UHDE
SOLUTIONS

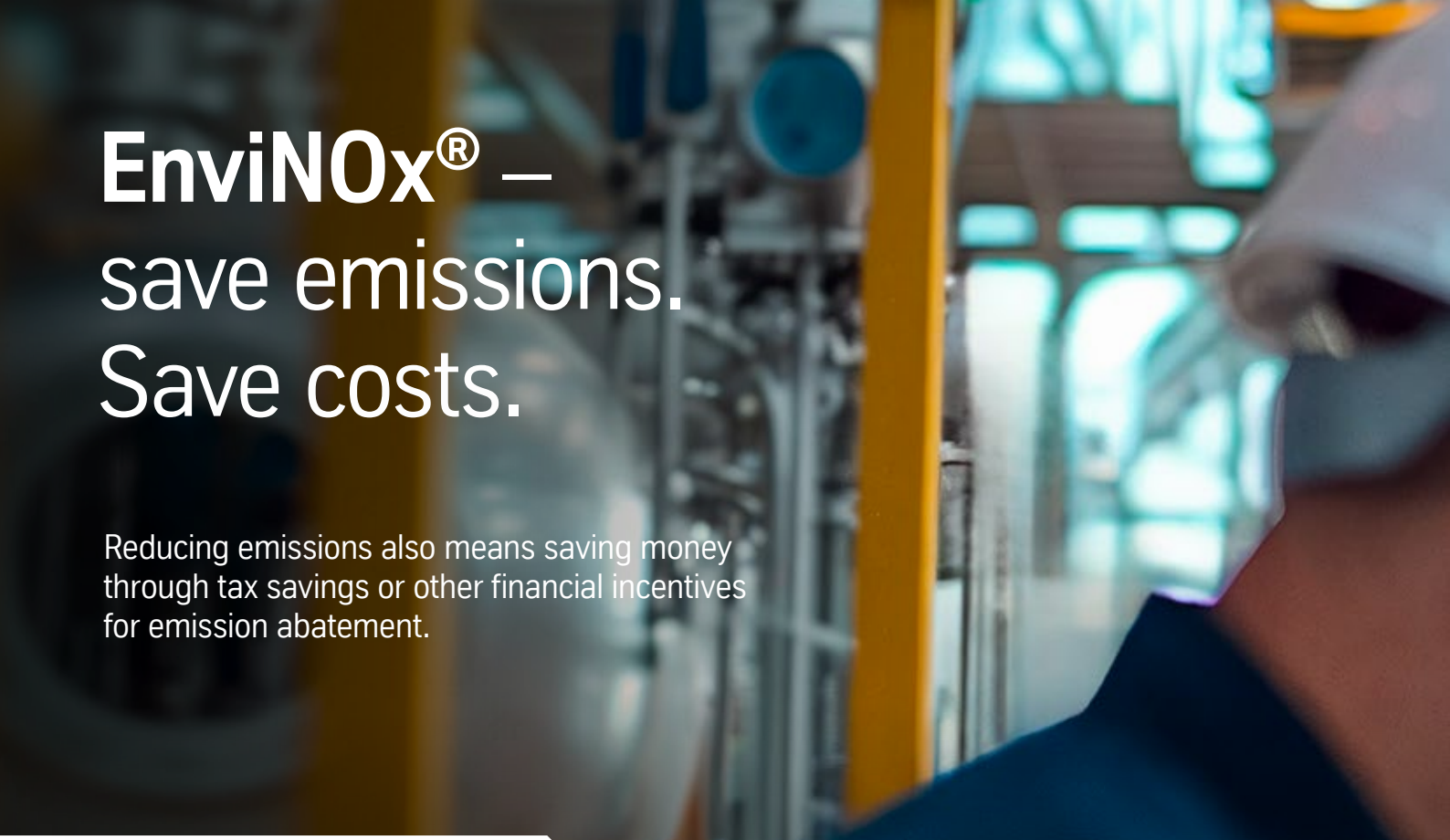
N_2O and NO_x removal

EnviNOx® climate protection

World-leading N_2O and NO_x removal technology

engineering.tomorrow.together.

thyssenkrupp



EnviNOx® – save emissions. Save costs.

Reducing emissions also means saving money through tax savings or other financial incentives for emission abatement.

Easy to install, cost-efficient, quick ROI

- Can be **easily integrated** into existing plants with low investment and operating costs
- **Modular design** allows for customized solutions to meet your operational and business needs
- Durable, low-maintenance catalysts and a hazard-free process **reduce risks** and long-term costs
- **Good ROI** (return on investment) in a short space of time through emission cuts and resultant emission reduction incentives

A safe and future-proof choice

- Nearly **100 % N_2O and NO_x removal** achieved in many reference plants, meeting strict regulations
- **Long-lasting, non-toxic catalyst** ensures sustainable, high-performance operation
- **One-stop shop** – from catalyst to equipment and integration – for guaranteed success
- **Proven technology** with more than 20 years of commercial operations
- **Over 500 years** of cumulative operating time

Setting the standard for clean air and sustainability
With over 40 years' experience in $DeNO_x$ systems, nearly 30 years in N_2O removal, and over 60 EnviNOx® systems installed worldwide, thyssenkrupp Uhde has set the gold standard for reducing harmful nitrogen oxide (NO_x) and nitrous oxide (N_2O) emissions. As pioneers in catalytic N_2O abatement technology, we provide cutting-edge solutions tailored to the needs of key global industries facing stringent environmental regulations.

