Knowledge grows

ES Stationary
SNCR TECHNOLOGY

NOx REDUCTION IN UTILITY & INDUSTRIAL BOILERS
Yara delivers sustainable solutions for agriculture and the environment

Agricultural products

Industrial products

Environmental solutions
Safety is always our top priority

• Ambition of zero injuries to people and no major process related incidents
• Product stewardship program
• Production according to high technical standards
• Reliable transport and shipping concepts
• Best practice sharing on storage and handling with partners and customers
Revenues and other income (2017)
NOK 93.8 billion

Number of employees
15,527

Located in more than 50 countries
Sales to more than 150 countries

27.2 million tons
Fertilizers

7.12 million tons
Industrial products

2.03 million tons
Ammonia trade
### Yara’s DeNOx product portfolio

#### DeNOx Reducing Agents
- **NOxCare products:**
  - Anhydrous ammonia
  - Aqueous ammonia
  - Solid urea
  - Urea solution

#### DeNOx Technologies
- **SNCR and HYBRID**
  - Boilers / Cogeneration
  - Industrial applications
- **SCR**
  - Boilers / Cogeneration
  - Industrial applications
  - Marine
- **Reagent Handling & Storage**
- **Urea to Ammonia**

#### DeNOx Services
- **Technology related Services**
  - Testing & Optimization
  - Upgrade & Modification
  - Spare parts & Maintenance
  - Catalyst Management
  - Operation & Maintenance training
- **Safety related Services**
  - Training: Online & Customized
  - Inspection, Audit & Advisory
NOxCare® – Full Service DeNOx Solutions
We Care For Your Operations

- SNCR, SCR and hybrid technology
- Reagent handling and storage equipment
- Reagent supply
- Services – optimization & upgrading of systems, safety trainings, spare parts and maintenance work
Yara is a leading supplier of solutions for reducing NOx emissions from industrial sources

- Power plants
- Waste incinerators
- Cement kilns
- Refineries
- Glass industry
Design philosophy

The YARA ET SNCR system is designed for:

- High Degree of Safety
- High Performance
- Reliable Operation
HIGH DEGREE OF SAFETY

○ The YARA ET SNCR system is designed and manufactured in accordance with the EU Machinery Directive 2006/42/EC for safe and reliable automatic operation.

○ The conformity is declared in a IIA certificate and with a CE marking.
Thanks to the stringent Swedish emission requirements and fee on NOx emission, YARA ET has been able to develop a high performance SNCR system.

High performance means high degree of NOx reduction with low ammonia slip and low consumption of reduction agent.
YARA ET Low NOx SNCR system

Unique features:

- Reduction agent: Ammonium hydroxide - Urea
- Three or more injection levels
- Unique injectors of YARA ET design
- Special software program developed by YARA ET
- Well proven design
- CFD modelling of the process
- Advanced temperature control
Reduction agent

Alternative reduction agents:

✓ **Ammonium hydroxide - NH\textsubscript{4}OH**
  also known as:
  Liquid ammonia, Ammonia solution, Ammonia water, Ammonical liquor, Ammonia liquor, Aqua ammonia, Aqueous ammonia

✓ **Urea - NH\textsubscript{2}CONH\textsubscript{2}**
  also known as:
  Carbamide, carbonyl diamide, diaminomethanal, diaminomethanone
Ammonium hydroxide is recommended due to:

- Urea is freezing at high temperature
- Urea is very corrosive to tube materials
- Urea gives higher slip
- Urea can not reach higher degree of reduction
- Urea generates laughing gas (N$_2$O)
- Urea generates CO
- Urea formats deposits
YARA ET SNCR low NOx system
CE marking

IIA certificate and CE marking by YARA ET provides:

- Complete delivery including software
- Standard system of well proven design
- Standard well proven components

If not complete delivery only IIB certificate
IIA certificate by other before start-up
Designed for continuous operation all around the year (>8,500 h/y)

- Well proven design
- Components of high quality
- Standardized modules
- FAT of complete system
- Service agreement
- Remote assistance via modem
YARA ET SNCR system is prefabricated in modular design, which makes the installation and the commissioning easier.

