

RÖHM

TRADITIONALLY
INNOVATIVE

RÖHM'S EXPERTISE FOR TAILOR-MADE HCN SOLUTIONS



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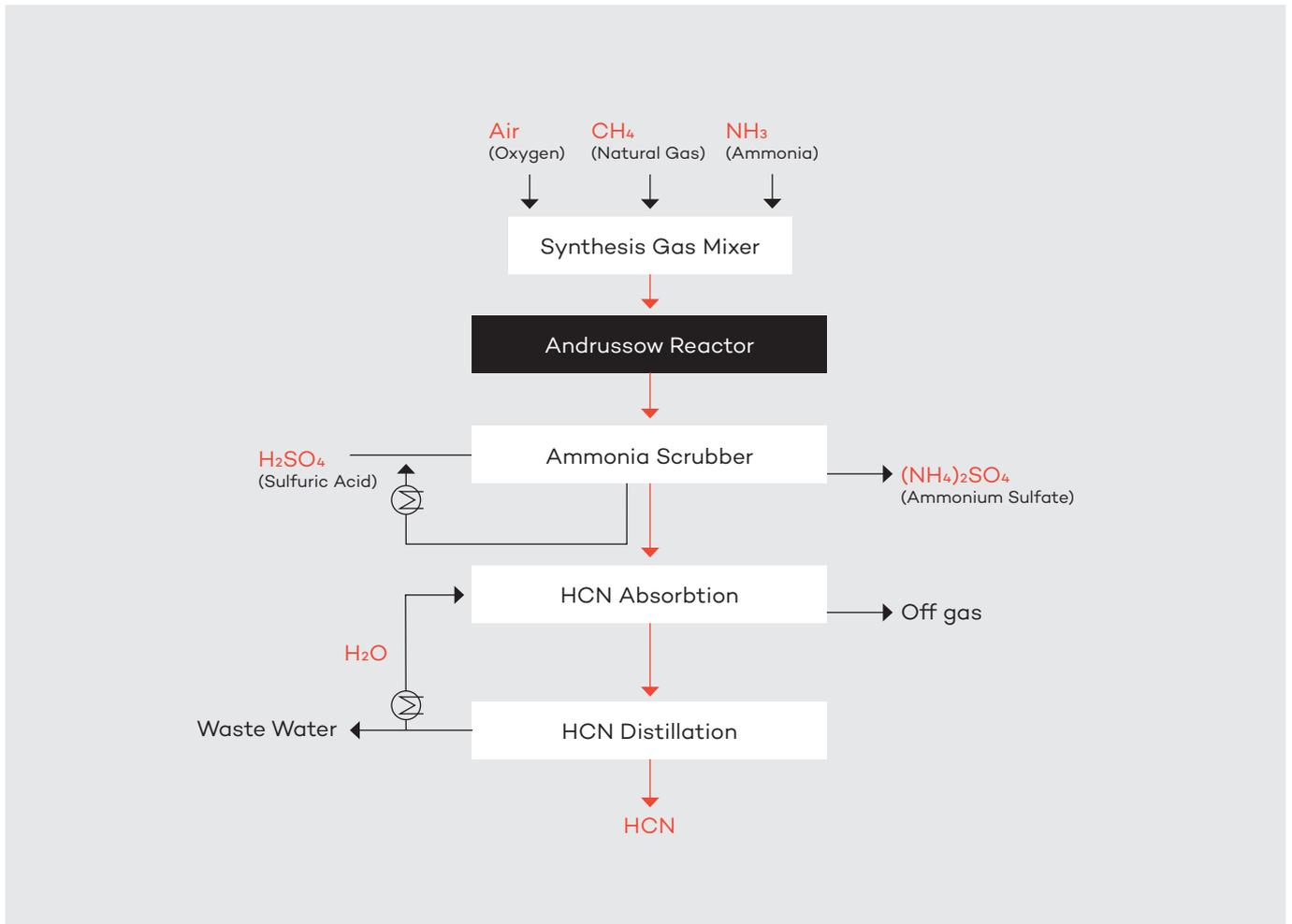
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MORE THAN 60 YEARS OF EXPERIENCE IN HYDROGEN CYANIDE (HCN) PRODUCTION!