EnviNOx® has become a global benchmark for industrial emission control.

2000s

2000
1st test plant in real tail gas stream of commercial HNO_3 plant

2003
First commercial plant in Linz

60+

EnviNOx® systems installed worldwide

Proven performance, seamless execution
At thyssenkrupp Uhde, our expertise spans the entire project lifecycle, from conceptual design and engineering to execution and long-term after-sales support. As an engineering powerhouse with over 100 years of experience in plant design and construction, we seamlessly integrate EnviNOx® technology into new and existing plants, ensuring optimal efficiency and minimal downtime.

2006
Abu Qir Fertilizers Co. (AFC) plant, marking first UN Clean Development Mechanism (CDM) project for emissions trading in HNO_3 plants worldwide

2007
Recognized as Best Available Technology (BAT) in EU, solidifying its status as an industry leader

2010s
1st commercial installation in caprolactam plant

2012
Designated BACT by U.S. environmental authorities, further cementing its global credibility

In the future

2020s
Continued innovation, integrating improved catalysts and modular designs for enhanced performance

Further applications, such as in uhde® ammonia cracking

Smart technology **with maximum flexibility**

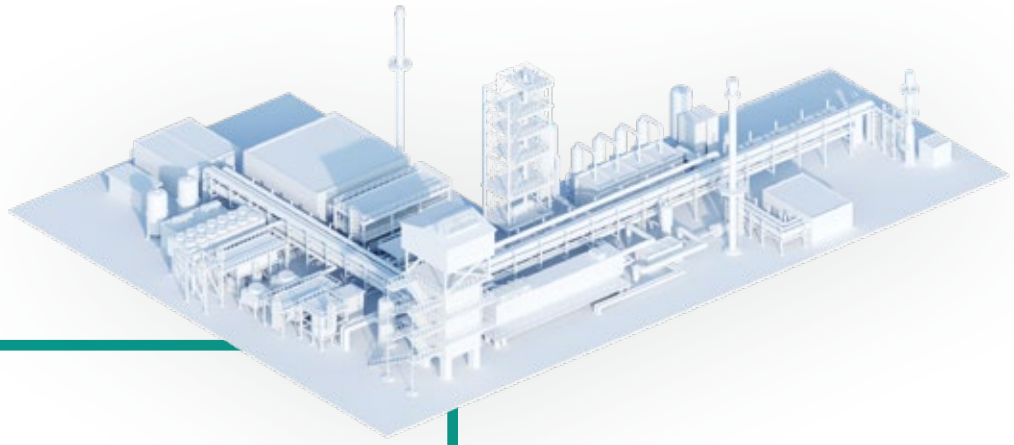
The EnviNOx® process by Uhde is a proven, versatile solution for effectively reducing nitrogen oxides (NO_x) and N_2O (nitrous oxide) in industrial exhaust gases. Originally developed for nitric acid plants, EnviNOx® has since been successfully adapted for use in a wide variety of industries, including caprolactam, adipic acid and niacin production. It is also being continuously developed for use in other chemical production processes, as well as in the energy and mobility sectors.

1 Nitric acid plants

- **Most widely used application,** with dozens of commercial references worldwide
- First reference plant in operation for more than 20 years
- **Suitable for all types of plant:** atmospheric-pressure, mono-medium-pressure, dual pressure and high-pressure
- **Flexible and robust:** Handles tail gases with temperatures ranging from **200 °C to 600 °C,** as well as varying compositions and load conditions.
- **Enhanced efficiency and reduced operating costs,** especially when combined with secondary measures (N_2O decomposition)

2 Caprolactam plants

- First reference plant in operation for nearly 15 years
- **Proven performance** in both **modified Raschig (HSO) and HPO processes** (hydroxylamine-sulphate-oxime / hydroxylamine-phosphate-oxime)
- **Tailored catalyst and process design** reliably deals with impurities such as sulphates and phosphates
- **Downstream installation** (tertiary measure) efficiently removes N_2O and NO_x generated in all stages of the caprolactam process



EnviNOx® – integral part of the innovative uhde® ammonia cracking process
This key technology for the global hydrogen economy enables the virtually emission-free reconversion of imported ammonia into hydrogen.

By choosing Uhde, you benefit from:
- **High efficiency & conversion rates**
- **Flexible operation**
- **Industry-proven technology base**
- **Ultra-low emissions in combination with EnviNOx®**

3 Exhaust gases from NH_3 combustion

- Unique capability to treat exhaust gases from combustion of **ammonia as a carbon-free fuel** for heating purposes or in internal combustion engines
- Can cope with large amounts NO_x and N_2O as well as of unburned ammonia
- Ideally suited for exhaust gas cleaning in NH_3-fired NH_3 cracking plants with the aim of setting ultra-low emission standard
- Integral part of the **uhde® ammonia cracking process**

4 Energy and other industries

- Can be used to treat a wide variety of exhaust gases from industrial production plants and energy generation plants
- Different process concepts and types of EnviNOx® catalysts available for low-temperature and low-pressure applications
- Can be combined with other exhaust gas purification stages, e.g. CO or VOC (volatile organic compounds) oxidation
- Demonstrable/Proven success in complex cleaning of exhaust gases in **production plants for specialty chemicals, e.g. niacin**

EnviNOx® – **Built to fit your requirements**

Each EnviNOx® solution consists of one or more reaction modules for the removal of N_2O and NO_x. These modules can be combined in a variety of ways to suit your individual technical and economic requirements. Our unique modular system is based on decades of practical experience and continuous research and development, offering world-leading quality and high flexibility.

