

# 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.

# Insights 2017

## Dear Reader,

This is the second edition of our "Insights" brochure. Take a look behind the scenes at Industrial Solutions. "Our businesses profit when we think and work as an integrated Group. 'together' is a promise we make to our customers, our partners, and ourselves," says Dr. Peter Feldhaus, CEO of the Industrial Solutions business in an interview on page 04. Together we are strong. We not only collaborate closely inside the Group, but also work hand in hand with customers and partners to ensure we always find the right solution.

In this brochure you'll find news and stories from our diverse business units: from new products and developments, to premium-class body-in-white lines, eco-friendly cement plants and innovative solutions for energy storage, to groundbreaking bucket-wheel excavators and modern fuel cell systems for submarines. Come and discover the world of Industrial Solutions.

Happy reading.

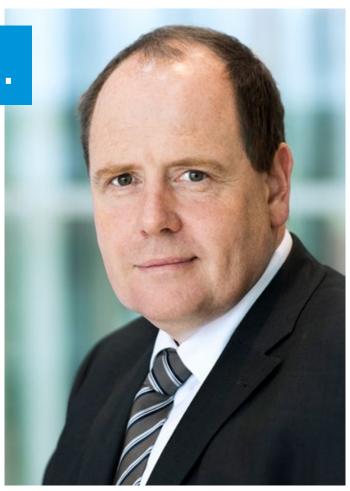
From thyssenkrupp Industrial Solutions

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# Three

questions for...



**Dr. Peter Feldhaus,** CEO thyssenkrupp Industrial Solutions

Dr. Peter Feldhaus took over as Chief Executive Officer (CEO) of the Industrial Solutions business area on May 4, 2017. He is responsible for Strategy, Markets & Development, Communications, Business Development & Sales, and Technology, Innovation & Sustainability.

Prior to his appointment Dr. Peter Feldhaus, who has a PhD in chemistry, was CEO of the Marine Systems business unit. He previously held the position of head of Corporate Strategy & Market Development at thyssenkrupp AG's head office in Essen. Before joining thyssenkrupp, Dr. Peter

Feldhaus spent more than 15 years with consulting firm McKinsey & Company, where he held various positions.

We spoke with Dr. Peter Feldhaus about Industrial Solutions, the strengths of the company, and his vision for the future.



Three questions for... 05

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Dr. Feldhaus, you have been in charge of the Industrial Solutions business area since May 2017. What links do you have with thyssenkrupp?

I grew up near the steel mill in Duisburg. thyssenkrupp holds very special significance for our family. My grandfather was an engineer in a steel mill in Duisburg and my great-grandfather worked as a notary for August Thyssen.

Even while I was studying chemistry Uhde was regarded as one of the top employers for chemists and process engineers. Later in my time as a management consultant I got to know thyssenkrupp better in numerous projects. Then in 2015 I officially became part of the thyssenkrupp family as head of strategy for the Group.

In that role I oversaw the start of the realignment of the Industrial Solutions business area and I'm delighted that I can now carry on and drive forward this work as CEO. I feel at home at Industrial Solutions.

# Forecasting the future is getting more and more difficult, the political map is changing. How is Industrial Solutions positioning itself?

To counter the volatility and growing uncertainty on the markets we are aligning our structures and organization even more closely with the needs of our customers. As a partner at the side of our customers we will use our engineering expertise and experience to provide technological and business solutions that make our customers better and more competitive — both in the developed countries and in the emerging economies.

In the Network of Excellence we are consolidating our global expertise in the areas of engineering, procurement and project management, among others. That way we will achieve maximum flexibility along with the highest quality standards.

In addition we are developing innovative services. We support customers in operating and maintaining their plants, in modernizing their equipment, and in spare parts management. Our offerings include remote monitoring of individual items of equipment or complete production plants, and precise monitoring of membrane condition in electrolysis plants. And these are just two examples out of many.

# What can customers expect from Industrial Solutions today and tomorrow?

Reliability, flexibility and the ability to develop tailored solutions for and with our customers – at any time, worldwide. Innovations, too, are no longer driven solely from Germany. We operate an international network and research around the globe. We recently established a competence center for oleochemicals in Thailand. In India we are developing groundbreaking solutions for the sugar industry. And then there's our barracuda®. Developed jointly by R&D teams in Germany, India and China, it represents a completely new generation of bucket wheel excavators.

In Germany we are concentrating our e-mobility activities in a competence center where more than 350 employees are planning and designing the mobility of the future. Digitization is going to transform our working world. Industry 4.0 is just starting, and it will enable a new form of working together in global value chains. Ultimately it's all about being as close to customers as possible and finding the best possible solution in each case.

"Reliability, flexibility and the ability to develop tailored solutions for and with our customers — at any time, worldwide."



# Over 17,600 machines and systems in use worldwide

Almost

500

submarines and naval vessels since 1960

320 end-of-line test stations on the market in the automotive industry

# Almost 70%

of our employees are engineers and technicians

500 coke plants worldwide

Over 2,500

chemical installations constructed worldwide

Over
90 years'
experience in the construction of fertilizer plants

plants in six regions

€5,744 million turnover

Over electrolysis plants worldwide

21,44
employees
worldwide More:

12,000 tons per day cement clinker

More than 200

years of engineering excellence

# In discussion with Helmut Knauthe.

Helmut Knauthe has been responsible for the Technology, Innovation & Sustainability division of thyssenkrupp Industrial Solutions AG since 2013. The graduate mechanical engineer has been working for thyssenkrupp for more than 33 years and has extensive experience in chemical plant engineering. In the interview, Helmut Knauthe talks about technological trends, the opportunities, and the challenges of Industrial Solutions.

### What in your view are the most important current trends in international plant engineering, at Marine Systems and System Engineering?

The plant engineering environment continues to be very challenging. The prices of raw materials, especially oil, remain at a low level. The overcapacities existing in some areas are holding back investment, leading to strong price and competitive pressure. Regional and international tensions are also inhibiting investment.

Marine Systems is profiting in particular from Norway's decision to cooperate with Germany in the submarine sector. A number of further projects have also contributed to a generally positive market outlook. In the surface ship sector the shorter-term outlook will depend on the national contract award for the class 130 corvettes and further progression of the MKS 180 project. At System Engineering growth opportunities are seen particularly in e-mobility.

### What are the main challenges for international plant engineering companies and how is thyssenkrupp positioning itself?

The biggest challenge is currently the volatility of our target markets. In particular, this is creating difficulties for the award of new plant construction contracts. On the project side the key drivers are aspects such as EPC/overall responsibility and local content coupled with challenging contractual terms. Industrial Solutions has to consider very carefully which projects have good prospects of success. To win over customers to our products and services, we are continuously strengthening our international presence and competitiveness. In parallel with this our engineers are working every day to improve our products and tailor them to the needs of our customers. This is especially being made possible by close cooperation between our business units and regions.

# Where do you see the biggest growth opportunities for thyssenkrupp in plant engineering?

Generally wherever new plants are being built! Here we have strong technological advantages over our competitors. But we're also stepping up our service business. The longer low-investment phases continue, the greater the need for service. As existing facilities grow older, service requirements increase.

# What is your assessment of the plant engineering market environment and where are the main growth markets (sectors, regions)?

With major projects subject to intense competition, we will need to win a lot of mid-size projects to achieve our targets. Our regional presence and local knowledge will help us with this. We are located close to our customers and know their needs inside out.

# What progress has thyssenkrupp made lately in digitization and Industry 4.0?

Industrial Solutions is developing digitization projects in all business units and implementing these in a targeted way. Our Tech Center Control Automation plays a pioneering role in this. We cover the full range of topics, including Virtual Reality/Augmented Reality, Big/Smart Data Analytics, Predictive Maintenance, Digital Twin, Human Robot Interface, and Additive Manufacturing. At Industrial Solutions, we have combined these projects in a cross-cutting initiative, but we're also working closely with other business areas and Corporate on the individual topics.

