Industrial Solutions

STAR process®

Propane and isobutane dehydrogenation with outstanding reliability

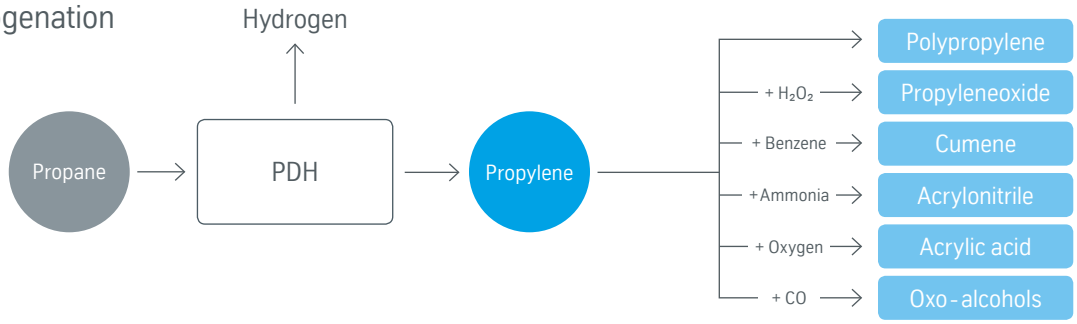
thyssenkrupp

STAR process® – Most reliable dehydrogenation technology

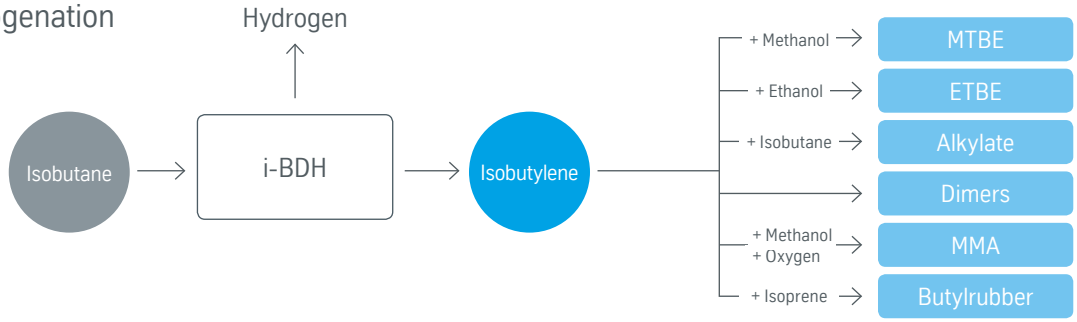
The STAR process® (Steam Active Reforming) is a commercially established technology for the production of propylene and isobutylene.

The technology is used to dehydrogenate lower paraffins (propane or butanes) into their corresponding olefins (propylene or butylenes), which can be further processed to valuable downstream products (see possible applications below).

Propane Dehydrogenation



Isobutane Dehydrogenation



Main advantages:

Superior availability
Smooth operability (no moving bed, in-situ regeneration);
On-spec quickly after restart leading to higher availability of more than 8,500 hours per year.

