

Industrial Solutions

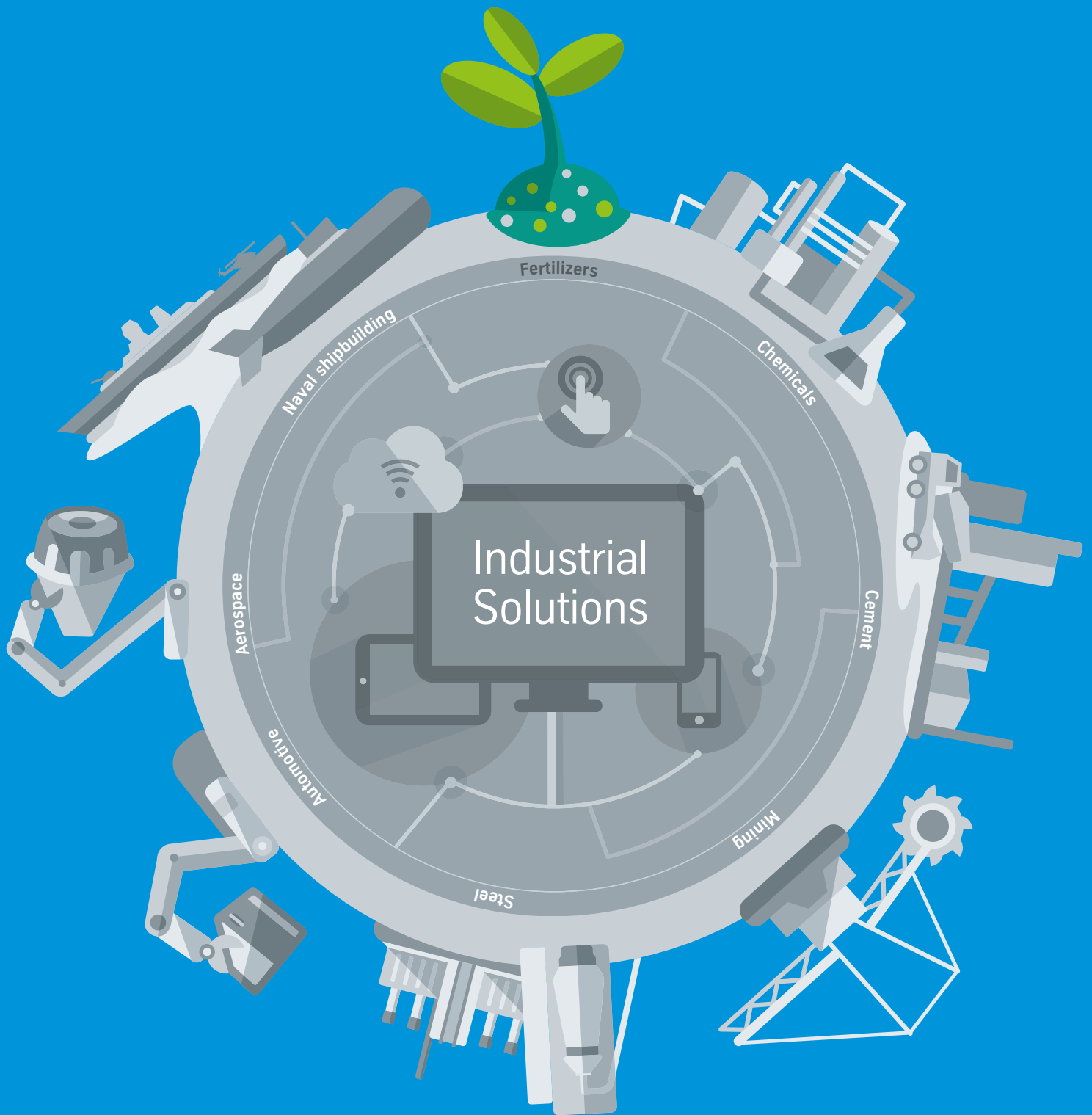
UFT Fluid Bed Granulation

Profit from our best-in-class technology and scalable solutions



thyssenkrupp





The power of true efficiency

The Business Area Industrial Solutions of thyssenkrupp is a world-leading engineering, construction, and service company in the field of industrial plants and systems. Together with our customers, we develop solutions of the highest quality and deliver efficiency, reliability, and sustainability throughout the entire life cycle of your plants. Our global network, with around 21,000 employees at over 100 locations, enables us to provide turnkey solutions worldwide, which set new benchmarks with their high productivity and, in particular, resource-conserving technologies. We are

at home in many different industries. Along with chemicals, fertilizers, coking, refinery, cement, and other industrial plants, our portfolio also includes equipment for open-pit mining, ore processing, and transshipment, as well as associated services. In the naval sector, we are a leading global system supplier for submarines and surface vessels. As an important system partner to our customers in the automotive, aerospace, and battery industries, we optimize the value chain and improve performance.

Why we are best in class.

thyssenkrupp Fertilizer Technology is the global market leader for urea fluid bed granulation technology and an independent licensor for this technology. Based on 40 years of experience in developing and licensing urea fluid bed granulation technology and on the practical experience of more than 70 plants in operation all over the world, we have built up a strong reputation as a highly reliable and independent partner in the fertilizer industry. As a part of thyssenkrupp Industrial Solutions' fertilizer business, a global network of 70 locations enables us to work closely with you.

