NX STAMI™ UREA ADIABATIC FLASH DESIGN 2.0

STAMICARBON

NEXTCHEM
MAIRE Sustainable Technology Solutions

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1 ABSTRACT

Stamicarbon, the nitrogen technology licensor of NEXTCHEM (MAIRE Group), has consistently pioneered urea process technologies that have become industry benchmarks, recognized for their reliability, energy efficiency, and innovative design. Over time, the process concept has evolved with variations in synthesis loop configuration, but in recent decades the focus has increasingly shifted toward plant concepts that enhance energy efficiency and reduce environmental impact. In response, Stamicarbon has developed a suite of advanced designs under the NX Stami™ Urea portfolio, including Adiabatic Flash Design, Adiabatic Flash Design 2.0, and Ultra-Low Energy Design. These configurations significantly reduce the overall steam consumption with minimal modifications to the traditional NX Stami™ Urea Pool Condenser Design (formerly known as Urea 2000plus®), aligning with modern sustainability and energy optimization goals.

Notably Adiabatic Flash Design 2.0 is the second generation of Adiabatic Flash Design and has been successfully implemented in both grassroots[1] and revamping[2] projects. This design builds upon the proven performance of its predecessor while incorporating further enhancements in energy integration and process intensification, making it a benchmark for high-capacity, low-energy urea production design.

Adiabatic Flash Design 2.0 demonstrates a substantial improvement in energy efficiency, achieving extracted HP steam consumption levels of about 610 kg/ton of product (at 23 bara, 330 °C) considering granulated product. This represents a significant reduction compared to the traditional Pool Condenser configuration, which typically requires ≤ 870 kg/ton, and the former Adiabatic Flash Design, which consumes approximately about 760 kg/ton of granules (at 23 bara, 330 °C). However, the Ultra-Low Energy Design – Stamicarbon's most recent and advanced design – achieves the lowest high-pressure steam consumption overall due to its extensive heat integration, typically around 540 kg/ton of granules (at 23 bara, 330 °C).

This paper outlines the key process design enhancements introduced in Adiabatic Flash Design 2.0 relative to the first-generation Adiabatic Flash Design, alongside operational insights from grassroot Adiabatic Flash Design 2.0 urea plants currently in operation. A comparative evaluation of critical performance metrics, including steam consumption and product quality, is also provided, highlighting the design's advantages in terms of energy efficiency and operational performance.

2 INTRODUCTION AND BACKGROUND

Stamicarbon has a longstanding reputation for advancing urea process technologies that balance operational efficiency, environmental performance, and economic viability. Among its most recent developments is the Adiabatic Flash Design 2.0, a next-generation urea synthesis concept that builds upon the original Adiabatic Flash Design and well-established Pool Condenser and Pool Reactor configurations (formerly known as Urea 2000plus®).

Adiabatic Flash Design 2.0 introduces a paradigm shift in energy integration by intentionally reducing the high-pressure (HP) stripper's efficiency. This counterintuitive approach significantly lowers steam consumption in the HP stripper, while aligning low-pressure (LP) steam generation with the internal demand of the melt and finishing sections. As a result, steam demand (from battery limit) for the urea process has been significantly reduced while maintaining balance in LP steam requirements for downstream sections. This process design optimization ensures that no LP steam is in excess for venting or export, thereby improving sustainability and enhancing water conservation.

The increased vapor load resulting from reduced stripping efficiency creates an opportunity for more effective utilization of process heat. Process heat integration is applied in both medium- and low-pressure recirculation sections. These are a two-stage process-to-process heat integration system. The first stage is implemented in the adiabatic flash step, operated at medium pressure, where the condensation of

[1] *Xinjiang Xinji Energy Chemical Co. Ltd. China (3791 MTPD) and Shaanxi Shanhua Coal Chemical Industry Group Co. Ltd. China (2700 MTPD).*
[2] *Qinghai YTH international fertilizer Co. Ltd China, Linggu Chemical Co. LTD China and Hulunbeier NewGold Chemical Co. Ltd. China.*

carbamate vapor serves as the heat source for the initial evaporation stage, consistent with the original Adiabatic Flash Design. The second stage occurs in the LP section, utilizing the condensation of LP carbamate vapor to facilitate pre-evaporation. These heat integration strategies significantly reduce the demand for LP steam in the evaporation sections. All these process design optimizations utilized proven technological developments made by Stamicarbon over the years.

Adiabatic Flash Design 2.0 is now contracted for four grassroots plants. Out of these, two plants have been operational since April 2025 [3] and two are in engineering phase[4].

3 ADIABATIC FLASH DESIGN

Adiabatic Flash Design was developed by Stamicarbon in the early 2000s, aimed at improving energy efficiency and reducing capital expenditure. Since then, the concept has been licensed globally, with approximately six projects to date, including four grassroots plants and two revamp projects. Based on operational data, the design consistently meets its targets for steam consumption and product quality.

In this concept, a compact in-line adiabatic flash step is introduced between the HP synthesis loop and the conventional LP recirculation section. This innovative addition enables a reduction in steam consumption of approximately 110 kg per ton of urea product compared to Stamicarbon's Pool Condenser and Pool Reactor designs. The reduction is achieved by intentionally lowering HP stripping efficiency. Since the HP stripper uses most of the HP steam in the urea plant, reducing its efficiency allows the condensation of the strip gas – either in the pool condenser or pool reactor – to generate only the amount of LP steam required by the plant. This approach minimizes, or even eliminates, excess LP steam production.

