World scale urea plants

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Content

Summary

Economy of scale is driving plant capacities higher and higher. Starting some fifty years ago with 70 mtpd, the current trend in urea plant capacities shows a continuous increase in larger capacities from 3000 mtpd some ten years ago to nearly 4000 mtpd currently.
At this moment (October 2010) Stamicarbon has six and Saipem one 3000+ urea plant in operation. During the next years another seven Stamicarbon and six Saipem 3000+ are expected to start production.
Debottlenecking technologies are an important tool to make larger plant technologies proven with limited risks. The Yara Canada first debottlenecking project for example initiated the row of 3000+ urea plant capacities.
Both Saipem as well as Stamicarbon have performed a preliminary design to confirm the feasibility of 5000+ urea plants. It is expected that the first 5000+ mtpd urea plant will be licensed in the next coming decade.

1. Introduction

The size of a world scale urea plant increases in time and is driven by the economy of scale. The figure below shows the typical trend in operational costs versus plant capacity.

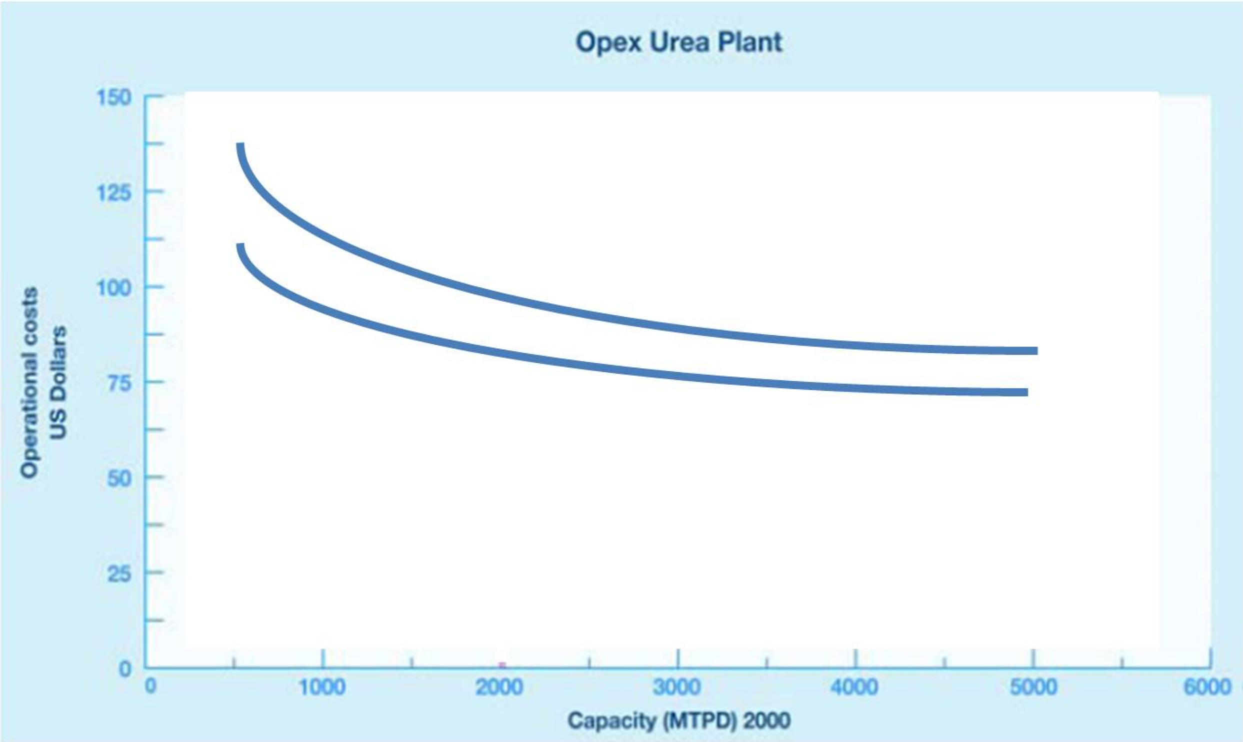

Figure 1: Typical trend of range in operational costs versus plant capacity

The continuous competition amongst urea producers to realize a minimum urea cost price results in a continuous search how to increase the capacities of ammonia and urea plants.[9)] The indicated operational costs for producing urea granules are based on a natural gas price of 2 US$/MMBTU and include the operational costs for producing ammonia (transfer price). The range indicates the difference between low and high cost countries. On can clearly see that although the operational cost reduction becomes smaller at higher plant capacity levels, it remains a significant difference in a bulk industry like urea.