Proven versatility
Uhde has already successfully commissioned over fifteen different variants for specific large-scale applications. These include flexible add-ons, such as heat exchanger loops, which utilize the heat released by the N_2O and/or NO_x reduction to economically heat up low-temperature exhaust gases – a concept that has been proven several times on an industrial scale for a variety of different applications. The patented combination of the various tertiary EnviNOx® modules and secondary N_2O abatement measures enables the particularly effective elimination of both N_2O and NO_x emissions.

$DeNO_x$ reaction module

NO_x reduction with NH_3

The **$DeNO_x$ reaction module** enables the selective catalytic reduction (SCR) of NO_x to nitrogen (N_2) and water (H_2O), using NH_3 as the reducing agent.

The specially developed iron zeolite catalysts used offer many advantages compared to conventional $DeNO_x$ catalysts. They allow for a very broad operating temperature range (approx. 180 °C to over 550 °C) and a wide range of possible NO/NO_2 ratios. Furthermore, the $DeNO_x$ modules used in the EnviNOx® process have a very low NH_3 consumption, while minimizing the risk of NH_3 slippage and the formation of ammonium nitrate.

close to 0 emissions

solution

DeN_2O® reaction modules

N_2O decomposition

In the case of catalytic N_2O decomposition, the metastable N_2O molecule is broken down into N_2 and O_2 over a catalyst. The iron zeolite catalysts used in the EnviNOx® technology are particularly favorable as their activity is promoted rather than inhibited by NO_x residues in the exhaust gas. This enables extremely high rates of tertiary N_2O decomposition within a broad temperature range (400 °C to 600 °C).

N_2O reduction
with various reducing agents

The iron zeolite catalysts used in the EnviNOx® system enable the reduction of N_2O with small amounts of reducing agents, such as ammonia, methane, LPG, other hydrocarbons, or simply carbon monoxide. In practical applications, N_2O reduction is often combined with a prior reduction of NO_x. This is particularly effective with the use of an integrated, iron-zeolite-based $DeNO_x$ module operated in either a single-bed or two-bed arrangement within a broad temperature range of 300 °C to 600 °C.

Variant 1 – high abatement with NH_3 as reducing agent

This basic EnviNOx® variant combines two-stage N_2O decomposition with simultaneous NO_x reduction by means of NH_3. It can be used at exhaust gas temperatures above about 400 °C, enabling high abatement rates of N_2O and NO_x with minimum consumption of the reducing agent.

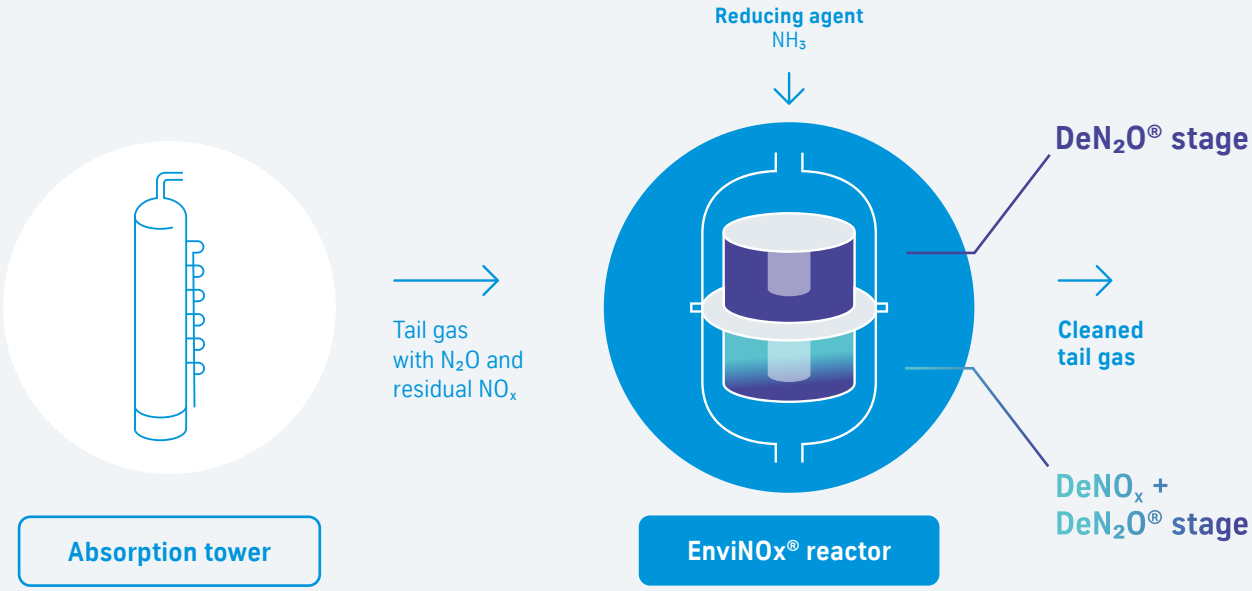
When implementing the EnviNOx® technology for tail gas cleaning in the HNO_3 production process, the EnviNOx® reactor is ideally located between the absorption tower and the tail gas turbine, typically after the final tail gas heater. This ensures the highest available temperature level for the catalytic decomposition of N_2O, preferably higher than 400 °C.