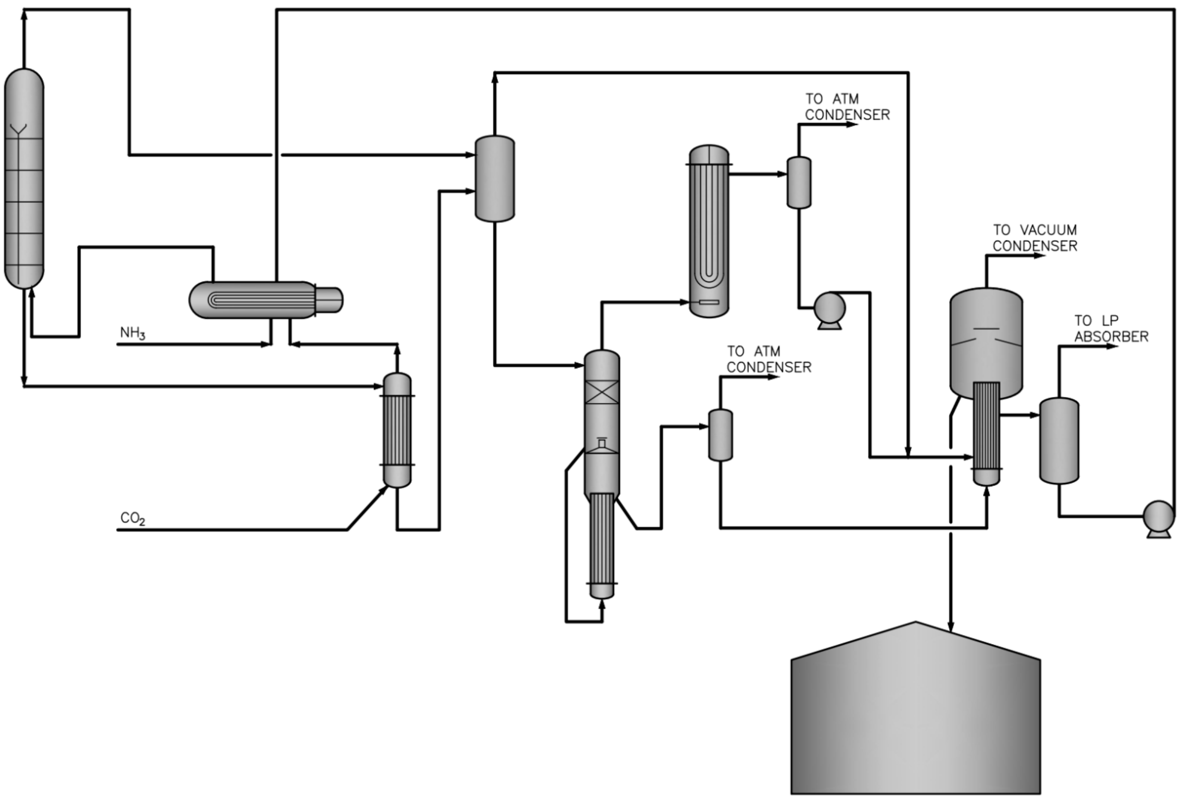


Figure 1: Adiabatic Flash Design scheme without HP scrubber.

[3] *Xinjiang Xinji Energy Chemical Co. Ltd. China (3791 MTPD) and Shaanxi Shanhua Coal Chemical Industry Group Co. Ltd. China (2700 MTPD).*
[4] *Genesis Fertilizers Project, Canada (2500 MTPD) and Celsia, Colombia (140 MTPD).*

The typical process configuration of the Adiabatic Flash Design is illustrated in Figure 1. For further details on this concept, refer to the paper by Meijboom, P. and Dieltjens, L. presented at the Stamicarbon Symposium 2022: “Experiences with LAUNCH MELT™ Flash Design.”

In this configuration, the urea solution from the HP stripper is flashed adiabatically at around 25 bara in a flash separator. The flashed vapors are directed to the shell side of a pre-evaporator/medium-pressure carbamate condenser (MPCC), where their heat of condensation is used to concentrate the urea solution on the tube side. Efficient heat integration reduces the need for LP steam for water evaporation, enabling urea concentration to reach about 80 wt%. The resulting MP carbamate from the shell side contains relatively lower water concentration, about 20 wt%. MP carbamate is recycled back to the synthesis loop using an HP carbamate pump without affecting the conversion in the synthesis section. The urea solution from the flash separator is then sent to the LP recirculation section operating at about 4.5 bara. The off gas from the shell side of pre-evaporator/MPCC is scrubbed in the LP absorber before being vented or further treated.

A key advantage of this design is its potential to eliminate the need for an HP scrubber, unless further purification of the inert off-gas leaving the synthesis section is deemed essential. In this configuration, the pre-evaporator or the MPCC performs the function of condensing ammonia and CO_2 from the reactor off-gas, effectively replacing the HP scrubber. This simplification reduces the number of HP equipment items, such as the HP scrubber, cooling water circulation pump, HP ejector, and associated HP piping, thereby lowering both CAPEX and OPEX.

Various implementations of the former Adiabatic Flash Design, both for revamping and grassroots applications, are discussed in the paper by Meijboom, P. and Dieltjens, L. “Experiences with LAUNCH MELT™ Flash Design.”

4 ADIABATIC FLASH DESIGN 2.0

Adiabatic Flash Design 2.0 represents the next generation of the Adiabatic Flash Design, developed to further enhance energy efficiency in Stamicarbon’s CO_2 stripping plants. The primary objective of this concept is to achieve a significant reduction in overall (specific) steam consumption compared to Pool Condenser/Reactor Design and other conventional Stamicarbon CO_2 stripping technologies, while maintaining compatibility with existing plant configurations.

Although the original Adiabatic Flash Design offers improved energy performance over the Pool Condenser/Reactor Design, its heat integration is limited to the MP section. This limitation restricts the potential for further reduction in overall steam consumption. A detailed evaluation of the thermal energy distribution across both the MP and LP sections revealed that a considerable amount of recoverable heat remains available in the LP section, where process temperatures range from 80 to 120 °C. This observation led to the development of an additional process-to-process heat integration strategy within the LP section.

In Adiabatic Flash Design 2.0, instead of condensing LP vapors in a single low-pressure carbamate condenser (LPCC), two heat exchangers are installed in series. The first unit, referred to as LP pre-evaporator (or pre-LPCC), utilizes part of the carbamate condensation heat present in LP vapors by condensing on the shell side to perform the pre-evaporation of water from the urea solution on the tube side. The second unit completes the condensation process in a manner consistent with the traditional configuration used in existing Stamicarbon CO_2 stripping plants. This staged condensation approach not only enhances energy recovery but also ensures compatibility with proven operational practices, thereby maintaining process reliability while improving overall efficiency.

The process scheme thus incorporates two levels of process-to-process heat integration:

- **MP section**: Retains the former Adiabatic Flash Design configuration, where the condensation heat from MP carbamate vapors is used for evaporating the urea solution in the first-stage evaporator.
- **LP section**: Introduces a new integration step, where LP carbamate vapors condensation is used to pre-evaporate the urea solution.

