HOW TO GET THE MOST OUT OF YOUR EQUIPMENT

STAMICARBON

NEXTCHEM
MAIRE Sustainable Technology Solutions

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SUMMARY

1 ABSTRACT

Stamicarbon, the nitrogen technology licensor of NEXTCHEM (Maire Group), provides the best solutions to get the most out of your critical high-pressure equipment. This paper highlights the key success factors for this achievement, summarized as follows:

- Continuous (open) innovation
- Best corrosion-resistant materials
- Full control of the supply chain of high-pressure equipment
- Partnerships with the sub-suppliers, such as steel mill and equipment manufacturers
- Know-how and experience built up over more than 60 years
- Full life cycle support

2 INTRODUCTION

Stamicarbon has more than 75 years of experience in the field of fertilizers and especially in urea. Next to its core licensing business, Stamicarbon offers full life cycle services which include support for the safe and reliable operation of critical high-pressure urea equipment. Years of expertise as part of a chemical company operating various fertilizer plants – such as ammonia, urea and nitric acid – make Stamicarbon the best partner to get the most out of your critical high-pressure urea equipment. These services are available not only for Stamicarbon-licensed urea plants but also for non-Stamicarbon technologies. Furthermore, the company has implemented an Emergency Response System to provide 24/7 assistance to urea producers worldwide in case of emergencies.

With respect to innovation, Stamicarbon has an impressive record in the introduction of cutting-edge technologies for reducing energy consumption and extending the lifetime of critical equipment, including the development of special repair methods resulting in reliable and efficient urea plants.

3 CRITICAL HIGH-PRESSURE EQUIPMENT

Urea equipment in the high-pressure (HP) synthesis section is critical but prone to degradation due to the severe corrosive environment. Over the years, Stamicarbon has continuously innovated the design of urea equipment and developed unique corrosion-resistant materials, including steel grades such as X2CrNiMo25.22.2 (BC.05) and Super Duplex E-type grade formerly known as Safurex® (BE.06). The specially designed HP urea equipment is proprietary and is provided solely by Stamicarbon.

In addition to supplying equipment, Stamicarbon has developed specialized inspection and monitoring technologies, as well as repair strategies and methods to ensure safe and reliable operations. During emergencies, repairs are challenging due to time constraints and require improvised solutions; examples of these will be discussed in this paper. Next to unplanned repairs, procedures have been developed to extend the lifetime of equipment, with two refurbishment cases to be presented. When equipment replacement is necessary, Stamicarbon always offers the opportunity to implement state-of-the-art technologies rather than replacing urea equipment in kind. Improvements are applied to mechanical design, materials, energy consumption and lowering the carbon footprint. Some examples of the latest innovations will also be discussed.

4 WHY IS UREA EQUIPMENT CRITICAL?

In the HP synthesis section of an NX Stami™ Urea Pool Condenser (formerly Urea 2000plus®) plant the following equipment can be distinguished: urea reactor, pool condenser, HP stripper, and HP scrubber, as seen in Figure 1. The process conditions are extremely corrosive, and the risk of catastrophic failure due to corrosion cannot be excluded. Figure 2 shows a urea reactor destroyed due to an unnoticed leak in the corrosion barrier of the reactor.

Note that this reactor belonged to a small urea plant based on the Stamicarbon CO_2 stripping process with a capacity of only 200 MTPD. Nowadays urea plants with capacities of up to 4000 MTPD are in operation and plants of larger capacities are under development.

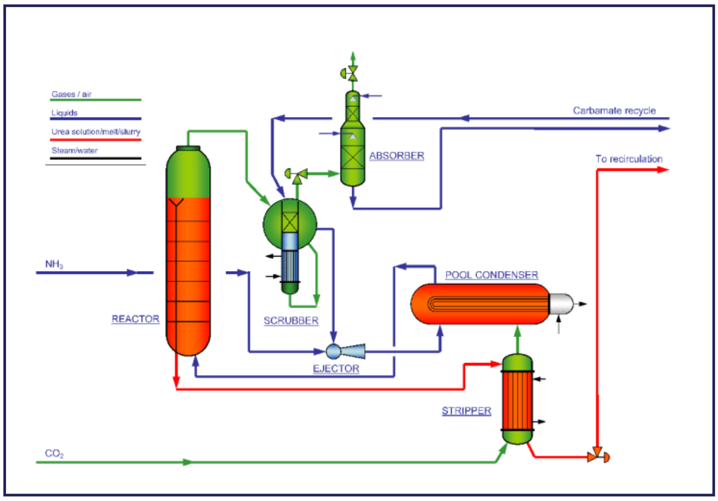

Figure 1: Flowchart of urea HP synthesis section based on Pool Condenser technology.