Contents

04	Three questions for...
06	UFT fluid bed granulation
08	Operational benefits
10	Environmental benefits
12	Research and Development
14	Pioneering new products
16	Worldwide operations
18	Services and Revamps

Three questions for...

Dr Matthias Potthoff, Managing Director of thyssenkrupp Fertilizer Technology provides a personal insight into the challenges of the fertilizer industry and our response to these challenges and opportunities.



Dr Matthias Potthoff

What challenges do you see in the fertilizer industry and how do you master them?

In general the fertilizer industry is a growing business with sound underlying drivers like global population growth and a shift in diets away from vegetarian to more protein- and fruit based food in many parts of the world. However, like any commodity business the fertilizer industry faces investment cycles that are leading to declining product prices in oversupply situations. This in turn results

in phases of reduced investment activities until demand growth has absorbed the overcapacities installed or the most uncompetitive plants close down. In recent years, fertilizer capacity was added in excess of the demand growth and the resulting oversupply has put fertilizer producers around the world under pressure to remain profitable at low product prices.

thyssenkrupp Fertilizer Technology is addressing these challenges by different means. With revamps we help customers to improve their operations by making production more efficient. Another option we offer is diversification. With our new product sulfur-enhanced urea granules we enable producers to diversify into a product with higher nutrient content and margins. As the implementation only requires minor modifications and add-ons in existing urea granulation plants, this is a very attractive route to take. Our newly developed alternative and formaldehyde-free additive extends the application range of urea granules from pure fertilizer usage to technical and even diesel exhaust fuel applications. These two developments are the result of our intensive Research and Development (R&D) activities, focusing on development of new products, further improvement of our fluid bed urea granulation technology and picking up critical HSE issues, such as the use of formaldehyde in the production process. At the same time we have intensified our service activities for operating companies by providing operational support and consultancy to enable them to operate their plants in a more efficient manner.



“By providing leading-edge technology and services we enable our customers to deliver top-level quality products in a most cost-efficient and environmentally friendly manner.”

What particularly characterizes your cooperation with your customers?

To understand the interaction between our customers and us it is important to understand the business model in general. As a licensor for fluid bed granulation technology we have basically two customer relationships to maintain. The first one is the relationships to customers who already operate a fluid bed granulation plant. Their plants have been established between very recently and up to more than 30 years ago. In such cases the operating companies are interested in continuous operational support for optimizing plant operations, sometimes trouble shooting as well as spare part supply, and want to keep their plants up to date with small modifications, e.g. increases in capacity, modifications in product specification or adjustment to new emission limit requirements. Here the customers benefit from our very experienced staff who can provide support in these areas, as well as from the worldwide thyssenkrupp Industrial Solutions network, which allows us as a group to offer engineering and other services going beyond the usual scope of a

licensor from a single source. This is a big advantage for the customer as he has a single point of contact and can choose services from pure basic or detail engineering up to a maintenance contract for his plants.

For new grassroots installations the focus is on minimizing the overall investment cost without sacrificing product quality and plant reliability. Here we work closely with the end user and the EP/EPC contractor to develop tailor-made solutions applying our cutting-edge technologies.

**And finally a personal question:
What do you find particularly fascinating about your work at thyssenkrupp Fertilizer Technology?**

The history of thyssenkrupp Fertilizer Technology goes back to the 70s when the original technology was developed by at that time NSM, later Hydro Agri Fertilizer Technology and Yara. In 2005 thyssenkrupp acquired the worldwide exclusive license rights for the fluid bed urea granulation technology from Yara and it was and is fascinating to be part of this success story: Thanks to our customers' trust and confidence in our technology the installed technology has nearly doubled during the past 15 years with many repeat orders from established customers. This is a very strong testimony to our ability to meet our customers' needs. The challenges new competitors gave us in the last couple of years have inspired and spurred us on to intensify our R&D activities with remarkable results. Many new development have been launched, such as the ultra-low emission scrubbing system Ammonia Convert Technology (ACT) that allows ammonium salt to be recycled from the acidic scrubbing into the final product and operating costs, a formaldehyde-free additive, and production diversification into sulfur-enhanced urea granules.

With these developments thyssenkrupp Fertilizer Technology has become the trendsetter in the market and our aim is to provide cutting-edge technology to all our customers in the future as well. Last but not least, it is very inspiring to work in a business area which is key to ensuring food security for billions of people and future generations of a growing global population.

UFT fluid bed granulation.

Full flexibility for maximum success

The UFT fluid granulation process can produce all required product sizes (2–8 mm) in the same plant with only minimal adjustments. The urea granules are well rounded, very hard, and ultra-resistant to crushing and abrasion. Consequently the urea granules remain dust-free, non-caking and completely free-flowing, even after long storage, frequent handling and shipping. With the superior features of bulk transportability, bulk blending suitability and greater agronomical efficiency, granular urea can be substituted for prilled urea in all applications.