In the LP pre-evaporator, the operating pressure is elevated to increase the condensation temperature, thereby enhancing heat transfer efficiency. This heat is used to raise the urea solution concentration to about 77–80 wt%. Subsequently, the heat of condensation from the MP carbamate condenser is employed in the first stage of evaporation, further concentrating the solution to around 90–93 wt%.

The overall process configuration of Adiabatic Flash Design 2.0 is illustrated in Figure 2.

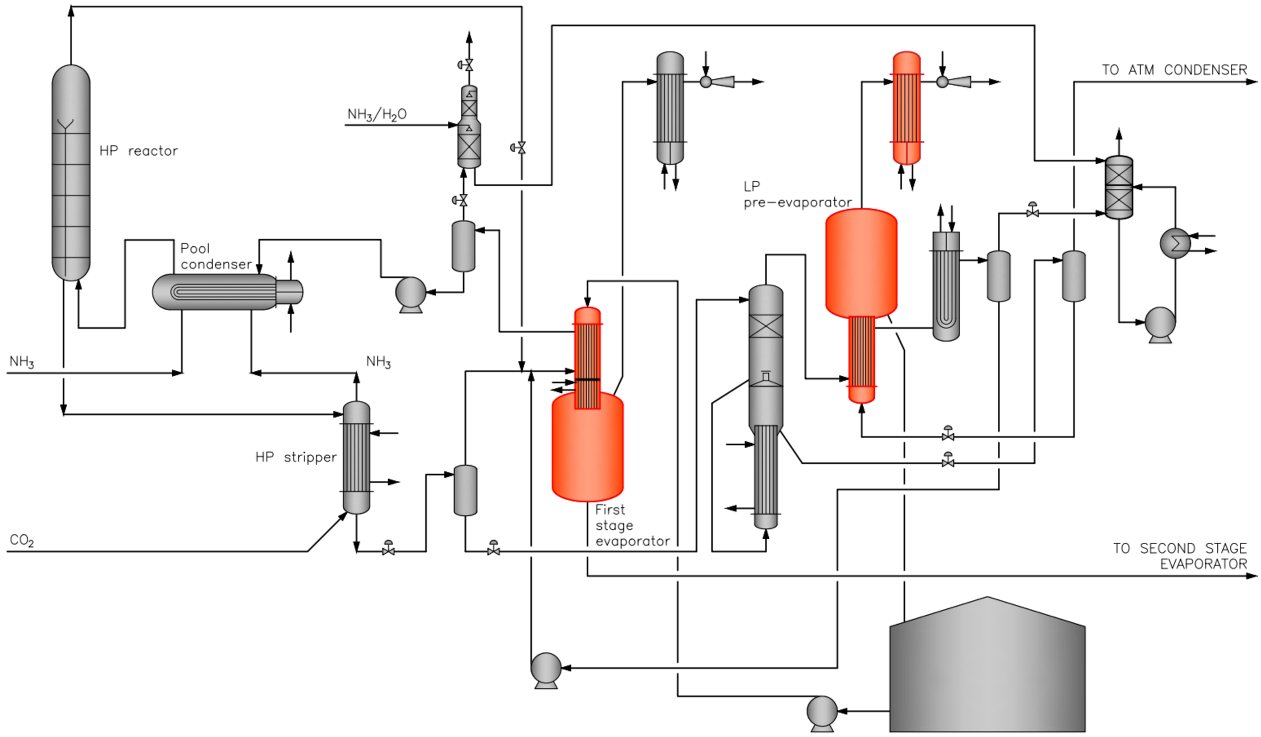


Figure 2: Adiabatic Flash Design 2.0 scheme.

4.1 Basics of Adiabatic Flash Design 2.0

In traditional urea synthesis processes, the thermodynamic design follows an N=2 heat integration concept, where HP steam is utilized twice: first as a heating agent in the HP stripper to achieve efficient stripping and then recovered by condensing the stripping gas in the HP pool condenser/reactor to generate LP steam. This LP steam, typically between 4.5-5.5 bara, is used downstream for purification and concentration of the urea product. In the case of Pool Condenser and Pool Reactor concepts, any excess LP steam may be used to power turbines, exported to other plants, or vented. However, as explained above, in both former Adiabatic Flash Design and Adiabatic Flash Design 2.0, the generation of excess steam is minimized or even eliminated through more efficient heat integration. Adiabatic Flash Design 2.0 builds upon the novel concept by implementing an N=3 heat integration scheme in the MP and LP sections. The heat of condensation from MP carbamate dissociation vapors in an adiabatic flashed separator is utilized to concentrate the urea solution in the evaporation section. Meanwhile, LP vapor generated in the LP section is utilized to pre-concentrate the urea solution. This approach significantly enhances overall energy efficiency and process integration.

Moreover, the integration of process-to-process heat exchange at the MP and LP pre-evaporators contributes to a noticeable reduction in cooling water demand compared to traditional Pool Condenser and Pool Reactor configurations.

The table below outlines the key parameters of the HP synthesis section, comparing three design concepts to highlight their primary differences, specifically focusing on the Adiabatic Flash Design 2.0 and the former Adiabatic Flash Design within a traditional Pool Condenser Design plant.

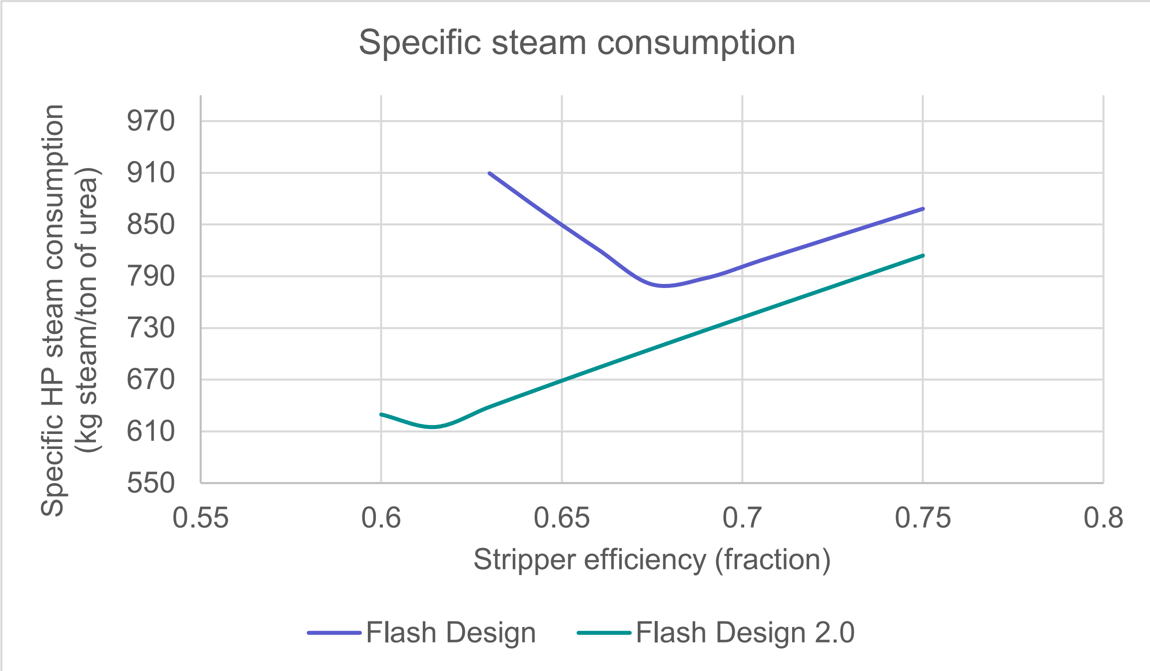
	Pool Condenser Design	Adiabatic Flash Design	Adiabatic Flash Design 2.0
Stripping efficiency, %	78	68	**62**
Ammonia concentration, wt %	8.6	12.2	15.0