Figure 2: Catastrophic failure of a urea reactor destroying a urea plant.

Stamicarbon has developed a range of mitigation strategies to avoid such mishaps, including the following:

- Development of the best corrosion-resistant materials
- Design requirements for critical equipment (for instance, closing the gap between the tube and tube sheet by expansion or rolling-in is not allowed for leak detection monitoring purposes)
- Design of special welding technologies for stainless steel parts, such as internal bore welding
- Development of special inspection technologies such as the automated ultrasonic scanner for tube-to-tube sheet welds
- Control of the supply chain of critical equipment through partnerships with suppliers
- Open innovation throughout the supply chain of critical equipment (development of E-type steel)
- Online leak monitoring systems, such as pressurized leak detection systems for lined equipment
- Definition of integrity operating windows
- Development of unique inspection technologies for in-service corrosion inspections, such as eddy current methods for accurate wall thickness measurement of heat exchanger tubes
- Introduction of unique repair strategies for emergency repairs and lifetime extension of critical equipment

5 WHAT MAKES STAMICARBON’S PROPRIETARY EQUIPMENT A SUCCESS?

The success of Stamicarbon’s equipment supply is the combination of the company’s knowledge, expertise and experience combined with those of its partners in the supply chain. Stamicarbon’s HP urea equipment is proprietary due to its unique design and corrosion-resistant steels. The probability of failure on demand of an E-type heat exchanger tube is less than 10-7, which is unprecedented and demonstrates the superior corrosion resistance of Stamicarbon’s proprietary steel grade. The high quality and reliability are secured by specifications, mainly related to the fabrication, testing and welding of stainless steels and scrupulous quality checks. Stamicarbon has partnerships with steel makers and selected equipment manufacturers. Through the open and continuous innovation, Stamicarbon has developed E-type stainless steel grades and designed the novel NX Stami™ Urea Ultra-Low Energy (ULE) pool reactor in cooperation with its partners. Figure 3 shows the latest design of the ULE pool reactor shipped to the plant site.

Figure 3: New ULE design (second generation) shipped to plant site.

6 HOW TO GET THE MOST OUT OF YOUR EQUIPMENT

As mentioned before, the HP urea equipment is operated under critical conditions due to the high corrosiveness of ammonium carbamate. To make the most out of your equipment, it is important to design and manufacture reliable and robust equipment with an expected lifetime of 20 years and beyond. Furthermore, know-how and experience are required to be able to repair damaged equipment in a safe manner during the service life.

6.1 Aging equipment in existing plants

When it comes to aging urea equipment in operating plants, expertise and experience with repair or modifications is essential. Stamicarbon has extensive experience and know-how in this respect, not only obtained through continuous innovation, but also by leveraging more than 60 years of experience with in-service inspections and repairs in urea plants worldwide. We can distinguish between emergency repairs and equipment refurbishments to extend the lifetime of equipment.

6.1.1 Emergency repairs

An example of emergency repair is shown in Figure 4. For more information, see reference [1].