Röhms GmbH is one of the world's leading manufacturers in the methacrylate business with more than 60 years of experience in safe and reliable hydrogen cyanide operations.

Röhms operates HCN plants at different sites and has extensive operational know-how in addition to techno-

logical expertise. The Andrussov process has been continuously optimized since the first plant went on stream in the 1950s, including latest developments like the oxygen enrichment technology. Röhms has already successfully granted several licenses for the Andrussov process to renowned companies world-wide.



RÖHM SUPPORTS THE CUSTOMER ALONG THE ENTIRE PLANT LIFECYCLE

A safe, reliable and economical operation of every license plant, right from the start, is one of the main benefits for Röhm's HCN license customers. The licensee will partici-

pate and profit from our expertise in the Andrussov technology and license project management.

Röhm identifies customer needs, prepares the needed technical solution and provides:

- Look-in Package
- Cost Estimation
- License Agreement
- BAFA Approval

Röhm provides:

- Process Flow Diagrams (PFDs)
- Process Data Sheets
- Utility Consumption List
- Equipment List
- Preliminary Trip Schedule and Logic Diagram
- Health and Safety Hazard data
- Analytical Manual

Röhm supports:

- Hazard Study
- Review of Engineering Documents
- Know-how Transfer

Röhm supports:

- 3D/MSR Review
- Review of Engineering Documents
- Operator Training at Röhm sites



**TAILOR-MADE
PROPOSAL &
AGREEMENT**

**PROCESS
DESIGN
PACKAGE**

**BASIC
ENGINEERING**

**DETAIL
ENGINEERING**

Röhm supports:

- Quality assurance for key equipment
- Site erection review
- Technical advise

Röhm assists:

- Start-Up/Commissioning
- Operator Training on site
- Process Guarantee Test Run

Röhm provides:

- Operational Excellence Consultancy
- Trouble Shooting





CUSTOMER'S BENEFITS RELYING ON RÖHM

Tailor-made solutions and project execution excellence

- Röhm offers Andrussow process technology, operating at elevated and low pressure
- Röhm provides oxygen enrichment technology to increase plant capacity at lower investment
- Röhm cooperates with engineering contractor to fit customer needs
- Röhm HCN experts from operations and engineering will provide major support to customer projects

Safety and operational excellence

- Röhm's high standard of safety related plant design and Röhm's experience of more than 60 years of operations will enable the licensee to run at most possible safe conditions

- Röhm will support the customer at its site with experienced engineers and operators from its HCN production facilities to ensure operational excellence right from the start
- Röhm guarantees plant performance

Expert training at Röhm's HCN plants

- Röhm provides real life training for customer's future operators at Röhm's HCN production facilities in Germany
- Continuous contact to the hydrogen cyanide experts from Röhm's operations team will guarantee most effective know-how transfer throughout customer's project

SCOPE OF A STANDARD HCN TECHNOLOGY LICENSE

Röhm GmbH offers plant designs for the production of gaseous and liquid hydrogen cyanide, using the Andrussov process technology.

Depending on the downstream application and the OSBL (OutSide Battery Limits) conditions, a tailor-made set-up is provided to the licensee.

