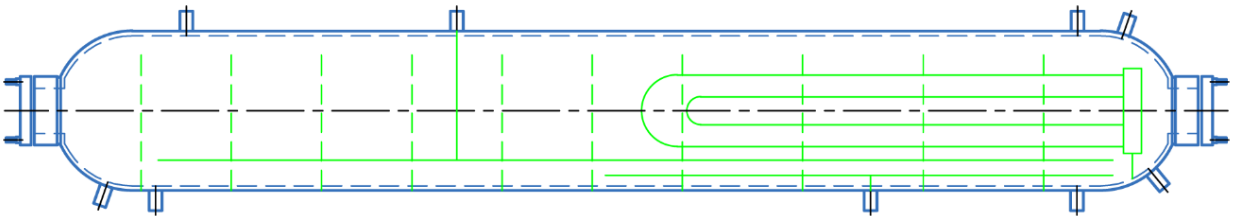

Figure 3: The conceptual layout of the ULE pool reactor.

The tube bundles and internals of the distribution box are accessible through the manway by opening the internal covers. As a result, Non-Destructive Testing (NDT) inspection can be performed without restrictions and dismantling of heavy parts as represented in Figure 4.

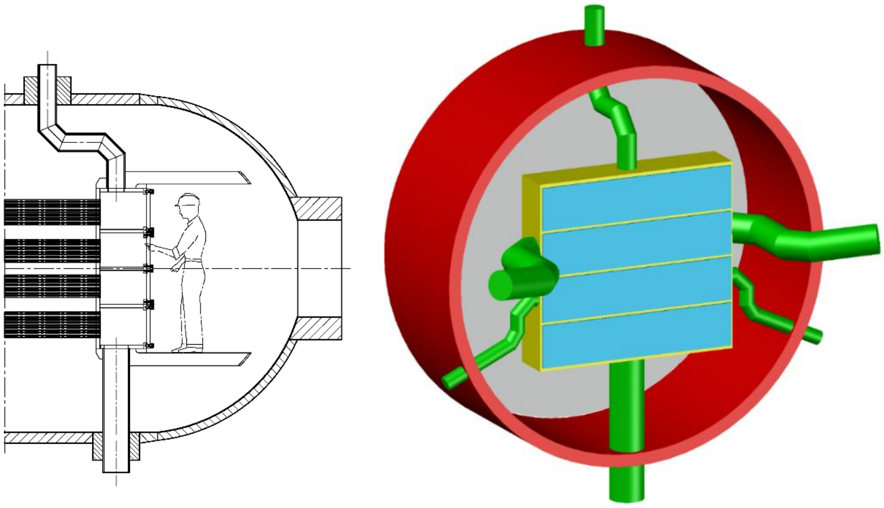

Figure 4: Accessibility of internal distribution box including covers.

A special sealing system on internal covers has been developed to withstand the different operating conditions of all distribution box compartments.

Piping elbows can be made either from segments (mitered) or from bent pipes, depending on the equipment size. The pool reactor is designed according to the standard design rules in combination with design by analysis, such as with help of the Finite Element Analysis (FEA) methodology. In addition, a Computation Fluid Dynamic study was performed to investigate the behavior of the MP outlet flow inside the pool reactor.

4.2 Mechanical design: Second generation

Stamicarbon recognized the need to create an alternative ULE concept in order to implement the ULE process in plants with capacities exceeding 2500 MTPD. For these larger plants, the first-generation concept was not feasible due to construction limitations.

The second-generation pool condenser or pool reactor is based on the proven design found in Stamicarbon's conventional Pool Condenser technology, which features a carbon steel tube sheet connected to the pressure shell. The dual U-bundle is connected to the tube sheet at the back side using internal bore welding (IBW), like in the conventional pool condenser. In the new design, the tube sheet has a stainless-steel weld overlay on both the back side facing the HP synthesis shell and the tube side where the medium process stream enters the MP carbamate bundle. Furthermore, the tube holes that facilitate the MP carbamate process flow need to be protected from corrosion with a stainless-steel corrosion barrier. This protection is achieved by installing stainless steel sleeves in the tube sheet holes, which are monitored by a leak detection system.

The conceptual layout of the second-generation pool condenser with a dual bundle is shown in Figure 5.