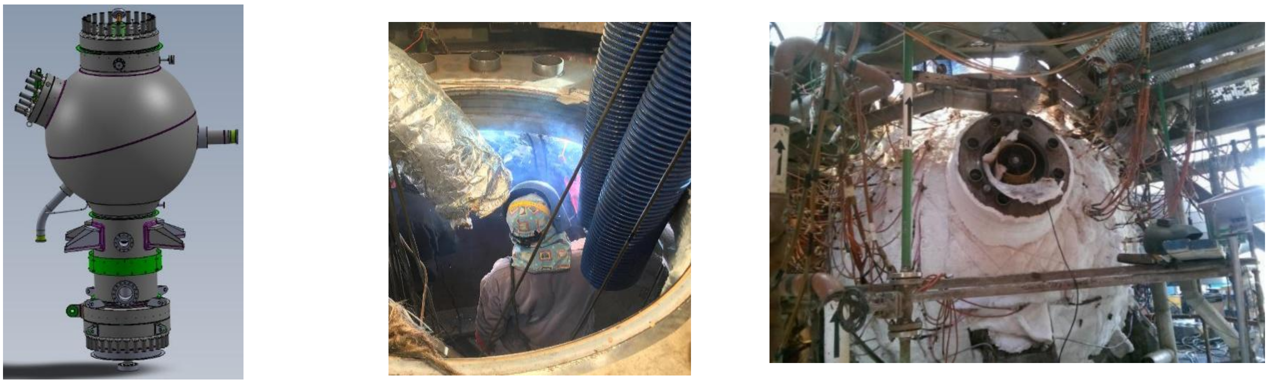

Figure 4: Repair of damaged sphere of the HP scrubber at Abu Qir, Egypt.

A leak in the liner in the sphere of an HP scrubber was not noticed, resulting in severe corrosion of the carbon steel pressure shell. Fortunately, a so-called leak-before-break occurred, and the plant was stopped timely before a catastrophic failure. This was a realistic scenario since the carbon steel was severely attacked causing not only severe wall loss, but also hydrogen-induced cracks. Hydrogen was formed due to the carbamate corrosion of the carbon steel shell. Due to the presence of hydrogen and the carbon-steel grade of the sphere (low-alloyed high-strength steel), the repair was delicate. Furthermore, special welding and heat treatment procedures were applied to avoid further formation of hydrogen cracks. This repair was successfully executed under the supervision of Stamicarbon by a local repair company, enabling the customer to run the HP scrubber safely for two years until the new replacement vessel arrived on site.

Another example is the emergency repair of a severely corroded tube sheet of a pool condenser, as seen in Figure 5 and reference [2]. A large cavity was formed in the upper part of the carbon steel tube sheet, where the two-phase flow of steam condensate leaves the tube bundle. Due to the synthesis pressure at the shell side, the stainless-steel weld overlay bulged into the cavity, pulling and bending the U-tubes.

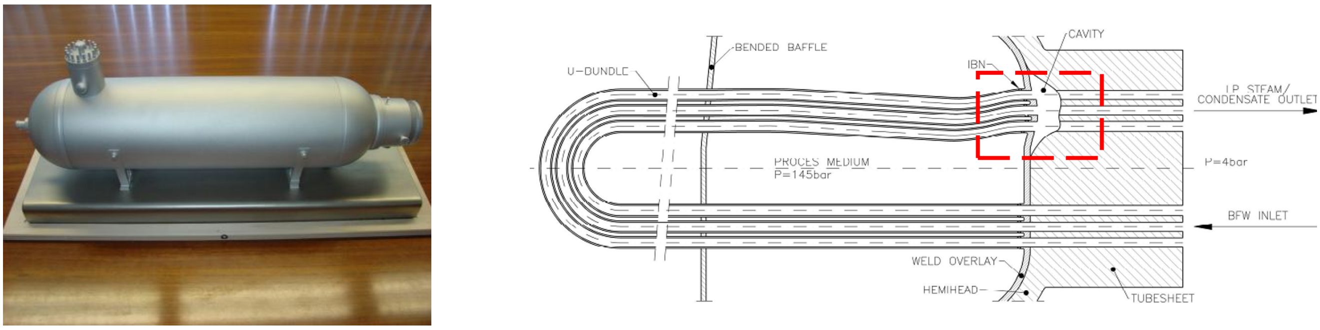

Figure 5: Severely damaged tube sheet and the repair concept.

The root cause of the damage was erosion corrosion due to improper water chemistry of the boiler feed water (BFW) used to produce the low-pressure (LP) steam in the tube bundle. BFW condensate enters the bundle at the bottom, and LP steam is produced by its partial evaporation, removing the heat of reaction. At the outlet of the tube bundle, the two-phase steam condensate flow created erosion corrosion damage also known as flow-accelerated corrosion. Due to the severity of the damage, it was decided to replace the pool condenser and to bridge the time until the new pool condenser arrives on site (expected to be in approx. two years) by executing a temporary emergency repair. The main challenge was to evaluate the repairability of the pool condenser. The condition of the inwards bent weld overlay at the back of the tube sheet was particularly problematic. For this purpose, all carbon steel was excavated at the outlet side of the tube sheet to get full access to the weld overlay for inspection and repair, as shown in Figure 6.