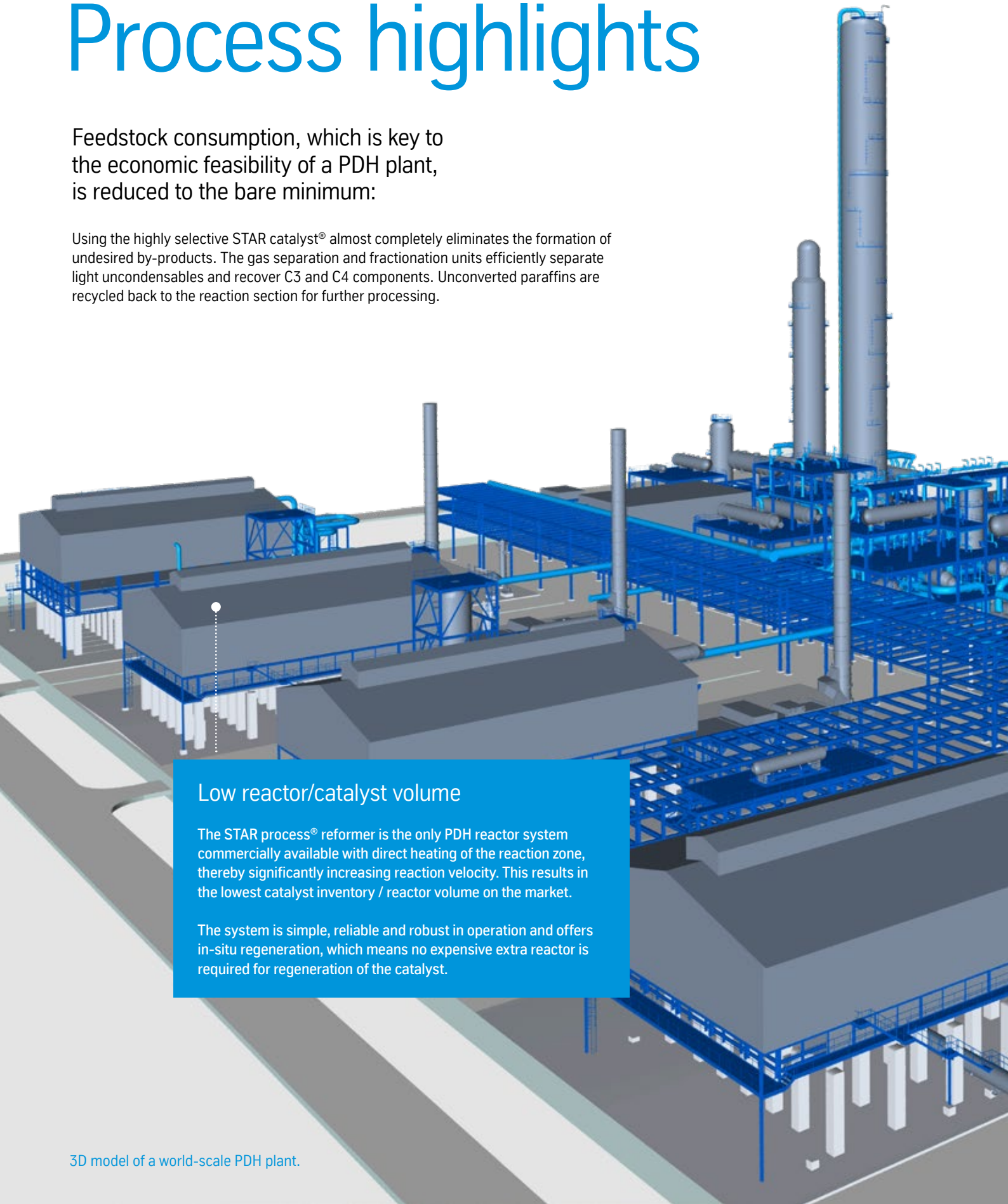
Low investment
Heated tubular reactor leading to smallest reactor volume and lowest catalyst costs on the market.

Highly selective catalyst
Olefins production using thyssenkrupp Industrial Solutions' proprietary STAR catalyst® is virtually free of by-product formation.

Process highlights

Feedstock consumption, which is key to the economic feasibility of a PDH plant, is reduced to the bare minimum:

Using the highly selective STAR catalyst® almost completely eliminates the formation of undesired by-products. The gas separation and fractionation units efficiently separate light uncondensables and recover C3 and C4 components. Unconverted paraffins are recycled back to the reaction section for further processing.



Low reactor/catalyst volume

The STAR process® reformer is the only PDH reactor system commercially available with direct heating of the reaction zone, thereby significantly increasing reaction velocity. This results in the lowest catalyst inventory / reactor volume on the market.