- Prefabricated storage tank
- Pump Modules for Water and Red. agent – PMW, PMR, etc.
- Process Units – PU cabinets
- Injectors
- Control and Management Module - CMM
- FAT with complete system
STANDARIZED EQUIPMENT
SNCR equipment

- Standardized, high reliability equipment
SNCR PID (for one dosing module)
The injector is designed for atomizing and cooling with compressed air and equipped with quick release coupling for easy inspection.
High performance injector

- **YARA ET Injector of special design**
  - The injector is of YARA ET special design for high performance and long lifetime with atomizer protected in an outer injector pipe

- **Long lifetime of outer injector pipe**
  - 3 – 6 months for waste incinerators
  - Over one year for cement plants
  - For severe conditions injector tip available in Inconel material

- **Easy to inspect/serve**
  - With quick release coupling to the flue gas chamber and flexible hoses for compressed air and reduction agent it will take only a few minutes to inspect or change outer injector pipe

- **Easy to install**
  - Small diameter of injector (18 mm) makes it easy to install
Container installation

As an option the equipment can be installed in a 10 ft. container. The container will make the installation work easier and protect the equipment from a rough environment as well as the weather conditions.
CMM cabinet

Control and Management Module (CMM) includes an advanced PLC based management program, an industrial PC with an operator program for local operation and a communication system for the DCS.
Control system of the SNCR

The control software is including

- a Nox regulator (calculation of the total reagent flow based on the NOx value at the stack, steamflow and other parameters)
- a NH3 slip regulator (reduces the reagent flow in case of high slip)
- PU module control (calculation of the flow in the single PU module, therefore, in each injector group as indicated in the injector layout drawing)
- 10 different recipes with the main set up parameters for different operating conditions

The system is very flexible and can divide the total reagent flow into different levels. On the single level the reagent can be divided in the different injector groups depending on the temperature profile.
Operator interface

The operator interface is an industrial PC with a touch screen with process pictures for local operation and supervision.
ADVANCED TECHNOLOGY FOR POWER BOILERS

- **ACL (air cooled lance)** – the new injection technology

- **UDL (urea decomposition lance)** – injection of urea between superheaters with no corrosion risk

- **CFD model** of the boiler / injection of reagent

- **Acoustic pyrometer or equivalent technologies** for temperature control in the boiler
ACL – the patented air cooled lance for SNCR
*Injection exactly where needed*
Movable ACL for small boilers – changing the position depending on the flue gas temperature

The movable ACL

- Adjusting automatically the penetration as a function of the temperature or other process conditions
- Lance up to 10 – 15m long
- For small boilers, one ACL can cover the complete boiler
- Less amount of nozzles, reduced air consumption and water injection
ACL for large boilers – the smart way to improve the coverage

- Large sections can not be covered by standard wall injectors
- With the ACL it is possible to inject inside the boiler, even between superheater banks
UDL (Urea decomposition lance)

- Patented technology to evaporate and decompose urea inside the lance avoiding the risk of corrosion inside the boiler
CFD modelling of the process
CFD modelling of the process

- CFD study for better understanding of the fluid dynamics properties inside the boiler
- More accurate injector placement
Acoustic Pyrometer / Infrared sensors for the optimization of the combustion

- Precise temperature profile in one or more sections of the boiler
- Improved SNCR performance, with limited ammonia slip
- Better understanding of the process conditions, and the combustion process
Advanced temperature and process control

- Online CFD, temperature profile in the complete boiler
- Advanced process control (APC), process control systems including Multivariable Model predictive control (MPC)
CASE STUDY 1: GAS FIRED STEAM BOILER ON YARA PRODUCTION PLANT

Main process information:

- Process type: gas fired steam production boiler
- Capacity: 120-190 ton/h of steam
- Gas flow: 140,000 Nm$^3$/h dry flue gas flow (estimated)
- NOx baseline: 650 mg/Nm$^3$ @6 % O$^2$
- NOx limit: 350 mg/Nm$^3$ @6 % O$^2$
- Temperature in the injection area: aprox. 1050°C normal load, 1140°C high load
- In operation since: end of 2015
CASE STUDY 1:
GAS FIRED STEAM BOILER ON YARA PRODUCTION PLANT

Boiler drawing
CASE STUDY 1:
GAS FIRED STEAM BOILER ON YARA PRODUCTION PLANT
NOx and NH3 - trend
CASE STUDY 1:
GAS FIRED STEAM BOILER ON YARA PRODUCTION PLANT
Performance of the YARA – SNCR system

![Graph showing NOx reduction vs. NH4OH flow rate](image-url)
CASE STUDY 2:
BIOMASS FIRED UTILITY BOILER

Main process information

- **Boiler:** OS-120
- **Fuel:** wood powder
- **Firing method:** tangential
- **Capacity:** 120 ton/h steam
- **NOx baseline:** 350 mg/Nm³ @6 % O²
- **NOx limit:** 190 mg/Nm³ @6 % O²
- **NH3 limit:** 5 mg/Nm³ @6 % O²
- **SNCR technology:** equipped with advanced temperature control and online CFD
- **In operation since:** end 2015
CASE STUDY 2:
BIOMASS FIRED UTILITY BOILER

Boiler drawing
CASE STUDY 2:
BIOMASS FIRED UTILITY BOILER
Performance of the YARA – SNCR system
CASE STUDY 2: BIOMASS FIRED UTILITY BOILER