Feedstocks

Sulfuric acid

Nitric acid

Urea

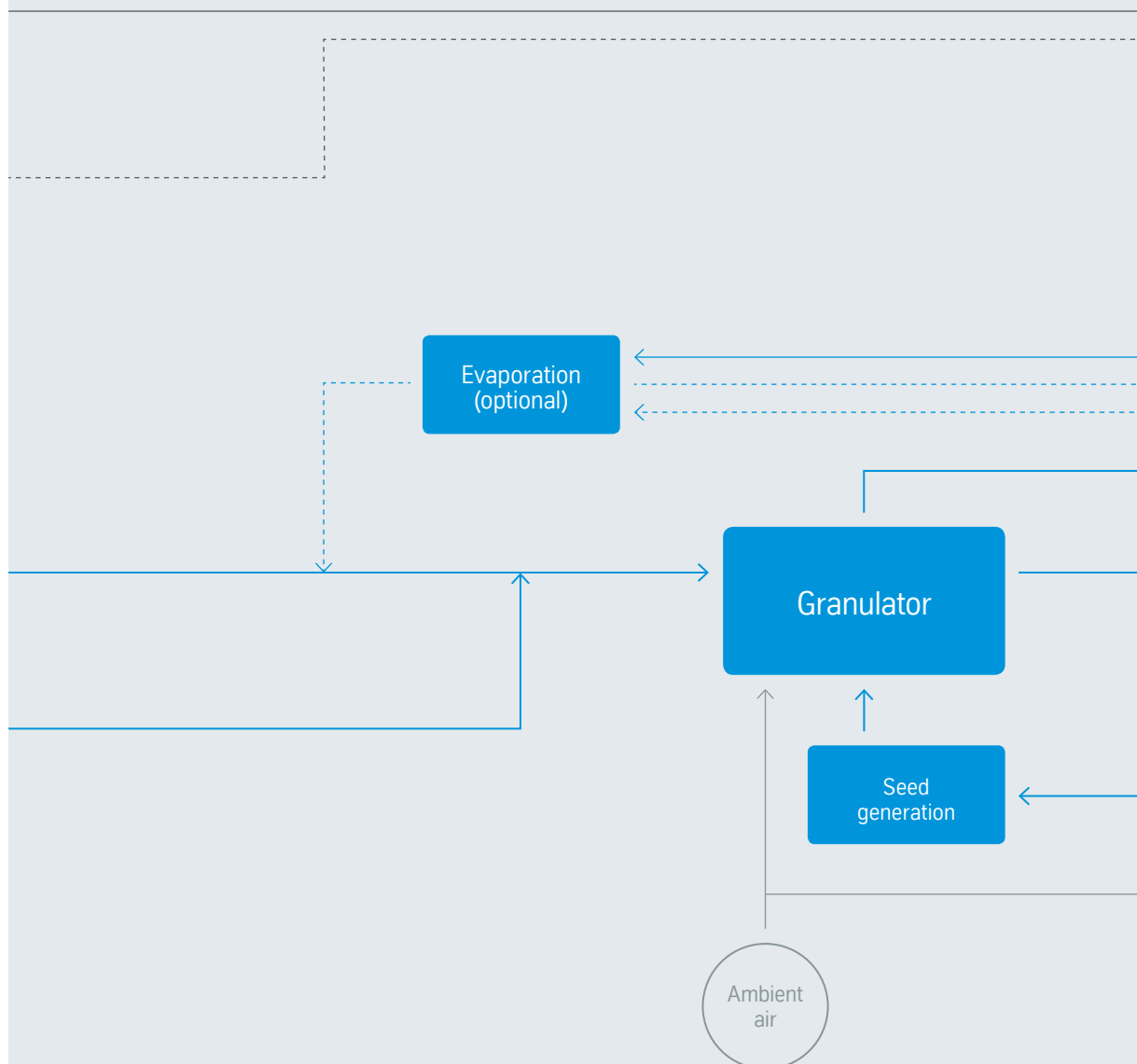
Additive

Evaporation
(optional)

