STAMICARBON, 70 YEARS OF KNOWLEDGE AND INNOVATION

STAMICARBON, A WORLD CLASS TECHNOLOGY LICENSOR

Stamicarbon was founded in The Netherlands in 1947 as licensing subsidiary of DSM. Since October 2009 it is part of the Italian Maire Tecnimont Group. The Stamicarbon headquarters is in Sittard, in the south of The Netherlands, with representative offices in Russia and China.
Nowadays the company is a global leader in the design, licensing and development of urea plants and a supplier of high-end equipment and services for the petrochemical industry, with more than 50% market share in urea synthesis and about 30% market share in urea granulation technology.
A pioneering company specialized in the fertilizer industry with the vision to help enable the world to feed itself and improve the quality of life.

Fig. 1: Stamicarbon's Head Office in Sittard, The Netherlands

During its 70 years history, Stamicarbon has licensed over 250 urea plants located in over 50 countries across the globe. Furthermore it has completed over 90 revamp projects in both Stamicarbon and non-Stamicarbon plants. Currently, the company is involved in 15 urea melt plants, 10 urea granulation plants and 5 revamping projects.
This year Stamicarbon is celebrating its **70th anniversary in knowledge and innovation**.

70-YEAR HISTORY

In 1947, DSM (then known as Dutch State Mines) formed the subsidiary Stamicarbon to obtain and exploit coal-washing inventions, patents, and know-how. The name Stamicarbon is a contraction of the words "State Mines" and "Carbon". The 70-year history of Stamicarbon shows its constant ability to respond and adapt to a wide range of market developments around the world.

Coal Mines

The first licensing of coal washing plants according to a float-and-sink process took place in 1948. As sales in Western Europe began to decline by the 1960s, Stamicarbon shifted its sales efforts to Eastern Europe, America and India and developed new uses for its cyclone process in ore washing and the separation of scrap metal from cars. The sales of the coal era ended in 1989.

Fertilizers

After World War II, fertilizers became extremely important for food production. In 1945, a breakthrough was made with the production of compound fertilizers, such as nitrogen-phosphate (NP) and nitrogen-phosphate-potassium (NPK), followed by calcium nitrate and later urea. Stamicarbon's first fertilizer licensing project involved a massive fertilizer complex near the Aswan Dam in Egypt, with a plant for the production of potassium-ammonium-sulphate. Over the years, next to urea, the majority of process licenses were sold for nitric acid and ammonium nitrate. During the 1980s, the market for some of these fertilizers became saturated and innovations drew to a close. The licensing of urea however continued to grow and became Stamicarbon's main business.

Chemicals and Petrochemicals

In the early 1960s, DSM began focusing on high-end chemical and petrochemical processes. Stamicarbon followed by expanding its licensing portfolio with technologies for caprolactam, phenol, melamine, ethylene propylene diene monomer, low-density polyethylene, linear low-density polyethylene (LLDPE), and high-density polyethylene. After the carve out of DSM's petrochemical activities in 2002, Stamicarbon ended these licensing activities, transferred its polyethylene technologies to SABIC and continued on its roots and broad expertise of urea technologies.

70 YEARS OF INNOVATION

Stamicarbon has been at the forefront of development and innovations over the past 70 years. Besides own developments Stamicarbon has also always encouraged open innovation in close collaboration with its customers, contractors, suppliers and research institutions.

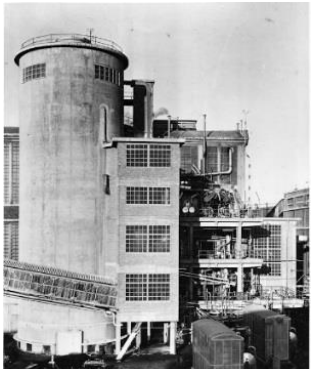

Fig. 2:1957 Société Carbochimique in Tertre, Belgium

Passivation with air

Large-scale production of urea was not possible in the 1950s as corrosion used to occur in urea plants, until Stamicarbon found that small amounts of oxygen greatly alleviated the problem. This discovery led to the oxygen patent in 1954, which, in a single stroke, established Stamicarbon's name in the urea industry. Montecatini had been the leading licensor until then, but in 1956 Stamicarbon's mother company, DSM, began operating their first own oxygen-passivated urea plant. A year later Stamicarbon sold this process for the first time to Société Carbochimique in Tertre, Belgium. The plant had a capacity of 70 tonnes per day.