On the other side reliable technologies, equipment and machinery realizing high on stream times at the expected plant capacities are very important. The key question is: What is proven ? And in case some part is non proven, is it acceptable to implement ? This paper targets to contribute to the answers to these questions, which are important for any party interested to build a new large scale urea plant.

2. Maximum licensed urea plant capacity: historical view

The figure below shows the maximum urea plant capacity licensed out in a certain year by either Stamicarbon or Saipem. The figure indicates that both Stamicarbon and Saipem are intensively competing and closely following each other with respect to the maximum urea plant capacity.

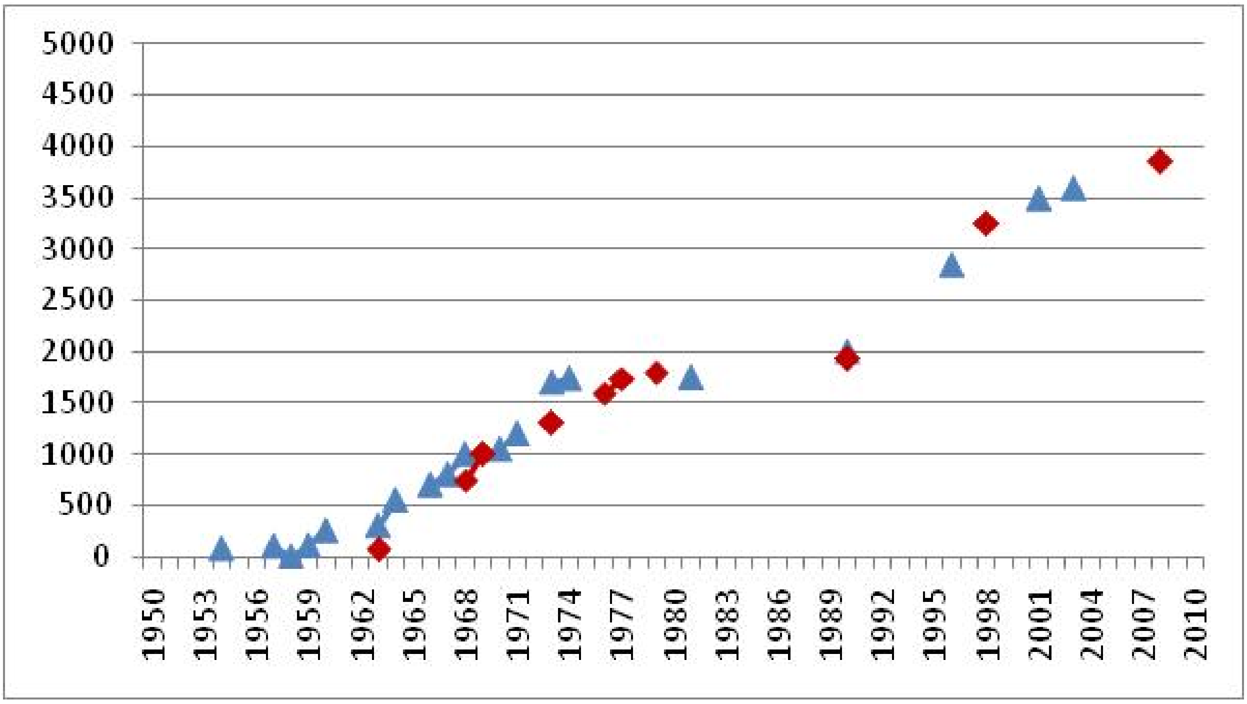

Figure 2: Maximum urea plant capacity licensed out in a certain year by either Stamicarbon (blue) or Saipem (red).