Granulator

Seed
generation

Ambient
air

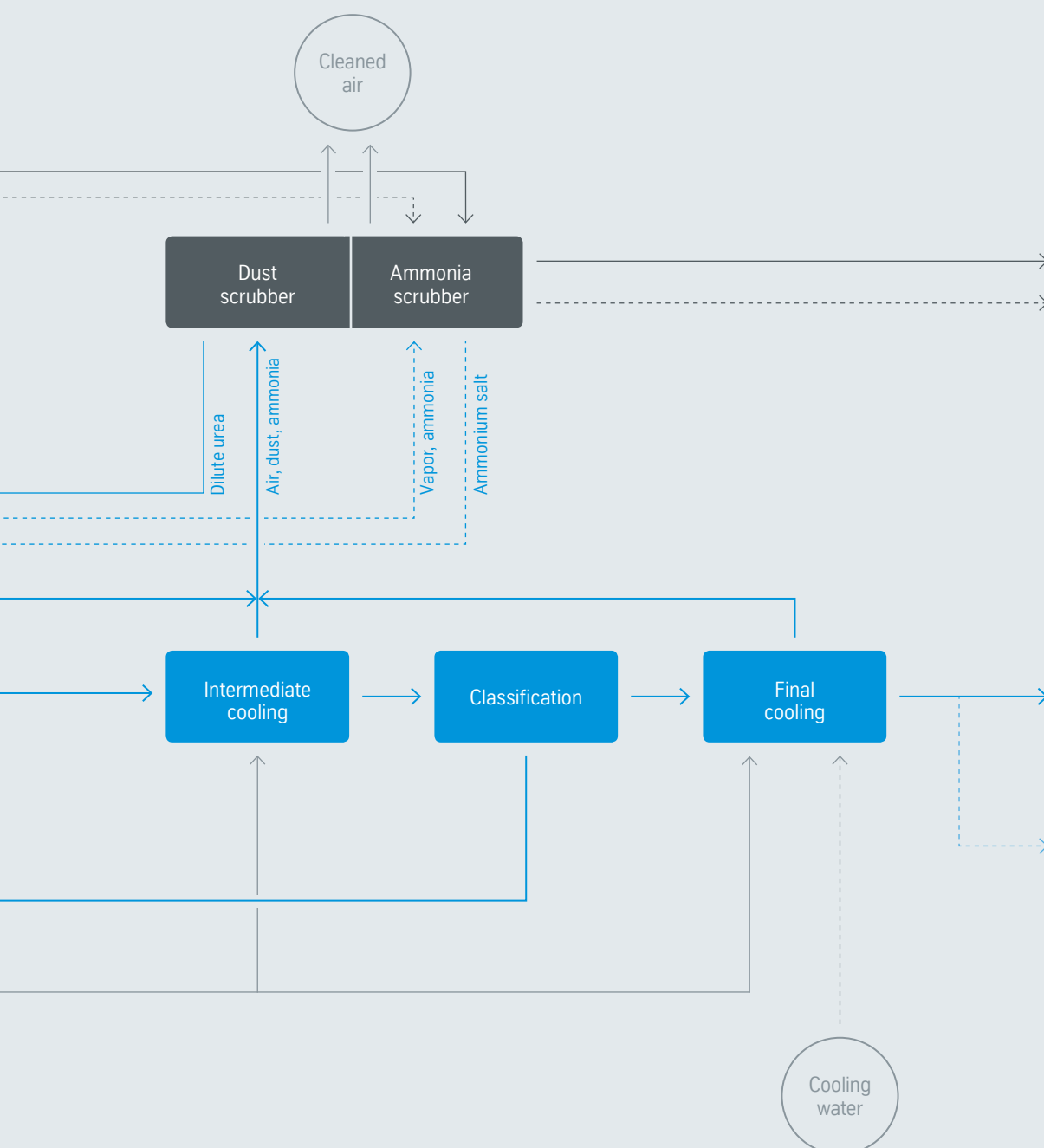


The granulation mode is accretion, which delivers a very hard granule that is far superior in quality to granules produced through layering or agglomeration-based processes.

Our fluid bed granulation plants are easy to operate and very reliable which result is a high on-stream factor. The granulator contains no moving parts, thus minimizing maintenance. The number of solid-handling equipment is significantly reduced when complied to other technologies to maximize plant uptime and reduce investment costs.

Urea product specification (typical)

	Standard size	Large size
Total nitrogen	46.3 wt %	46.3 wt %
Biuret	0.7-0.8 wt %	0.7-0.8 wt %
Moisture	0.2 wt %	0.3 wt %
Crushing strength	4.1 kg (Ø:3 mm)	10.0 kg (Ø:7 mm)
Average diameter	3.2 mm	6.3 mm
Size distribution	95 wt % (2-4 mm)	95 wt % (4-8 mm)
Formaldehyde	0.4 wt %	0.4 wt %



Products

Ammonium sulfate

Ammonium nitrate

Urea granules

Technical grade* granules

--- optional

* Technical grade granules = formaldehyde-free granules





A vital boost to your competitiveness.

There are many good reasons for choosing our benchmark-setting UFT fluid bed granulation technology, as our global market share of over 75% in capacity terms proves. The benefits our plants bring to your bottom line are operational flexibility, production security and product quality.

World-class experience

The excellent product quality of UFT fluid bed granulation technology has made it the global market standard for granular urea. What's more, this technology looks back on some 40 years of proven operational successes. More than 70 of our plants are now operating worldwide under widely varying climatic conditions. We are the only licensor of urea granulation technology to have licensed 20 plants with capacities of 3,000 mt/d or more.

Excellent design

Our single-stream capacities are always large enough to handle the largest urea synthesis units developed to date. With various alternative plant concepts for small or medium-sized plants available, you can also be sure of a customized design concept to meet your specific needs. The use of a 97% urea solution coupled with low recycle ratios results in a simplified design concept requiring only a single-stage evaporation unit. This leads to lower steam and cooling water consumption, minimal power consumption, and reduced investment and operating costs for the urea synthesis plant. The compact layout ensures maximum operability coupled with minimum investment costs.

One for all – for optimal operation

Our process design takes climatic conditions, product quality, product size distribution, environmental regulations, product diversity, and utility costs into account to ensure you obtain a plant with the lowest costs per product ton. We utilize state-of-the-art computer-based design tools backed by over 40 years of operating experience. Each plant is designed to operate optimally under its specific operating conditions.