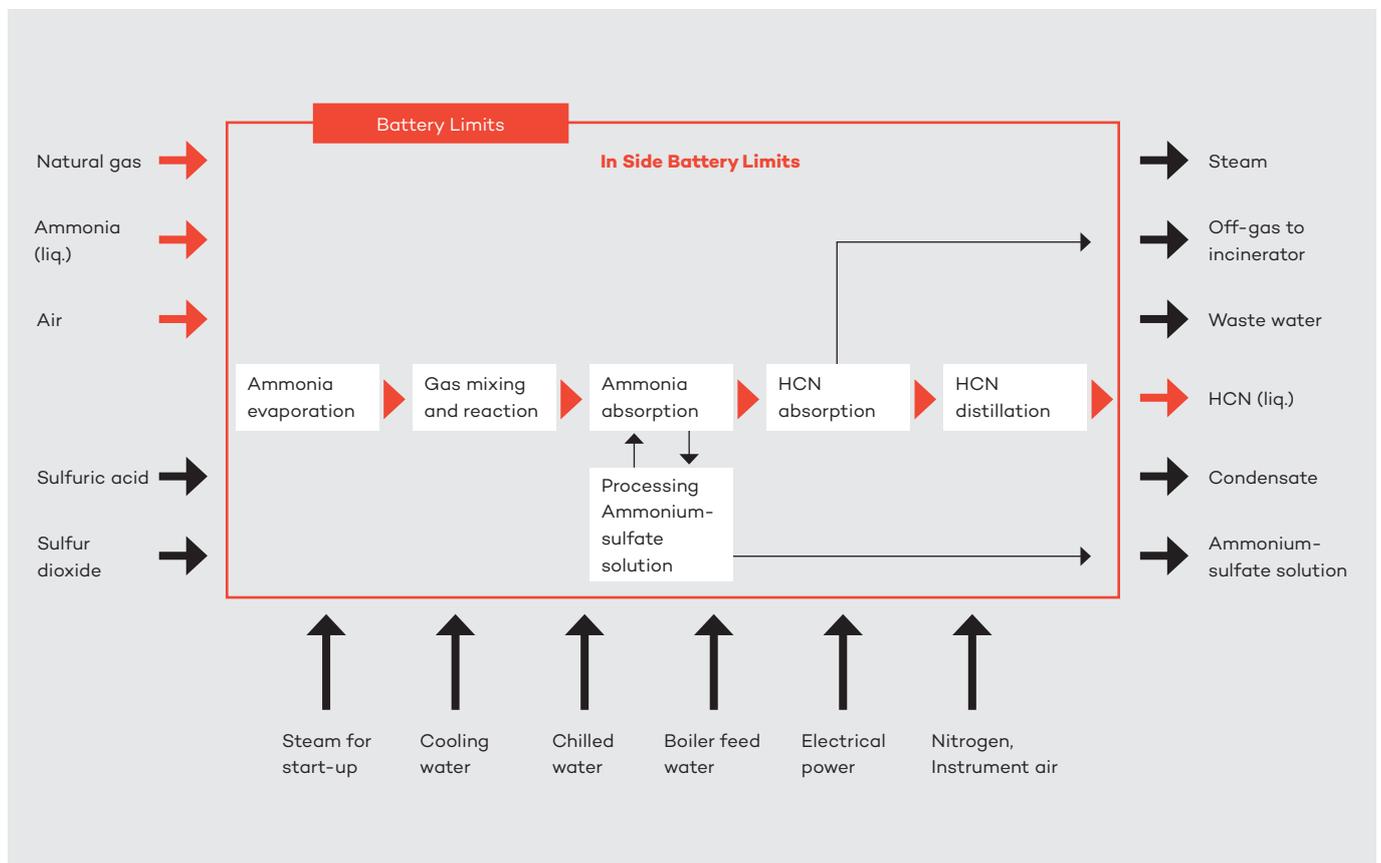
Feedstocks:

Natural gas, ammonia, air

Catalyst:

Gauzes made from a platinum/rhodium alloy

The main process steps (for the production of liquid HCN) are shown in the ISBL (InSide Battery Limits) chart below.





RÖHM'S EXPERTISE FOR TAILOR-MADE PLANT LAYOUTS

At Röhm's site in Worms, Germany, Andrussow plants have been in operation since 1950. Starting from small reactors and plant capacities, we have continuously improved the HCN technology and became one of the leading HCN producers in the world. Currently, more than 15 Andrussow reactors are in operation based on this know-how. Those facilities differ in production capacity and technical set-up depending on the downstream application. Common to all plants is the highly sophisticated safety concept implemented in the plant set-up. The integrated interlock & trip systems have been continuously improved over decades.

On a regular basis we are in discussions with our licensees, external colleagues within the global HCN production community and technology partners (e.g., catalyst manufacturers) for further improvements (technology, safety and economically) of the Andrussow technology.

Therefore, Röhm is in the unique situation to offer a comprehensive license package tailored to the specific needs of the customer. This ensures a safe and economical operation right from the start.

Röhm will provide a tailor-made Process Design Package (PDP) to the licensee. With this PDP, the main Hydrogen Cyanide process know-how is transferred to the licensee.

The licensee's project management is supported by a team of experts from Röhm. This team consists of engineers and chemists from different departments, such as plant managers and plant engineers operating and optimizing Röhm's production facilities. All project phases along the licensee's plant lifecycle will be supported by this experienced team of HCN experts.