This figure shows that Stamicarbon's first license was in 1954 where Stamicarbon licensed out two lines of 75 mtpd to DSM in Geleen, the Netherlands.[1)] Saipem's first license was in 1963 where Saipem licensed out a 70 mtpd urea plant to Industrial Import in Victoria, Rumania.[2)] The technology of these first urea plants were according the conventional total recycle urea technology in which the urea high pressure synthesis section did consist of only a high pressure reactor. Downstream the reactor a medium and low pressure recirculation section was present to recycle back the unconverted ammonia and carbon dioxide in the form of liquid carbamate. Further pure ammonia was separated from the carbamate and recycled back from the medium pressure to the reactor.

During the 1960's the maximum urea plant capacity licensed by both Stamicarbon and Saipem grew from 70/75 mtpd to about 1000-1100 mtpd in the early 1970's when the technology was still according the conventional total recycle urea technology. Then in 1967 Mr. Petrus J.C. Kaasenbrood of Stamicarbon revolutionized the urea process by the invention of the High Pressure CO_2 Stripper. Saipem followed and improved the conventional total recycle technology by means of the High Pressure NH_3 Stripper.
The high pressure stripper technologies could reduce the specific steam consumption of a urea plant with a factor two, which has proven to be a vital advantage during the energy crisis in the 1970's.

During the 1970's and 80's the maximum urea plant capacity remained around 1600-1800 mtpd, which corresponded to an ammonia plant capacity of about 1000-1100 mtpd. In the early 1990's the urea plant capacity increased to 2000 mtpd, while the capacity of ammonia plants grew to 1500 mtpd.

Coming close to the year 2000, Stamicarbon and Saipem showed many activities to further develop their technologies. Debottlenecking projects did contribute significantly to the development of grass root technologies for larger scale urea plants. For example the Yara Canada debottlenecking project, licensed out by Stamicarbon in 1996, increased the single line urea plant capacity to 2850 mtpd and was a milestone for a 3000+ grass root urea plant technology.

In 1998 Saipem followed with a 3250 mtpd urea plant at Profertil in Argentina where after in 2001 Stamicarbon licensed a 3500 mtpd urea plant to Qafco in Qatar and Pardis in Iran. In 2003, Stamicarbon licensed a 3600 mtpd urea plant to Safco in Saudi Arabia and in 2008 Saipem licensed out a 3835 mtpd urea plant to Engro in Pakistan.

The first decennium of the third millennium shows thus a progressing trend in larger urea plant capacities and it is expected that this trend will continue for the next coming years.

3. Current large scale urea plants

Let us focus on the development and licenses of the 3000+ mtpd urea plants for both Stamicarbon and Saipem. Figure 3 shows the number of licenses of large scale urea plants for Stamicarbon and Saipem during the last 15 years.