Table 1: Stripper operation as key variable for Adiabatic Flash Design 2.0 compared to other process designs with reactor total pressure of 144 kg/cm^{2}a.

From Table 1, it can be observed that the significant difference is the stripper efficiency, which refers to the extent of ammonia conversion occurring downstream of the stripper. It is determined by calculating the proportion of ammonia transformed into urea/biuret relative to the total ammonia feed, expressed on a molar basis. As the process design evolves from the traditional Pool Condenser concept to Adiabatic Flash Design and subsequently to Adiabatic Flash Design 2.0, the stripping efficiency intentionally decreases from 78% to 68%, and then to 62%, respectively. This reduction leads to an increased recycle of carbamate back to the reactor, though it does not significantly compromise the overall process performance.

Although implementing Adiabatic Flash Design 2.0 leads to a relative reduction in synthesis efficiency – evidenced by reduced stripping efficiency – it achieves a notable improvement in overall energy performance. Specifically, the consumption of HP steam by the HP stripper, which accounts for most of the steam usage, is reduced compared to both the Pool Condenser process and the former Adiabatic Flash Design. This reflects the core principle of Adiabatic Flash Design 2.0: strategically trading off synthesis efficiency to minimize net energy input. The overall impact on energy consumption is illustrated in Graph 1 (excluding the contribution of equivalent LP steam generated at higher stripping efficiencies given that the value of the excess LP steam is lower than the value of HP steam). A similar trend can be observed in the former Adiabatic Flash Design, though the absolute energy savings are less pronounced than in Adiabatic Flash Design 2.0.

Adiabatic Flash Design 2.0 has significantly lower optimal stripping efficiency compared to the Pool Condenser process and the former Adiabatic Flash Design, so the HP stripper operates at a lower steam pressure on the shell side. This results in a shell temperature reduction of more than 10-15°C (especially compared to the Pool Condenser Design). Lower shell temperature substantially decreases passive corrosion effect, thereby extending the operational lifetime of the HP stripper. Consequently, in such plant configurations, the stripper's service life is no longer limited by the durability of the heat exchanger tubes. In fact, with the shell temperature reduced by over 10°C, the corrosion rate of the stripper tubes is significantly lowered, making it the least critical corrosion concern in the overall design.



Graph 1: Specific steam consumption as a function of stripper efficiency for a typical former Adiabatic Flash Design and Adiabatic Flash Design 2.0 (at HP steam of 330°C and 23 bara).

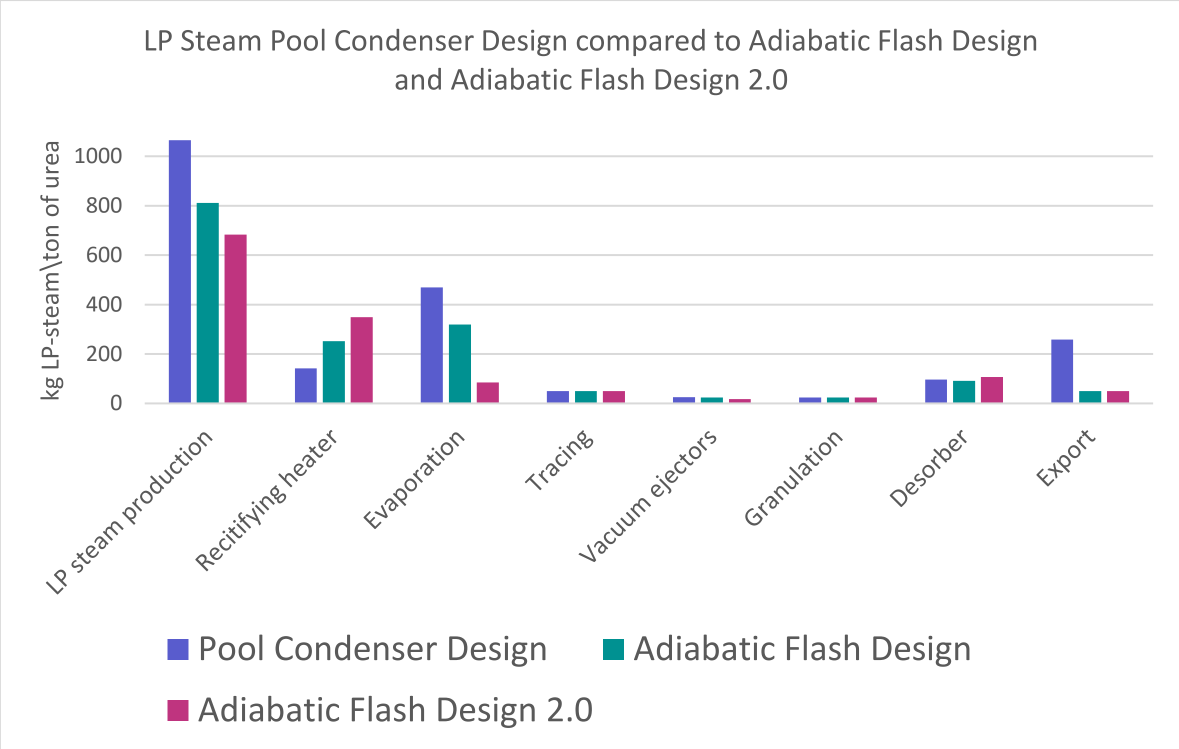
4.2 LP steam generation and consumption dynamics

As described above, Adiabatic Flash Design focuses on optimizing LP steam production and consumption. When LP steam production exceeds plant demand, the excess is typically vented or condensed in the atmospheric steam condenser, which is common in traditional CO_2 stripping designs.

