OPERATIONAL EXPERIENCE WITH HIGH-PRESSURE EQUIPMENT IN A STAMICARBON UREA PLANT

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PPL Mangalore

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ABSTRACT

The ammonia and urea plants at PPLM were commissioned in 1976 with design capacities of 660 TPD and 1,030 TPD, respectively. The urea plant is based on Stamicarbon's CO_2 stripping process. Over more than four decades of operation, the plant has undergone multiple revamps and debottlenecking initiatives aimed at increasing capacity, improving reliability, and enhancing on-stream performance. This paper discusses the historical revamps and capacity enhancements, as well as long-term operating experience with a high-pressure stripper fabricated from Safurex® Infinity. It further covers the subsequent manufacture and replacement of the stripper with a Safurex® Star unit, along with operational feedback on liquid divider assemblies of welded construction and Hot Isostatic Pressed (HIP) designs.

INTRODUCTION

Paradeep Phosphates Limited (PPL) is one of India's largest private-sector fertilizer producers, with an installed capacity of 3.2 MTPA of phosphatic fertilizers and 0.9 MTPA of urea. The company operates four manufacturing units located at Paradeep (Odisha), Zuarinagar (Goa), Mangaluru (Karnataka), and Mahad (Maharashtra). PPL is promoted by Zuari Maroc Phosphates Pvt. Ltd. (ZMPPL), a joint venture equally held by Zuari Agro Chemicals and OCP Group of Morocco, with ZMPPL holding a 50.31% stake in PPL.

PPL has a strong market presence, serving over 12 million farmers through a robust distribution network of more than 110,000 retailers across 18 states in India. The company is a pioneer in promoting high nutrient use efficiency (NUE) products, including biogenic Nano Shakti DAP and Nano Urea, along with organic products and soil conditioners.

The Mangaluru unit (PPLM), formerly known as Mangalore Chemicals & Fertilizers Limited, was merged into PPL in October 2025. The main products at PPLM are Urea, Di-Ammonium Phosphate (DAP), Ammonium Phosphate Sulphate (Grade 20:20:00:13), Ammonium Bi-Carbonate (ABC) - Food grade, Sulphuric Acid, Specialty fertilizers and Nutrient products consisting of Water-Soluble Fertilizers, Micronutrients & Soil Conditioners and Sulphonated Naphthalene Formaldehyde (SNF), an industrial product.

Urea Plant Historical revamps:

The urea plant at PPLM was designed by Stamicarbon based on its CO_2 stripping process and was commissioned in 1976 with an original capacity of 1,030 tpd.

The first major revamp was carried out during 1999–2001 in two Phases spread across annual turn arounds of the plant. In the first phase, the urea reactor was relined with SS 25-22-2 material, and the existing reactor trays were replaced with Stamicarbon's new high-efficiency tray design.

The second phase of revamp executed in 2001. The LP scrubber (V1203) was replaced with a new modified design, and a new design reflux condenser, along with its associated tank and cooler, were installed to reduce ammonia vent losses. In the urea hydrolyser section, the internals of both the hydrolyser and desorption columns were replaced with newly designed trays to improve column performance. A pre-evaporation section was added to reduce the load on the existing first- and second-stage evaporators, and the old ejectors were replaced with new, higher-capacity units. Additionally, a new low-pressure condenser was installed in series with the existing condenser to share the condensation load of the low-pressure section and reduce vent losses. A modified prill bucket was installed to improve product quality. The liquid distribution systems in the high-pressure carbamate condenser and high-pressure stripper were upgraded.

The revamp has increased capacity from 1030 t/d to 1290 t/d and improved reliability of the plant.

In 2004, the pneumatic control system was replaced with a distributed control system (DCS). An online N/C meter and a water-in-carbamate analyser were also installed.

Further revamps were undertaken in 2006 to enhance plant safety and reliability. A medium-pressure (MP) scrubbing system was introduced, including the installation of a new MP scrubber, MP condenser and level tank, MP carbamate pumps, and MP flush pumps. A new high-pressure stripper fabricated from advanced Safurex® Infinity material was installed, along with a new higher-capacity high-pressure carbamate pump. In addition, a pair of hydrogen converters was installed at the CO_2 compressor discharge to convert hydrogen in the CO_2 stream to water, thereby preventing hydrogen accumulation in the system. The LP scrubber was also relocated from the prill tower top to a new elevation at 20.0 meters.