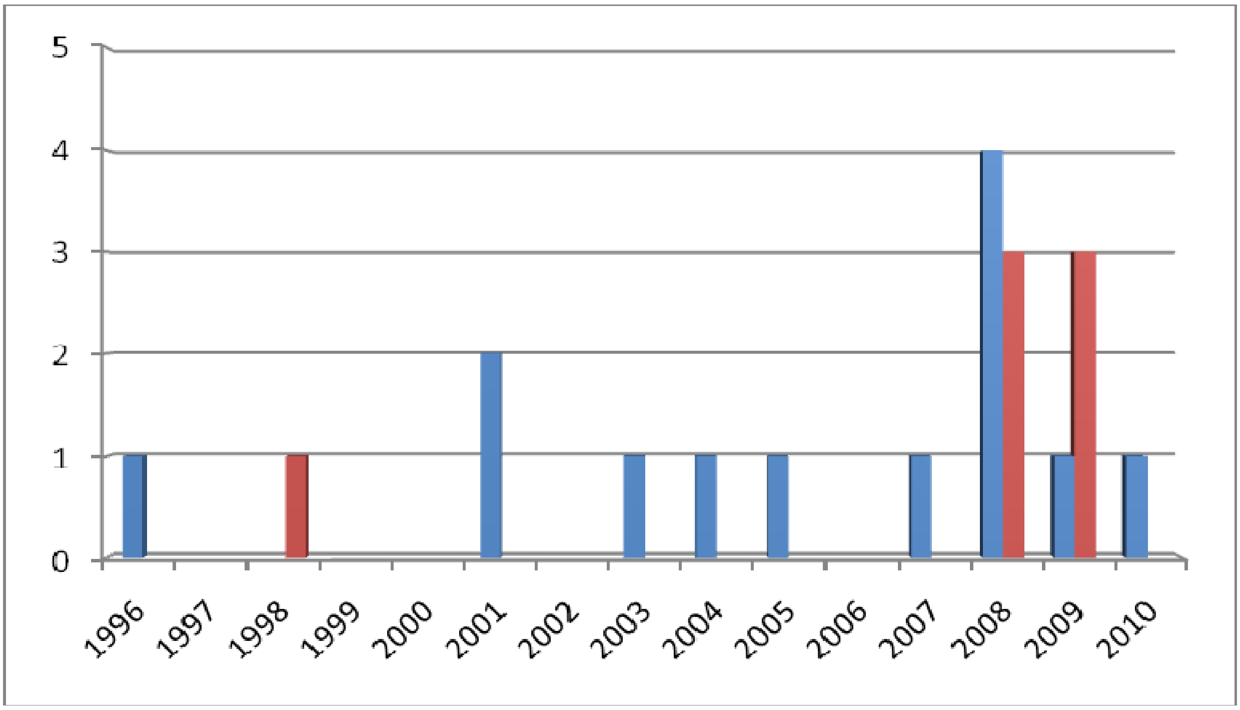

Figure 3: The number of licenses of large scale urea plants for Stamicarbon (blue) and Saipem (red) during the last 15 years.

From figure 3 one can conclude that Stamicarbon did license 16 large scale urea plants of which are six in operation now (Yara Canada, Qafco 4, Pardis 1, Safco 4, Erdos and Pardis 2). Saipem did license seven large scale urea plants of which is one in operation at this moment (Profertil). The definition of large scale single line urea plants used here are urea plants which are able to produce a minimum of one million tons of urea in one year. The status of each of these projects will be detailed out here below. Please be advised Figure 3 includes the licenses as indicated in the Stamicarbon and Saipem reference lists. Some other licenses are currently in the news but mostly involve new projects which are in feasibility study phase only.

In 1996 Stamicarbon licensed the Double Stripper Debottlenecking Technology to Yara Canada in Belle Plain, Sasketchewan in Canada, which debottlenecked the Stamicarbon CO_2 stripping urea plant from an original design capacity of 2000 mtpd to a new design capacity of 2850 mtpd. The plant started up successfully and was the first single line urea plant which produced more than one million metric tons of urea in one year.[3)]

Picture 1: YARA Canada in Belle Plain, Sasketchewan, Canada

The ammonia plant was a Uhde license and the finishing section of this plant is a UFT fluid bed granulation, which can produce some 3000 mtpd and further is a UAN section part of this plant.

In 1998 Saipem licensed out the first 3000+ urea plant to Profertil S.A. in Bahia Blanca in the south of Argentina. Profertil is a joint venture between Agrium and YPF. The capacity of the ammonia plant is 2050 mtpd from Haldor Topsoe A.S. and BASF. At the time of completion in 2001, the Bahia Blanca Fertilizer Complex included the largest single train urea plant in the world, with the design granular urea production capacity of 3250 mtpd. It was the first plant to break the 3000 mtpd production target in single stream urea. In 2006 it produced 1,280,718 metric tons urea in a full year of operation, achieving in 360 days of operation an average daily production of 3558 mtpd, with a maximum peak of 3700 mtpd. The urea plant operates two UFT fluid bed granulation plants in parallel each with a design capacity of 1850 mtpd.

Picture 2: Profertil in Bahia Blanca, Argentina

During the start-up period Agrium reported two incidents. In July 2000 a gas release from a ring joint flange caused a fire in a pipe rack in the ammonia unit. The incident was said to have been brought rapidly under control and no one was injured. The damage was restricted to a section of pipe rack and associated piping, cable tray and instrument/electrical cabling.
A second incident in November 2000 saw a minor ammonia release. Argentina's environmental agency ordered that the urea plant stop production. Profertil sought a judicial review on the order.
The courts decided not to intervene, instead suggesting that the matter be resolved through government administrative procedures for appealing against such decisions.