Figure 6: Excavation of the carbon steel tube sheet.

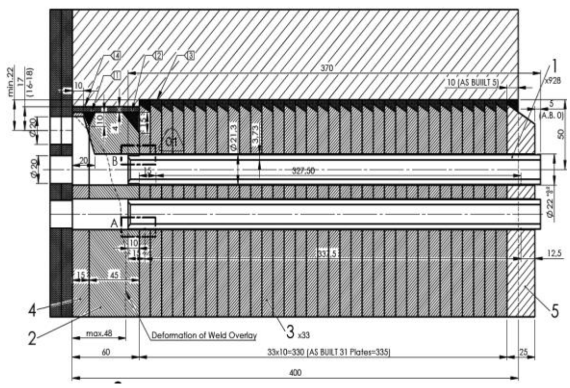

Figure 7: Closing the cavity by steel plates.

The condition of the bent weld overlay made the repair possible. After repairing the weld overlay, the cavity was subsequently closed by installing thin pre-drilled carbon steel plates with holes to allow steam condensate to pass through. This solution was chosen to avoid post-weld heat treatment of the tube sheet, which was not possible. The installed plates were only tack welded to the tube sheet and further connected to each other by expanding stainless steel sleeves into the holes, as seen in Figure 7 and 8. This emergency repair took about four months, and the pool condenser had been operating successfully for two years without any problems until it was replaced. Based on the root cause analysis, this damage mechanism cannot be excluded for other pool condensers. Therefore, Stamicarbon informed all customers operating pool condensers to take the necessary actions to mitigate the risks of a similar mishap.

Figure 8: Expansion of sleeves.

6.1.2 Lifetime extension refurbishment

In the previous section, two examples of emergency repairs were presented. Another way of getting the most out of your equipment is to extend the lifetime of your aging vessels by at least 15 to 20 years. Stamicarbon has ample experience with lifetime extension refurbishments, and this section will discuss two examples. The first example is the re-tubing of an HP scrubber, and the second example is the complete relining of a urea reactor.

6.1.2.1 Re-tubing of an HP scrubber

Instead of replacing an end-of-life HP scrubber, it was decided to extend the lifetime of the vessel by replacing all heat exchanger tubes. The HP scrubber has a spherical dome with a heat exchanger connected at the bottom, as demonstrated in Figure 9. The HP scrubber under study is part of a Stamicarbon CO2 stripping urea plant commissioned in 1996 and operating for 26 years at the time of refurbishment. The material of construction of the stainless-steel parts, including the heat exchanger tubes, was 316L UG (urea grade). The heat exchanger has 501 tubes with a length of 2.8 m and the end of life of the scrubber is determined by the wall loss of the heat exchanger tubes as well as severe cross-cut end attack of the tube ends in the bottom tube sheet. Figure 10 makes it evident that the severely corroded tubes were mainly located in a certain area at the outer periphery of the tube sheet. Next to this, the tube ends were severely corroded in the bottom tube sheet (Figure 11).

Figure 9: HP scrubber with sphere.

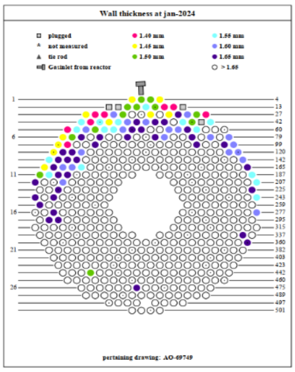

Figure 10: Tube sheet layout.

Figure 11: Severe crosscut end attack.

Since the spherical part of the HP scrubber was still in good condition, it was decided to completely re-tube the heat exchanger. This presented an economically feasible option given the limited number of tubes affected.

Removal of the existing tubes and re-installation of the new tubes was performed via the top tube sheet. For this purpose, all internals inside the spherical dome were removed, as seen in Figure 12.