High-Pressure Stripper Replacement

The HP stripper enables efficient carbamate decomposition, minimizing recycle, improving urea yield, and ensuring energy-efficient and reliable operation of the entire synthesis loop. The High-Pressure (HP) stripper is one of the most critical proprietary high-pressure equipment items in a Stamicarbon CO_2-stripping urea plant. It is supplied and licensed by Stamicarbon B.V., The Netherlands, and plays a decisive role in plant capacity, reliability, and corrosion performance. Over the plant lifetime, the HP stripper has undergone major replacement phases, which are described below.

Original HP Stripper (1976–2006)

The original HP stripper (H1201), installed at the time of plant commissioning, remained in service from inception until 2006.

Design and Fabrication Details

- **Vessel manufacturer:** Rheinstahl, Germany
- **Year of fabrication:** 1974
- **Tube material:** X2CrNiMoN 25.22.2 (Stamicarbon specification BC.05)
- **Tube manufacturer:** Sandvik, Sweden (Type 2RE69)
- **Tube dimensions:** 32 mm OD × 25 mm ID
- **Number of tubes:** 1,680
- **Liquid divider holes:** 3 holes of 2.3 ± 0.05 mm
- **Channels, covers, and tube sheets:** Overlay welded with BC.01, nominal thickness 8 mm

During operation, progressive corrosion was observed. By 2004, a total of 39 tubes had been plugged based on inspection findings. In the same year, Stamicarbon conducted a detailed inspection and recommended plugging of an additional 48 tubes, along with complete replacement of the HP stripper, as the equipment had reached the end of its design life.

- **Average tube wall thickness:** 2.26 mm
- **Minimum measured wall thickness:** 1.45 mm
- **Average corrosion rate since installation:** 0.05 mm/year

Consequently, the original stripper fabricated with Sandvik 2RE69 material was replaced in 2006.

During the operation period of this stripper, Urea production was 0.262 million tonnes/year and a cumulative production of 7.9 million tonnes.

Safurex® Infinity HP Stripper (2006–2025)

The second-generation HP stripper incorporated significant metallurgical and design improvements using Safurex® infinity.

Design Improvements

- Change in tube and liner material from Sandvik 2RE69 (BC.05) to Sandvik Safurex® (BE.06)
- Increase in the number of tubes from 1,680 to 1,840
- Reduction in tube wall thickness from 3.5 mm to 2.5 mm, improving heat transfer efficiency
- Overall stripper redesign by Stamicarbon to accommodate these enhancements

Equipment Details

- **Vessel manufacturer:** Schoeller-Bleckmann Nitec, Austria
- **Equipment No.:** H1201
- **Year of fabrication:** 2005
- **Tube material:** Sandvik Safurex® Infinity (BE.06)
- **Tube dimensions:** 31 mm OD × 2.5 mm wall thickness
- **Number of tubes:** 1,840
- **Liner material:** Sandvik Safurex® (BE.06), 4 mm thickness

This stripper remained in service for approximately 6,000 on-stream days until its replacement in December 2025. During this period, the stripper was regularly inspected by Stamicarbon B.V. in 2008, 2010, 2012, 2014, 2017, 2020, 2022, and 2023.

During the operation period of this stripper, Urea production was 0.373 million tonnes/year and a cumulative production of 7.5 million tonnes.

End-of-Life Assessment and Replacement Decision (2022–2025)

Inspection Findings (June 2022)

During the June 2022 inspection, Stamicarbon B.V. reported the following observations:

- **Average tube wall thickness:** 1.35 mm
- **Minimum measured wall thickness:** 1.10 mm
- **Average corrosion rate since installation:** 0.07 mm/year

Based on the corrosion trend, Stamicarbon recommended plugging 300–350 tubes to ensure reliable operation for the next three years. It was also highlighted that tube plugging could accelerate corrosion in adjacent tubes and lead to further plugging requirements, resulting in a reduction in urea production capacity.

Based on these findings, replacement of the HP stripper within three years of effective on-stream operation was recommended to ensure continuous and reliable plant operation. During the October 2023 inspection, Stamicarbon recommended plugging seven tubes with wall thickness below 1.0 mm. Since the measured thickness remained above the defined retiring thickness PPLM decided to continue operation without tube plugging. However operational measures were taken to keep the corrosion rate at the minimum levels by maintaining low heat rate to the tubes. No tube leakage or tube plugging incidents were observed until the stripper was finally replaced in December 2025.

Liquid dividers: Welded construction and HIP

Liquid divider assemblies are critical components of the high-pressure (HP) stripper in a urea plant, as they directly influence stripping efficiency, corrosion behaviour, and tube life. Each stripper tube is fitted with a liquid divider assembly to ensure uniform liquid distribution and controlled flow through the tube bundle. Consequently, the condition and performance of each liquid divider assembly have a direct impact on the corrosion rate and service life of its associated tube.