The system is simple, reliable and robust in operation and offers in-situ regeneration, which means no expensive extra reactor is required for regeneration of the catalyst.

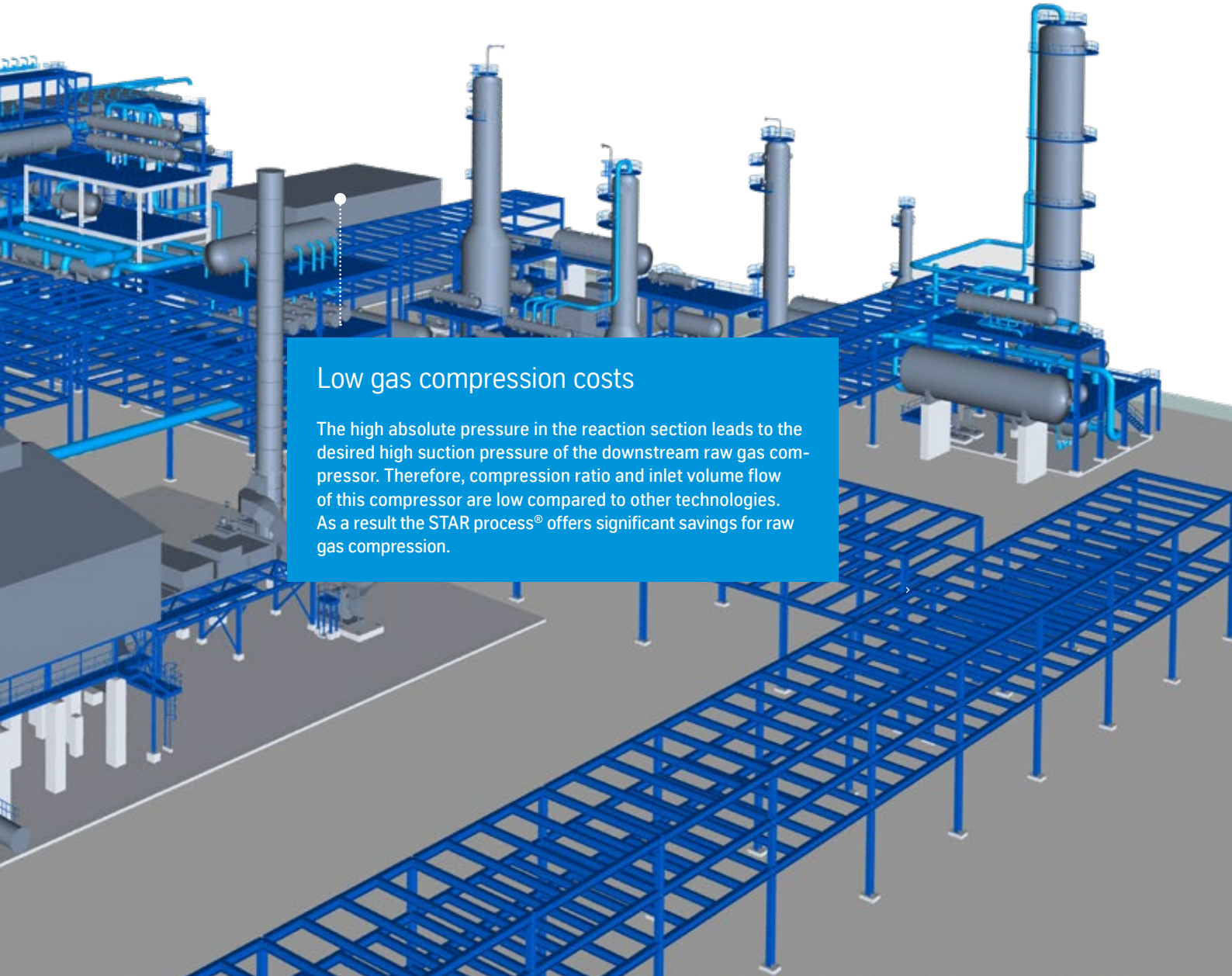
3D model of a world-scale PDH plant.