Since LP steam has lower value compared to HP steam, it is more efficient to reduce HP steam use in order to minimize LP steam excess within a urea plant. In CO_2 stripping plant designs, the HP stripper is the main HP steam consumer. Lowering stripping efficiency reduces HP steam consumption at the stripper and the LP steam generated inside the pool condenser or pool reactor tubes. This also increases the carbamate load on downstream sections, especially the LP rectifying heater. The increased LP steam demand is offset by using condensation heat from flashed vapor (from the LP section and MP adiabatic flash) to pre-concentrate and concentrate the urea solution, reducing the LP steam demand for evaporation.

Graph 2 below compares LP steam production and consumption across Adiabatic Flash Design 2.0, Adiabatic Flash Design, and the Pool Condenser Design. Adiabatic Flash Design 2.0 shows significantly lower LP steam use in evaporation due to optimized heat integration, although rectifying heater demand slightly rises due to lower stripping efficiency.

Overall, Adiabatic Flash Design 2.0 minimizes LP steam export and reduces HP steam import with optimized stripping efficiency and synthesis conditions. However, if LP steam export turns negative, HP steam must be imported to meet internal LP steam demand, which is an undesirable scenario. Therefore, the optimal stripping efficiency ensures minimal LP steam export without triggering HP steam import.



Graph 2: An overview of LP steam production and consumption in a CO_2 stripping urea plant.

4.3 Plant concept comparison

As outlined earlier and compared to other commonly used by Stamicarbon concepts, Adiabatic Flash Design 2.0 achieves significantly lower OPEX – measured by HP steam consumption – than Pool Condenser, Pool Reactor and Adiabatic Flash Designs. However, Ultra-Low Energy (ULE) Design, Stamicarbon's latest concept, achieves the lowest HP steam consumption – approximately 540 kg/ton of urea – through advanced heat integration between the synthesis and MP section.

Regarding ISBL CAPEX, Adiabatic Flash Design 2.0 is comparable to the former Adiabatic Flash Design. While it includes a newly added LP pre-evaporator, the unit is based on a commodity heat exchanger with a lower design pressure and adds only a minor incremental cost. Overall, Adiabatic Flash Design 2.0 has lower CAPEX than the Pool Condenser and Pool Reactor Designs because it requires fewer HP equipment items. It also has lower CAPEX compared to the ULE Design, which uses more MP equipment. Further details are provided in Table 2 below.

Design concept[5]	HP Steam consumption (at 23 bara, 330°C) [kg/ton of urea granules]	Number of HP equipment items	Number of MP equipment items
Pool Condenser Design	~ 870	4 (excluding the ejector)	-
Adiabatic Flash Design	~ 760	3	4
Adiabatic Flash Design 2.0	~ 610	3	4
ULE Design	~ 540	3	6

Table 2: An overview of CAPEX and OPEX comparison.

[5] *All concepts are evaluated based on Pool Condenser configuration for plant capacities higher than 3000 MTPD.*

While the ULE concept achieves the lowest energy consumption through extensive heat integration, Adiabatic Flash Design 2.0 offers a compelling balance of efficiency and simplicity. With only minimal modifications and further optimization, Adiabatic Flash Design 2.0 can provide notable energy improvements without altering the synthesis section, thereby retaining the traditional equipment setup. Its synthesis section remains straightforward, utilizing a single-bundle pool condenser or pool reactor configuration, which is less complex than the ULE's double-bundle design. This makes Adiabatic Flash Design 2.0 an attractive option for operators seeking significant energy improvements with lower complexity. In addition, Adiabatic Flash Design 2.0 is well-suited for revamp applications, as it allows the synthesis section to remain unchanged. Further details on revamp options and applications will be explored in the following section.

4.4 Adiabatic Flash Design 2.0 as a revamp option

Adiabatic Flash Design 2.0 is a well-suited concept for plant revamping projects. It can be effectively applied to reduce overall steam consumption, debottleneck the HP stripper, and enable moderate capacity increases, with or without modifications to the existing condenser and reactor configurations in the synthesis. Applying Adiabatic Flash Design 2.0 as part of the NX Stami™ Urea Energy revamp requires a comprehensive assessment of the plant's steam system, since minimizing excess LP steam generation leads to the reduction in HP steam demand. The benefits are particularly significant when surplus LP steam cannot be fully utilized or is not integrated into the CO_2 compressor turbine.

Compared to the Pool Condenser process, Adiabatic Flash Design 2.0 offers several configuration options for plant revamps. Three representative examples are presented here; however, the optimal revamp configuration must be determined based on the specific conditions and constraints of the existing plant. By evaluating factors such as available plot space, the condition of high-pressure equipment, steam-balance characteristics, long-term capacity targets, and overall energy efficiency potential, the Stamicarbon team can identify and recommend the revamp scenario that offers the best balance of performance improvement, investment cost, and implementation feasibility. As of three typical examples, the key distinction lies in the design of the adiabatic flash step, which can be arranged either with or without the integration of off-gases from the HP synthesis section. When off-gases from the HP reactor are directed to the adiabatic flash step, the conventional HP scrubber becomes redundant. This configuration is particularly advantageous for plants where the HP scrubber is approaching the end of its service life. By eliminating both the HP scrubber and HP ejector, the HP synthesis section is simplified, the number of high-pressure components is reduced, and the extent of HP piping is minimized.

Moreover, with proper heat integration in the MP and/or LP sections, this configuration can lead to substantial energy savings, reducing steam consumption by approximately 150 to 250 kg per ton of urea produced. A typical configuration is illustrated in Figure 3, where the newly expected equipment items are highlighted in red.