Inspections conducted over several operating cycles revealed progressive deterioration of early liquid divider designs, particularly at weld seams and heat-affected zones (HAZ). The observed damage mechanisms included uniform corrosion, selective HAZ attack, pinhole formation, and enlargement of liquid distribution holes. These degradation modes adversely affected liquid distribution, leading to localized corrosion acceleration and reduced stripper reliability.

HP stripper contained a total of 1,840 tubes, each equipped with a liquid divider assembly, persistent performance and reliability issues associated with these assemblies had a cumulative and significant impact on overall stripper efficiency, tube integrity, and operating life.

Original Design and Construction

The liquid divider assembly consists of two main components: the liquid divider head and the gas tube. In the original design, the liquid divider head was manufactured in two parts and welded together. Three liquid distribution holes were drilled through the weld at angular positions of 0°, 120°, and 240°. This welded joint and the associated heat-affected zone (HAZ) later proved to be corrosion-prone areas during operation.

Inspection History and Observed Degradation (2006–2014)

The liquid divider assemblies installed during the commissioning of the Safurex® HP stripper in 2006 were inspected by Stamicarbon during multiple Annual Turn Around, with the following observations:

- **ATA 2008:**
  Liquid divider assemblies were smooth and free from corrosion.
- **ATA 2009:**
  Seven liquid divider assemblies were found corroded and replaced.
- **ATA 2010:**
  Random visual inspection by Stamicarbon revealed slight corrosion, which was assessed as negligible. Two liquid divider assemblies were replaced as a precautionary measure.
- **ATA 2012:**
  Ten liquid divider assemblies with pinholes (some exhibiting leakage) and one assembly with severe corrosion were replaced. Detailed examination revealed multiple corrosion mechanisms concentrated around the weld region, including:
    - Uniform corrosion of the weld
    - Corrosion at weld end craters
    - Selective attack of the HAZ
    - Pinhole formation
    - Selective corrosion at the weld between the liquid divider and gas tube

- Enlargement of liquid distribution holes from 2.3 mm to 2.4–2.5 mm

2012 : Weld seam corrosion / HAZ corrosion.

Escalation of Corrosion and Design Change (2014–2015)

During the Stamicarbon inspection in April 2014, a significant increase in the amount of severely corroded liquid divider assemblies was observed. All liquid divider assemblies installed in May 2006 showed corrosion, ranging from moderate to severe.

Although partial replacement based on corrosion severity was initially considered, PPL determined this approach to be imprudent. Partial replacement would have required sacrificing a significant portion of the operating life of new ferrules to ensure functional compatibility with the remaining moderately corroded assemblies.

Consequently, it was decided in 2014 to replace the most severely affected ferrules using the 50 available spare liquid divider assemblies. During testing based on Stamicarbon Delta-P test method, 13 liquid divider assemblies were found leaking.

2014: Corrosion on external and internal weld seam

In 2015, all liquid divider assemblies were replaced with a modified design, in which:

- The weld within the liquid divider head was eliminated
- The liquid divider head was manufactured as a single piece and welded directly to the gas tube

Continued Degradation and Operational Challenges (2017–2020)

Inspection in 2017 showed minimal corrosion at the welds of the redesigned assemblies. However, several liquid divider assemblies exhibited etching in the HAZ at the weld between the liquid divider cup and the gas tube.

Subsequent inspections revealed that the liquid divider assemblies installed in 2015 were in poor condition:

- Gas tubes exhibited selective corrosion at the welds
- Liquid divider surfaces were roughened
- Liquid distribution hole diameters increased significantly, generally ranging from 2.50 mm to 3.20 mm, with some holes measuring up to 3.7 mm

Due to the poor condition of the 2015-installed assemblies, liquid divider assemblies removed earlier were reused during 2018, 2019, and 2020 to maintain operability.



Condition of ferrules in 2018 / 2019 /2020

Adoption of HIP Technology and Performance Improvement (2022–2025)

In 2022, all liquid divider assemblies were replaced with Safurex® Hot Isostatic Pressed (HIP) liquid divider assemblies.