Graph with NOx trend
CASE STUDY 3:
COAL FIRED UTILITY BOILER 100 MWt

Main process information

- Fuel: Coal
- Capacity: 100 MWt
- NOx in: \( \leq 450 \text{ mg/Nm}^3 \), @ 6 % \( \text{O}_2 \), dry, as NO\(^2\) (24h average)
- NOx out: < 180 mg/Nm\(^3\), @ 6 % \( \text{O}_2 \), dry, as NO\(^2\) (24h average)
- NH\(_3\)-slip: < 18 mg/Nm\(^3\), @ 6 % \( \text{O}_2 \), dry, in gas phase (24h average), in reality less than 5 mg/Nm\(^3\)
- Flue gas data:
  - Flow: 165 000 Nm\(^3\)/h (wet)
  - \( \text{O}_2 \) 5,5 %, (wet)
  - \( \text{H}_2\text{O} \) 8,0 % (wet)
- Technology: advanced temperature control system with IR sensors, wall injectors
- In operation since: end of 2016
CASE STUDY 3:
COAL FIRED UTILITY BOILER 100 MWt
Typical 24h trend
CASE STUDY 3:
COAL FIRED UTILITY BOILER 100 MWt
Typical long period trend (appr. 4 months)
CASE STUDY 4: COAL FIRED UTILITY BOILER OP-380 – TEST INJECTION

Main process information

- Boiler: OP-380
- Capacity: 380 ton/h of steam
- Fuel: coal
- Flue gas flow: up to 450,000 mg/Nm³
- Nox baseline: 600 mg/Nm³, @ 6 % O₂, dry,
- Section of the boiler: aprox. 12 x 6 meters
CASE STUDY 4:
COAL FIRED UTILITY BOILER OP-380 – TEST INJECTION

Boiler drawing
CASE STUDY 4: COAL FIRED UTILITY BOILER OP-380 – TEST INJECTION

NOx trend

Coal fired utility boiler
NOx trend left stream

- NOx as NO2 [mg/m³]
- Average NOx before injection
- Average NOx during injection
CASE STUDY 4:
COAL FIRED UTILITY BOILER OP-380 – TEST INJECTION
Performance for high load conditions
CASE STUDY 5:  
GRATE FIRED COAL/BIO MASS BOILER OR-32 – PILOT PLANT  
Main process information

• Capacity: 28 MWt  
• Firing system: gate firing  
• Fuel: coal / biomass (typically one week coal, one week biomass)  
• NOx baseline: 300-450 mg/Nm³, @ 6 % O₂,  
• NOx with SNCR: 140-180 mg/Nm³, @ 6 % O₂, depending on load and baseline  
• Section of the boiler: approx. 5 x 4 meters  
• Technology: One ACL (air cooled lance), furnace flue gas recirculation  
• Status: ACL in operation since 02/2017, SNCR under final optimization
CASE STUDY 5:
GRATE FIRED COAL/BIO MASS BOILER OR-32 – PILOT PLANT
ACL – *the injection from the center of the boiler*
CASE STUDY 5:
GRATE FIRED COAL/BIOMASS BOILER OR-32 – PILOT PLANT
SNCR performance

NOx = 156 mg/Nm3
NH3 slip = 9.9 mg/Nm3
CASE STUDY 6: COAL FIRED UTILITY BOILER 500 MWel – PILOT PLANT

Main information

- Capacity: 500 MWel
- Maximum continuous rating: 1,675 t/h steam
- Pressure of superheated steam: 178 kg/cm²
- Temp. Superheated steam: 540°C
- Fuel: coal
- SNCR reagent: urea solution
- NOx baseline: 500 mg/Nm³, @ 6 % O₂
- Target NOx with SNCR: 300 mg/Nm³, @ 6 % O₂
- Section of the boiler: approx. 15.8 x 19 meters
- Technology: horizontal ACL, vertical UDLs
- Status: Under construction, startup
CASE STUDY 6: COAL FIRED UTILITY BOILER 500 MWel – PILOT PLANT
Injection technology
CASE STUDY 6: 
COAL FIRED UTILITY BOILER 500 MWel – PILOT PLANT
Injection technology

- Horizontal air cooled lance (ACL, patented)
  - Penetration into the boiler in order to reach the main flue gas (up to 3m)
  - Special design to resist at high temperatures, cooled by ambient air

- Vertical urea decomposition lances (UDL, patented)
  - Urea is decomposed inside the lance
  - Injection between the superheaters of gaseous urea with no corrosion risk
  - Immediate reaction, no residence time needed in the flue gas for evaporation / decomposition of the urea
CONCLUSION

- Yara ET can reduce the NOx value in the range of 35 – 65%, depending on the type of fuel, boiler and size, keeping the NH3 slip at limited values.

- 45-60% reduction for boilers with capacity up to 200 ton/h, 35 – 45% reduction for boilers with higher capacity