Typical specific consumption

Electric power	25 kWh/mt ¹
LP steam	35 kg/mt
Process water	0.5 m ³ /mt
Cooling water	none

¹ depending on climatic conditions

Reducing emissions right from the start.

UFT fluid bed granulation technology is not only good for your bottom line; it is also beneficial for the environment in several significant ways. For example, our recommended horizontal cross-flow scrubbing system reduces dust emissions to under <1 mg per Nm^3 of air and its horizontal design prevents back-mixing and cross-contamination of the dust removal and acid handling streams.

Urea dust removed

As dust removal efficiency in excess of 99.9% can be easily achieved, dust outlet concentrations of under 0.01 kg/t of urea produced are possible. The horizontal cross-flow scrubbing system that enables such outstanding emission figures is exclusively available in combination with our fluid bed granulation technology.

99.9%
dust removal efficiency



> 90%
ammonia removal
efficiency

Ammonia emissions efficiently controlled

By using acid scrubbing systems ammonia emissions can be reduced to $<15 \text{ mg/Nm}^3$ of air, thus complying with the most stringent environmental regulations. A conventional acidic scrubbing system produces a side stream of dilute ammonium sulfate solution. Our proprietary Ammonia Convert Technology (ACT) avoids this side stream by recycling the ammonium sulfate solution into the final product. Traces of the micronutrient ammonium sulfate in the urea granules upgrade the resultant fertilizer with an additional economic benefit.



Zero
liquid effluents

No contaminated water

Another key environmental benefit of our fluid bed granulation technology is that no liquid effluents are released into the sewage system.

Formaldehyde-free urea

Although urea formaldehyde is still the state-of-the-art urea granulation additive, it is categorized as a carcinogenic substance by the International Agency for Research on Cancer and adds to the VOC emissions from an ammonia/urea complex. That is why we have developed a new formaldehyde-free additive that significantly reduces the environmental impact by virtually eliminating VOC emissions and ensures compliance with health and safety regulations on formaldehyde, while guaranteeing the same or even better granulation performance and product quality. Besides, the new formaldehyde-free additive extends the application range of urea granules with no or negligible impacts on plants.

Formaldehyde-free
additive significantly
reduces environmental
impact

Lowest emissions and lowest pressure drop with horizontal cross-flow scrubbing system

Our scrubbing system consists of horizontal cross-flow scrubbers with specially designed scrubbing pads from Kimre, a specialist manufacturer of highly efficient phase separation technology. These scrubbers have the following features:

- Pressure drop much lower than other technologies to reduce overall power consumption of the granulation plant
- Proven dust emission figures to $<1 \text{ mg/Nm}^3$ of air
- Clear separation between dust and acid stages to avoid backmixing and cross-contamination
- An Optional low pressure drop AEROSEP® stage allows removal of fine urea dust particles



How our Research and Development makes you more profitable.

Research and Development is one of our major activities. The main objective is to further improve our fluid bed granulation technology and keep it in line with market requirements. To this end, we cooperate with universities, research institutes and industrial partners worldwide so that your operations can become more competitive and profitable.

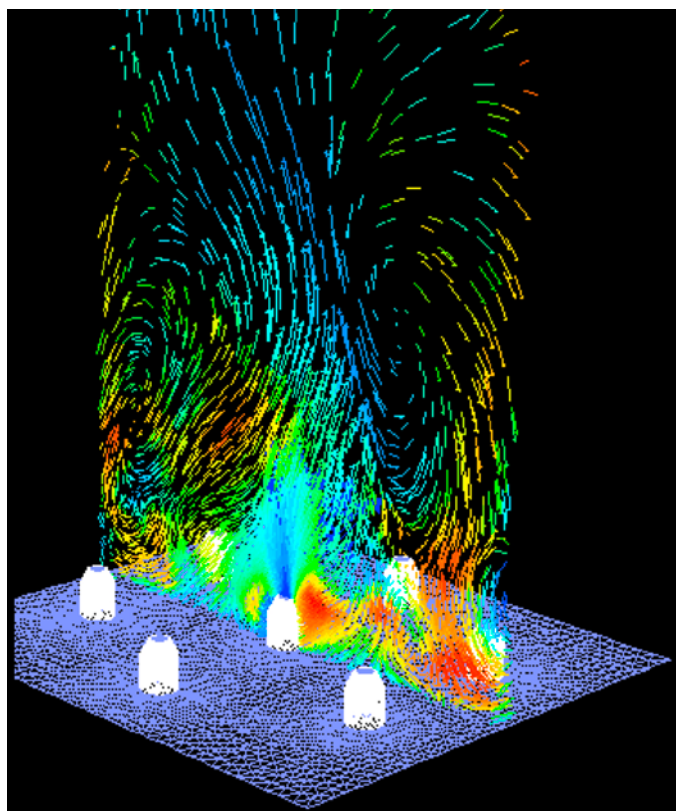
BoPP pilot plant

At thyssenkrupp Fertilizer Technology we operate our own batch-operated pilot plant (BoPP). It is mainly used for continuously improving our technology but also is available to customers for product or process tests. The plant is capable of producing granulated urea products with or without sulfur and utilizing different additives. Even combinations of additives or micronutrients are possible.

