GORE® DeNOx CATALYTIC FILTER BAGS

A new solution for reliable and stable NOx compliance

W. L. Gore & Associates, Inc.

Together, improving life

Driving Forces for pollutants abatement

- Awareness and demand for clean and healthy environment
- Increasingly strict regulations
- Incentives

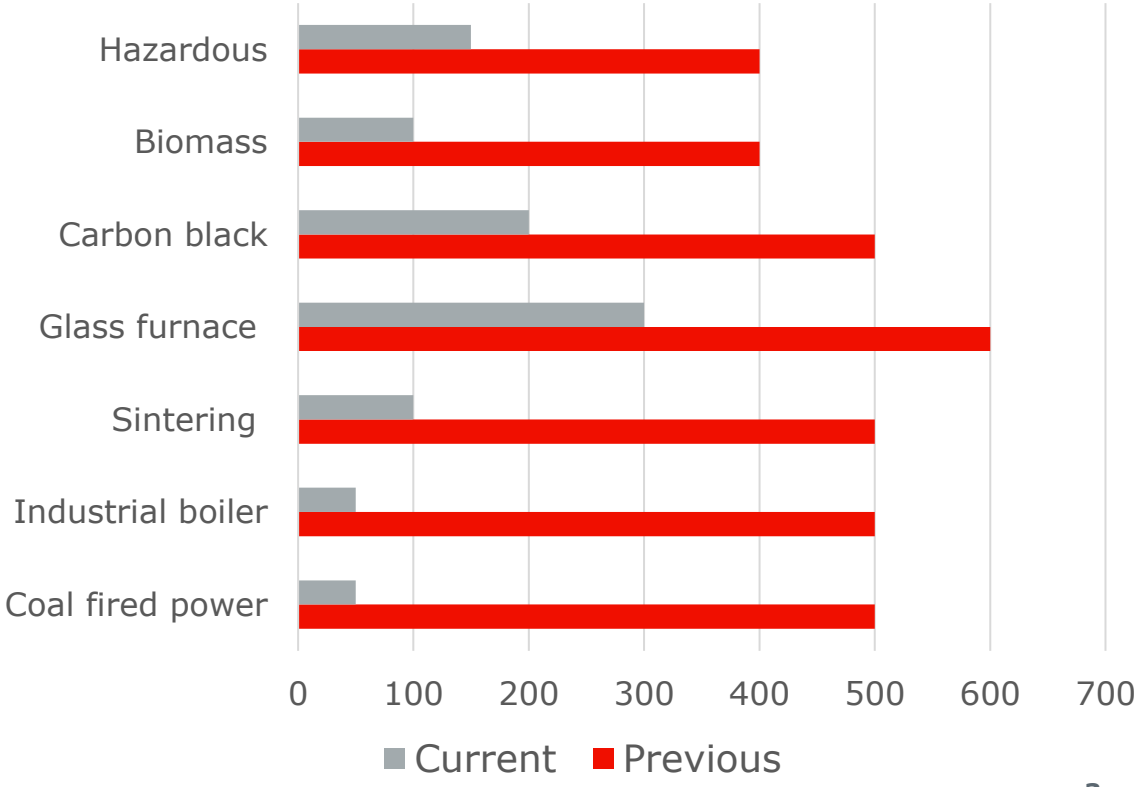
Continuous Enforcement of Regulations for NOx Emissions

European NOx Emission limit (mg/Nm³)

European Directive (IED)	=	150 mg/Nm³*
Austria	=	70
Netherlands and others	=	80
France (for tax rebate)	=	80
Italy (regionally)	=	80
Switzerland	=	80
Regional	=	50

* For SCR

China NOx Emission limit (mg/Nm³)
(regional variances)



Pollutants from thermal processes

With long-term impact on health and environment

Thermal processes → **Pollutants** → **Solution**

- Waste incineration
- Calcination (Cement/Lime)
- Metal processing
- Chemical manufacturing
- Power generation

- NOx (NO and NO_2)
- Dioxin/ Furan
- Mercury
- Particulate
- SOx (SO_2 and SO_3)
- Carbon dioxide
- Other acid gases (HCl, HF)