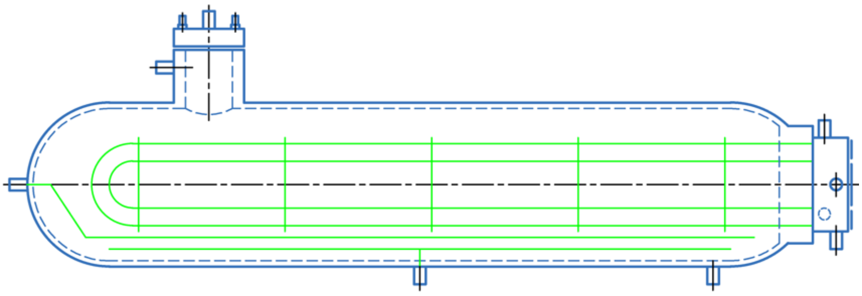

Figure 5: Conceptual layout of the ULE pool condenser.

As shown in Figure 5, the distribution box is now located outside the vessel, directly attached to the tube side of the tube sheet. Removable covers and internal parts make the tube sheet fully accessible for inspections and maintenance activities.

In addition, a special sealing system on the distribution box covers has been developed for this design to withstand different operating conditions of all vessel compartments. The design of the gasket configuration has been verified using FEA. Furthermore, an additional hydro test performed during the manufacturing process validated the seal tightness of the distribution covers by simulating the deformation of components as anticipated in operating conditions.

For this purpose, Stamicarbon predefined the load cases for the entire FEA model, including the loading sequence for this detailed design of the equipment. Below are concept drawings showing the configuration of the tube sheet and the distribution box.

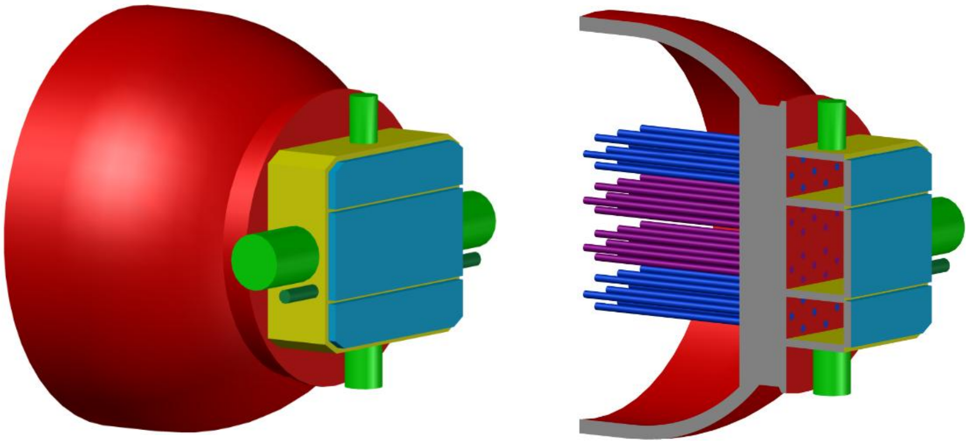

Figure 6: Concept drawings of the tube sheet and distribution box.

Inspection requirements defined for all critical parts formed a basis for the inspection and testing plans during equipment fabrication. In addition, special efficient NDT techniques have been developed for critical components and welding connections at the tube sheet and distribution box to validate and secure the integrity and reliability of the vessel. For instance, a sophisticated UT scanning method has been developed for checking the critical sleeve welds, as shown in Figure 7. Furthermore, repair and plugging options are designed and tested thoroughly on a mock-up, resulting in workable repair procedures if required.

