Worldwide trends in urea process technologies

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Summary
Urea demand is booming as never before. Since the financial crisis in 2008 the number of new urea plants yearly awarded nearly doubled! What are the drivers behind this?
This paper will further provide a historical overview of the market share of the various urea process technologies (Stamicarbon, Saipem, TEC, Casale, NIIC and Chinese design institutes) with the focus on the last decade, as well as a prediction of the market shares for the near future. Which process technologies and which materials of construction are applied in the latest references of each urea technology? What are the chosen design capacities and which final product has been selected? And what is the actual experience of these latest references? Finally the paper will discuss the worldwide trends in urea process technologies.
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Worldwide trends in urea process technologies

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1. INTRODUCTION UREAKNOWNHOW.COM

www.UreaKnowHow.com is the internet platform to exchange technical information within the urea industry with the target to improve the performance and safety of urea plants.

UreaKnowHow.com offers:
- World’s largest urea E-Library including more than 650 technical documents including 350 urea patents;
- A Gallery with more than 650 urea related pictures, figures, drawings and movies including a description;
- A Round Table with more than 1000 active discussions in the field of process, operations, mechanical, maintenance, inspection, safety, environmental, product quality or whichever topic you are interested in; not only for urea but also ammonia, nitric acid, phosphate and other fertilizers.
- A Urea Plants Overview in Google Maps showing a complete overview of all urea plants worldwide including China with detailed information about each plant;
- A Job Portal for Urea Engineers and Managers
- A Used Equipment Market
- A Urea Incidents Database
- A chat function
- Technical Papers for all Members; Biweekly a new Technical Paper covering process/operations or mechanical/maintenance topics will be distributed to all Members

UreaKnowHow.com is world’s largest meeting point in the urea industry with more than 3300 Engineers & Managers working in nearly 235 urea plants, which represents >98% of all urea plants outside China.

2. DRIVERS IN THE UREA MARKET

The financial crisis of 2008 did not hit the urea industry, on the contrary since 2008 the urea industry is booming as never before. What is causing this and lets have a closer look at the main drivers.

The main drivers for urea consumption and new urea plants are the following:
- Population growth
- Diet change in China
- Biofuel US, South America & Europe
- Regulations AN
- Food prices
- Monetizing on natural gas resources
- Change over from gas to coal in China
- Shale gas revolution in US
- Politics
In this paper we like to elaborate on those drivers, which in our opinion are currently most significant and thus have the largest impact: Diet change in China, Change-over from gas to coal in China and the exploration of shale gas in the US.

**Diet change in China**
Economic progress in China has led already to a strong growth of meat consumption in China. The graphs below show this increase in meat consumption in China but compared to the meat consumption in the US, they still consume only 40% of what Americans consume. Refer to Figure 2 and 3 for a comparison between China and the United States.

![Fig. 2 and 3: Meat consumption per person (Figure 2) and total meat consumption (Figure 3)](image)

Animal feed is a key driver for grain consumption. Beef requires 7 kg grain per kg beef, pork 4 kg grain per kg and poultry 2 kg grain per kg. As currently the meat consumption per person in China is still significantly lower than in for example the US, it is expected more meat will be consumed in the near future and more grain and more urea will be consumed. At the same time the fertilizer application per hectare in China is already relatively high meaning that China will need to import meat and grain to fulfill this need. And this means that urea consumption outside China will be driven by this Chinese demand...

**Change over from natural gas to coal in China**
China has a natural gas shortage and priority is given to power plants, which are located close to urban areas for environmental reasons. Also coal is an important feedstock for power consumption and it has been the policy of the Chinese government that every new coal mine had to construct also a chemical or fertilizer plant in order to develop the local industry. As an ammonia/urea complex is relatively simple it is to construct many new urea plants were constructed, leading to an overcapacity of some 20 mln mtpa urea currently. This has led to a pressure on natural gas based plants to close or relocate...

**Shale gas revolution in US**
In spite of the high meat consumption, the US produces currently about 7% of the worldwide urea production. Until today US has become a large urea importer due to high gas prices. Everybody knows that the drilling for shale gas has caused an industrial revolution in the US, leading to about 15 new urea prospects of which some 8 are already under construction. It is expected the urea import to US will end soon and the question is will the US become a urea exporter in the future...

**3. UREA PROCESS TECHNOLOGIES**
Let’s have a look which urea process technologies are applied in the 510 urea plants currently in operation. Refer to Figure 4.
A significant part of these plants (42%) are still operating with conventional technologies, meaning urea technologies without a stripper. Most of these have still a relatively high energy consumption and a relatively low capacity. These technologies include amongst others Stamicarbon, GIAP, TEC, Tecnimont, Chemico and Chinese technologies. Further 24% of the plants are based on Stamicarbon CO₂ stripping technologies, 10% with Chinese CO₂ stripping technologies, 16% Saipem NH₃ stripping technologies and 9% TEC CO₂ stripping technologies.