The tail gas entering the EnviNOx® reactor first flows through a dedicated DeN_2O® stage, where a significant portion of the N_2O content is broken down, leveraging the co-catalytic effect of NO_x entering this stage. In a second stage, a further catalytic decomposition of the residual N_2O occurs in parallel to the selective NO_x reduction by means of NH_3. Both catalyst beds are housed in a single pressurized vessel and typically contain the EnviNOx® catalysts in pelletized form.

The individual catalyst beds are designed in the form of radial baskets located one above the other. The NH_3 is fed via a lance into an internal tubular mixer, which ensures even distribution and high selectivity of the NO_x reduction.

The high effectiveness of this variant of the EnviNOx® process was first demonstrated successfully in 2003 with the much-noted installation of an industrial-scale reference plant at Agrolinz Melamin International in Linz/Austria (AMI). The variant has been shown to achieve N_2O abatement rates of over 98 % and an NO_x reduction to less than 20 ppmv.

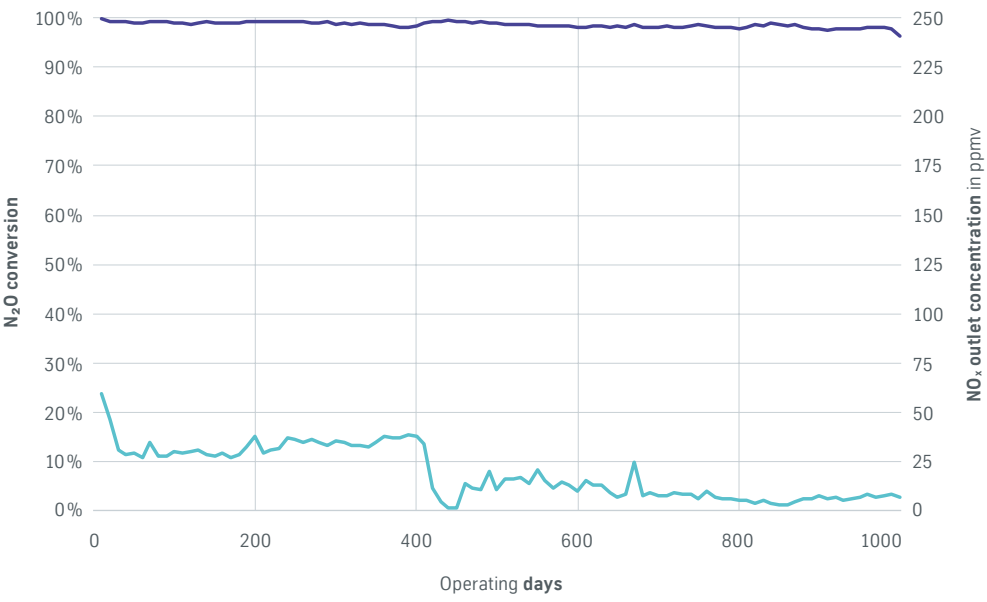
Application example: **nitric acid plant**



PLANT DATA

LAT Nitrogen (former AMI), since 2003

Location: Linz, Austria
Process: Dual pressure
Capacity: 1,000 mtpd NA
Tail gas flow rate: 120,000 Nm³/h
Tail gas temperature: 435 °C
Reducing agents: NH_3