# A lot of plant engineering companies are feeling competitive pressure from China/Asia. How can thyssenkrupp withstand this competition?

There's no one-size-fits-all answer to this. If only because, depending on the business unit, China is also our supplier and partner. But in terms of direct competition we need to consider very carefully whether it makes sense to compete, i.e. what our prospects of success are. Our goal is to always have the better technological solution. That's our plus factor!

# Is Industrial Solutions working on any interesting research projects?

We're currently focusing on areas such as resource efficiency, the transition to renewable energies, climate protection, and digitization. I can give you some examples: The Cement Technologies business unit is working on new cement additives and the use of alternative fuels. The Electrolysis & Polymers Technologies business unit is

developing big redox flow batteries and water electrolysis cells for the production of  $H_2$ , for example using wind and solar power. Industrial Solutions is also working closely with the Steel Europe business area and thyssenkrupp AG on the Carbon-to-Chem project. Our digitization initiative cuts across all business units.

# What do our customers need most and how can we best support them?

Many of our plant technology customers are in the primary materials industry. That means that our equipment has to operate reliably and efficiently while maintaining consistent product quality. It needs to be low-maintenance and quickly back in operation after servicing or repair. This describes the requirements profile for our research and development. Service and the area of automation/digitization are also playing an increasingly important role.

# "We are located close to our customers and know their needs inside out."



Helmut Knauthe, Head of Technology, Innovation & Sustainability, thyssenkrupp Industrial Solutions AG



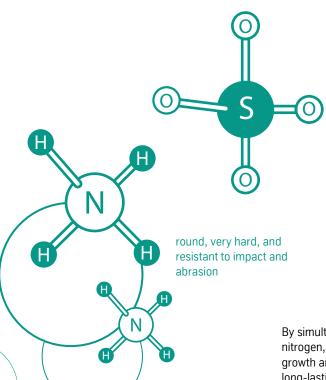
# Feeding the world — with ammonium sulfate's help.



With the global population heading towards 10 billion by 2050 and urbanization eating away at farmland, a significant rise in agricultural productivity will be needed to feed the planet in the future. As plant growth is largely dependent on the soil's nutrient content, fertilizers play a key role. A new process developed at thyssenkrupp by Dr. Jens Mathiak and his team enables premium granulation of ammonium sulfate, a key component of nitrogen fertilizers.

Fertilizers 11

# "We want to give fertilizer manufacturers the opportunity to convert an industrial by-product into high-quality nitrogen fertilizers."



By simultaneously supplying sulfate and nitrogen, ammonium sulfate boosts crop growth and yields. It also guarantees a long-lasting supply of nutrients and promotes the transfer of micronutrients, such as manganese, iron, and boron, from the soil to the plants. "There is a worldwide demand for granular ammonium sulfate, which very few manufacturers currently make," explains Dr. Jens Mathiak, whose team has invested years of energy and innovative thinking to develop this new premium process. "We want to give fertilizer manufacturers the opportunity to convert an industrial by-product into high-quality nitrogen fertilizers." The key benefits of granular ammonium sulfate as opposed to liquid or crystalline solutions are its improved storage, spreading, and mixing qualities.

The patented thyssenkrupp process starts with ammonium sulfate solution, an industrial by-product occurring mainly in the production of caprolactam and coal oven gas. An additive is mixed into the solution to reduce dust formation during granulation and give the end product high crushing strength. Then the liquid mixture is sprayed into a fluidized bed granulator and processed into solid granules, which are screened so that oversized pieces can be crushed and returned to the granulator along with any undersized particles. The resultant granules are round, very hard, and resistant to impact and abrasion.

Right now, ammonium sulfate is mostly sold in crystalline form, which is difficult to incorporate into granulated fertilizer blends. Moreover, as conventional granulation plants are unable to process ammonium sulfate solutions, they require more expensive ammonia and sulfuric acid as starting materials. Following successful lab and bench-scale tests, thyssenkrupp built a pilot plant in 2016 with an initial capacity of 500 kg per hour. "As all the tests have also been successful here, we are upping the process to industrial scale with capacities of 5-20 metric tons per hour," Dr. Mathiak says. "Fertilizer manufacturers worldwide will benefit from improved cost efficiency." The beneficial effects will not only be felt along the entire value chain. Ultimately, such an inexpensive premium process can help to extend the availability of fertilizers in the world's poorer food-producing regions where soils are undernourished. And that way, this innovation can help feed a global population that is growing fastest in the poorest countries.

# Safety starts in the mind.

# What thyssenkrupp is doing to make construction sites safer.

Susan Smith and her two children want dad back from work safe and sound. Everyone at thyssenkrupp Industrial Solutions will do their best to ensure Bill Smith and their colleagues get home in good health.

In recent years, there has been a growing awareness of how important OSH is in the world of industry. thyssenkrupp customers gain a great deal if a construction project is completed safely. Not only is it good for their corporate reputation and reflects positively on their concern for their own employees, it's also fine for their bottom line: the fewer lost time incidents (LTIs) there are, the guicker a construction project will be finished. Consequently, OSH is an issue of great significance to thyssenkrupp and its subcontractors and customers.

### Zero accidents goal

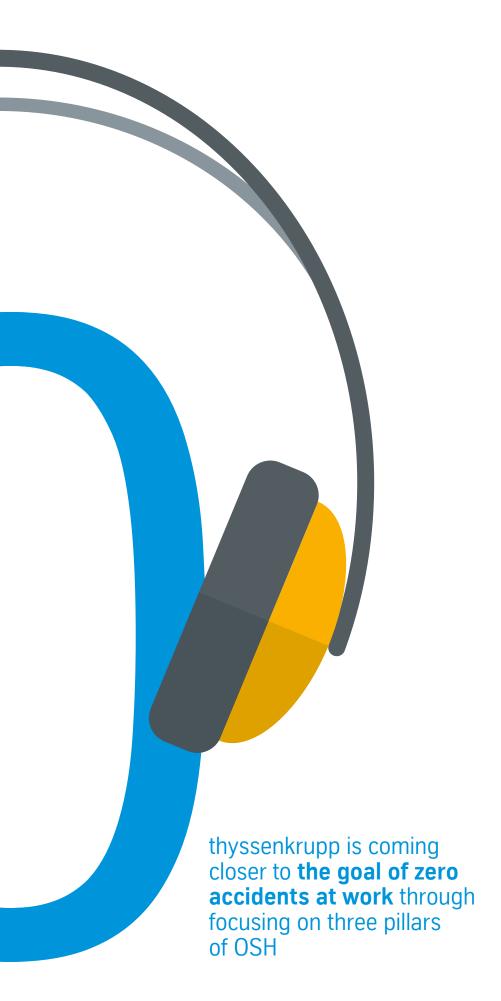
thyssenkrupp is coming closer to the goal of zero accidents at work through focusing on three pillars of OSH: internal safety management systems, monitoring of activities, and measures to heighten safety awareness levels amongst its own employees and contracted personnel. The safety procedures thyssenkrupp has in place are elaborate by anybody's standards. State-of-the-art OSH management systems help to minimize the risk of accidents at work. Strict, regular monitoring of procedures and systems helps thyssenkrupp to evaluate how well they are working. Yet all that would be ineffective if people did not behave correctly.

on behavior: enhancing safety awareness levels; changing perceptions of safety for the better; promoting relevant soft skills; and ensuring everybody speaks the same safety language.

### Focus on behavior

No matter how airtight OSH management is, there is always one unpredictable component: human behavior. In real life, around 90% of accidents are triggered by unsafe behavior. That is why thyssenkrupp has developed a Behavioral Based Safety (BBS) program to positively influence safety-





related behavior. The BBS program focuses on four main pillars: pinpointing desired behavior through means such as management staff leading by example, and pinpointing undesired behavior by means of mandatory procedures and regulations; measuring progress using predetermined criteria that record behavior, detect gains and recommend room for improvement; feedback involving everyone acting responsibly towards coworkers, intervening to stop unsafe actions, and discussing the potential risks; heightening awareness of the consequences to avoid negative ones and encourage positive ones.