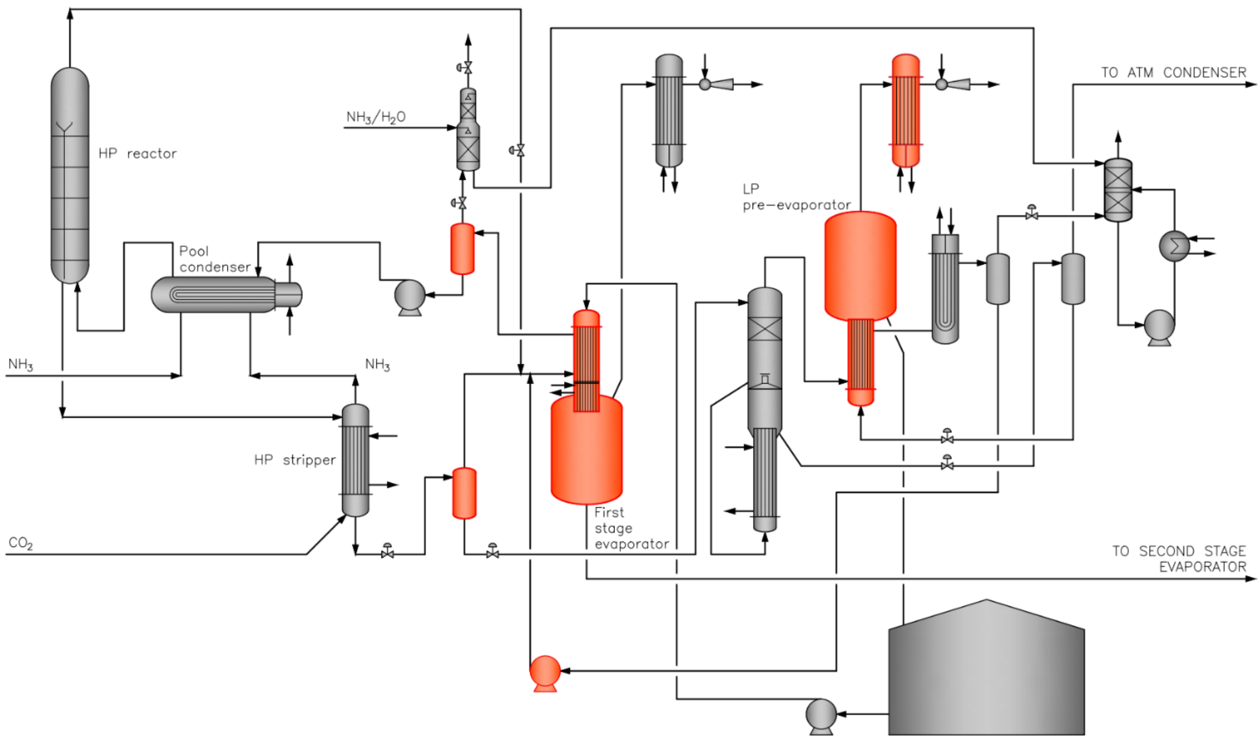


Figure 3: Adiabatic Flash Design 2.0 scheme without HP scrubber.

Alternatively, Adiabatic Flash Design 2.0 can be configured to retain the HP scrubber. In this configuration, the inert off-gas exiting the synthesis loop via the HP scrubber is further purified in an LP absorber, consistent with the Pool Condenser concept, before being released into the atmosphere (see the typical configuration in Figure 4, where the newly expected equipment items are highlighted in red).

In this configuration – aside from the primary modification of incorporating an adiabatic MP flash stage along with heat integration within both the MP and LP sections – minimal changes are required in the HP synthesis section after the revamp. As previously described, the stripping efficiency in the HP stripper is deliberately reduced. This adjustment allows for significant HP steam savings and ensures an adequate flow of carbamate gases to the MP section, where they support heat recovery in the newly introduced first-stage evaporator. The reduction in stripping efficiency is achieved by lowering the pressure on the shell side of the HP stripper.

As a result, additional carbamate must be recycled and processed within the synthesis section. To prevent overloading the HP scrubber and compromising its performance, this additional carbamate flow can be redirected to the pool condenser, bypassing the HP scrubber entirely, without compromising plant capacity or synthesis performance.

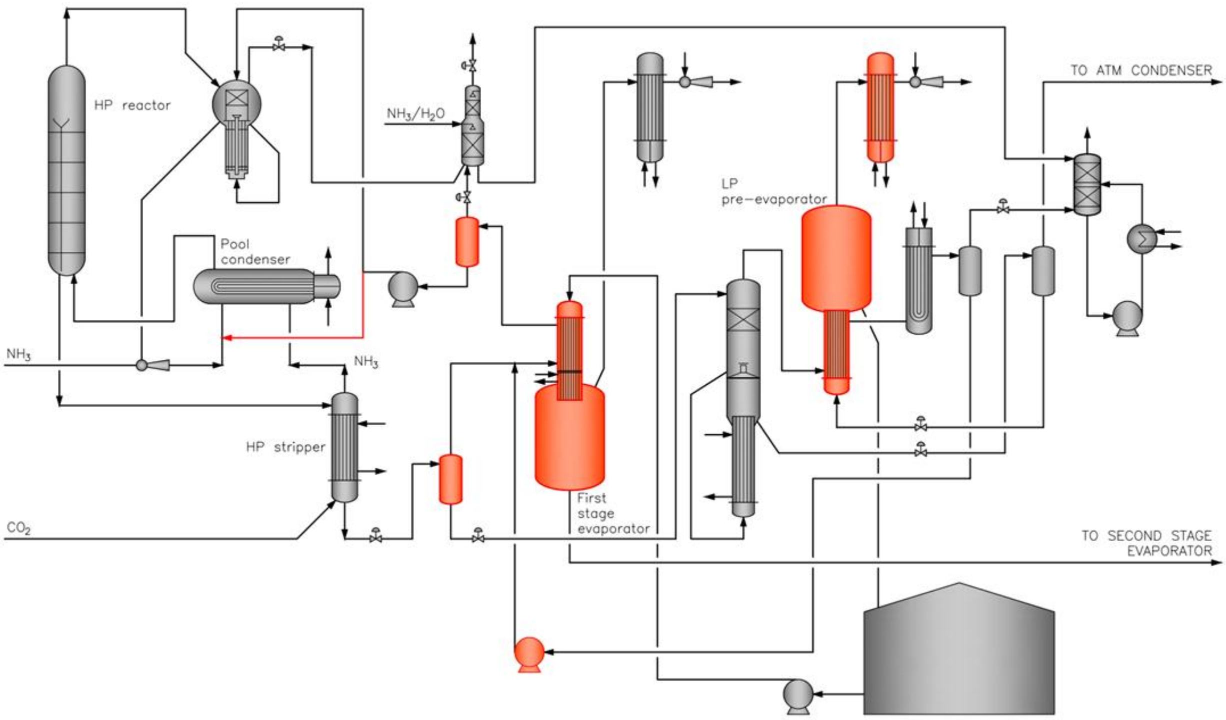


Figure 4: Adiabatic Flash Design 2.0 scheme with HP scrubber.