CO_2 stripping process

Following extensive fundamental research in the 1960s, Stamicarbon developed the CO_2 stripping process. Stamicarbon sold the first license for this revolutionary process in 1965. It turned out to be a major invention as it was possible to decrease energy consumption to half as compared with previous conventional plants. In 1967, the first commercial urea stripping plant was put into operation for DSM, with a capacity of 220 mtpd.

Safurex®

Corrosion in urea synthesis has always been a major problem. Although adding oxygen worked well against corrosion, it increased the risk of explosions in the high pressure urea synthesis section of the plant. From the early 1960s, Stamicarbon was involved in the development of better materials to resist corrosion. One example is X2Cr.Ni.Mo.N 25.22.2., a type of stainless steel with high content of chromium and nickel to increase corrosion resistance. However, austenitic stainless steel also

emerged as having disadvantages like susceptibility to stress corrosion cracking (SCC) in combination with chlorides.

Fig. 3: Safurex® corrosion free material

In the search for better materials, Stamicarbon and the Swedish Sandvik joined forces and investigated special duplex steel types. A new steel called Safurex® was introduced in 1996. By using Safurex®, investment costs are reduced by 5 to 10 percent, because vessels can be designed smaller and lighter, and some equipment can even be left out entirely.
The use of Safurex® as a construction material became the standard in new urea plants, but is also regularly used in replacing old high pressure equipment items. 20 Years of operational experience confirms that most of the typical corrosion issues do not exist, not even at low oxygen levels.
Stamicarbon and Sandvik jointly developed in 2014 a premium Safurex® grade with improved corrosion resistance at the process conditions that prevail in the heat exchanger tubes of the HP Stripper.

Urea pool condenser and pool reactor, a new design breakthrough

After the CO_2 stripping process, the next innovation in urea production was the development of the Safurex® pool condenser in 1990, initiated by the design of a new urea plant near to an airport in Bangladesh, requiring a lower plant height. Stamicarbon designed a horizontal pool condenser. The pool condenser is responsible for part of the urea reaction, so that the reactor vessel can be made one-third smaller and lower. As a consequence, the construction is also much lower, only 42 instead of 60 meter and lighter and hence cheaper.

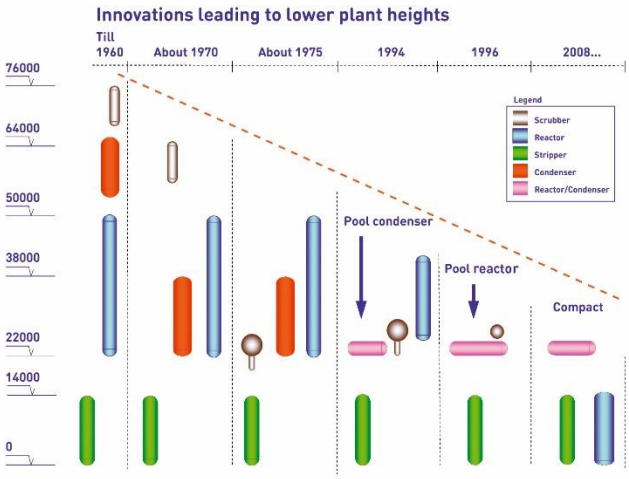

Fig. 4: Innovation leading to lower plant heights

Stamicarbon next developed the Safurex® pool reactor. In this design the function of the condenser and the reactor is taken over by one single item the pool reactor, which once again vastly simplifies the plant, and makes it again cheaper. See figure 4.
The pool reactor was first employed in 1998 at DSM in The Netherlands, a plant with a capacity of 1150 mtpd. Thanks to these new designs, the instability characteristic in the process control of the traditional stripping process, was eliminated.
Stamicarbon protects its long list of innovations by more than 100 urea related patent families, totaling more than 1000 individual patents registered in many countries around the world.

FULL LIFE CYCLE PHILOSOPHY

Stamicarbon distinguishes itself by its Full Life Cycle Philosophy: a commitment to provide a full range of reliable tailor-made technology solutions, products and services for every stage of a urea plant.