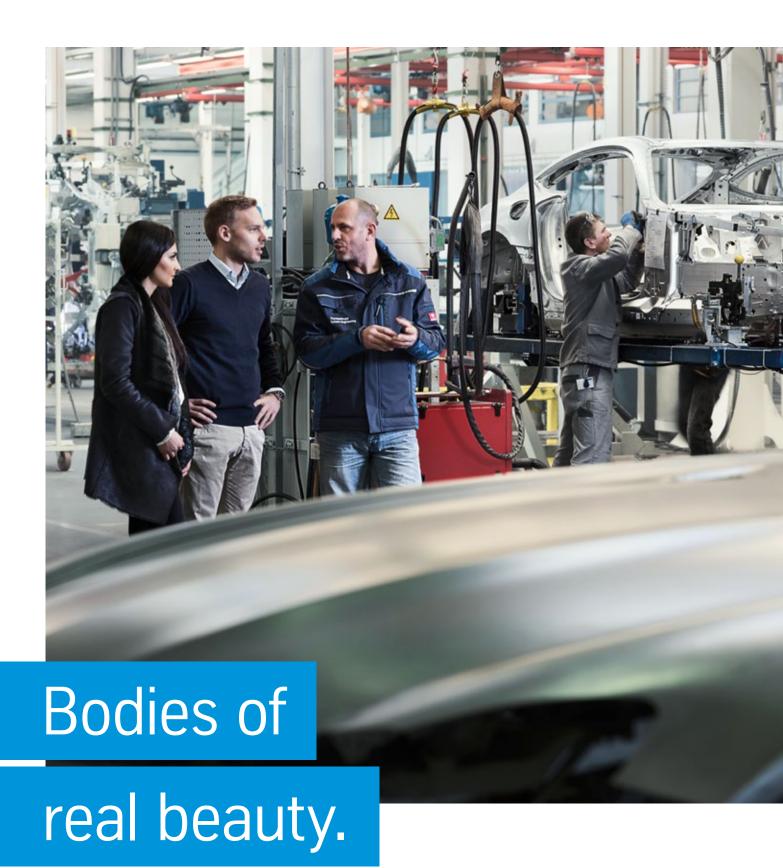


### **OSH e-learning module**

One of the challenges in a company that operates globally like thyssenkrupp Industrial Solutions is communicating key OSH messages to the entire workforce in a wide variety of industries worldwide. An e-learning module developed collaboratively by teams from OSH and Construction went online at the end of May 2017 and uses state-of-the-art learning techniques to solve this problem. Within an hour, all employees who visit or work at construction sites – everyone from new recruits to top management - can learn all about their roles and responsibilities in OSH, what procedures and tools exist, how incidents should be reported, where the main hazards lie, and how BBS works out in practice. And they can do that at any time and in any place worldwide. One highlight of the module is a new assessment tool that makes use of cartoon pictures to help the e-learner spot unsafe behavior at a construction site.

The BBS program and OSH module are helping to raise safety awareness and achieving the zero accident goal – with all the associated benefits for both the company and its customers, as well as the families and friends who look forward to their loved ones coming home from work safe and sound.





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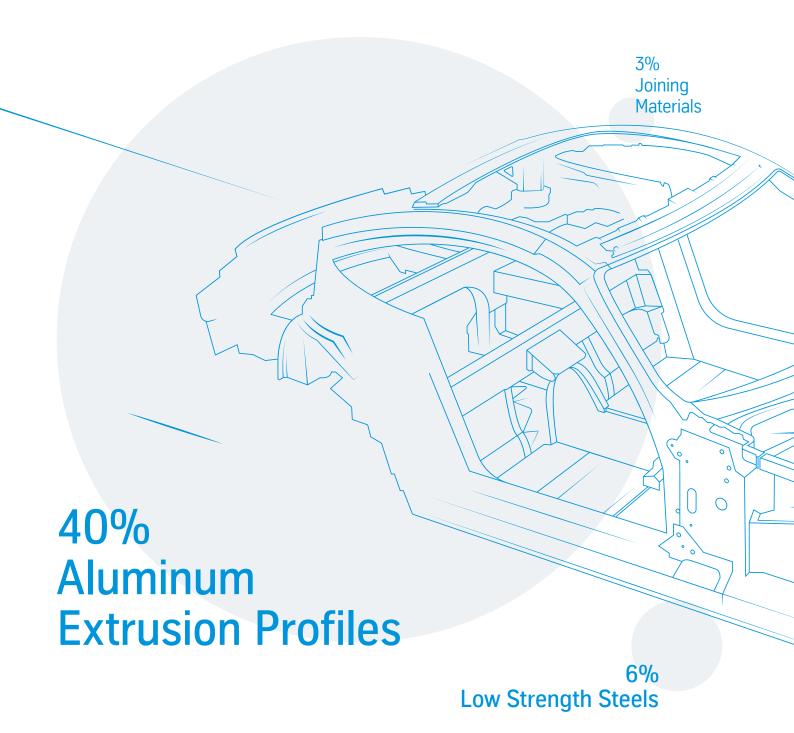


thyssenkrupp System Engineering sets new standards in car body manufacturing. Standout cars like the Mercedes-AMG GT are pure emotion. And a great deal of state-of-the-art technology. As one of the automotive industry's leading internationally operating system partners, thyssenkrupp has been building the aluminum body of the AMG GT since 2014.

Lamborghini, McLaren, Aston Martin, Audi: Mercedes-AMG isn't the only illustrious label thyssenkrupp has built car bodies and subassemblies for. Turning emotive designs into automotive reality makes thyssenkrupp a key player in the premium OEM segment. Whether aluminum car bodies and subassemblies are built in manual, partially, or fully automated processes, the strengths of this thyssenkrupp team are the ultra-precise workmanship required for highly complex aluminum car bodies. The team's extensive expertise and experience in manufacturing complex car bodies means thyssenkrupp is much in demand as a partner for car manufacturers.

"Turning emotive designs into automotive reality makes thyssenkrupp a key player in the premium OEM segment."