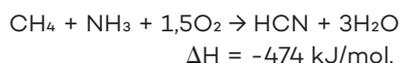
We support the licensee in basic & detail engineering, construction, start-up and during plant operation. Due to our long-term experience, we will find the best configuration for the plant on the respective site considering the given OSBL conditions (Steam production from off-gas, utilization of cooling media, treatment of ammonium sulfate solution, etc.).

ANDRUSSOW PROCESS

The process is based on the ammonoxidation of methane, described for the first time by Leonid Andrussow (1930).

Gas mixing and reaction

The components methane (supplied as natural gas), ammonia (from evaporators), and oxygen from the air are mixed and reacted over a platinum/rhodium catalyst to form hydrogen cyanide:



The product gases, at about 1000°C, are quickly quenched by passing through tubes of a waste heat boiler. The generated steam can be utilized for heating purposes in downstream processing steps. The remaining surplus steam can be fed to an on-site steam system.

The gases are sucked or pushed through the plant by blowers, located downstream of the HCN absorption column or upstream of the HCN reactor (depending on the plant design).

Ammonia absorption and processing of ammonium sulfate solution

Downstream of the waste heat boiler, the gases are routed to a scrubber column to remove unreacted ammonia with sulfuric acid from the gases. Within this process step an ammonium sulfate solution product stream is generated. This stream is further processed in a stripper column in order to desorb the HCN dissolved in the ammonium sulfate solution.

HCN absorption

Hydrogen cyanide is absorbed with cold water in the second scrubber column. The bottom product, an aqueous solution of HCN, is discharged and stabilized.

The head product of the scrubber column, the off-gas, is routed to an off-gas treatment facility.

HCN distillation

The HCN solution is routed to a distillation column. The water discharged at the bottom is recycled to the HCN absorption. Excess water, generated during the HCN reaction, is discharged and purified.

On top of the HCN distillation column the HCN vapor is condensed. The liquid HCN can be fed immediately to a downstream production unit.

RÖHM'S EXPERTISE IN R&D

Within Röhm there is an experienced R&D department working on various Hydrogen Cyanide projects. The outcome of these projects is transferred to Röhm's production facilities and are finally implemented into the plant set-up of the licensees plants.

Andrussow chemistry

With more than 60 years of Andrussow operations and a large number of R&D projects, Röhm has an extensive

knowledge in HCN technology providing excellence in safe and effective HCN production.

Catalyst set-up

In the past, Röhm had several cooperation projects with catalyst manufacturers to identify the most effective catalyst gauze configuration for the Andrussow process.