Gore's expertise in pollution abatement

GORE – A PIONEER & LEADER IN CATALYTIC FILTRATION

A long-term leader in innovative filtration technology

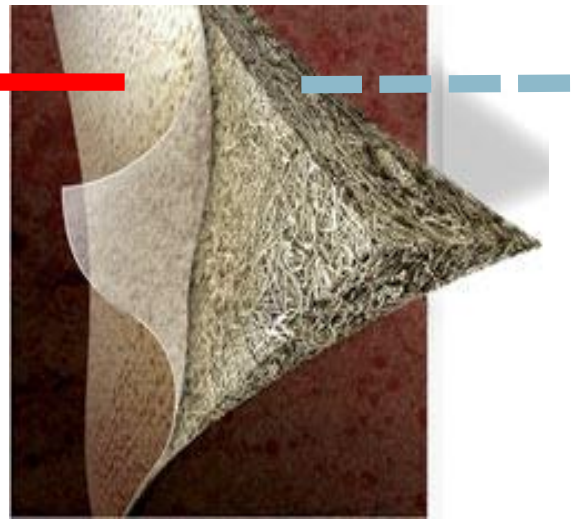
History of Gore Particulate Filtration & Gas Phase Remediation

1972	1998	2013	2015	2018	2020
Membrane-based particulate filtration	**GORE® REMEDIA® Catalytic Filter Bags**	**GORE Mercury Control System**	**GORE® DeNOx Catalytic Filter Bags**	**Generation 2 GORE® REMEDIA® Catalytic Filter Bags**	**Generation 2 GORE® DeNOx Catalytic Filter Bags**

Concept of Catalytic Filtration Technology

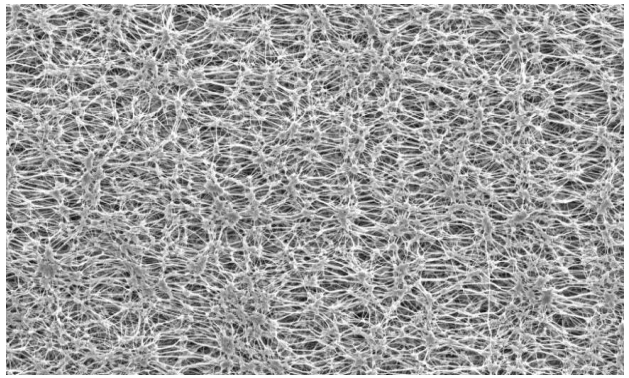
Combines particulate filtration & catalytic reaction in a single unit