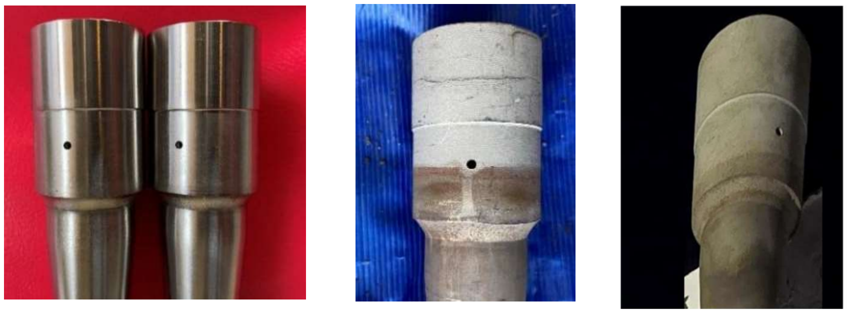
Safurex® HIP is a manufacturing process in which Safurex super duplex stainless steel powder is consolidated under high temperature and isostatic gas pressure, resulting in fully dense components with:

- Elimination of welds
- Homogeneous microstructure
- Superior corrosion resistance

Inspection of the HIP liquid divider assemblies in 2023 showed excellent performance:

- Virtually no corrosion observed
- Liquid distribution hole diameters measured in the range of 2.28–2.34 mm
- Holes were round and free from deformation

Further inspection in 2025 confirmed that Safurex® HIP liquid divider assemblies remained in good condition, and these assemblies were subsequently installed in the new HP stripper.



Condition of ferrules in 2022/2023/2025

Replacement Planning – Safurex® Star HP Stripper (2023–2025)

- **Procurement Initiated:** February 2023
- **Installation and Commissioning:** December 2025

Instrumentation Upgrade and Operational Experience

The replacement HP stripper is equipped with a radar-based level measurement system, building on the successful operational experience of radar level measurement in the existing vessel. Notably, PPL Mangalore was the first urea plant worldwide to replace radioactive level measurement in the HP stripper with radar technology, resulting in a significant improvement in operational safety and reliability.

The newly installed radar system complies with the latest design standards and is expected to further enhance measurement accuracy, operational efficiency, and long-term reliability.

Design and Process Upgrades in the New HP Stripper

The following upgrades have been incorporated to improve safety, reliability, and energy efficiency:

1. **Tube Upgrade and Capacity Enhancement**
   - Stripper tubes have been upgraded to **Safurex® Star**, and the total number of tubes has been increased to 1,980.
   - The design supports a daily urea production capacity of 1,425 MTPD, compared to 1,350 MTPD for the existing HP stripper.
2. **Manway Improvement**
   - Manway cover liners have been replaced with overlay welding, improving mechanical integrity and corrosion resistance. Also, it avoids the need to disconnect and reconnect the Leak Detection Monitoring System during every turnaround, as well as the associated risk of forgetting to reinstall it.
3. **Enhanced Venting Arrangement**
   - Additional vent nozzles have been provided at the mid-section of the stripper to facilitate effective venting of inert gases.
4. **Improved Operating Pressure**
   - In the revamp configuration, the HP stripper is designed to operate with steam pressure of 15.5 bar on the shell side, resulting in improved stripping efficiency and overall energy performance.

Design Codes and Manufacturing Details

The HP stripper was designed by Stamicarbon and manufactured by Lointek, Urduliz, Bilbao, Spain, under strict quality control and licensor supervision.

Design and Construction Standards:

- **Design Code:** ASME Section VIII, Division 1, 2021 Edition
- **Standards Applied:** TEMA-R / EJMA, IS-1893 (latest edition)
- **Licensor Specification:** Stamicarbon General Specification A4-51381
- **Wind Loads:** As per ASCE 7-95, basic wind speed 39 m/s
- **Seismic Loads:** As per IS-1893, Zone 3

Materials and Key Dimensions:

- **Tube Material:** Safurex® Star (BE.06)
- **Tube Dimensions:** 31 mm OD × 2.5 mm thickness
- **Number of Tubes:** 1,980
- **Liner Material:** Sandvik Safurex® (BE.06), thickness 5 mm

Manufacturing of High-Pressure Stripper

The manufacturing of a High-Pressure (HP) Stripper for urea service is a highly complex and rigorously controlled process due to the combination of high pressure, elevated temperature, and highly corrosive operating media. Compliance with stringent code requirements and licensor specifications is mandatory throughout the manufacturing cycle.

The process begins with detailed engineering validation, including the review and approval of mechanical design calculations, fabrication drawings, welding procedures, and inspection and test plans in accordance with ASME Section VIII and applicable standards.

Material procurement is executed under strict traceability control for all pressure-retaining components, including plates, forgings, tubes, and corrosion-resistant materials such as Safurex®. Incoming materials undergo comprehensive inspection, including chemical composition verification, Positive Material Identification (PMI), dimensional checks, and visual examination prior to release for fabrication.

Critical manufacturing activities include fabrication of tube sheets, shell courses, and major pressure boundaries. Tube sheets undergo extensive machining followed by application of buffer layers and corrosion-resistant weld overlays to ensure long-term resistance against carbamate corrosion. Each overlay layer is subjected to surface and volumetric non-destructive testing, along with ferrite measurement and PMI verification.