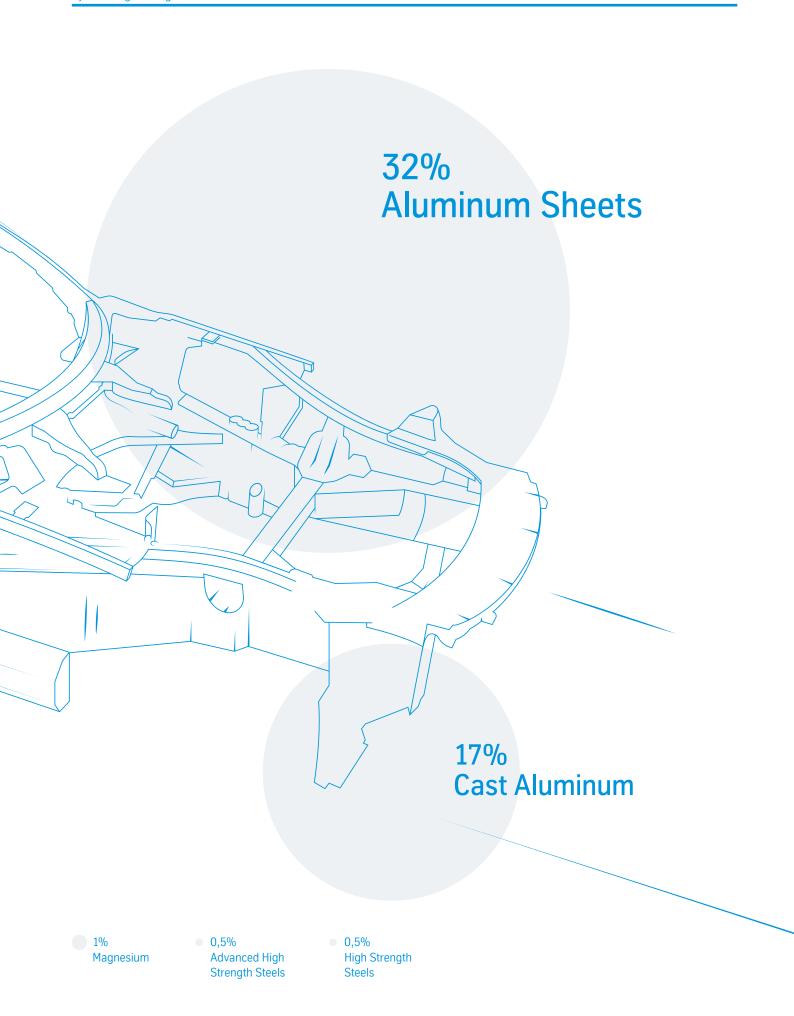




In this multi-year project thyssenkrupp is building car bodies for the Mercedes-AMG GT, a two-door, two-seater fastback coupé that was unveiled at the Paris Motor Show in October 2014. The outstanding features of this GT are its front mid-mounted 4-liter, twin-turbo V8 engine, a rear-wheel-drive layout with transaxle, and a space-frame chassis and body made of aluminum alloys. Those aluminum car bodies are manufactured by thyssenkrupp.

The highlights of the AMG GT process include 5-axis machining of the door sill, trim-line bar, and taillight ready for individual assembly; automated CMT welding of the aluminum body shell for improved surface quality on the visible parts while retaining the same strength; and batch-optimized subassembly production of the outer side panel for four different models on a single multifunctional line. Benefits that persuade standout car manufacturers to go for bodies of real beauty from thyssenkrupp.

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thyssenkrupp's subsidiary Uhde High Pressure Technologies offers a broad spectrum of applications for the food, cosmetics, and pharmaceutical industries. When you're drinking a cup of decaffeinated coffee, have you ever wondered how they take the caffeine out of the coffee bean? Of course there are various possibilities, and these days you can do just about anything with chemistry. But who really wants chemicals in their coffee? One solution – supercritical CO<sub>2</sub> extraction – does without chemicals entirely. Supercritical CO<sub>2</sub> might sound extremely exotic, but if you take a closer look at this technology, you soon realize what an impact it has on our everyday lives, e.g. natural aromas obtained from spices or herbs, pharmaceutical applications or decaffeinated coffee.

Supercritical fluids are rather interesting substances that are neither liquid nor gas once a certain critical temperature and pressure have been exceeded. In this state they are almost as dense as a liquid, but have a similar viscosity to gas. Supercritical  $\rm CO_2$  offers clear advantages, as it is easily available, inexpensive, non-toxic, non-explosive, not an organic solvent, and ensures gentle treatment of the product at moderate temperatures (<100°C) as well as easy separation of solvent and extract. Uhde High Pressure Technologies (UHPT) is a world leader in plants and processes that use supercritical  $\rm CO_2$  as an extraction agent.





# Advantages of supercritical CO<sub>2</sub>:

- Easily available
- Inexpensive
- Non-toxic
- Non-explosive
- Not an organic solvent

Supercritical extraction plays a key role in manufacturing high-quality products from natural raw materials, e.g. herbs or spices. The herbs or spices are dried, ground to a powder, and filled into a product basket, which is then placed in the extractor.  $CO_2$  is fed into the pre-pressurized extractor via a high-pressure pump where it dissolves the extract from the original product. The high pressure improves the solubility of the substances that are to be dissolved. Once this process has been completed, the  $CO_2$  can be recondensed for reuse in the next extraction.

Extraction with supercritical fluids has a wide range of practical applications in the food, cosmetics, and pharmaceutical industries, for example. Using this technology to extract natural substances gives us such everyday products as decaffeinated coffee, essential oils, flavors, and color pigments. The pharmaceutical applications are particularly interesting. With supercritical fluids you can generate or modify micro- or even nano-sized particles with a defined particle size distribution – processes that are making new drugs with exact and controlled properties possible.

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Aerogels, high-performance insulation materials with exciting new properties, are another high-tech application where supercritical  $CO_2$  acts as a uniquely advantageous drying agent.

When it comes to designing and setting up a supercritical extraction facility, thyssenkrupp can point to a comprehensive service portfolio, including extraction experiments to collect process data, and plant process engineering from lab to production scale. Complete turnkey plants ranging from small compact plants (2–6 liters, 200-1,000 bar) to large production facilities (3-6 m³, 300-750 bar) are supplied pre-mounted in modular form or delivered in parts for on-site assembly.

Extraction technology brings us many everyday benefits. But the engineering know-how needed to efficiently and effectively implement the high-pressure technology of the supercritical processes described here is anything but commonplace. Next time you drink some decaffeinated coffee, you'll know where the heart-friendly taste comes from.

"Using this technology to extract natural substances gives us such everyday products as decaffeinated coffee, essential oils, flavors, and color pigments."

# Silent, safe, efficient.

The HDW Fuel Cell System offers world-beating fuel-cell technology in submarines. Non-nuclear submarines can stay submerged longer and are undetectable thanks to an unique propulsion system manufactured by thyssenkrupp Marine Systems. The no-noise propulsion and air-independent system with no moving parts provides strategic advantages navies worldwide are looking for.

Air-independent propulsion (AIP) is a must for modern non-nuclear submarines and thyssenkrupp Marine Systems is the only company to offer the unique and missionproven HDW Fuel Cell System. To generate electrical power for their submarines six navies around the world are already enjoying the benefits of this AIP technology: silent running, no exhaust gases, high efficiency, minimal waste heat transfer, low maintenance, and the environmentally safe reactants oxygen and hydrogen. Whereas oxygen is stored in liquid form in on-board tanks, hydrogen requires a more sophisticated storage solution – a metal hydride system developed in Kiel and in production since 1997. Since then, the demand has been so great that more than 1,000 of these H<sub>2</sub> storage cylinders have been produced.

In a fuel cell, energy is converted in an electrochemical process where H<sub>2</sub> and O<sub>3</sub> react to produce electrical current and water - with no combustion and, importantly, no moving parts. As the reactants are stored on board, there is no need to snorkel while the fuel cell is operating so a submarine can stay submerged longer and remains undetectable thanks to the no-noise operation. "This is the ideal airindependent propulsion technology for a modern-day non-nuclear submarine," says Matthias Kunert, who heads the H2 Storage Manufacturing Unit. "And it has certainly proved its worth in our HDW Class 212A, HDW Class 214, and HDW Class Dolphin AIP submarines, as the feedback from our customer navies proves." The cigar-shaped storage cylinders are 5 meters tall and weigh around 4.5 tons. "The demand for our H<sub>2</sub> storage cylinders is so great we are currently extending our hall to double our production capacity," Matthias adds.

Although the "silent, safe, and efficient" fuel-cell technology from thyssenkrupp is an underwater winner, the company's AIP experts have already moved on to engineer solutions for tomorrow's world. In response to demands by navies for increased AIP speeds and endurance, they have developed the HDW Methanol Reformer System, which produces H<sub>2</sub> on board by reforming methanol, a liquid fuel available worldwide in large quantities at low cost. This propulsion system is scheduled for installation on large submarines. And although methanol-powered propulsion removes the need for metal hydride H<sub>2</sub> cylinders, the demand for these sophisticated storage solutions is set to grow for years to come.

"This is the ideal air-independent propulsion technology for a modern-day non-nuclear submarine."