N_2O conversion
NO_x outlet concentration

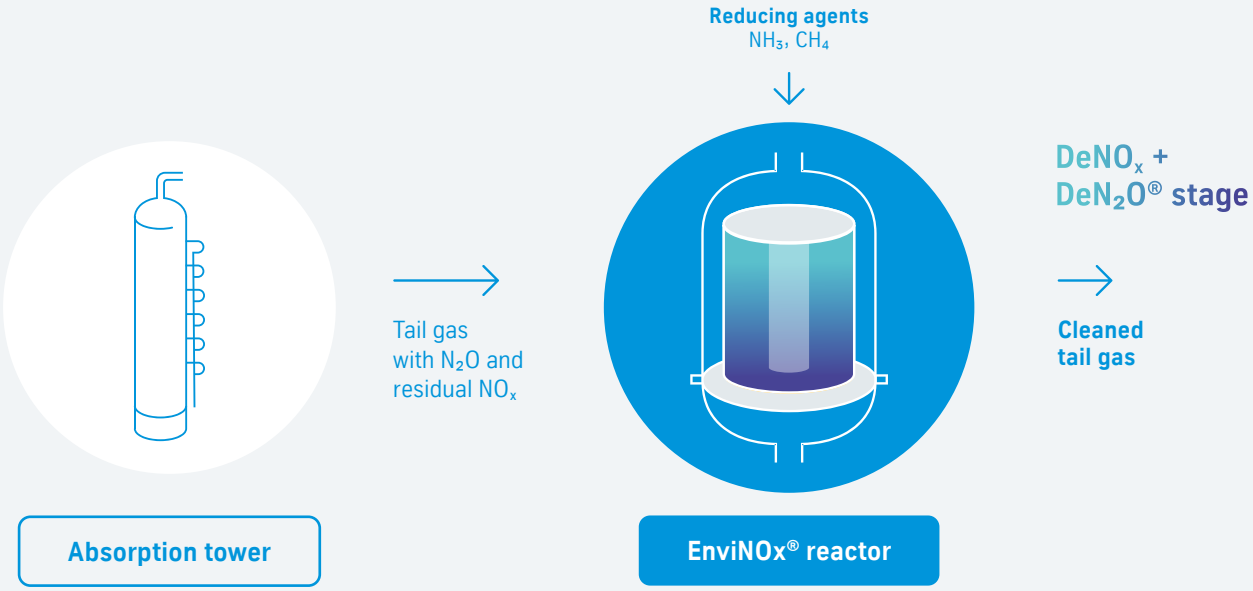
Variant 2 –
versatile & robust

This frequently used process variant combines a $DeNO_x$ module for NO_x reduction using NH_3 with a DeN_2O® module for N_2O reduction using hydrocarbons (e.g. natural gas or LPG), CO, or other substances.

The $DeNO_x$ stage can be placed either upstream of the N_2O reduction stage or, more commonly, integrated into it. Since the catalytic reduction of N_2O using hydrocarbons is inhibited by NO_x, the NO_x must be reduced to virtually 0 ppmv, and this is achieved in practical applications. Due to the very small quantities of reducing agents required, the CO_2 emissions caused by the oxidation of the hydrocarbons are negligible compared to the greenhouse gas reduction achieved through the N_2O reduction. The combined N_2O reduction with hydrocarbons and NO_x reduction with NH_3 over catalysts is currently the most widely used variant for tertiary N_2O abatement from the tail gas of HNO_3 production plants as it can be operated at comparatively high space velocities in a broad temperature range of approximately 300 °C to 600 °C.

A major milestone in climate protection
The variant was first used on an industrial scale at a 1830 mtpd HNO_3 production plant belonging to Abu Qir Fertilizer Co. in Egypt in 2006. N_2O abatement rates of over 99 % have been achieved here, while the NO_x content has even been reduced to virtually zero ppmv. The project also marked the world's first N_2O, or rather CO_2, emissions trading project at an HNO_3 plant under the flexible mechanisms of the Kyoto Protocol.