Shell courses are fabricated through controlled rolling and welding of longitudinal and circumferential seams, followed by installation of nozzles, manways, and attachments. All pressure-retaining welds are examined using appropriate NDT methods such as Radiography (RT), Ultrasonic Testing (UT), Phased Array (PAUT), or TOFD, ensuring full compliance with acceptance criteria prior to further assembly.

The assembly phase includes tube bundle fabrication, tube insertion, and tube-to-tube sheet welding, which are among the most critical operations in HP stripper manufacturing. These activities are carried out under tightly controlled welding parameters, supported by staged inspections to ensure weld integrity and dimensional accuracy.

Subsequent fabrication of top and bottom channels and hemispherical heads includes machining, transition overlay welding, liner fit-up, and post-weld heat treatment. Final assembly is completed with comprehensive dimensional checks, hydrostatic pressure testing, and leak testing to demonstrate mechanical integrity and leak tightness under design conditions.

Erection:

The HP Stripper erection was carried out strictly in accordance with the approved lifting drawings and the lifting plan. The equipment was erected using a two-crane lifting method, with one crane connected to the main lifting trunnions and the other to the tailing trunnions, enabling controlled rotation from the horizontal to the vertical position. During lifting, the load distribution progressively shifted to the main lifting trunnions until the stripper reached the vertical orientation, after which the tailing slings were removed.

The stripper was positioned vertically on the foundation, ensuring that the bracket holes were properly aligned with the anchor bolts while maintaining the recommended vertical tolerance (maximum deviation of 1 mm per 1 m). Leveling plates and shims were placed under the support brackets prior to tightening the anchor bolts to achieve true vertical alignment, which was verified using a plumb line. After completion of alignment, nozzle fit-up was carried out, and welding was performed by Safurex-qualified welders. All welds were subjected to non-destructive testing (NDT).

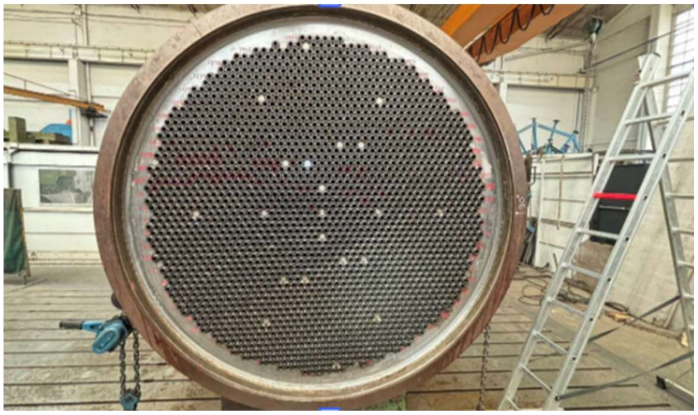
The hydrostatic test was successfully completed after completion of all welding activities. The equipment was then flushed and dried. The liquid divider assembly and other internals were subsequently installed. The HP Stripper was boxed up with a new gasket and successfully commissioned

Conclusions

The long-term operating experience at PPLM highlights the critical importance of metallurgy, design evolution, and inspection-driven decision-making for high-pressure urea equipment. The transition from welded liquid dividers to HIP technology and from Safurex® Infinity to Safurex® Star tubes has significantly improved reliability, safety, and corrosion resistance. These learnings provide valuable guidance for life-extension and revamp strategies in mature urea plants

STRIPPER MANUFACTURING AT LIONTEK SPAIN, Transportation and Erection

Shell courses with Expansion Bellow during fabrication



Tube sheet after tube insertion and before channel shell assembly

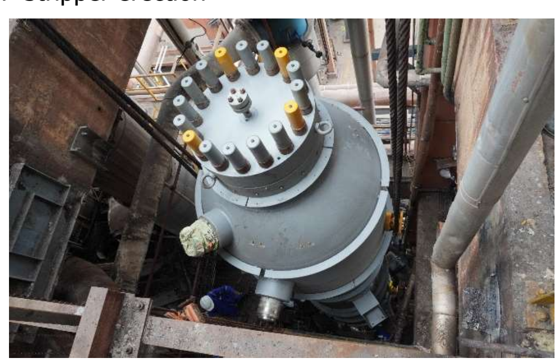
Shell and Channel assembly

Local PWHT with special Air-cooling header arrangement

Stripper loaded to vessel for transportation

HP Stripper unloaded from vessel and transported by road to PPL, Mangalore

HP Stripper erection



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