In terms of operability customers will benefit from the following:

Low maintenance fixed bed reactor type
– No moving catalyst
– No hot switching valves
– Simple and robust operation

High availability and reliability
– Independent parallel reactor trains
– Wide operational window makes trips less likely

Shortest start-up and overall shut-down time in the unlikely event of a reactor trip
– Shorter re-start from “hot stand-by”
– Demonstrated plant availability of 98%



Low gas compression costs

The high absolute pressure in the reaction section leads to the desired high suction pressure of the downstream raw gas compressor. Therefore, compression ratio and inlet volume flow of this compressor are low compared to other technologies. As a result the STAR process® offers significant savings for raw gas compression.

Process description

Typically, the feedstock is first sent to a feed preparation unit to separate any heavier components or possible contaminants.

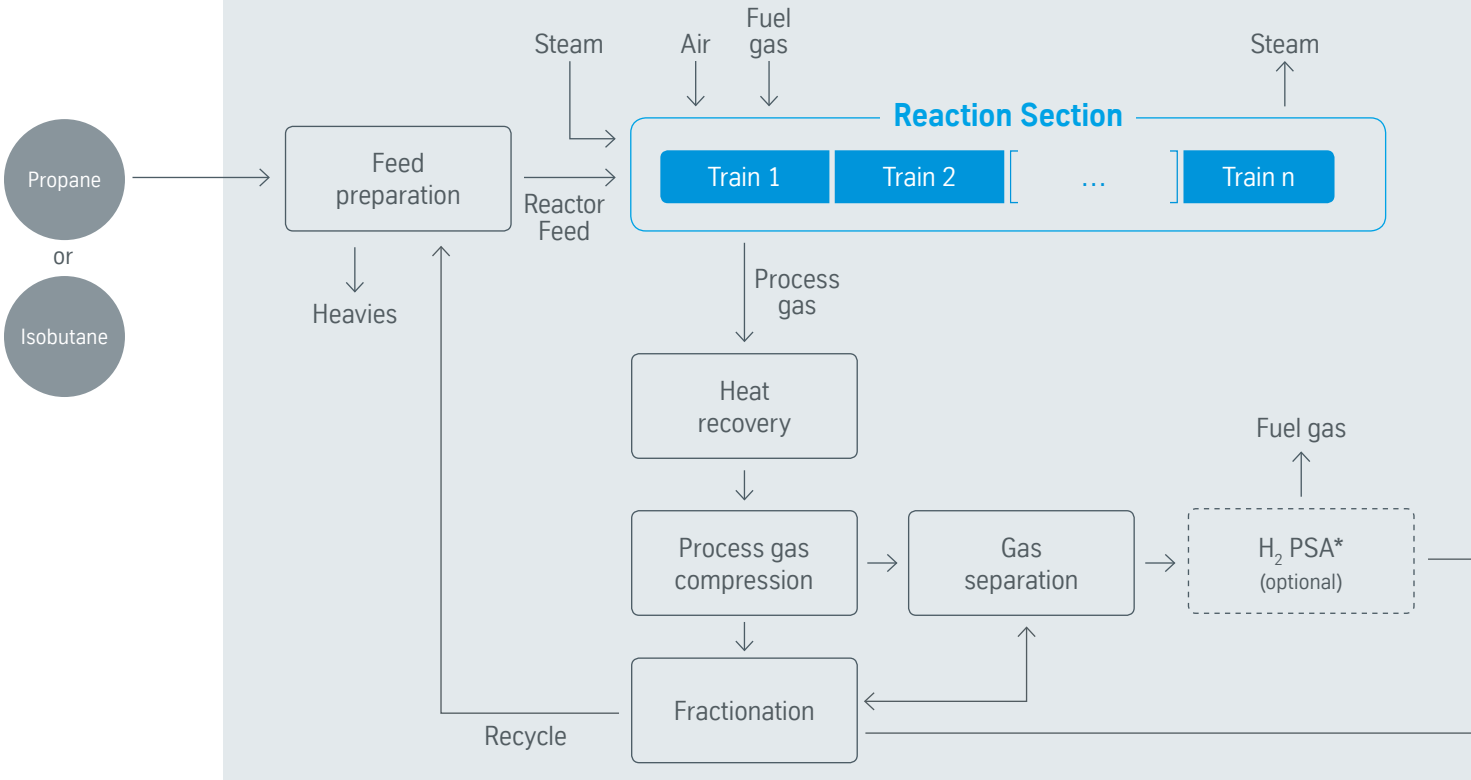
The remaining paraffin is fed to the reaction section where it is heated up and mixed with process steam before it is sent to the externally heated and catalyst-filled reformer tubes. After reacting inside the catalyst bed the hot reactor effluent is cooled down in several steps, recovering energy for feed preheating and steam generation.