Following a meeting between Profertil and government officials the urea plant was back in operation before the end of 2000. To address concerns from the nearby community a 24 inch flare stack was installed to reduce ammonia emissions from the urea plant.[6,10]

Another problem occurring during the first couple of years was the reliability of the bimetallic High Pressure NH_3 Stripper. Excessive corrosion problems caused several shut downs and capacity limitations of the urea plant. The plant owners decided to install temporarily an existing and available Safurex® Stamicarbon High Pressure Stripper. This High Pressure Stripper was some four years in operation after which Saipem supplied a new High Pressure NH_3 stripper made completely out of zirconium.[4,5]

Finally it was decided to install two refrigeration units, one for each granulator of fluidized bed, thus, improving the plant capacity during the hot season.[4]

In 2001 Stamicarbon licensed two 3500 mtpd urea plants, one for Qafco in Qatar (Qafco 4) and one for Pardis in Iran (Pardis 1). Qafco 4 started up successfully in 2004, producing up to 3800 mtpd[7], while Pardis 1 started up in 2008. Both plants operate a single line UFT fluid bed granulation, while Qafco 4 operates a Uhde ammonia plant and Pardis 1 a KBR ammonia plant.

Picture 3: Qafco 4 in Qatar

Picture 4: Pardis 1 in Iran

On March 18, 2005 MEED quoted Qafco CEO Khalifa al-Suwaidi as saying: "The timing was excellent. Supply and demand was narrowing for fertilisers and we managed to catch the price curve at just the right time. It wasn't luck. It was planned... Within one month of [Qafco-4's] start-up, we were running it above nameplate capacity: we have already operated the urea plant at 3500 t/d"[8]

In 2003 Stamicarbon licensed out a 3600 mtpd urea plant for Safco in Saudi Arabia (Safco 4) with a one line UFT fluid bed granulation as the finishing section. The material of construction of the synthesis section was completely made out of Safurex. The plant started up successfully in 2007 and could produce more than 3850 mtpd.[7]

Part of the Safco 4 plant is a cooling tower to cool down the sea water taken from the Arab Gulf. This shows the strict environmental regulations which are valid in this region. The ammonia plant is a Uhde license and has a design capacity of 3300 mtpd. Its start up experiences has been presented at the 20th AFA International Annual Technical Conference Tunisia 2007.[11]

Picture 5: Sea water cooling tower of Safco 4

In 2004 Stamicarbon licensed a 3250 mtpd urea plant to Pardis 2, which started up in July 2010. The plant operates a single line UFT fluid bed granulation and a KBR ammonia plant.

In 2005 Stamicarbon licensed a very interesting debottlenecking technology to Erdos Unichem in China. Erdos Unichem did buy the Namhae ammonia and urea plant, relocated it from South Korea to Inner Mongolia in China and debottlenecked the plant. The original design capacity were two urea lines according TEC TR-C Improved design with a design capacity of 1000 mtpd each, while after the debottlenecking the urea plant should produce 3520 mtpd. This would be the largest urea debottlenecking project ever.
Stamicarbon's Urea2000*Plus*™ PoolCondenser Technology convinced the client to award the project to Stamicarbon.

Figure 6: Impression of the new Erdos site in Inner Mongolia.

The PoolCondenser Technology made it possible to design one common synthesis section leading to a significant investment reduction compared to two synthesis sections. Safurex® made it possible to operate the plant at low loads without any risk for active corrosion assuring full operational flexibility.
Local Chinese companies were involved in the Basic and Detailed Engineering (CECC, Chengdu), procurement or other equipment and construction activities including the prilling bucket and machine for the largest prilling tower in the world.

The plant started up successfully in 2008 just after the Olympic games and managed to remain successfully in operation during its first winter season in an area where minus 40 °C is considered quite normal.

Picture 7: 3520 mtpd natural draft prilling tower

In 2007 Stamicarbon licensed a grass root 3450 mtpd urea plant to Sorfert in Arzew, Algeria with a Uhde ammonia plant and a single line UFT fluid bed granulation, which is expected to start up end of 2010. Further Stamicarbon licensed another interesting debottlenecking project: Yara Canada, already mentioned above, increased its capacity from the design capacity of 2850 mtpd to 3450 mtpd by means of the Medium Pressure Add On Debottlenecking Technology.