Application example:
nitric acid plant

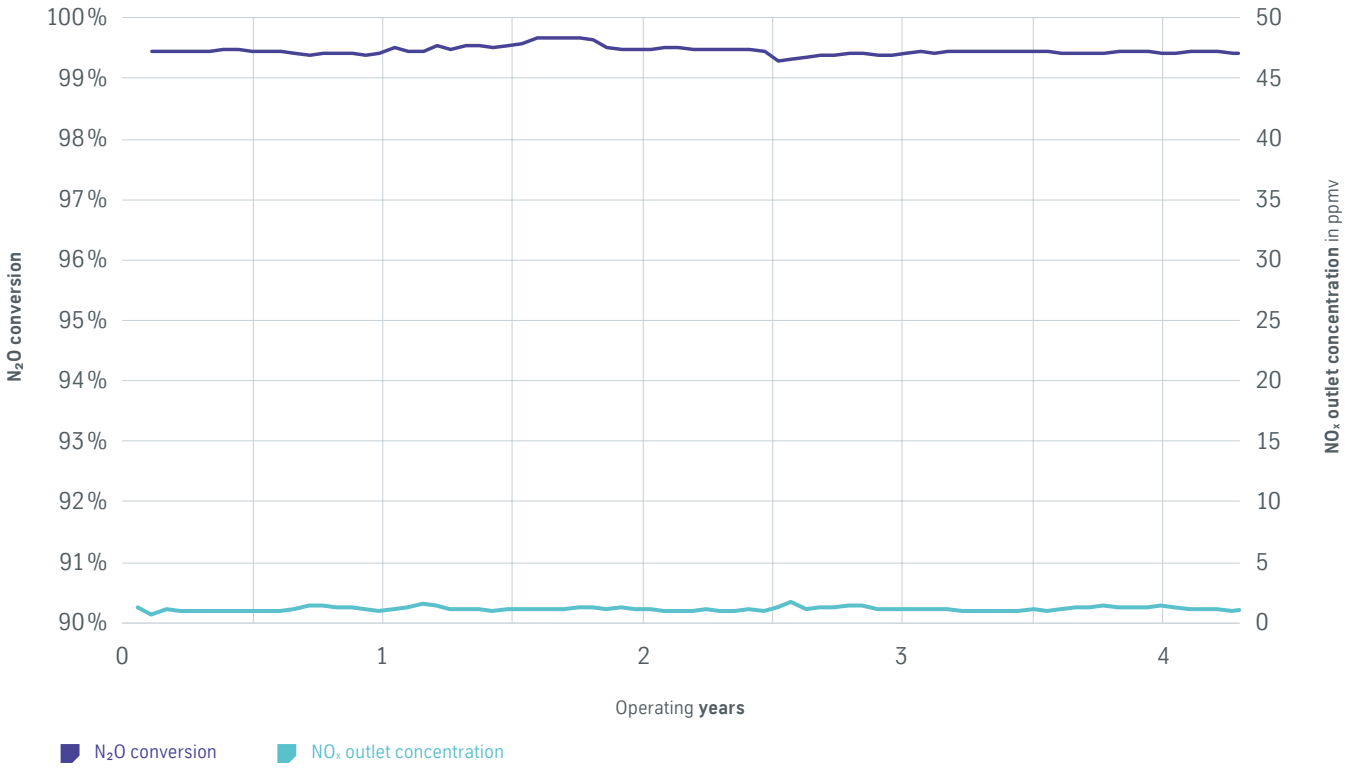


PLANT DATA

Abu Qir Fertilizer Co. – since 2006

Location: Alexandria, Egypt
Process: Dual pressure
Capacity: 1,830 mtpd NA

Tail gas flow rate: 230,000 Nm^3/h
Tail gas temperature: 418 °C
Reducing agents: NH_3, natural gas



Variant 3 – cost-effective and efficient

Uhde's patented combination of secondary N_2O decomposition and a tertiary iron zeolite-based reaction module for joint N_2O and NO_x reduction is synergistic, enabling maximum abatement rates with minimal investment and operating costs.

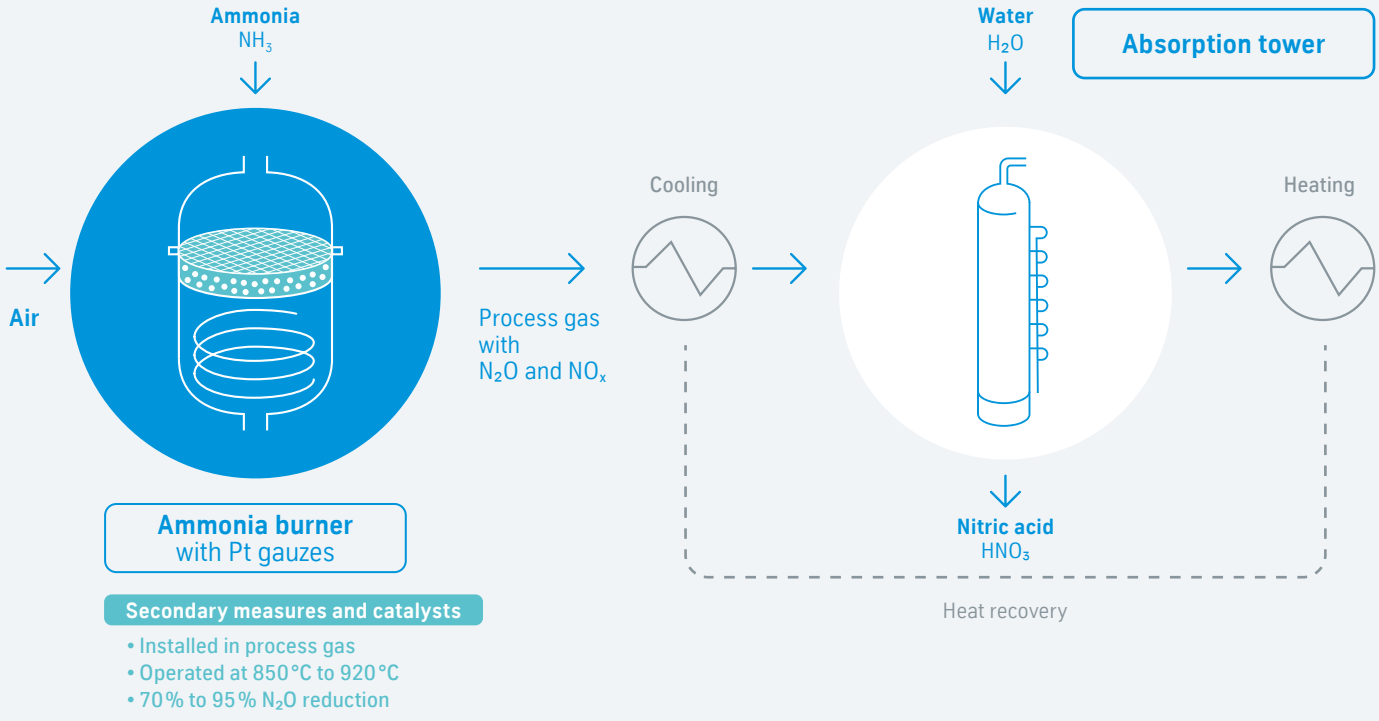
By skillfully combining a secondary measure for N_2O decomposition with a tertiary measure for N_2O and NO_x reduction, the advantages of both can be leveraged. This is especially true when using ammonia as the reducing agent. The preceding decomposition of N_2O by the additional secondary catalyst enables extremely high N_2O removal rates to be achieved and minimizes the consumption of reducing agent in the downstream tertiary stage for joint N_2O and NO_x reduction.