Subsequently, all the steam contained in the process gas is condensed and the heat is recovered by heating the distillation columns in the fractionation unit.

The remaining dry process gas is compressed and partially condensed. The liquid phase is directly fed to the fractionation unit while gaseous components are fed to the gas separation unit. In a cryogenic process light uncondensables are removed. Optionally high-purity hydrogen can be generated by applying pressure swing adsorption (PSA).

The fractionation unit of a dehydrogenation plant consists of a stripper column to remove light uncondensables, which are fed to the gas separation unit, and a splitter column to separate olefin product and unconverted paraffin. For C4 applications such a splitter column may not be required depending on the downstream products. Finally, unconverted paraffin is recycled back to the feed preparation unit.

Feedstocks



*pressure swing adsorption

High process reliability and performance

resulting from the following main advantages of the STAR process® technology:

The reactor system is based on several independent parallel reaction trains. If one reaction train is stopped the remaining trains will be able to continue production.

Due to in-situ regeneration coke deposits are effectively removed from catalyst and reactor internals at the same time. An annual time-consuming cleaning step is not needed.

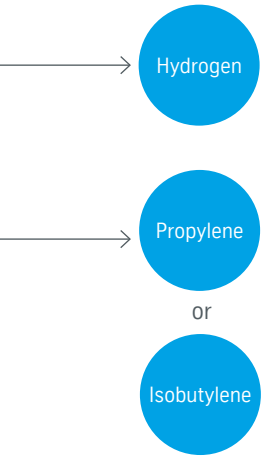
98%

achieved availability of more than 8,500 hours per year

As the STAR process® additionally uses process steam the risk of coking is even further reduced and fewer safeguards to prevent coking are required. As a result trips are generally less likely with the STAR process® compared to other technologies

Even in the unlikely event of a trip, production of a STAR process® plant will start within minutes after solving the potential problem thanks to the so-called hot stand-by mode, in which the plant is kept in safe but hot condition just by closing the hydrocarbon feed to the affected reactor(s). No cool-down sequence and long-lasting re-heat of the reactor system is required. Therefore, in the event of a reactor trip a PDH plant based on the STAR process® is usually back in operation one shift faster than with competing process technologies.