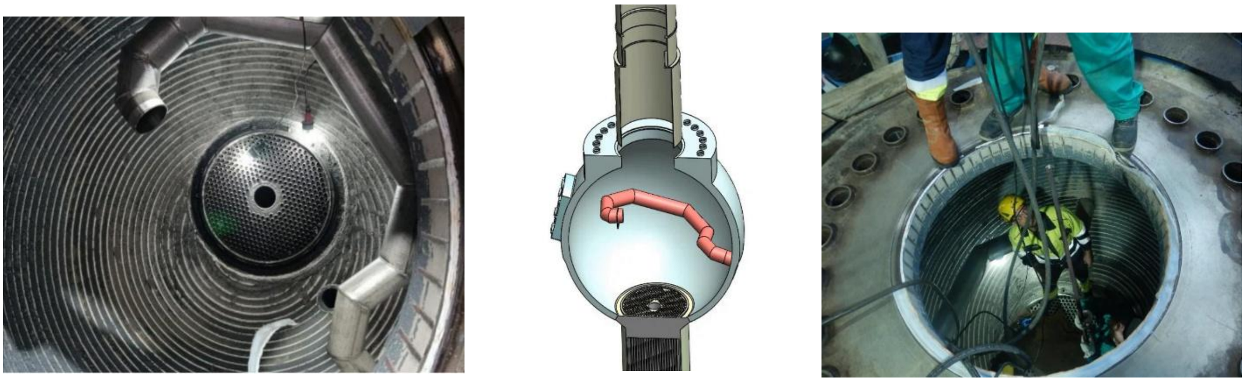

Figure 12: Full access to the top tube sheet for removal and re-installation of the heat exchanger tubes.

For this repair, both an automatic orbital welding machine and manual welding were qualified (see Figure 13). The quality of all tube-to-tube sheet welds was checked using an ultrasonic scanner (see Figure 14).

Figure 13: Orbital welding of the top tube sheet

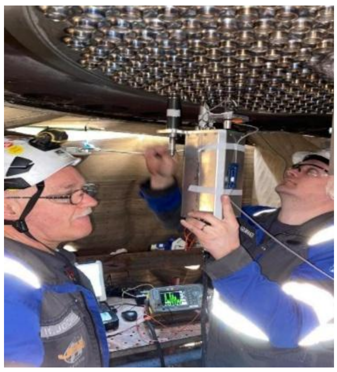

Figure 14: UT examination of the tube-to-tube sheet welds at the bottom

The repair took 36 days, which was well within the planned 40 days. This was realized by setting up a detailed repair procedure and an inspection of the HP scrubber a year before the execution of the project.

The information obtained during this pre-inspection was crucial to optimize the procedure due to some significant differences observed between the as-built drawings and the actual situation, which could have otherwise led to severe delays in the execution. Amongst others, the actual length of the tubes was longer than indicated in the as-built drawing. Moreover, the accessibility of all tube-to-tube sheet welding required some manual welding as well.

6.1.2.2 Complete relining of a urea reactor

The second example is the complete relining of a Urea Reactor originally built with a Zirconium liner. The Urea Reactor is part of a non-Stamicarbon urea plant commissioned in 1965. The Urea Reactor was suffering from leakages in the liner. Repair attempts were not successful, and since welding Zirconium in-situ is difficult, it was decided to completely reline this reactor in Stamicarbon proprietary steel (E-type grade). The choice for this material was motivated on one hand by its similar good corrosion resistant properties compared to Zirconium, and on the other hand, because it is much easier to weld. Because of this relining the client did not need to change the operating conditions and procedures and could still profit from its advantages, such as running the reactor with low passivation oxygen content and unlimited blocking-in times. The relining procedure entailed the removal of the existing Zirconium liner, which also made it possible to refurbish the leak detection system to the state-of-the-art system of Stamicarbon.

Since the man-way opening was relatively small, it was decided to lift the reactor from the structure and cut the reactor in two halves to have better accessibility for the relining job. For this purpose, the reactor was placed in a workshop close to the facility. Figures 15 to 20 show some of the steps: cutting the reactor into two halves, removal of its Zirconium liner, preparing (rolling) of the new liner, installing the new liner, welding both reactor parts back together and finally a hydrostatic pressure test in accordance with the ASME design code requirements.

The total refurbishment took 65 days, and the Urea Reactor was put safely and reliably into operation again.

Figure 15: Reactor cut into two halves.

Figure 16: Removed Zirconium liner.

Figure 17: Preparation of the new liner.

Figure 18: Installation of the new liner.

Figure 19: Re-welding of the reactor shell.

Figure 20: Pressure test.

6.2 New equipment in grassroot plants

Stamicarbon, as an innovative company, continuously improves the design of the critical HP urea equipment, not only mechanically, but also from a process point of view. Stamicarbon has a long track record in this respect. Nowadays, Stamicarbon focuses on energy savings and lowering the carbon footprint.