HYDROGEN CYANIDE – A MAJOR BUILDING BLOCK

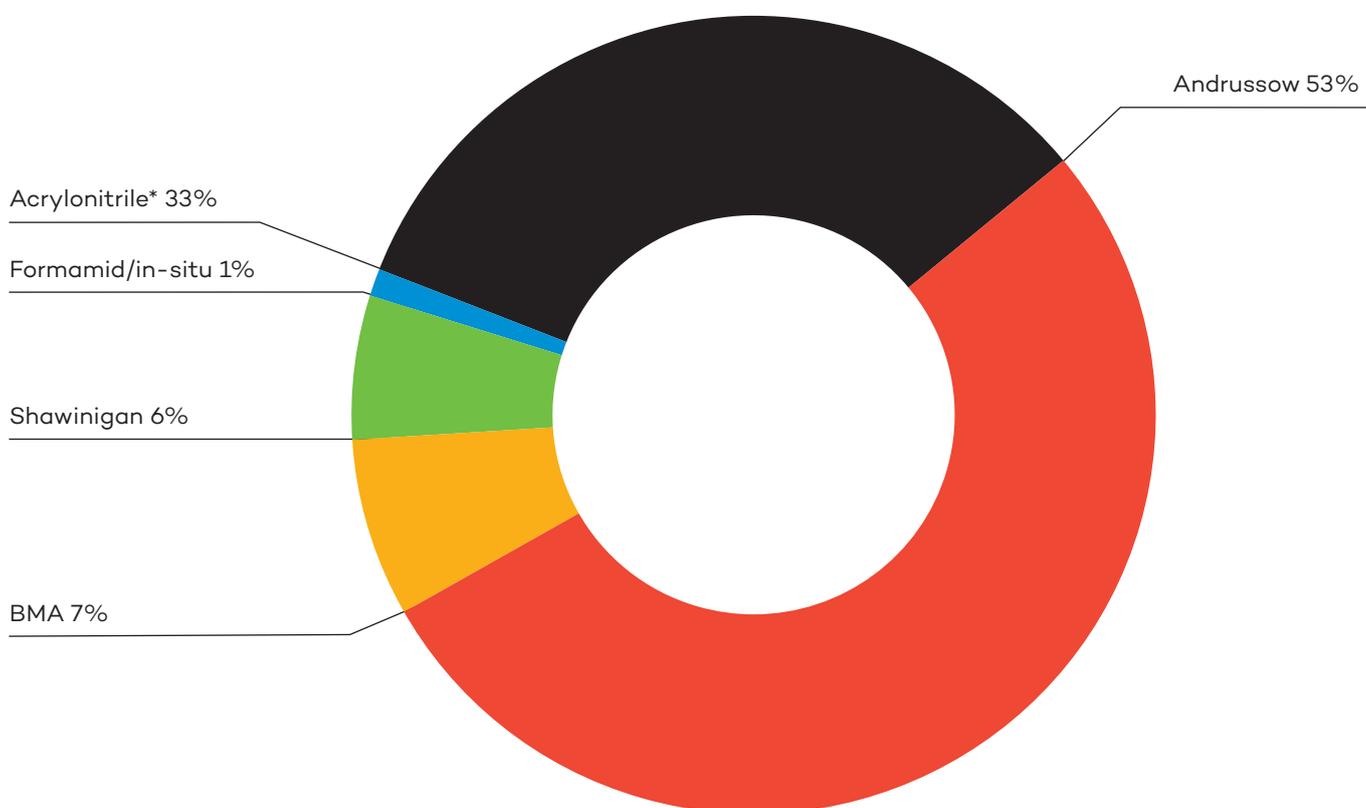
In the chemical industry, globally around 2.5 million tones of hydrogen cyanide are used as a major building block for several fields of application.

Hydrogen Cyanide is not traded on the world market. Due to its hazardous properties HCN is generally converted into the desired downstream product directly at the site of production and not transported. Hydrogen Cyanide is also regulated under various laws, e.g. the “War Weapon Control Act”.

For the production of this building block several processes are installed worldwide. The Andrussow process is the leading on-purpose process for the production of Hydrogen Cyanide and accounts for more than 50% of the globally installed HCN capacity.

Today, almost every new on-purpose production facility for Hydrogen Cyanide is based on the Andrussow technology.

TECHNOLOGY SHARE ON GLOBAL HCN CAPACITY



* HCN as a byproduct

Source: Röhm HCN-database

HYDROGEN CYANIDE – USED FOR A VARIETY OF APPLICATIONS



Methacrylates (MMA, ...)

MMA and other methacrylates are used in a wide range of products, from Plastics (e.g. Plexiglas®), construction chemicals, coatings adhesives and pharma products. Acetone cyanohydrin (ACH), a key raw material for methacrylates, is produced from hydrogen cyanide and acetone.

Polyamide 6.6

Synthetic fibers from Polyamide 6.6 are mainly used in textiles, carpets and the automotive industry.



Chelating Agents

Important applications are pulp and paper processing; industrial water treatment; household, institutional and industrial cleaning compounds. Chelating agents are also used in metal finishing; agriculture; photography; rubber processing; food, pharmaceutical and textile treatment.

Cyanuric Chloride

Cyanuric chloride is mainly used as a pesticide in the agriculture industry. It is also used for substantive dyes in the textile industry.



Glyphosate

The non-selective herbicide glyphosate is used to prepare agricultural areas by clearing weeds. This preparation helps to increase yields and generate economical value.

Amino Acids

Amino acids enable effective and resource efficient access to vital protein – and thus make an important contribution to sustainable provision of high-quality protein for a growing global population.

Sodium cyanide

Gold and silver mining are the main applications for sodium cyanide. Sodium cyanide is produced from hydrogen cyanide and caustic soda.





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