Products

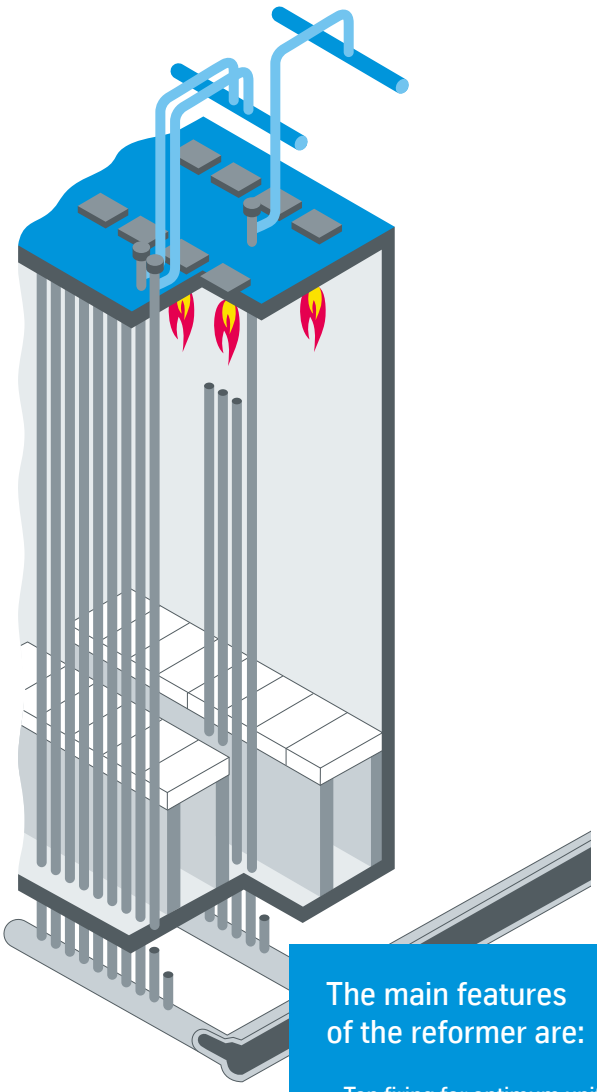


The STAR process® reformer

is an industrially well-known and commercially established top fired “steam reformer” of tubular fixed bed type not susceptible to catalyst attrition.

Since 1966 thyssenkrupp Industrial Solutions has installed more than 70 reformer units of this type in various parts of the world to generate synthesis gas for the production of ammonia, methanol, oxo alcohols and hydrogen.

As shown in table below operating conditions for the above mentioned applications are far more stringent than those required for dehydrogenation. The top fired reformer design ensures a uniform temperature profile with a steady increase of temperature in the catalyst bed, thus efficiently utilizing the activity of the catalyst.



Commercial applications of thyssenkrupp Industral Solutions reformer technology

Application	Pressure [bar a]	Temperature [°C]
Ammonia	40	780 – 820
Methanol	20 – 25	850 – 880
Hydrogen	20 – 25	880
Oxogas	9 – 12	900
Olefins (STAR process®)	5 – 6	550 – 590

The main features of the reformer are:

– Top firing for optimum uniformity of tube skin temperature profile

– Internally insulated cold transfer line made from carbon steel located externally

– Efficient heat recovery by feed preheating and steam generation

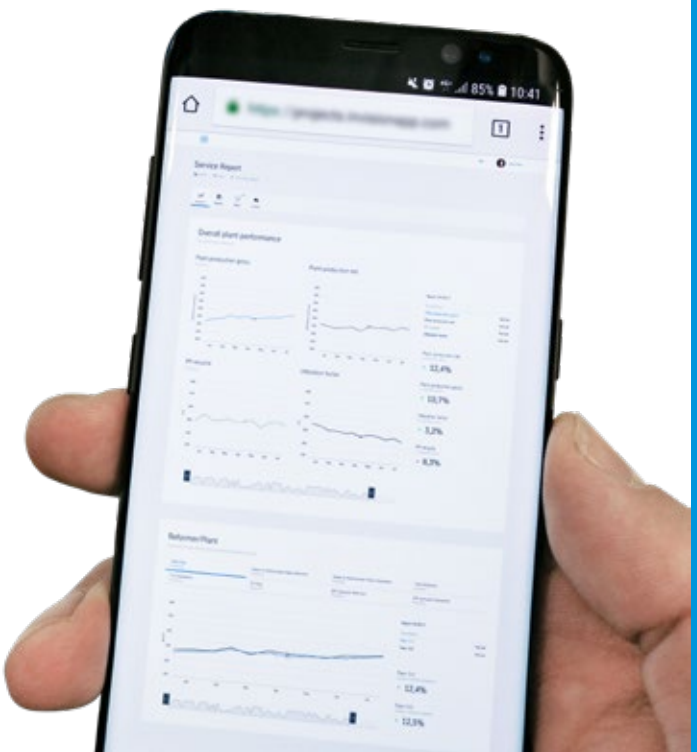
STAR catalyst® – high yield and long lifetime