At the same time, there is only minimal risk of NH_3 slippage, and only minimum amounts of tertiary catalyst are needed.

Another benefit of the above combination is that the high reduction performance can even be achieved at partial load of the nitric acid plant. The temperature-induced decrease in N_2O conversion in the tertiary stage is typically offset by an increase in the secondary N_2O decomposition, attributable to the reduced flow of process gas.

A tertiary EnviNOx® system with catalysts combined with different types of secondary catalysts is equally suitable for retrofitting existing HNO_3 plants that are already equipped with a secondary measure, and for equipping new HNO_3 plants for the first time. Uhde holds patents for this variant in many countries. Numerous reference installations in nitric acid plants around the world testify to its effectiveness.

Application example: **Ostwald process for nitric acid production**

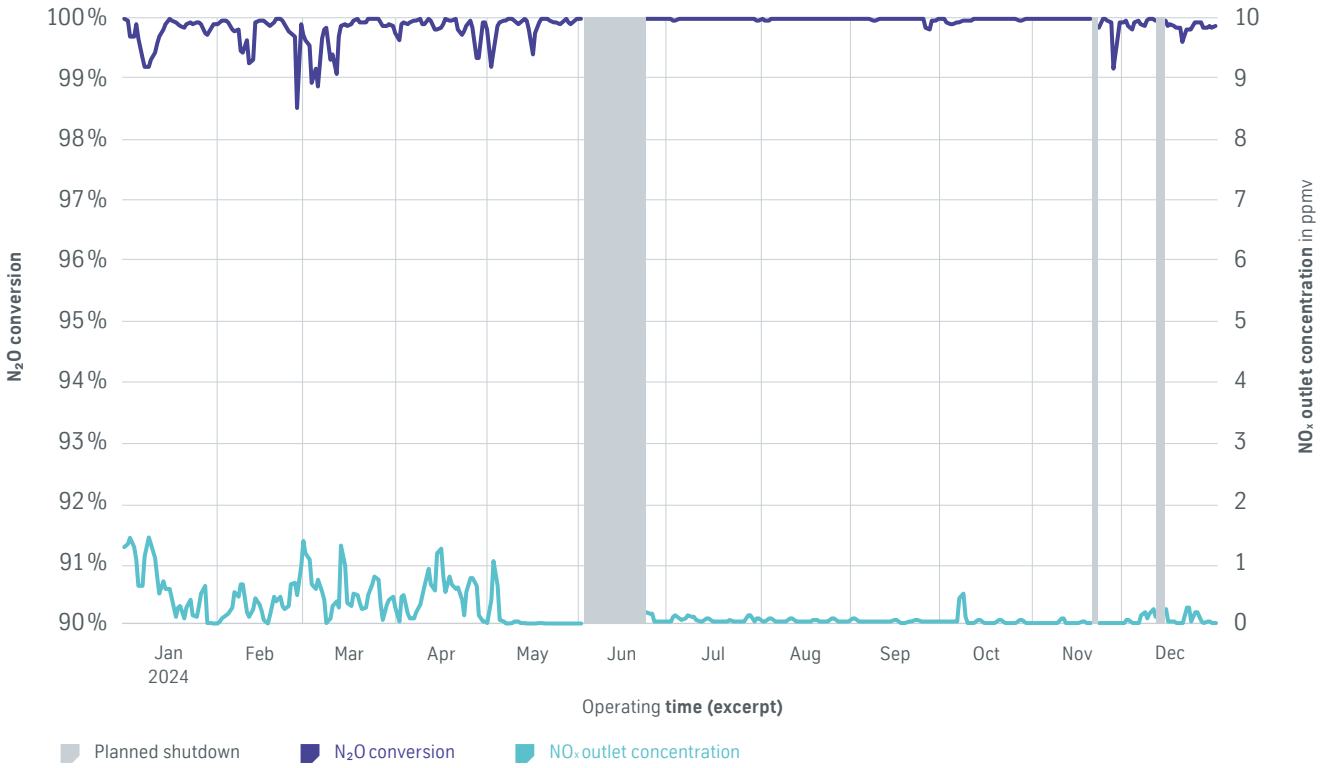


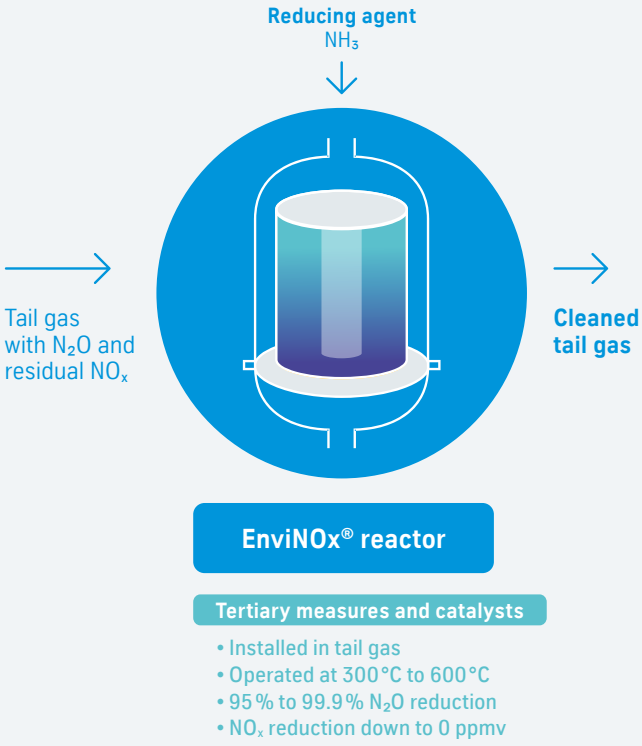
PLANT DATA

Fertiberia – since 2022

Location: Sagunto, Spain
Process: Dual pressure
Capacity: 940 mtpd NA

Tail gas flow rate: 135,000 Nm^3/h
Tail gas temperature: 395 °C
Reducing agents: NH_3