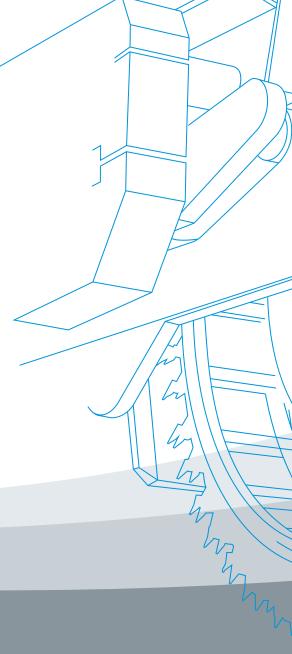


# The first of its kind.

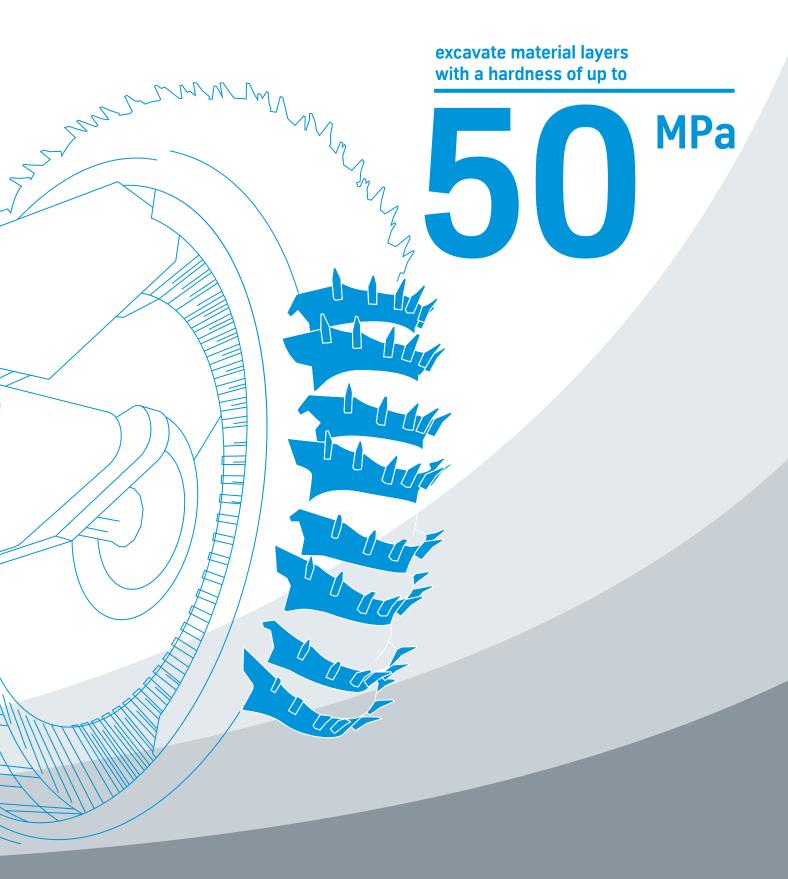
The new barracuda® compact bucket wheel excavator conserves resources and spares the environment.

The new compact bucket wheel excavator is an impressive sight. It is capable of tackling even particularly hard material layers with ease. The newly developed bucket and tooth design immediately catches the eye and enables the barracuda® to excavate material with average hardnesses of up to 50 MPa. And that's pretty hard – by comparison, rocky ground has a hardness of up to 20 MPa. So environmentally harmful and dangerous blasting is no longer necessary in many open pit mines with this new type of compact bucket wheel excavator.

When developing new products, the engineers from thyssenkrupp Industrial Solutions focus first and foremost on how they will benefit the customer. At the same time environmental protection, energy efficiency, and climate protection are integral components of the company's engineering and its environmental management system. The barracuda® is a good example of an innovative mining solution that offers added value to customers while also conserving resources.



Mining 27



Zazann



"The barracuda® is a good example of an innovative mining solution that offers added value to customers while also conserving resources."



Mining 29



The Huaneng Group – one of China's biggest independent power generators – recently ordered the world's first barracuda® from thyssenkrupp for its Yimin He mine in northern Inner Mongolia. The barracuda® will be able to play to its strengths here and continue to excavate the frozen overburden even at temperatures below minus 30 degrees Celsius.

The two companies have a long and successful partnership. This is the second time that thyssenkrupp has succeeded in convincing the Huaneng Group to invest in a promising and innovative technology. Back in 2006 the Chinese customer bought what was at the time the first fully mobile crawler-mounted crushing plant. It enabled the continuous extraction and transportation of coal via conveyor systems, significantly reducing the number of trucks used in the mine. It is still in operation today, offering a throughput of 3,000 tons per hour.

The barracuda®, which has a capacity of 6,700 loose cubic meters per hour, is part of a new continuous mining system for overburden. From the barracuda® the overburden is transported via a belt wagon and a conveyor system to a spreader, which deposits it onto a stockpile. Industrial Solutions' scope includes engineering, delivery, erection supervision, and commissioning of the complete system.



# Efficient operation, low emissions.

Our innovative solutions – i.e. high performance heat recovery, a closed loop system for the entire sulfuric acid plant, an emission-free sulfur melting unit, and an optimized converter – reduce the emissions from sulfuric acid plants and enable their reliable, cost-efficient operation. Since our sulfuric acid plants are self-contained, they are insensitive to interruptions in production caused by frequently occurring downstream shutdowns. This minimizes the very common corrosion risk affecting your plant components and thus prolongs the design life and maintenance cycles at your plant.

### One-stop shop

Thanks to our broad portfolio of various in-house technology solutions from a single source you can get an optimized tailor-made plant concept from thyssenkrupp Industrial Solutions.

A range of process technologies for the production of sulfuric acid is available for feedstocks such as solid sulfur, sulfuric off-gases from mineral processing, spent sulfuric acid, and hydrogen sulfide.

As sulfuric acid is difficult to transport, it is mostly sold locally or used directly for downstream processing into more valuable products. Thus, it is common practice to build such plants locally at the place of need. That is where our extensive know-how and global presence bring you clear benefits. And at our one-stop shop you get everything you need in the most convenient way possible.

### **Comprehensive service**

As your EPC partner, we can offer you a comprehensive service package ranging from feasibility studies to handing over a lump-sum turnkey plant with the entire engineering, procurement, and construction (EPC) spectrum included. This way, you minimize your overall costs, including those for interface management.

As we offer our own technology, you save the typical license fee for your project and plant concepts. Sulfuric acid solutions from thyssenkrupp Industrial Solutions are most certainly good for your bottom line.



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# Paving the way to a sustainable future – with electrochemical energy storage and hydrogen production.

The renewable revolution is in full swing — and that's a good thing. But the ever-increasing energy production from renewable sources naturally fluctuates as wind and weather do, so energy has to be stored for later use. Denis Krude, CEO of thyssenkrupp Uhde Chlorine Engineers, explains how thyssenkrupp's redox flow batteries and water electrolysis can fill the gaps between renewable energy production and demand, and how sustainable chemicals help to reduce  $\mathrm{CO}_2$  emissions.



**Denis Krude,** CEO of thyssenkrupp Uhde Chlorine Engineers

# There are many ideas and technologies out there to store energy from renewable sources. What is special about thyssenkrupp's solutions?

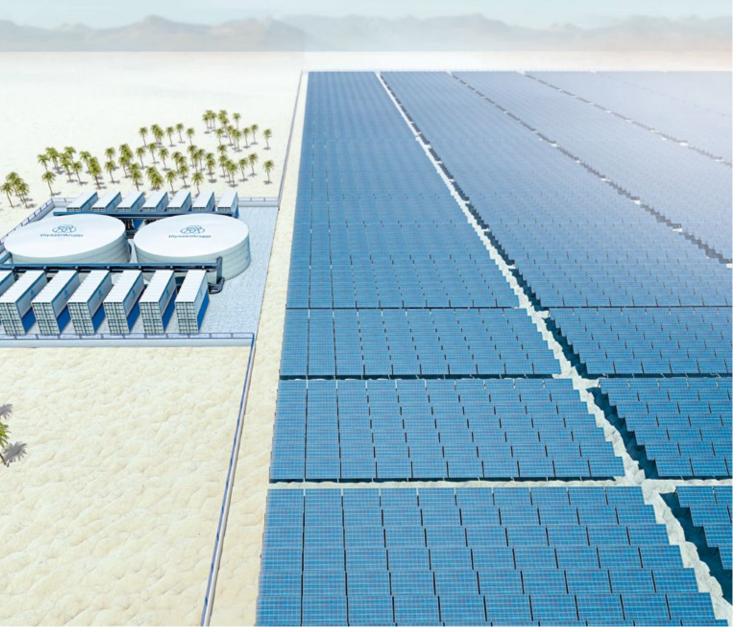
There are many factors but, for both redox flow batteries and water electrolysis, cost and efficiency key. This means in the first place economies-of-scale. Both technologies are based on our large cell design and on our electrolysis technologies proven in over 600 plants worldwide. This makes our solutions the right choice for large-scale projects. And we know how to build these plants very well.