Fig. 5: Stamicarbon's Full Life Cycle Philosophy

LAUNCH series includes everything needed to build a reliable and profitable new urea plant, from feasibility study and tailored process design to project management and start-up of the plant.
ADVANCE series optimizes plant performance, allowing an existing plant to stay competitive with production improvements, monitoring and inspection, training and support.
Eventually the EVOLVE series comprises several upgrade concepts for existing plants to remain compliant with changes in legislation and competitive by adapting to changes in the market conditions by revamping it to increase capacity and/or improve efficiency with several debottlenecking concepts and tools.

TECHNOLOGY SOLUTIONS TO LAUNCH A NEW UREA MELT PLANT

Stamicarbon designed several LAUNCH MELT™ technologies with different synthesis concepts for various plant capacities and business requirements.

The **Pool Reactor Design** is a technology for small capacities up to 2500 mtpd. It is a low-height plant design with a minimal amount of piping and high-pressure equipment that integrates a pool ondenser and a vertical reactor into one piece of equipment: the pool reactor.
For plants with capacities from 2500 to 5000 mtpd Stamicarbon has a widely used **Pool Condenser Design**, which has optimal heat transfer, excellent process stability and high on-stream time. This design includes a high-pressure pool condenser combined with a relatively short vertical reactor.
The **Mega Capacity Design** can be used as an alternative for the largest capacities of up to 6000 mtpd.

Besides these capacity variations there are several other melt concepts available. The **Compact Design** is based on a low plant height. It has a different layout with the synthesis section at a lower elevation from the ground. The total plant height is brought down to only 22 meters, irrespective of the plant capacity, thereby making construction work easier and reducing investment cost.

As **energy saving** has become increasingly important, Stamicarbon recently introduced its new **Flash Design** with an adapted in-line stage in the urea synthesis process, thereby significantly reducing steam consumption.
The **ultimate reduction of steam** intake can be established by the **Low Opex Design**. See figure 6. The steam intake of the urea plant is minimized to an unprecedented low level (in the range of 500-600 kg/t urea), resulting in the most energy efficient design available on the market.