2008 was a very successful year for both Stamicarbon as well as Saipem and at the same time it was the first year after ten years that Saipem licensed again 3000+ urea plants. Saipem licensed three 3000+ urea plants:

A 3250 mtpd urea plant to Hengam Petrochemical Company in Assaluyeh in Iran with a single line UFT fluid bed granulation. This plant is under construction.

Further a 3835 mtpd urea plant to Engro Chemical Pakistan Limited in Pakistan. The ammonia plant is a 2194 mtpd from Haldor Topsoe and the finishing section is a prilling tower. This plant is under construction and is close to commissioning.

Picture 8A/B/C: The construction of the Engro urea plant in Pakistan.

And finally a 3850 mtpd urea plant to Qafco in Qatar (Qafco 5). The Qafco 5 project also included 2 ammonia plants with a design capacity of 2300 mtpd each and a single line UFT fluid bed granulation. This plant is expected to start production early 2011 and will the largest single line urea plant at this moment.

Picture 9A/B: The Qafco 5 project in Qatar with its 3850 mtpd will the largest single line urea plant.

In the same year 2008 Stamicarbon licensed four 3000+ urea plants. Three 3250 mtpd urea plants to Iran: Lordegan, Golestan and Zanjan, all with a Stamicarbon fluid bed granulation section. These three plants are under construction. And further a 3500 mtpd urea plant to Yara in Sluiskil, the Netherlands, which will start production in 2011.

In 2009 Saipem licensed two lines of 3500 mtpd urea plants to Algeria Oman Fertilizer Company In Arzew Algeria and another 3850 mtpd urea plant to Qafco in Qatar: Qafco 6 which is in fact a copy of Qafco 5. All three plants are scheduled to start up in 2012. While Stamicarbon did license in 2009 one

3500 mtpd urea plant to Ruwais in Abu Dhabi, which will operate a UFT fluid bed granulation and a Haldor Topsoe ammonia plant (expected start of production in 2013).

In 2010 Stamicarbon did license one 3600 mtpd urea plant to Petrobras in Brasil, which will operate a UFT fluid bed granulation and a KBR ammonia plant. This project is in the engineering phase at this moment and is expected to start production in 2014.

Where are large scale urea plants built ?
The above list of twenty 3000+ urea plants are built in the following countries: Canada (1), Argentina (1), Qatar (3), Iran (6), The Netherlands (1), Saudi Arabia (1), China (1), Pakistan (1), Abu Dhabi (1), Algeria (3) and Brasil (1). All are based on natural gas as feedstock.
Interesting to see is that large scale urea plants are not only build in the typical urea export countries with a low gas price but also in countries with large urea consumption (growth) figures like Canada, China, Pakistan and Brasil.

4. 5000+ mtpd urea plant technology

Both Stamicarbon and Saipem have proven to be able to license successfully urea plants with capacities close to 4000 mtpd.

Innovations in the urea technology focus on developing better materials of construction, which are critical to further improve the reliability and on stream times of urea plants.
Stamicarbon has revolutionized the urea technology with Safurex®, which opens the door for a zero oxygen urea plant and has much better mechanical properties and a much better corrosion resistance. Furthermore Stamicarbon introduced pool condensation in the urea synthesis section which has proven to be very successful and is followed by other urea licensors like TEC and Urea Casale. Safurex® and pool condensation are standard features since the Safco 4 project in 2003.
Saipem has been developing further the reliability of their High Pressure NH_3 Stripper. After Titanium, Bimetallic tubes now Omega Bond tubes or a complete Zirconium High pressure Stripper are the preferred solutions. The first commercial application of the Omega Bond tubes are at GPIC in Bahrain in operation since early 2010, while Profertil operates a full zirconium High Pressure NH_3 Stripper.

Both Stamicarbon as well as Saipem have debottlenecking technologies available and several successful references of the debottlenecking concepts to increase urea plant design capacities with some 30-50% and thus to realize 5000-6000 mtpd urea plants based on the current proven large size urea plants.