Dirty & polluted flue gas



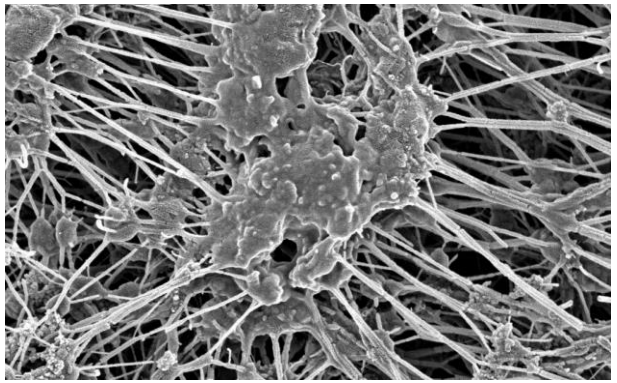
Clean gas

Expanded PTFE membrane



Efficient filtration of particulates

Catalyst-filled felt

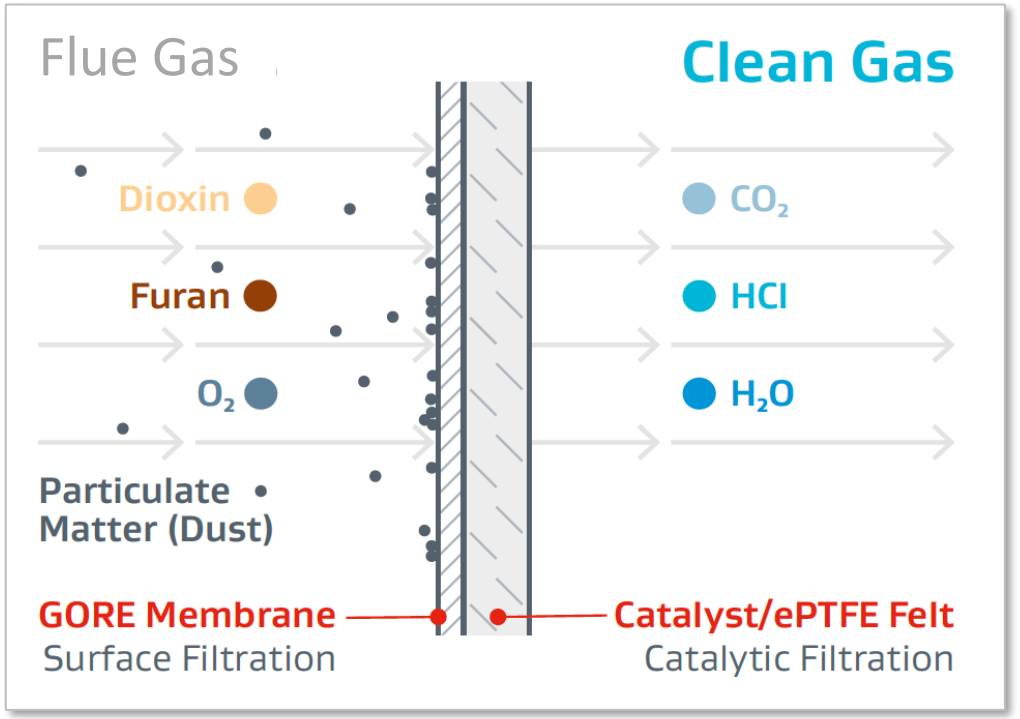


Efficient contact with catalyst

Long-term Expertise in Catalytic Filtration

GORE® REMEDIA® Catalytic Filter Bags

- Designed for dioxin/furan reduction
- Over 20 years of experience in catalytic filtration
- Proven performance in waste incineration and other applications
- More than 250 installations globally