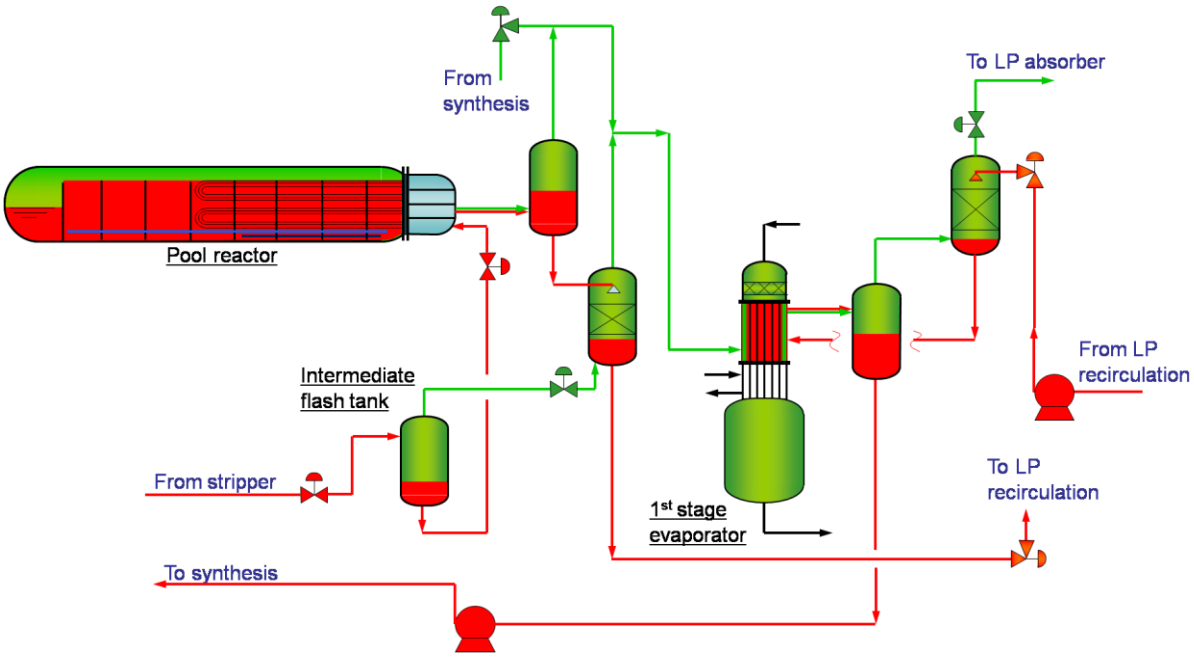

Fig. 6: Flow sheet LAUNCH MELT™ Low Opex Design

TECHNOLOGY SOLUTIONS TO LAUNCH A NEW UREA FINISHING SECTION

Depending on market requirements a producer has different end product needs. These can be in the solid form of urea granules, prills or pastilles or in liquid forms such as Urea Ammonium Nitrate (UAN) or Diesel Exhaust Fuel (DEF). Stamicarbon offers a complete portfolio of LAUNCH FINISHING™ technologies for all forms of urea. Their latest developments are in granulation and Urea Ammonium Sulphate (UAS).

Granulation

Stamicarbon's granulation technology is a fluid bed technology that uses a minimum amount of formaldehyde, allowing for substantial savings. The design has the world's lowest dust production, ensuring less fouling and long production times between the cleaning cycles.

The latest version of this technology simplifies the design even further by reducing the number of equipment items resulting in reduced investment and operational costs.

Micro-Mist™ Venturi scrubber

Worldwide, sub-micron particulate emission regulations are becoming increasingly strict. Stamicarbon and EnviroCare have co-developed a high efficiency off-gas scrubbing technology and integrated this with Stamicarbon's latest fluidized bed urea granulation technology. By quenching and accelerating the granulation off-gas through MicroMist™ Venturi (MMV) tubes, particulate emissions as low as 10 mg/Nm^3 can be achieved. An additional polishing wet electrostatic precipitator (WESP) can further reduce particulate emissions to unprecedented low levels.

Fig. 7: 3-D of Representative MMV Scrubber

Dry finishing, an alternative for granulation

Stamicarbon invented and patented a new technology in which the crystallization of urea into a urea solid happens in the melt part of the urea plant. The crystallized urea product leaves the urea melt part of the plant and can be used for several purposes such as fertilizer grade granulate and DEF/Ad Blue® application. This new Dry Finishing technology eliminates finishing emissions by means of an inline solution.

Urea Ammonium Sulphate (UAS)

Because of an increasing demand for granulated urea containing macro- and micro-nutrients, Stamicarbon developed a process for the production of granulated urea containing ammonium sulphate. Given the flexibility of this UAS-process, it can also be used to produce granulated urea containing other nutrients.

Urea Ammonium Nitrate (UAN)

An alternative way of fertilization is presented by the liquid UAN product, which has a low crystallization temperature, facilitating transport and storage, while application by spraying devices is easy and economical. UAN also allows for a more uniform distribution and portioning, even if mixing with other liquid fertilizers is desired. Stamicarbon's LAUNCH FINISHING™ UAN Design entails an integrated urea / ammonium nitrate solution plant, ideal for the manufacturing of UAN solutions with low investment costs.

DEF/AdBlue®

More stringent emission standards require vehicles to significantly reduce their NOx engine emissions. Therefore Diesel Exhaust Fluid (DEF) or AdBlue® is sprayed into the exhaust, reducing the NOx gases to nitrogen and oxygen. As a licensor of urea technology, Stamicarbon was in the ideal position to develop a state-of-the-art LAUNCH FINISHING™ AdBlue® Design solution and related services to take into account all industry regulations and requirements.

PRODUCTS AND SERVICES TO ADVANCE THE PERFORMANCE OF A UREA PLANT

Changes in market demand, personnel, regulations, energy prices and technology all affect business and plant operation. With Stamicarbon's ADVANCE products and services plant owners can maintain a competitive edge for the entire operational lifetime of a urea plant and even extend its longevity, resulting in a better return on investment.

Fig. 8: Plant inspection

Plant Inspections

Plant managers should be assured that their equipment is safe, reliable and always available in order to prevent unsafe conditions and unscheduled plant stops. As corrosion properties of carbamate hold a serious threat to the integrity of urea process equipment, it is important to inspect the high-pressure equipment and piping to extend beyond the design life and continue to produce urea safely and at a competitive cost. Similar inspection services are available for ammonia plants and ammonia storage tanks.