In these debottlenecking projects Saipem increases the load on the High Pressure NH_3 Stripper while adding an additional high pressure carbamate condenser.[12)] One high pressure carbamate condenser operates with 3.5 barg steam while the other operates with a steam pressure of 5.6 barg. The load on the medium pressure recirculation section increases, which is solved by adding a tempered cooling water system for the medium pressure carbamate condenser. The higher load on the low pressure recirculation section is taken care of by applying the 5.6 barg steam from one of the high pressure carbamate condenser and by installing a condenser in the waste water treatment section. The concentration section is typically unloaded by adding a pre-concentrator section. Similar debottlenecking schemes were amongst others implemented at Chambal Fertilizer and Chemicals Ltd in India (from 1125 to 1750 mtpd) and Iffco Phulphur in India (from 1500 to 2125 mtpd).
Saipem offers nowadays their grass root technology Snamprogetti™ Urea technology at a 5000+ mtpd level and did perform a preliminary design to confirm the feasibility of this option.

Stamicarbon has various debottlenecking technologies available and for 5000+ mtpd Stamicarbon offers two options. The first option is the Medium Pressure Add On debottlenecking Technology: Parallel to the High Pressure CO_2 Stripper a Medium Pressure Add On section is installed, while the evaporation section is typically unloaded by a pre-evaporator. This debottlenecking technology is amongst others implemented at Daqing in China (from 1620 to 2300 mtpd) and SKW in Germany (from 1050 to 1500 mtpd). The second option is to upscale the Stamicarbon grass root technology Urea2000*Plus*™ or AVANCORE® to a 5000+ mtpd level and Stamicarbon did perform a preliminary design for this option.[13)]

Other aspects to realize successfully a 5000+ mtpd urea plant are proven and reliable ammonia plant technologies. Together with the Safco 4 urea plant Uhde has designed and constructed a 3300 mtpd Dual Pressure ammonia plant.[11)] Haldor Topsoe performed a preliminary design for a 3500 mtpd ammonia plant.

Further the rotating machines like compressors and high pressure pumps, high pressure equipment and high pressure piping need a careful consideration, although for these equipments a parallel operation of two smaller items can also be considered as it can provide benefits with respect to the minimum required turn down ratio.

5. Conclusions

The current trend in urea plant capacities is a continuous increase in larger capacities from 3000 mtpd some ten years ago to nearly 4000 mtpd currently.

At this moment (October 2010) Stamicarbon has six and Saipem one 3000+ urea plant in operation. During the next years another seven Stamicarbon and six Saipem 3000+ are expected to start production.

Debottlenecking technologies are an important tool to make larger plant capacities proven with limited risks. The Yara Canada first debottlenecking project for example initiated the row of 3000+ urea plant capacities.

Both Saipem as well as Stamicarbon have performed a preliminary design to confirm the feasibility of 5000+ urea plants. It is expected that the first 5000+ mtpd urea plant will be licensed in the next decade.

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Mark Brouwer was born on July 6, 1966 in Groningen, The Netherlands. He graduated in 1988 at the Technical University of Eindhoven at the faculty of Chemical Engineering. His thesis was about the production of ethylene by partial oxidation of natural gas.
After University Mark joined Military Services, Dutch Royal Navy where he was working at the Prins Maurits Laboratory of TNO in Rijswijk. In this period he was involved in Process simulation studies on the absorption of poisonous gasses on active carbon.

In 1990 he joined DSM, working for the Ethylene Plant No.4 as a Process Engineer. In these seven years he was involved in the Basic Engineering of a debottlenecking project of the ethylene plant at Stone & Webster in London and in the implementation of the first of its kind styrene extraction process (from conceptual engineering up to the successful start up).

Early 1997 he joined Stamicarbon as Licensing Manager Urea Revamps active in several countries like China, Russia, Iran, India and the Arab countries. Later he became Manager Stamicarbon Services responsible for all Stamicarbon's activities in existing urea plants, such as After Sales Services, Plant Inspections, Debottlenecking Projects, Reselling projects etc. In these nearly twelve years he did visit more than one hundred urea plants worldwide and was involved in numerous revamp, relocation, debottlenecking and grass root projects.

Since January 1, 2009, Mark Brouwer left Stamicarbon and started up UreaKnowHow.com.
UreaKnowHow.com is an independent group of urea specialists with an impressive number of years experience in designing, maintaining and operating urea plants. UreaKnowHow.com's mission is to support, facilitate and promote the exchange of technical information in the urea industry with the target to improve the performance and safety of urea plants.

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