New spray nozzles

The UFT fluid bed granulation process requires micro-droplets with a uniform size distribution. This reduces dust formation in the fluidized bed, which in turn reduces scaling, ensures high operability and plant availability, and reduces the evaporation load. A new spray nozzle design makes uniform-sized micro-droplets possible.





State-of-the-art fluidized bed process simulator

Fluidized bed granulation processes are difficult to simulate as a result of the huge number of particles and the complicated interactions between the particles and the droplets from the nozzles. This is due to extensive particle size distribution (from μm to cm) and the high complexity of solid recycling. Intensive research and testing activities as well as feedback from more than 70 operating plants worldwide have resulted in a sophisticated software tool. This gives you an optimum equipment and tailor-made granulator design.

Cutting-edge R&D

Our ability to carry out tests in pilot plant-scale facilities, coupled with the experience gained from operating the plants of selected customers, enables our R&D results to be implemented in industrial-scale plants. And all this ensures you continue to enjoy a future-proof and scalable technology for granulated urea production that safeguards your ongoing profitability and competitiveness.

Inherent process flexibility enables higher-margin products.

We are always open for new product developments – in collaboration with you. As our UFT fluid bed granulation process is very flexible, it can be used for the production of different products, e.g. granulated sulfur and ammonium nitrate. Our main research focus is on urea-based products for agricultural and technical applications that bring clear benefits for agriculture, operator health, and your profit margins.

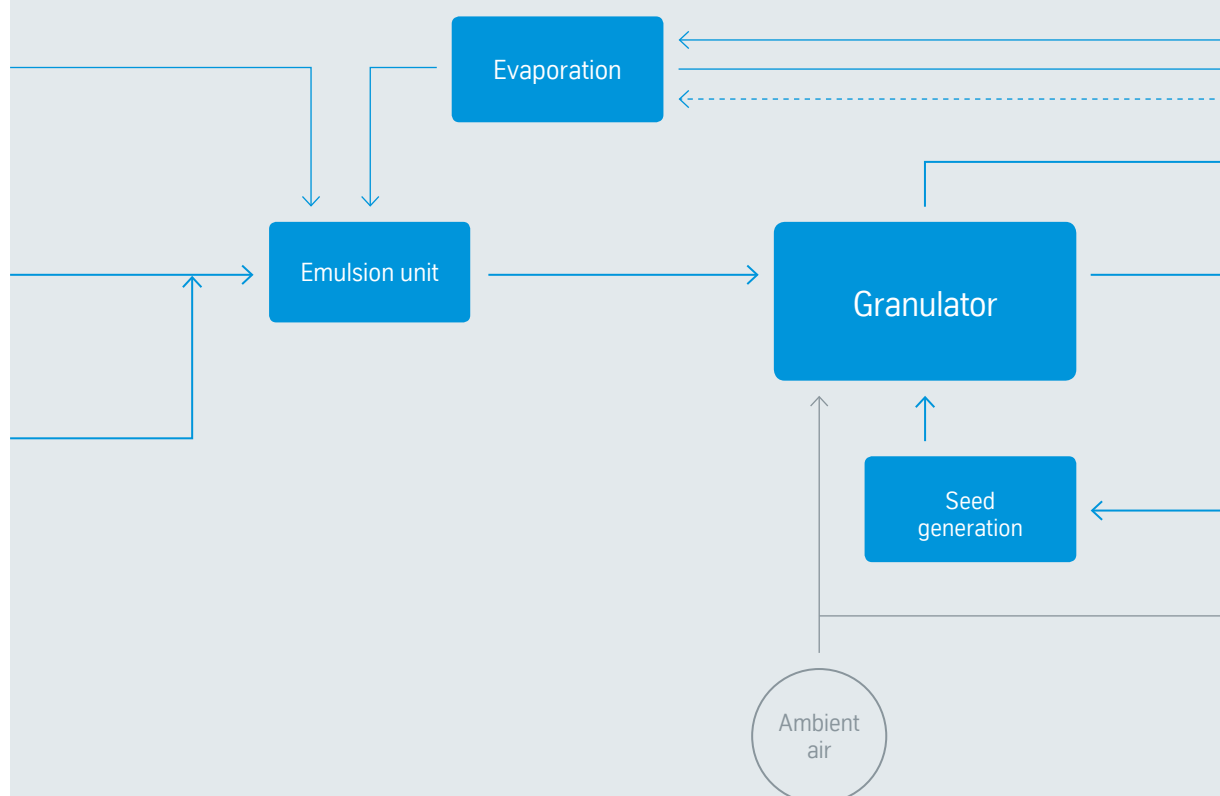
Feedstocks

Sulfuric
acid

Sulfur

Urea

Additive



Urea-ES helps boost crop yields

The increased use of sulfur-free fertilizers, intensified cropping systems, and reduced sulfur dioxide emissions have resulted in a soil-sulfur deficit that is negatively affecting crop productivity worldwide. In 2015 experts estimated that 10 million tons of sulfur needed to be added to soil to address this sulfur deficiency and increase crop yields. Urea granules are an ideal carrier for sulfur.