EnviNOx®
after-sales service

If you already have an Uhde $DeNO_x$, DeN_2O® or EnviNOx® system, our after-sales team can help ensure optimum performance throughout its lifetime. Although these systems are generally low-maintenance and easy to operate, they may require slight adjustments due to changing conditions over time. From optimizing the reducing agent to carrying out comprehensive revamps, our specialists are always there to support you in maximizing the efficiency and cost-effectiveness of your abatement system.

Performance assessment and revamp support
If you are planning a plant revamp, it may affect your abatement system. We offer advice to ensure you still get the best out of your EnviNOx® system. After the revamp, we conduct a thorough reassessment of system performance under the new conditions and provide recommendations for optimum post-revamp operating conditions.

Catalyst evaluation and replacement
We analyze samples of the used catalyst and assess current operating data in our in-house laboratory and pilot plant facilities. Based on the results, we can advise on whether the catalyst needs replacing, and provide efficient solutions to help you maintain and even improve peak performance.

EnviNOx® spare catalyst
If, for whatever reason, spare catalyst is needed, it can be supplied quickly and reliably.

Optimization of reducing agent usage
We fine-tune the use of reducing agents to optimize OPEX and enhance the efficiency of your abatement system. We particularly recommend checking their usage when changes in plant operating conditions have occurred over time.

System conversions and upgrades
Whether you want to convert to ammonia as the sole reducing agent in order to decarbonize your system, upgrade your Uhde $DeNO_x$ system to EnviNOx®, or even adapt your system to meet evolving industry standards – for example, by replacing the old catalyst or modifying the reactor internals – our experts are here to support you and help you get the most out of your abatement system.

Troubleshooting and system diagnostics
Whether on-site or via remote diagnostics with secure connection credentials, you can count on us to assist with any troubleshooting if the system does not perform as expected.

Advanced emission control strategies
We offer guidance on optimizing plant start-up and shutdown to minimize NO_x emissions with our EnviNOx® system. Our emission-reduced start-up and shutdown procedures minimize stack plume visibility and improve environmental compliance.

Comprehensive customer support and training
Our team of EnviNOx® specialists not only has extensive experience in EnviNOx® system design and commissioning, but all also have wider experience in the host technologies. This ensures an all-round approach to problem-solving.

When it comes to abatement systems, Uhde is your go-to partner.

EnviNOx® catalysts – a safe and environmentally friendly choice

The EnviNOx® catalysts are the heart of the EnviNOx® process, enabling the effective abatement of nitrous oxide (N_2O) and nitrogen oxides (NO_x) by converting them into environmentally harmless components: nitrogen (N_2), oxygen (O_2), and water (H_2O).

The unique catalysts used in the EnviNOx® process were specially developed by Uhde in cooperation with selected catalyst manufacturers, and have been continuously optimized over the years. In particular, distinct zeolite catalysts loaded with iron are used as they are highly active, thermally stable, and non-toxic, providing both high efficiency and operational safety.

The oxidation activity has been finely tuned to prevent the unwanted slippage of NH_3 when it is used as a reducing agent. In industrial practice, Uhde-certified EnviNOx® catalysts have demonstrably achieved their expected lifetimes of 10 years or more.

For pressurized gases, such as the tail gas from HNO_3 plants, EnviNOx® catalysts are typically in pellet form and installed in radial basket reactors based on a proprietary Uhde design. For unpressurized exhaust gases, such as those found in caprolactam plants or in NH_3 combustion, honeycomb monolith catalysts encased in adapted metal modules are used in the EnviNOx® system to minimize further pressure losses. All catalysts are quality tested in Uhde's in-house laboratory before delivery to ensure they are fully on spec and fit for the intended application.

The preferred catalysts are produced exclusively for thyssenkrupp Uhde by BASF. They deliver exceptional performance across a wide temperature range of 200 °C to 600 °C.

BASF
We create chemistry

About BASF Chemical Catalysts and Adsorbents

BASF is a leading global manufacturer of catalysts for the chemical industry, with solutions across the chemical value chain. The business comprises chemical catalysts, adsorbents and custom catalysts. Priority is given to developing new and improved products that enable the chemical industry transformation to net-zero emissions.

To learn more, visit
www.chemical-catalysts-and-adsorbents.basf.com

EnviNOx® – Clean air, smart returns
Slash N_2O & NO_x for a cleaner future and reap the benefits.

CONTACT US
TO GET STARTED!

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UHD 01/e/50/202510/HE/URD printed in Germany