Equipment supply

Replacement of equipment in plants gives the opportunity to upgrade equipment to the latest design and material standards. Stamicarbon is

able to design the equipment to the current process conditions to prevent corrosion issues and optimize the equipment performance and plant longevity accordingly.

Coating

Most fertilizers have the tendency to form lumps or agglomerates during storage and transportation, which is commonly referred to as "caking". Besides the causes of caking and approaches to cake prevention, like anti-caking agents, a new method of rendering prilled urea cake-resistant, based on coating with a novel, high-quality Stamicarbon coating agent named ADVANCE COAT™, has been introduced in the market.

Plant operation monitoring

Stamicarbon has developed an on-line tool called ADVANCE INSIGHT™ for monitoring the performance of a urea plant that will give information 24/7 about the identified process key performance indicators. It is based on a first principles process model, making use of advanced thermodynamic and kinetic models that are tuned to the specific urea plant and it runs on-line in parallel with daily operation. The monitoring system has proven to be able to increase the plant output and lower energy cost substantially.

Urea Simulator and Training

Stamicarbon offers a real-time dynamic process simulator and simulator training for the urea melt and granulation plant for plant operators, engineers and production managers. The process simulator behaves like a real plant with the look and feel of a real DCS system with unlimited opportunities for experimenting and learning.

REVAMP CONCEPTS TO EVOLVE THE LIFELINE OF A UREA PLANT

There are many old plants using outdated technology, even though their operational costs are becoming exorbitant, making it difficult to compete on the open market. Revamping is a very economical way to increase the profitability of an existing plant if designed and constructed correctly. Stamicarbon offers detailed plant-performance studies to determine revamp needs and has several revamping technologies available, taking full advantage of the plant's design margins, boosting urea production, while minimizing investment in additional resources and infrastructure.

Depending on the client's need for capacity increase, emission reduction, energy saving or process optimization, one or a combination of solutions can be used. The revamps carried out, range from simple reactor tray upgrades to major plant revisions, not just in Stamicarbon plants but also in plants based on TEC, SAIPEM, Chemico or even older technologies.

Fig. 9: Equipment replacement during a revamp

Debottlenecking

One of the revamp solutions to increase capacity is debottlenecking the plant with one of the EVOLVE CAPACITY™ designs. The extent depends on the availability of feedstocks, utilities and particular plant limitations. Stamicarbon offers several designs; More-in-More-Out, Double Stripper, MP Add-on or Pool condenser/Reactor design.

Emission reduction

With regards to emission legislation there is not a fixed list of worldwide emission limits, they differ per region as local authorities set the standard. For Stamicarbon this means that every new project, either grass root or revamp, asks for a tailor made approach in close cooperation with the plant owner, the engineering contractor and local authorities. EVOLVE EMISSIONS™ offers a portfolio of emission reducing technologies.

FUTURE

When it comes to building a new urea plant, or revamping an existing plant, urea producers will take a lot more into consideration when making a decision. New plants are favorable in areas with low gas prices, or in isolated landlocked areas with a growing domestic fertilizer demand. A careful selection of technologies can lead to a competitive advantage.Existing urea producers with relatively high feedstock costs could optimize their economic cost position by smart revamping and focus on energy efficiency, or diversify its product portfolio by adding specialty products like enhanced efficiency fertilizers and technical grade urea.

As of late 2018, fewer capacity additions are foreseen, leading to a rebalanced supply demand with increasing urea prices on the medium term. However, due to today's relatively low fertilizer prices, current project initiatives are facing higher uncertainty in terms of financial close. Project financing becomes more important, which means that successful projects require strong sponsors or a financial consortium. Stamicarbon's Project Development activities can facilitate the arrangement of off-take agreements, debt facilities, ECA coverage and favorable EPC contracts. By investing early in upgrading of existing plants or building of new urea plants, some producers will have a first mover advantage by the time the urea industry is rebalanced.

Next to urea technology, Stamicarbon is now also expanding again its licensing efforts to adjacent processes. Since this year, Stamicarbon's renewed dual pressure nitric acid technology is commercially available; a proven design that offers lowest energy consumption.

Over the past 70 years of its existence Stamicarbon has adapted its business and innovations to market changes and technology developments and it will continue to be a reliable partner in shaping the fertilizer business.