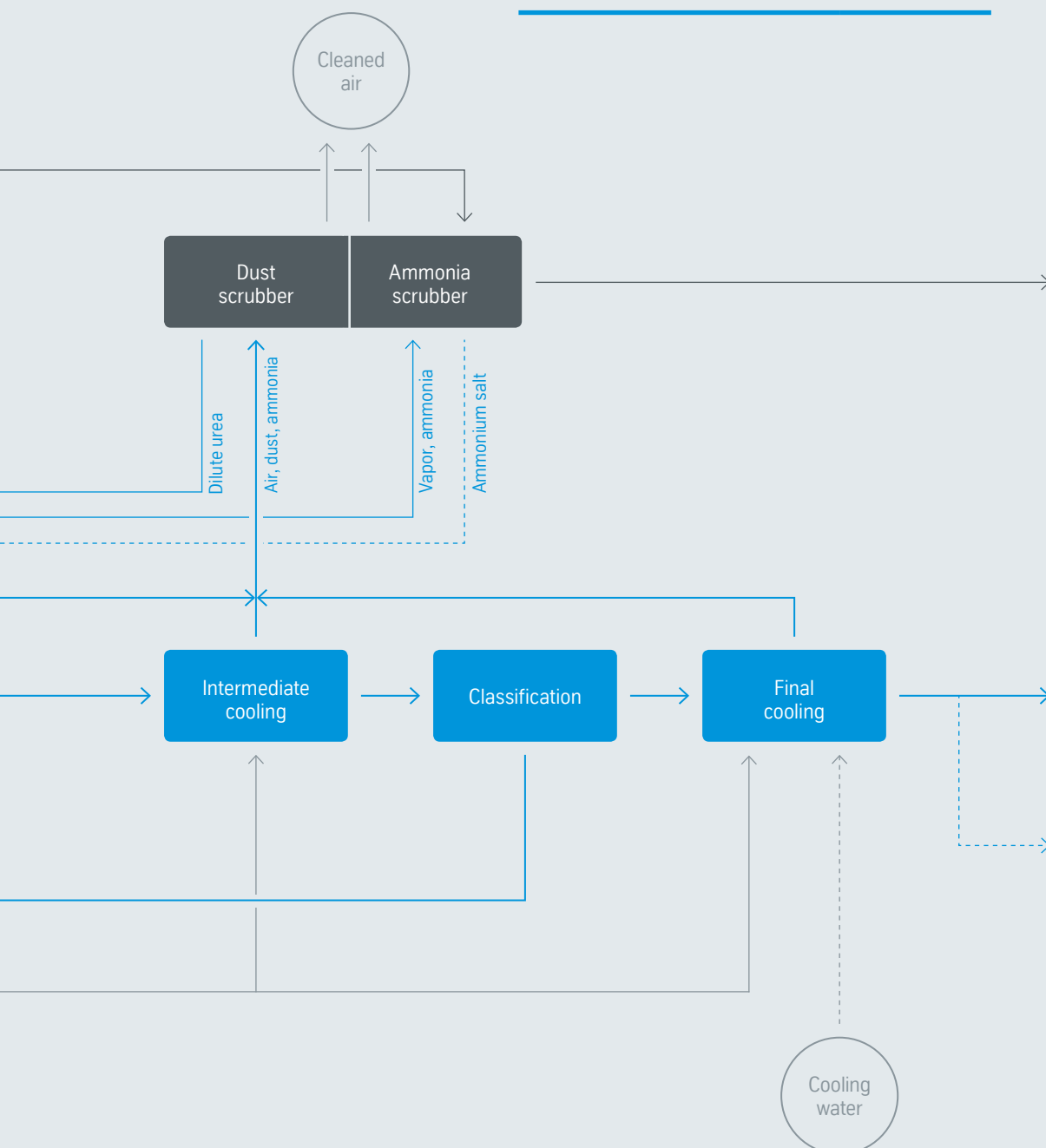
By integrating the Shell Thiogro® technology into our UFT fluid bed granulation process micro-particles of elemental sulfur can be included into urea to form Urea-ES. Besides agronomic advantages, our sulfur-enhanced urea granules considerably improve your production efficiency.

Formaldehyde-free granules for DeNOx and other applications

Our newly developed formaldehyde-free granulation additive performs as well as or even better than urea formaldehyde. This improves the working environment as hazardous formaldehyde emissions are eliminated. The new formaldehyde-free product opens new market opportunities for you, e.g. for DeNOx applications in power plants or as a fuel additive.