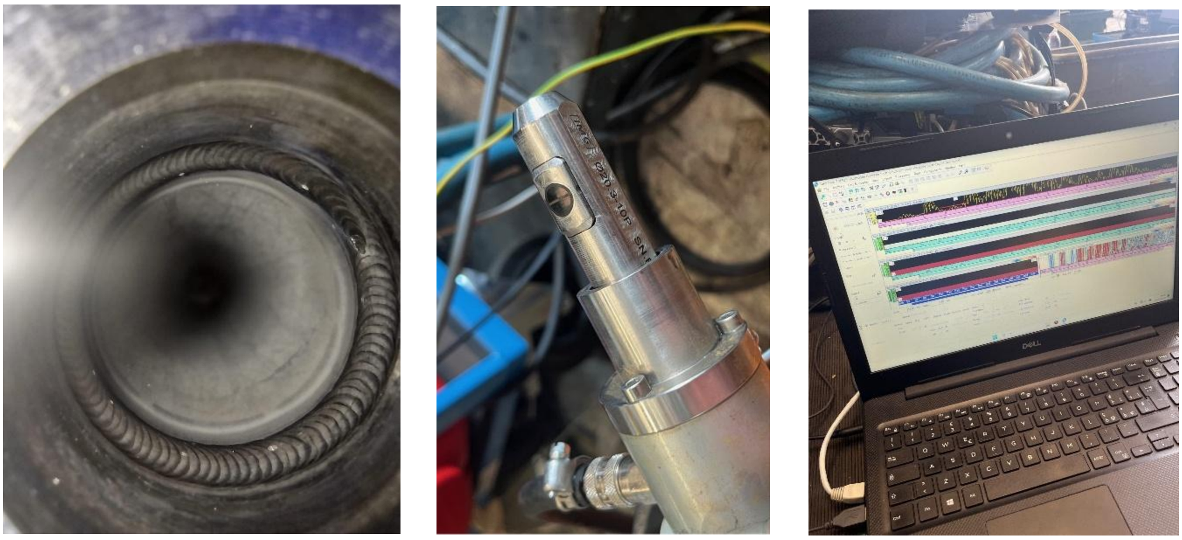

Figure 7: UT scanning sleeve weld; left: IBW weld of sleeve, middle: UT probe, right: UT c-scan.

The fabrication (welding) technologies, inspection (NDE) methods, fabrication sequence, and inspection and test plan (ITP) for the second-generation ULE pool condenser were developed in close cooperation with the equipment manufacturer. This approach ensured an efficient fabrication process, high quality and reliability of the new design, and optimized equipment delivery time. All potential risks for the development and fabrication of this second-generation ULE Pool Condenser were identified by a so-called quantitative risk assessment conducted at the start of the project. Based on this study, effective mitigation actions were defined and implemented during the execution of the project, ensuring its smooth execution.

5 OPERATIONAL EXPERIENCES

Six ULE urea plants in China and Turkey went into operation successfully since the beginning of 2021 until the date of this paper, including Jiujiang XLX (XLX-1), Sanning, Runyin, Henan XLX (XLX-2), Gemlik and Jiujiang XLX-3. Nameplate capacities of the operational plants vary between 1640 MTPD and 3850 MTPD. Three additional ULE pool reactors for grassroot plants in China are in the manufacturing phase.

The picture below shows the first second-generation pool condenser for the ULE Design ready for transport.

Figure 8: First manufactured second-generation pool condenser for the ULE Design ready for transport.

Operational plant staff from several customers received training by means of a toolbox session during the pre-commissioning of the plant. They received detailed instructions about design peculiarities, inspection details, and start-up preparations for the equipment. Furthermore, a Risk-Based Inspection program dedicated to the ULE pool reactor and ULE pool condenser has been developed. It defines inspection locations and inspection techniques and should be executed during the regular planned turnarounds.

All ULE plants have been running stably since they began operation. Targeted energy savings were within expectations and are further elaborated in the paper "Operational experiences with Ultra-Low Energy plant" presented during this symposium.

6 CONCLUSIONS

To date the ULE plant concept has already licensed ten times. The following six grassroot plants in China and Turkey have been operating successfully since the start-up of the first two plants in 2021:

- Jiujiang XLX-1, China
- Sanning, China
- Runyin, China
- Henan XLX-2, China
- Jiujiang XLX-3, China
- Gemlik, Turkey

The nameplate capacities of the licensed ULE plants vary between 1640 MTPD and 3850 MTPD. The plants are running stably, meeting the targeted energy savings. Three additional grassroot plants based on the ULE concept are currently in the construction phase.

The successful commissioning and stable operation of the first ULE plants validated the mechanical design of the first-generation ULE pool reactor. For larger plant capacities, the stable operation of XLX-3 urea plant proves the process and mechanical concept of the second-generation design. This new design fully employs the superior corrosion-resistant properties of E-type steel, leveraging vast experience with Stamicarbon's conventional Pool Condenser technology. The internal parts of the distribution box are easily accessible for maintenance and inspection purposes.

7 REFERENCE DOCUMENTS

- Stamicarbon Symposium 2022 paper “Mechanical aspects of the pool reactor for the Ultra-Low Energy plant,”
- Nitrogen and Syngas 2024 paper “Mechanical design of the second-generation ULE reactor for large-capacity urea plants,”
- Stamicarbon symposium 2026 paper “Operational experiences with Ultra-Low Energy plant.”

Stamicarbon B.V.

REGISTERED OFFICE
Mercator 3, 6135 KW Sittard,
The Netherlands
P.O. Box 53 - 6160 AB Geleen
P +31 46 4237000
F +31 46 4237001

a.scheerder@nextchem.com
Principal Engineer

m.wagemans@nextchem.com
Senior Mechanical Engineer

k.lakhe@nextchem.com
Mechanical Inspector

stamicarbon.com

STAMICARBON
NEXTCHEM Sustainable Technology Solutions

NEXTCHEM