We predict that the market shares of TEC and Chinese CO₂ stripping plants will increase, while the market share ratio Stamicarbon / Saipem remains constant for the next five years.

Nowadays China is very active in further developing the urea technology. For example Wuhan Engineering Corporation in Wuhan developed a urea technology called “Technology of High Efficiency Synthesis and Energy Saving (THESES)”, which is a combination of a vertical submerged condenser and a reactor together with a low elevation lay out by means of a high pressure ejector. Refer to Figure 5 for the lay out of this synthesis section. This innovative technology is proven at 500 mtpd since January 2014 at Meifeng in Sichuan.
Another example of innovative Chinese urea technology is the “JX Urea Technology” developed by the company JX in Chengdu. They improved the conventional urea technology (so only a high pressure reactor as synthesis section) and realise consumption figures similar to the stripping technologies. Furthermore the investment figure is significant lower. This technology is proven at 1000 mtpd since Jan 2009 and there are several references at 1500 and 2000 mtpd. Refer to Figure 6 for a DCS print of the synthesis section.

4. MEGA UREA PLANTS

Figure 7 shows the number of 3000+ mtpd urea plants awarded so far by Stamicarbon (blue), Saipem (red) and TEC (green) during the last two decades. Before this period no 3000+ mtpd urea plants were in operation.
Fig. 7: 3000+ mtpd urea plants awarded during last two decades

One can easily recognize that MEGA size (here defined as 3000+ mtpd) urea plants become more and more popular. The three major urea licensors Stamicarbon, Saipem and TEC are active and successful in this field. The other urea licensors are not yet active in MEGA urea plants although the Chinese CO\textsubscript{2} stripping technology reaches 2700 mtpd currently.

Stamicarbon has been awarded totally 17 MEGA urea plants of which 9 are in operation, Saipem has been awarded totally 15 MEGA urea plants of which 6 or 7 are in operation and TEC has been awarded 3 MEGA urea plants of which 1 is (nearly?) in operation. All these MEGA urea plants produce fluid bed granules except 3 (Engro in Pakistan, Erdos in China and Matix in India), which produce prills.

Table 1 shows the current status of these MEGA Urea Plants.

<table>
<thead>
<tr>
<th>Stamicarbon</th>
<th>Saipem</th>
<th>TEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>In operation are:</td>
<td>Qafco4, Saftco4, Pardis1&amp;2, Yara Canada, Erdos, Ruwais, Yara Sluiskil, Sorfert</td>
<td>Profertil, Qafco5&amp;6, Engro, AOA Algeria (2 lines) (?), Matix (?)</td>
</tr>
<tr>
<td>First is in operation since:</td>
<td>2004 (Qafco4)</td>
<td>2001 (Profertil)</td>
</tr>
<tr>
<td>Remarks:</td>
<td>At Sorfert, first months some non-technical issues leading to hold of production\textsuperscript{2) }</td>
<td>At Profertil first years some technical issues,\textsuperscript{3) } Engro still suffers from gas shortage regularly,\textsuperscript{4) }</td>
</tr>
</tbody>
</table>

5. WORLDWIDE TRENDS IN UREA PROCESS TECHNOLOGIES

What are the trends worldwide in urea process technologies?

Trend #1: Larger and larger and larger...

Lets have a closer look how the design capacity of urea plants has developed in time. Figure 8 shows the largest design capacity of Stamicarbon (blue), Saipem (red) and TEC (green) awarded in a certain year.
From Figure 8 one can conclude that the design capacity of urea plants has always increased in time and all major urea licensors have been active in this field. Currently Saipem has 4000+ mtpd urea plants under construction in China (Wuulan), Argentina (Profertil) and TEC in Nigeria (Indorama). Currently the planned Matix2 project in India seems to become the largest urea plant worldwide with 4430 mtpd design capacity, although there is some delay in the supply of the coal bed methane.

Also note that several times debottlenecking technologies have enabled licensors to make proven a new maximum design capacity. Examples are Yara Canada, a Stamicarbon licensed plant (originally 2000 mtpd, now running at 3300 mtpd), Profertil, a Saipem plant (originally 3250 mtpd, now debottlenecked to 4200 mtpd however actually operating at some 3950 mtpd), Erdos, a Stamicarbon plant (via a debottlenecking project from 2 times 1000 mtpd to a single train with a capacity of 3520 mtpd) and Sichuan Chemical Works aTEC plant (via a debottlenecking project the ACES21 process became proven at 2460 mtpd).

Economy of scales work apparently and one can expect the first 5000+ mtpd urea plant withing the next 5 years. For example when one would apply the Stamicarbon Medium Pressure Add On Debottlenecking Technology in one of the Stamicarbon MEGA urea plants, one will already produce 5000+ mtpd urea.