In fact, all chlor-alkali plants produce hydrogen, so we are the world's No. 1 supplier for electrolytic hydrogen production. This differentiates us clearly from small start-ups and shows that we know how to handle hydrogen as well as high currents, or the grid connections of large-scale energy consumers.

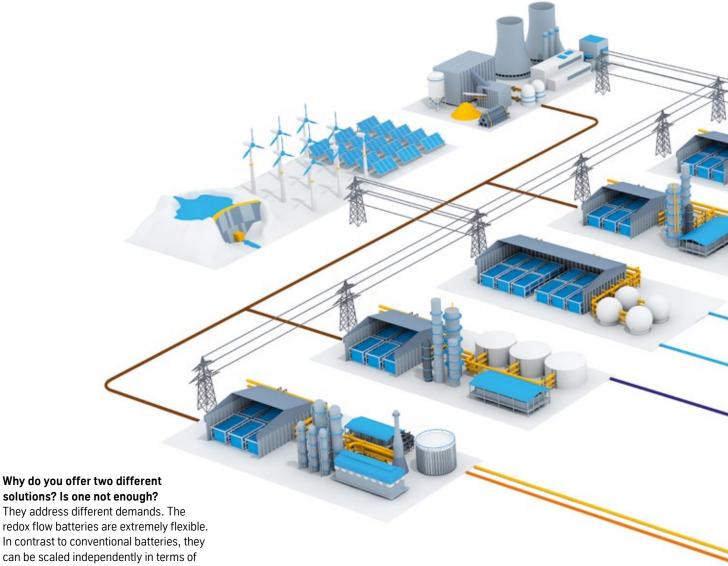


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They address different demands. The redox flow batteries are extremely flexible. In contrast to conventional batteries, they can be scaled independently in terms of power and storage time. This is ideal, e.g. for transferring solar power to nighttime, balancing out wind energy, but also for stabilizing the energy grid and many other applications for storage times of 4–10 hours. But this is just pure storage and release of energy. When power has to be stored for longer or if "green" hydrogen made from renewable energy is needed for sustainable chemicals, water electrolysis is the better option.

Could you give us an example of "sustainable chemicals"?

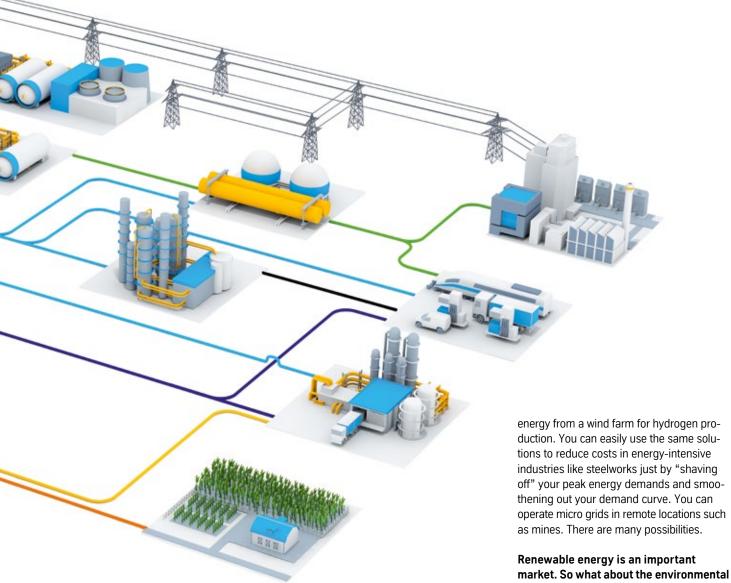
Hydrogen is a basic feedstock for many chemical "routes" that lead to products we all need and use: fuels or fertilizers are good examples. thyssenkrupp Industrial Solutions can offer complete process chains from a single source, e.g. for ammonia and subsequent fertilizer production. With solar

power, hydrogen from water electrolysis, and nitrogen from the atmosphere, we can produce ammonia out of sunlight, air, and water. This eliminates the  $\mathrm{CO}_2$  emissions that would occur in the standard process, which uses natural gas as a feedstock.

# This sounds great, but what about the economic side?

There we have many advantages, not only through the scale effects I mentioned, but also by providing our customers with additional revenue streams. It does not stop at renewable energy production, where you can fill the gaps between production and demand, or use the otherwise curtailed

Electrolysis & Polymers 35



"When storing energy the scale effects are the key to profitability."

# aspects?

They are very good, especially if you look at the complete life cycle of our solutions. Both the redox flow batteries and the water electrolysis plants are expected to have a lifespan of at least two decades, with low maintenance efforts. And after that, the majority of the materials and components can be recycled very easily. Other battery solutions are much more problematic in this respect. In our redox flow batteries, even the vanadium electrolyte, which accounts for a large part of all the materials, is nearly 100% reusable.



Working together to improve plant performance.

Germany

Successful refurbishment of high-pressure grinding roll through Australian-German collaboration. Close collaboration between thyssenkrupp teams in Australia and Germany made this all-in HPGR refurbishment possible and provided a comprehensive engineering solution for a high-pressure grinding roll. It showed that thyssenkrupp's service knowhow can bring a customer added value - whether the equipment is from thyssenkrupp or a third party.



Service 37

Refurbishing a high-pressure grinding roll (HPGR) brings clear benefits to the customer. A refurbishment costs less than a new supply, yet can offer a similar service life. Refurbishments are done in local workshops, which allows for better control of logistics, quality, and schedule. Moreover, the refurbishment process can be extended to include ongoing improvement and optimization. Over time, this benefit increases as the thyssenkrupp team becomes more and more familiar with the customer's plant.

An Australian customer asked thyssenkrupp to carry out a total refurbishment of their HPGR. thyssenkrupp were asked to deliver the refurbishment instead of the original manufacturer because the HPGR's previous performance had not come up to the er's expectations. As the HPGR was third-party equipment and not a thyssenkrupp design, the refurbishment project presented an extra challenge that required close collaboration between the regional office in Australia and the design teams in Germany. The refurbishment was carried out within the thyssenkrupp Service Center in Australia, while parts were provided by thyssenkrupp Germany – a highly successful example of working together for the customer's benefit. This Australian customer was very happy with the way the entire project was carried out and the enhanced performance of the HPGR.

The experience gained on this HPGR project has provided the thyssenkrupp service team in Australia with new options for refurbishing this type of third-party equipment. In addition, the design and implementation processes developed during this refurbishment project are now being shared with other thyssenkrupp Service Centers globally. By working together so closely within its global network, thyssenkrupp is engineering high-quality service solutions





### Parts & supply management

Spare parts supply | wear parts solutions | advanced parts solutions

A defective part can lead to unexpected and costly downtime. Forecasting the need for parts helps increase the reliability and availability of your plant, as well as reducing your overall operating expenses. We advise you on the correct time to replace components and which parts are suitable, deliver and fit the parts, ensure high quality and rapid availability, and supply an electronic catalog to save you time and effort in finding the right parts. In addition to optimizing your parts' supply and management, we also assist in streamlining your warehousing processes.