Furthermore, it is also possible to revamp existing Adiabatic Flash Design with the specific objective of achieving further reduction in steam consumption, thereby enhancing overall process efficiency[6].

Another common revamp option for increasing capacity while achieving energy savings is the implementation of a bypass over the stripper and HP scrubber. This approach maintains the same liquid load to the stripper and the gas/liquid load to the HP scrubber, while utilizing the existing fixed sizes of HP synthesis equipment. As no additional synthesis volume or heat transfer area is required, this concept enables both capacity enhancement and improved energy efficiency.

A detailed evaluation of the capacity of the existing compressors, pumps, and other process sections can be conducted to determine the achievable level of capacity increase and energy savings (see the typical configuration in Figure 5, where the newly expected equipment items are highlighted in red).

[6] *Qinghai YTH international fertilizer Co. Ltd China; Linggu Chemical Co. LTD China; Hulunbeier NewGold Chemical Co. Ltd. China.*

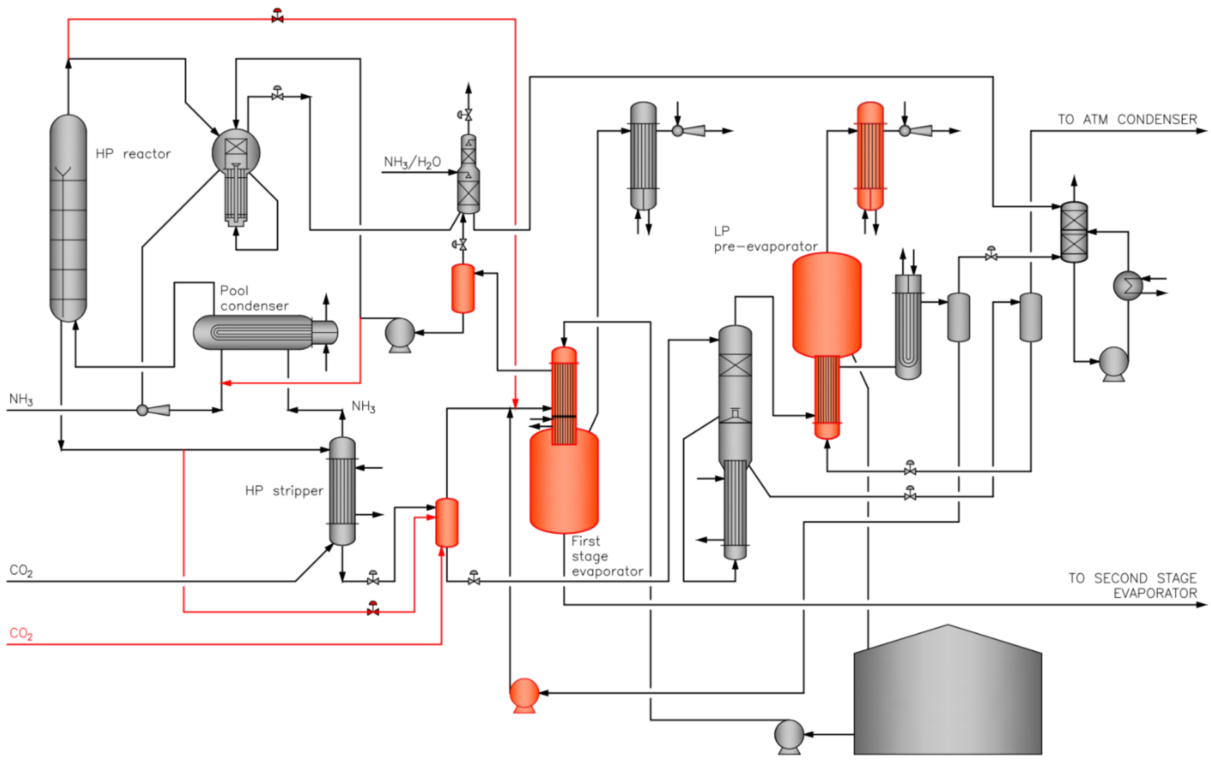


Figure 5: Adiabatic Flash Design 2.0 scheme with HP scrubber for capacity increase and energy saving option.

4.5 Adiabatic Flash Design 2.0 for large-capacity plants

Adiabatic Flash Design 2.0 has been thoroughly evaluated for large-scale applications, with capacities up to 6000 MTPD in a single synthesis line. Equipment sizing was assessed independently, while operational flexibility was analyzed using Stamicarbon's in-house Technology Training Simulator (TTS). TTS is a dynamic flow-sheeting tool for simulating plant operations, built on proprietary thermodynamic and kinetic models whose accuracy is demonstrated by numerous successful industrial references. Simulations conducted with this software have directly supported the design of multiple projects. Comprehensive internal assessments have confirmed the suitability of Adiabatic Flash Design 2.0 for HP synthesis, MP, LP, and downstream equipment.

Adiabatic Flash Design 2.0 retains the same three core synthesis components as the Pool Condenser process: a vertical reactor, pool condenser, and HP stripper. Building on the proven performance of Pool Condenser Design in plants operating at about 4300 MTPD, the synthesis section has now been validated to support capacities up to 6000 MTPD. This makes the concept suitable for the next generation of large-scale urea plants. Thorough process design and detailed internal evaluations at this scale confirm the robustness and scalability of Adiabatic Flash Design 2.0, ensuring its readiness for commercial deployment.

4.6 Operational experiences with Adiabatic Flash Design 2.0

Currently, four plants are operating with the Adiabatic Flash Design 2.0 configuration, including two grassroots and two revamp projects. The grassroots plants have been operating since April 2025, with smooth startups and no major issues reported.