**Trend #2: Lower elevation of urea synthesis section**

In order to minimize investment costs all licensors develop technologies, which require a lower elevation of the urea synthesis section. Saipem and TEC are applying a high pressure ejector, while Stamicarbon in their Avancore process still can rely on gravity. Refer to Figures 9, 10 and 11 below.
Trend #3: Submerged condensation in synthesis section

Submerged condensation has several benefits:

- A significant more efficient condensation (heat transfer coefficient of submerged condensation is 40% higher than that of falling film condensation).
- As residence time is available for carbamate at high temperatures already urea conversion takes place leading to a higher LMTD in the condenser.
- A more easy and stable operation as the submerged condenser acts as a buffer for fluctuations in for example the N/C ratio.

Stamicarbon introduced submerged condensation in the synthesis section in 1996 with the PoolCondenser and TEC followed with the Vertical Submerged Carbamate Condenser (VSCC). Later Casale introduced a revamp scheme changing a falling film high pressure carbamate condenser into a submerged type called Full Condenser.

Trend #4: Lower emissions

There are several examples that more and more existing and especially new urea plants need to adhere to more strict emission requirements. For example:
All urea plants (also the existing ones) in Saudi Arabia have recently implemented acid washing to minimize NH₃ emissions from prilling tower and granulation plants. 

Note: Permit emission levels in existing urea plants are typically not challenged

Environmental permits for new plants in the US are very strict (upto 10 ppm NH₃ and urea dust and discussion about opacity)

Flares are standard nowadays although flares are more a safety than environmental measure

Lower emissions from for example prilling towers are in some cases realised in combination with the Sandvik Process System Rotoform Technology to produce specialties (technical urea, AdBlue or Urea+AS)

Trend #5: Higher alloys

Another interesting trend in urea process technologies is the development and implementation of higher alloy materials, thus with higher corrosion resistancies.

Stamicarbon and TEC developed super duplex materials for their high pressure synthesis section respectively called Safurex® and DP28W™. More than 25 Stamicarbon urea plants operate with a synthesis section completely in Safurex®. Two TEC urea plants are in operation with all the high pressure equipment items from DP28W™. These higher alloy materials have many benefits like higher strength figures, lower wall thickness required, less oxygen required and not sensitive for chloride stress corrosion cracking.

Saipem developed recently Omega Bond NH₃ stripper technology, which contains in the Stripper heat exchanger tubes made from a combination of zirconium (tube inside) and titanium at the outside and uses nowadays 25-22-2 austenitic stainless steel for their high pressure carbamate condenser and reactor. Currently two Omega Bond strippers are in operation (for GPIC, Bahrain & FFC, Pakistan), of which the first one since 2009 at GPIC. Both Omega Bond strippers were inspected already during a turnaround. Another advantage if Omega Bond heat exchanger tubes are used is that the stripper bottom operating temperature can be increased to 208°C, and maybe even to 212°C.

Applying higher alloy materials lead to a higher reliability and higher safety standard and as a result of that, higher on stream times, beneficial for all.

Trend #6: Multi-nutrient urea products / higher nitrogen efficiency

The nitrogen efficiency when applying urea is only about 60-70%, which means that 30-40% of the nitrogen produced and applied does no reach the crop and is lost to air and water. This is a huge economical loss and a huge environmental burden, which will soon or later backfire to the urea industry.

However we see a very important trend that more and more urea plants produce multinutrient urea products and/or urea products realising higher nitrogen efficiency.

For example Yara, SKW in Germany and Abu Qir Fertilizers in Egypt produce multi-nutrient urea products like urea+sulphur, urea+ammoniumsulphate, urea+magnesiumsulphate etc. We like to refer to the Sandvik Process Systems Rotoformer technology, which is perfectly suited to produce these multi-nutrient urea products.
Others produce urea products, which realise a higher nitrogen efficiency like ESN of Agrium and several Indian urea producers like NFL, GNFC, TATA, IndoGulf, etc produce NEEM coated urea. NEEM coated urea products is a simple, effective and easy way to produce urea products with a higher nitrogen efficiency.

In this respect we like to refer to the Virtual Fertilizer Research Center (VFRC), which is a research initiative that fosters the creation of the next generation of fertilizers and production technologies to help feed the world’s growing population and provide sustainable increases in global food production, and this global issue requires a global solution. The VFRC comprises the work of multiple research institutions around the world cooperating to advance a unified research agenda (www.vfrc.com).

6. CONCLUSIONS

Urea industry is booming, driven for a major part by:

- Diet change in China
- Change from gas to coal in China
- Shale gas revolution in US

Future Licensor market shares:

- Ratio Stamicarbon / Saipem remains similar
- TEC and Chinese market shares will increase

Trends in Urea Process Technologies are:

- Urea Plants become larger and larger
- Low elevation concepts
- Submerged condensation
- Lower emissions
- Higher Alloys
- More multi-nutrient urea products / higher nitrogen efficiency

7. References

2. AICHE 2014, Vancouver, Safe Start-up of Ammonia / Urea Plants under Challenging Circumstances, Klaus Noelker, ThyssenKrupp Industrial Solutions AG.