Examples of energy savings are the introduction of CO_2 striping technology in the 1970s and more recently the new ULE concept, including the ULE Pool Reactor. Already the second generation of the ULE Pool Reactor has been introduced recently (see also Figure 3). More details are presented during this symposium (see reference [3]).

With respect to lowering the carbon footprint the advantages of Stamicarbon's proprietary E-type material are evident, such as fewer inspections and maintenance (TA intervals up to 6 years are common), high reliability and availability of the equipment, unlimited blocking-in time of a urea plant and flexibility in turn-down ratio.

Stamicarbon is successful in delivering proprietary HP equipment and since the introduction more than 20 years ago we have delivered more than 200 pieces of equipment, not only for Stamicarbon urea plants, but also non-Stamicarbon urea plants such as Saipem, Toyo and Weatherly amongst others. An example is a kettle type high pressure carbamate condenser for a Saipem plant, as shown in Figure 21.

Figure 21: Kettle-type HPCC in proprietary E-type steel.

As mentioned before, Stamicarbon offers innovative solutions to improve and upgrade the equipment. Some examples are listed below:

- Upgrades of our proprietary steel (Safurex® Star and Safurex® Degree)
- Composite valves (E-type sleeve in valve body)
- Pressure transmitters using E-type membrane (see Figure 22)
- Radar level measurement (see Figure 23)
- New grid design in the shell side of HP strippers (see Figure 24)
- Compact flanges (smaller and compacter design)
- Improvements Pool Condenser (distribution boxes and baffles)
- Mechanical plugs (E-type)
- Upgraded NDE methods for quality control during manufacturing of critical equipment

Figure 22: E-type pressure transmitter.

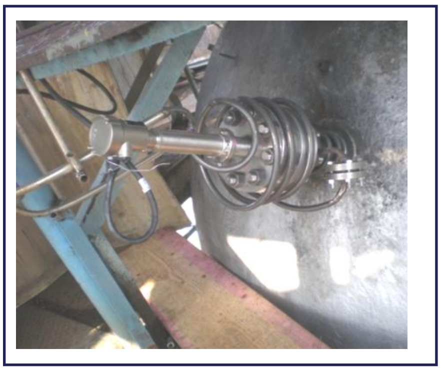

Figure 23: Radar level transmitter.

Figure 24: Grid design HP stripper.

The upgraded proprietary steel grades (Star and Degree) offer a further improvement in the corrosion resistance to ammonium carbamate. The Star grade is exclusively developed for the heat exchanger tubes in the HP stripper which provides an additional 10 to 20 % increase in expected lifetime. The Degree grade is successfully developed to significantly increase the lifetime of liquid dividers in the HP stripper.

The composite valve technology is a cost-effective alternative for larger (larger than 6”) control valves, whereby the full E-type body is replaced by a standard duplex body with an internal E-type sleeve.

An interesting innovation is the pressure transmitters equipped with an E-type membrane, which improves the expected lifetime compared to the existing Tantalum designs, which in many cases suffer from corrosion in the weld connection.

Radar level measurement is another successful innovation by Stamicarbon, which avoids the use of conventional radioactive systems. Not only is it safer, but it also provides a long lifetime and easy maintenance and calibration.

Some examples of improvement of existing HP equipment are the new grid design of the larger HP Strippers which results in better distribution of the steam at the shell side, improving stripper efficiency and reducing corrosion in the peripheral heat exchanger tubes. In Pool Condensers and Pool Reactors, the design of the condensate inlet box has been improved to minimize condensate passing. Also, the TEMA baffle design has been optimized to minimize the risk of baffle hammering. Finally, by using excellent corrosion resistance as well as the high strength of the E-type material, compact flanges were successfully introduced in the synthesis section of the urea plant. The advantages are not only the lightweight design but also ease of maintenance.

7 CONCLUDING REMARKS

This paper has discussed Stamicarbon’s expertise in delivering the best solutions for getting the most out of your critical HP urea equipment. This is achieved through the following factors:

- Continuous (open) innovation
- Best corrosion-resistant materials
- Full control of the supply chain of HP equipment
- Partnerships with the sub-suppliers, such as steel mill and equipment manufacturers
- Know-how and experience built up over more than 60 years
- Full life cycle support

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