Urea-ES product specification (typical)

	Urea-ES 7	Urea-ES 13
Total nitrogen	43 wt %	40 wt %
Total sulfur	7 wt %	13 wt %
N/S ratio	6	3
Biuret	0.7–0.8 wt %	0.7–0.8 wt %
Moisture	0.2 wt %	0.2 wt %



Products

Ammonium sulfate

Urea-ES granules

Urea granules

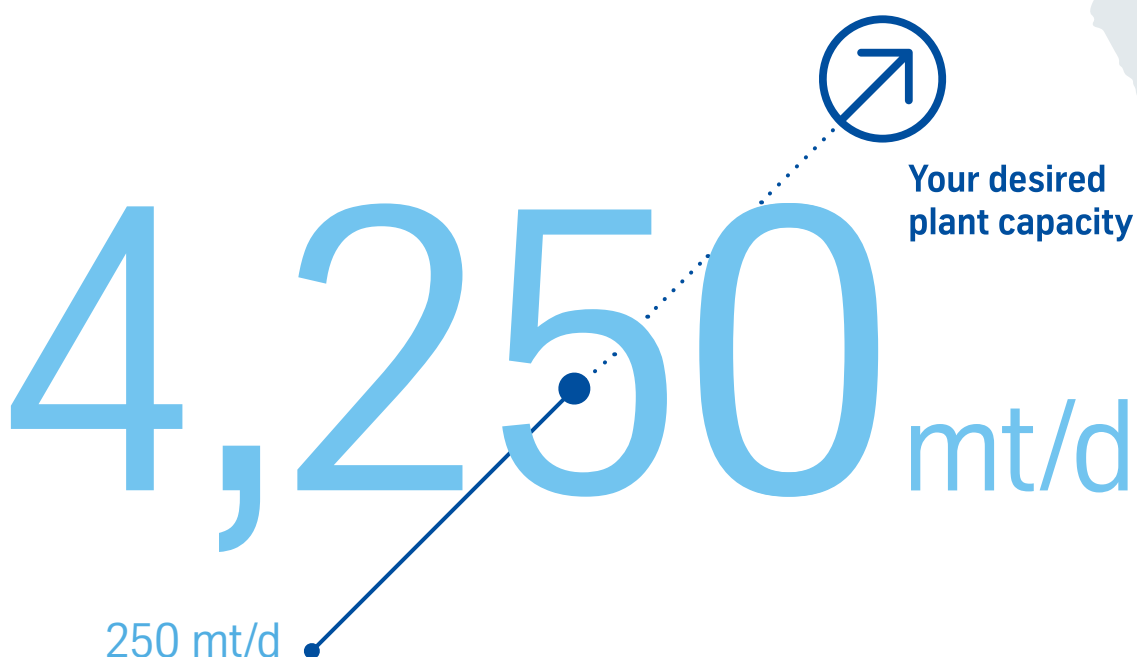
--- optional

Where proven scalability makes all the difference.

The scalability of our fluid bed granulation technology enables standard, mega or jumbo plants to be designed and built, as more than 70 plants operating worldwide prove. The flexibility of this technology gives you a competitive advantage. Our worldwide presence ensures efficient service and support, wherever your plant may be located.

Global benchmark

The fluid bed granulation technology we license has been setting the global market standard in granular urea for four decades. Whatever size of plant you require, we can deliver a tailor-made design. The biggest single-line plant in operation to date has a nameplate capacity of 3,850 mt/d and is running at 4,250 mt/d under stable operating conditions.



Over
75%
of global urea fluid bed
granulation production
technology

Selected references

Customer	Location	Capacity (mt/d)	Special features
Brunei Fertilizer	Brunei	3,900	Largest plant in Asia
Turkmenchimya	Turkmenistan	3,500	Repeat order (3 rd)
CFI	USA	2 x 3,500	Repeat order (3 rd)
QAFCO 5 & 6	Qatar	2 x 3,805	Repeat order (4 th)
AOFP	Algeria	2 x 3,850	2 x 4,200 design capacity/acidic scrubbing
Petrobas	Brazil	3,600	Ammonia Convert Technology
SAFCO 5	Saudi Arabia	3,600	Repeat order (5 th)
CNOOC	China	2,700	Largest plant in China
AFC, EFC & MOPCO	Egypt	3 x 2,000	Identical design

How we make your plant future-proof.



Our fluid bed granulation technology has been bringing customers benefits for decades. Our Revamps, worldwide Service, and Research and Development activities ensure this technology stays future-proof.



“Our understanding of service is that we assume joint responsibility for your production.”

Global service from a single source

Hand in hand with our customers and based on our worldwide network infrastructure we can offer a 360° service that includes after-sales service, troubleshooting, and delivery of spare parts. Our service team is ready to assist you at any time and any location.

Tailored revamps

Small revamps (10–15%) at fluid bed granulation plants are easy to implement if spare fluidization air is available. In such cases, the urea spray system can cope with the extra capacity with no modifications. Larger revamps are no problem, either. The granulator can be upgraded by increasing the number of urea sprayers installed and the residual cooling section enlarged by adding an additional cooling section. All other equipment can be adapted to the new capacity requirement on a case-by-case basis. Notable revamps include:

References of note

Customer	Location	Increase
KAFCO	Bangladesh	1,725–2,100 mt/d (22%)
EFC	Egypt	2,000–2,250 mt/d (13%)
ABF	Malaysia	1,500–2,450 mt/d (63%)*
Yara Belle Plaine	Canada	2,000–2,850 mt/d (43%)
PCS Nitrogen	Trinidad	1,620–1,800 mt/d (11%)

* in two steps

Industrial Solutions

thyssenkrupp Fertilizer Technology GmbH

Vosskuhle 38

44141 Dortmund, Germany

P: +49 231 547 2203

F: +49 231 547 3515

www.thyssenkrupp-fertilizer-technology.com