The STAR catalyst® consists of a platinum promoted basic calcium and zinc aluminate which is very stable in the presence of steam at high temperatures. It shows high selectivity at near equilibrium conversion. Regeneration is simple and sustainable by simply using air to burn off coke deposits and to re-oxidize the precious metal.

No chemicals are required for catalyst activation or coke suppression. Before delivery to site tkIS will qualify the performance of the catalyst in its test facilities. In order to continuously improve the performance of the STAR process® plants tkIS has established a continuous catalyst development program together with its production partner.

Digital Solutions for PDH

Big data analyses use statistical methods to optimize plant performance from pure plant measurement data (mainly temperature, pressure, flow, composition). Additional process models use the power of a chemical process simulator (e.g. Aspen Plus) to predict the missing (not measured) process data as well as calculate physical properties and equipment performance parameters (heat transfer coefficients, efficiencies, activities, pressure drops, etc.), thus creating an even bigger set of data to be mined.



This is why clients of the STAR process® can greatly benefit from digital service solutions using models that can process the large amount of plant data in order to:

- Track plant and equipment performance parameters in real time
- Track plant profit in real time
- Optimize plant profit by adjustment of parameters in real time
- Recognize correlations and patterns between process variables
- Conduct what-if/case studies
- Develop operating strategies
- Plan maintenance intervals
- Debottleneck the process
- Develop and train engineers

How we define service

Professional service is vital if complex plants are to run with minimal downtime and generate maximum added value. We make running a complex plant easier by providing 360° service, which starts with the engineering of a plant and continues through commissioning and the commencement of operations right up to the end of a plant's working life. We provide a holistic portfolio of high-quality service solutions focusing on our customer's added value over the plant's entire lifecycle. That's what we call 360° service.

360° service
Hand in hand with our customers, we implement a wide variety of projects and, thanks to our expertise and decades of experience, can ensure the successful erection of the most complex plants, even in difficult environments. And we don't stop there. All our customers, wherever they are in the world, can rely on thorough, fast and comprehensive support in operating and, if required, maintaining their plant – a service we also provide for plants from other manufacturers.

Asset Management

Spare Parts Supply & Management

Revamps

Service Center & Field Services

Tailored to your needs
Our parts, asset management and revamp services are particularly relevant for customers. Forward-looking parts management increases your plant's uptime and reduces operating expenses. Our asset management service is based on proactive maintenance, which helps reduce your total cost of ownership and boost plant performance. As demands on your plant change over time, we can revamp it to improve uptime, optimize raw material use, lower energy consumption and ensure compliance with environmental standards. Our understanding of service is that we assume joint responsibility for your production – as true partners.

Globally networked infrastructure
In servicing and maintenance work, our customers can fall back on a wealth of technical and business know-how supplied through our globally networked infrastructure. Our parts management service ensures cost-effective parts and the fastest possible delivery – not least thanks to our online ordering system PSPN. The well-trained personnel at our local service centers have all the necessary know-how to lend a helping hand on site. Our specialists define optimum operating and service intervals, enhance your cost efficiency and equipment life through modernization and maintenance, and even handle relocation and decommissioning. And we work closely with our customers to adapt automation technology to their specific requirements. That's how we define service.

Save time when looking for our services

thyssenkrupp Industrial Solutions provides high-quality parts and extensive services as your lifecycle partner.

The Service Product Finder on **www.thyssenkrupp-industrial-solutions.com** offers an overview of all our service solutions.

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