### Field & workshop services

Technical inspections | repairs and field support | workshop services | operator & maintenance training courses

Anywhere in the world we can apply our specific plant know-how as your local service partner. Thanks to our network of service centers and local workshops, we offer fast assistance when you need it most—in overhauling strategic parts, maintenance or servicing. By detecting and eliminating problems early, we increase your plant uptime. Our custom recommendations for maintenance and modernization help you to precisely plan plant stoppages. Moreover, we offer training courses and seminars to keep your staff up to date and safe.



### Revamps & outages

Analysis, engineering and manufacturing | plant improvements | revamps execution up to EPC | turnaround management

Over the course of time, the demands placed on production plants may well change. In order to meet these changing demands, we offer you services in the fields of revamps and retrofitting, debottlenecking and capacity expansion, emission reduction, efficiency enhancement, converter revamping, and outages. When we implement such a revamp or upgrade, plant stoppages are minimized and the outcome brings benefits such as improved uptime, optimal raw material use, lower energy consumption, and compliance with stricter environmental standards.





### **Asset management**

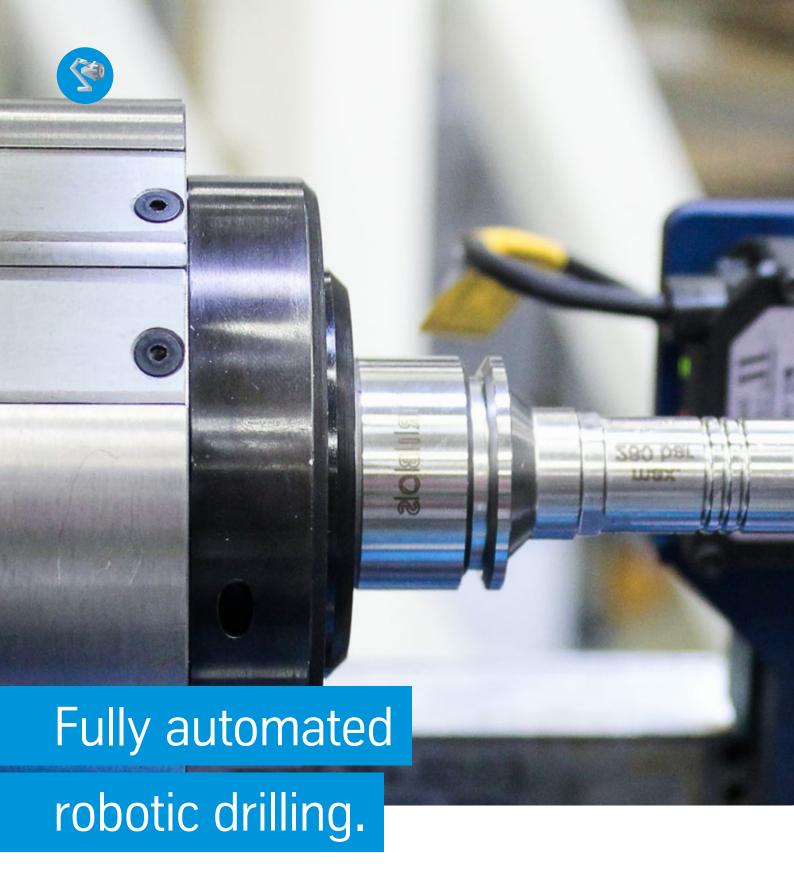
Consulting & audits | technical guidance | operation & maintenance contracts

At thyssenkrupp we assume joint responsibility as true partners for your production, including the risks involved. Thanks to our many years of experience in the field of plant engineering, we can help to optimize plant availability and minimize maintenance costs. Since our asset management is based on proactive maintenance, it helps to reduce your total cost of ownership by lowering your operating expenses, and boosting reliability and performance, thereby increasing the profitability of your plant.

Integrated service concept 39

We deliver service solutions along the entire plant life cycle to enhance our customers' competitiveness. That's what we call 360° Service.

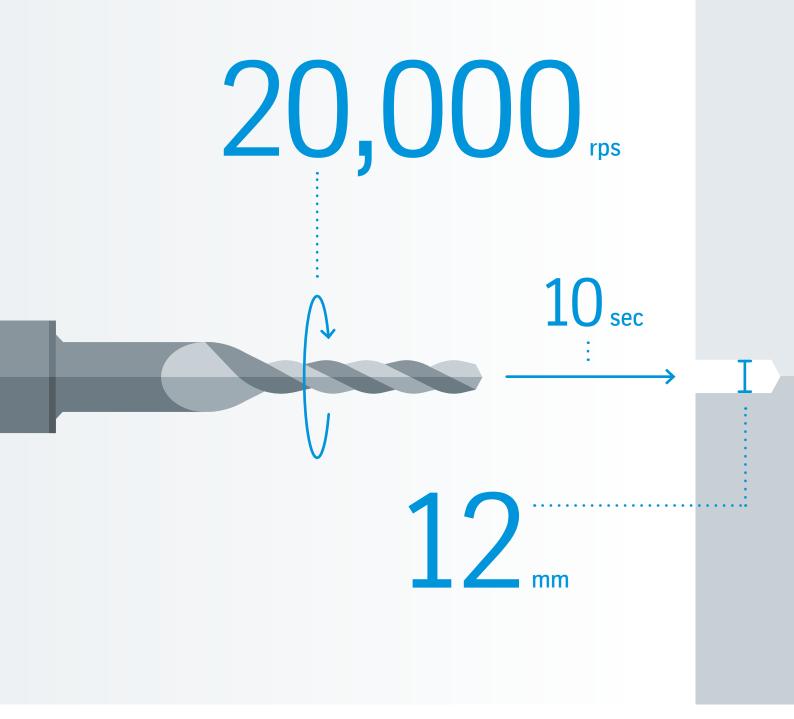




### Single-step drilling, countersinking, and quality control.

Flexible and scalable process automation is key to optimizing and automating processes with the aim of increasing competitiveness through more flexible manufacturing, boosting quality by reducing error rates, and increasing production systems' uptime. The robot-based application arcarde (Assembly Robotic Cell Application for Riveting and Drilling End Effector) brings these benefits to aircraft manufacturers.

Aerospace 41



Focused on customer needs engineers from thyssenkrupp System Engineering developed arcarde. This robot-based application enables the most common process in aircraft production – positive connection of structural parts – to be fully automated at high levels of precision. arcarde makes drilling and countersinking possible in a single process step that includes post-process quality control.

With the help of a stereo camera, the robot-assisted tool is highly accurately positioned on a part with complex geometries (double-curved surfaces). In a typical drilling process for aircraft manufacturing, the tool drills a hole with a diameter of up to 12 mm in no more than 10 seconds. The 20,000 rpm spindle enables very accurate holes to be drilled through stacks of almost any kind of

relevant material. Productivity data are transferred automatically into a database that can be accessed from anywhere. Though implementation of additional process steps, such as sealant application or rivet setting, is still at the trial phase, these operations are expected to be available in the near future.

In addition to the excellent performance data arcarde is maintenance- and repair-friendly. The deployment of standard components from well-known manufacturers means spare parts can be purchased quickly and cost-effectively thanks to the support of thyssenkrupp's global after-sales service network. Together with thyssenkrupp, aircraft manufacturers can equip themselves to face the challenges of tomorrow's world.



## Bringing high-tech to bulk storage.

Piles of limestone, gypsum, clay, or iron ore: a storage facility for bulk materials used in cement production lines looks like a typical low-tech operation. But now thyssenkrupp Industrial Solutions has developed a pioneering fully automated storage system that brings high-tech to bulk storage – and numerous key benefits as well.