In grassroot projects[7], Adiabatic Flash Design 2.0 offers significant advantages, including reduced HP steam consumption, which lowers OPEX, and a simplified setup with fewer HP components. The design also minimizes excess LP steam, allowing full utilization of HP steam savings. As a result, a proven specific HP steam consumption as low as 610 kg/ton of urea granules has been achieved (at normalized HP steam

[7] *Xinjiang Xinji Energy Chemical Co. Ltd. China (3791 MTPD) and Shaanxi Shanhua Coal Chemical Industry Group Co. Ltd. China (2700 MTPD).*

conditions of 23 bara and 330 °C). This represents approximately a 32% reduction in HP steam consumption compared to the Pool Condenser plant concept. Meanwhile, in revamping scenarios Adiabatic Flash Design 2.0 typically achieves a 15–25% reduction in HP steam consumption, further demonstrating its efficiency benefits across different project types.

Operational data from all four plants confirm consistent performance improvements over traditional NX Stami™ Urea CO_2 stripping designs. Some actual DCS screens from operation are shown in Figure 6. The inclusion of an adiabatic flash vessel with integrated MP and LP heat recovery helps buffer synthesis disturbances before they affect the LP section. Vapors from the flash vessel are routed to the first-stage evaporator, while the LP flash vapors are sent to the LP pre-evaporator (partly condensing the LP vapors), minimizing downstream disruptions. As a result, fluctuations in reactor N/C ratio, stripping efficiency, and plant load have a reduced *impact on plant stability.*

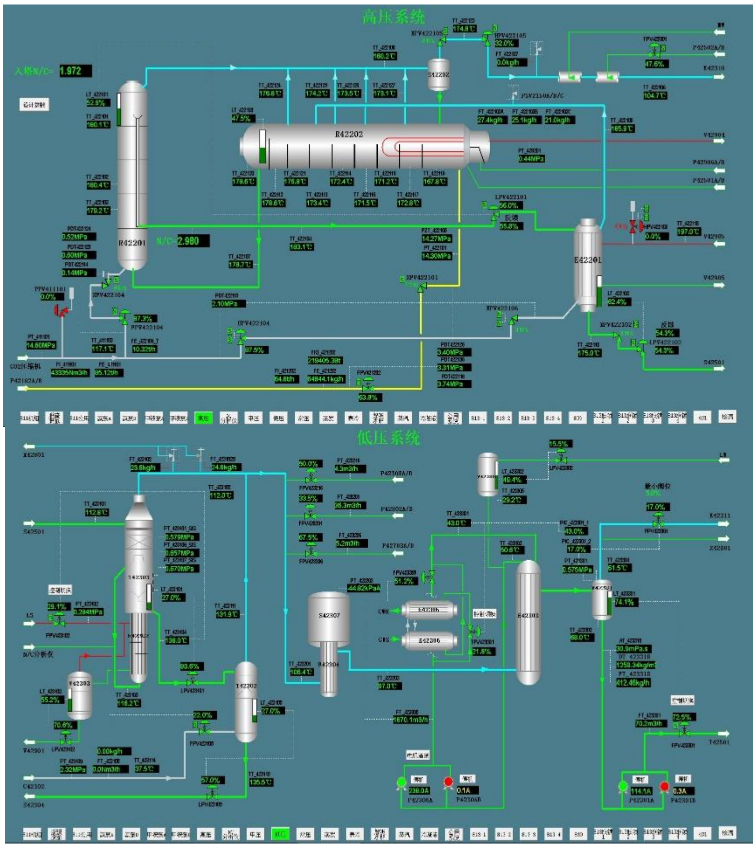


Figure 6: DCS screenshots of Shaanxi Shanhua urea plant from 100% plant load operation based on a low-elevation synthesis concept including the LP (process-process heat exchanger) section.

Beyond energy efficiency, Adiabatic Flash Design 2.0 also enhances operability and product quality. The process achieves lower biuret levels in the final urea product (<0.80 wt%), representing a reduction of more than 0.05 wt% compared to traditional processes. This improvement is attributed to milder operating conditions in the stripper and optimized heat exchange between process streams in the first-stage evaporator and LP pre-evaporator. Specifically, the shell-side steam temperature in the HP stripper is approximately 10-15 °C lower than in conventional designs, resulting in milder process conditions. This not only reduces biuret formation but also extends the operational life of the CO_2 stripper.

Considering ISBL CAPEX, the overall cost of Adiabatic Flash Design 2.0 is equivalent to the former Adiabatic Flash Design and lower than the traditional Pool Condenser and Pool Reactor Designs, as the comparison is driven by the lower number of HP equipment items and reduction in HP pipelines. The additional LP and MP equipment items are based on standard materials of construction following Stamicarbon material specifications and do not significantly contribute to equipment cost.

5 CONCLUSION

To date, Adiabatic Flash Design 2.0 plant concept has been licensed six times, for both grassroots and revamping projects. Notably, two grassroots plants in China, Xinji and Shanhua, have been successfully operating since April 2025, with production capacities of 3791 MTPD and 2700 MTPD, respectively. These plants demonstrate the full optimization of the design, operating stably and achieving targeted energy savings. Additionally, two more grassroots plants are currently in the engineering phase.

Operational data from Chinese plants confirms that Adiabatic Flash Design 2.0 achieves a reduction in steam consumption of approximately 32% compared to the traditional Pool Condenser and Pool Reactor Designs. In terms of OPEX, expressed as HP steam consumption, Adiabatic Flash Design 2.0 positions itself between the standard Pool Condenser and Pool Reactor Designs and the ULE Design. Furthermore, the integration of process-to-process heat exchange at the MP and LP pre-evaporators reduces cooling water consumption by approximately 15% compared to the traditional Pool Condenser and Pool Reactor Designs.

From a CAPEX standpoint, Adiabatic Flash Design 2.0 offers a more cost-effective solution compared to the Pool Condenser and Pool Reactor Designs, primarily due to the elimination of the HP scrubber, HP piping and a reduced number of MP equipment items.

In addition to energy efficiency, Adiabatic Flash Design 2.0 also delivers notable improvements in product quality like the advantages of ULE Design. Specifically, the biuret concentration in the final product is reduced by approximately 0.05 wt% compared to traditional stripping processes. This enhancement is attributed to the unique process characteristics of Adiabatic Flash Design 2.0: milder operating temperatures in the stripper, resulting from lower shell-side steam pressure, and effective process-to-process heat exchange in the first-stage evaporator and LP pre-evaporator sections. Furthermore, the lower shell-side steam temperature of the HP stripper contributes to reduced passive corrosion, thereby extending the equipment's operational lifetime.

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