Operator health is the key issue with conventional storage solutions for the bulk additives and correctives required for cement production. Every time the equipment that stacks the raw materials into piles (belt stacker) has to be moved to a different pile, somebody has to enter the dust-filled storage facility to operate the machine. The same is true of the reclaimer, the equipment used to remove the required quantity of the raw material for cement production. The dust levels in a conventional facility can be a health risk, and in many countries the relevant health and safety regulations have become much stricter. Furthermore, the other issues with conventional storage solutions are, on the one hand, the high cost of labor and, on the other hand, the inferior reliability of the equipment.

2-D
scanning



Cement 43

The fully automated storage system developed by thyssenkrupp means operators no longer need to breathe in the dusty air inside the storage facility. This high-tech solution not only eliminates the health risk, but also lowers labor costs and enhances both reliability and efficiency.

### Automation is the answer

thyssenkrupp has successfully developed, designed, and put into operation a fully automated tailor-made longitudinal storage system where correctives for raw meal grinding are stored on one side of the facility and additives for cement grinding on the other. A 180° slewing belt stacker installed in the middle runs up and down on rails to stack the additives and correctives in piles. Two portal scrapers, one on each outer side, reclaim the materials as required.

The key feature of the automated solution from thyssenkrupp is its intelligent radar sensor technology that collects reliable data on the pile shape and positioning of the equipment. The belt stacker is equipped with two radar sensors for 2-D scanning and one radar sensor for precise positioning of the belt stacker.

### 3-D models

The stockpile management software then converts the data transmitted from this radar system into 3-D models of the piles. This high-tech storage system enables four key tasks to be carried out automatically: moving the stacker from pile to pile; moving the reclaimer from pile to pile and precisely undertaking the first cut; avoiding any collisions between the stacker and the two reclaimers; and determining the respective pile volume. With conventional systems the first cut is always tricky to perform because after stacking, the pile surfaces are not at all even. As the thyssenkrupp software precisely knows the height and shape of each pile, it automatically directs the reclaimer to exactly the right position.

Being able to determine the volume of each pile is particularly useful because it provides an overview of the used and remaining quantities of additives and correctives, thus facilitating forecasting of future demand.



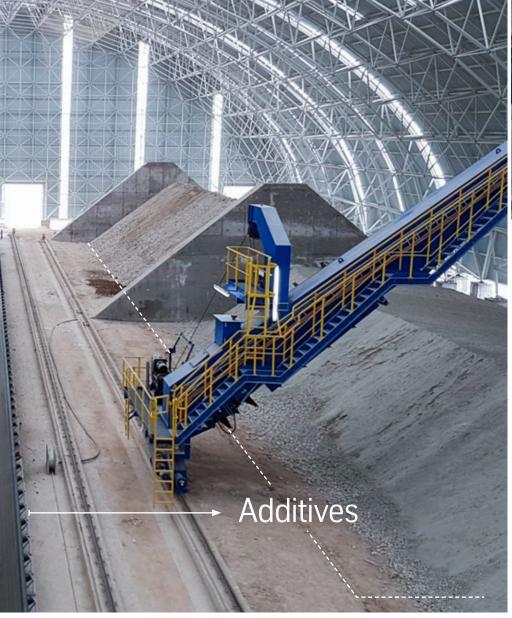
### Health, cost, and efficiency benefits

Probably the most important benefit of this fully automated storage system for the operator is improved employee health. No longer does anybody need to breathe in the dusty air during routine bulk-handling operations. And that's not the only significant benefit. In countries where labor is expensive, the cost savings achieved by using this system are possibly a key factor, too. Moreover, by scanning and creating 3-D models of the stockpiles, the software also allows the volume of the piles to be determined with previously unattainable accuracy, thus enhancing the efficiency of stockyard management. Last but not least, the compact design of this automated storage system saves space, which also helps to cut costs.





45 Cement





### **Applied expertise**

As one of the world's leading full-line suppliers to the cement industry, thyssenkrupp can point to vast experience and expertise in this field. The first-ever high-tech solution for storing the bulk materials required in cement production lines shows how industry-leading know-how can be deployed to deliver concrete benefits to cement manufacturers and, in particular, their personnel.



**Fully automated** storage system

### Our portfolio

### **Fertilizers**

- Ammonia
- Urea
- Nitrates
- Phosphate fertilizers
- Ammonium sulfate
- Granulation technologies
- Coal gasification
- Services



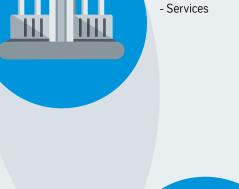
### Steel

- Coke making equipment
- Metallurgical injection systems
- Materials handling equipment



### Chemicals

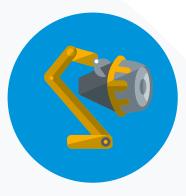
- Electrochemical technologies
- Hydrogen
- Methanol
- Organic chemicals
- Polymers
- Dehydrogenation
- Polycondensation technologies
- High pressure technologies
- Oleochemicals
- Services



### Mining

- Mining systems
- Mineral processing
- Materials handling
- Services

Our portfolio 47



### Aerospace

- Planning and technical assessment
- System integration
- Assembly lines
- Automation solutions
- Handling & transport
- Jigs & tools
- Services

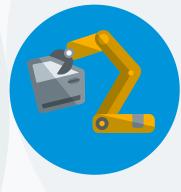


### Naval shipbuilding

- Submarines
- Naval surface vessels
- Naval electronic systems
- Services

### Cement

- Raw material preparation
- Clinker production
- Cement manufacturing
- Services



### **Automotive**

- Battery & testing solutions
- Assembly systems
- Car body technologies
- Forming dies
- Lightweight solutions
- Services



### Services 360°

- Asset management
- Revamps
- Service center & field services
- Parts supply & management



# At home the world over

Along with its lengthy experience in the field of plant engineering, thyssenkrupp Industrial Solutions is primarily known for one thing: its international competence.

At over 100 locations, Industrial Solutions offers its customers a wide range of engineering skills for numerous processes and competent all-round service. In future, Industrial Solutions will enhance its presence even further in the regions.

### America

Argentina: Buenos Aires

**Brazil:** Belo Horizonte, Diadema, São Paulo **Chile:** Antofagasta, Santiago de Chile

Canada: Calgary, Victoria

Mexico: Colonia Lomas de Chapultepec,

Querétaro

Peru: Arequipa, Matarani

**USA:** Atlanta, Auburn Hills, Bridgeville, Denver, Greenwood Village, Janesville,

Milwaukee, Yorktown

### **Africa**

Egypt: Cairo Ghana: Accra

Morocco: Casablanca Mozambique: Maputo

Saudi Arabia: al-Khobar, Riyadh South Africa: Sunninghill

United Arab Emirates: Abu Dhabi, Dubai

Qatar: Doha



Bremen, Burghaun, Cologne, Dortmund, Emden, Essen, Flintbek, Hagen, Haltern am See, Hamburg, Heilbronn, Hohenstein-Ernstthal, Kiel, Langenhagen, Leuna, Lübeck, St. Ingbert-Rohrbach, Wadern-Lockweiler

Czech Republic: Brno Denmark: Rungsted Kyst

Finland: Espoo

France: Aix-en-Provence, Ensisheim,

Sarreguemines

Great Britain: Ascot, Coleshill, Coventry, London, Port Talbot, West Sussex, Winfrith

Newburgh Italy: Milan, Turin Netherlands: Roermond

Russia: Dzerzhinsk, Kaluga, Moscow, Nischni

Nowgorod

Switzerland: Domat (Ems), Schwerzenbach,

Zurich

Spain: Barcelona, Madrid, Rubí

India: Maharashtra, Mumbai, New Delhi,

Pune

Indonesia: Jakarta Japan: Tokyo, Yokohama Kazakhstan: Almaty Malaysia: Petaling Jaya Pakistan: Islamabad Philippines: Makati City

Singapore

South Korea: Changwon City

Thailand: Bangkok Vietnam: Hanoi

### Australia

Australia: Macquarie Park, Melbourne, Perth - Henderson, Perth - Stirling

### **Industrial Solutions**

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