GORE® DeNOx CATALYTIC FILTER BAGS -

An Innovative Solution For Reliable & Cost-Effective NOx Reduction

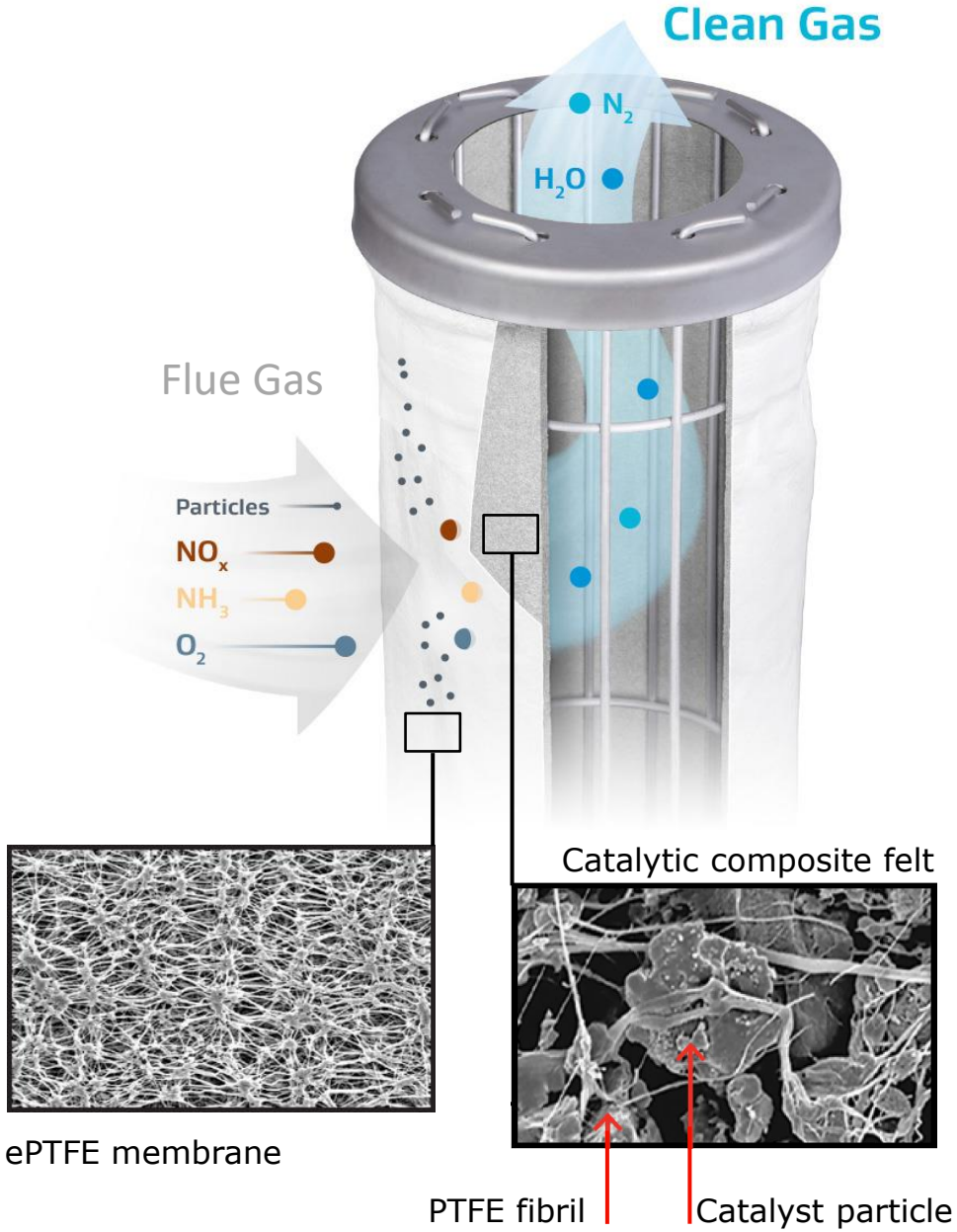
GORE® DeNOx Catalytic Filter Bags

For NOx & NH_3 Reduction

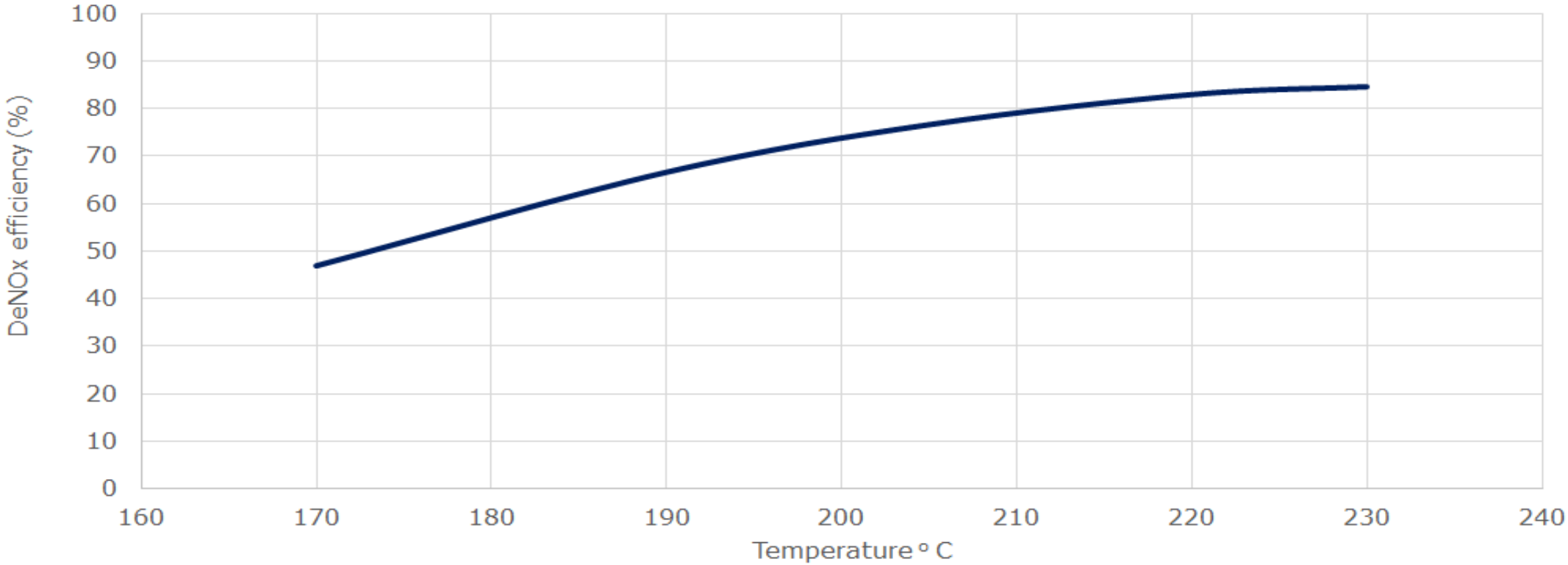
- Particulate filtration & destruction of NOx in one unit
  - Outer ePTFE membrane for efficient particulate removal
  - Catalytic composite felt for NOx and NH_3 reduction

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$
$$4NO_2 + 8NH_3 + 2O_2 \rightarrow 6N_2 + 12H_2O$$

- Reaction is more efficient at temperatures >180°C
- Temperature limitation for continuous use: 260°C



DeNOx Performance

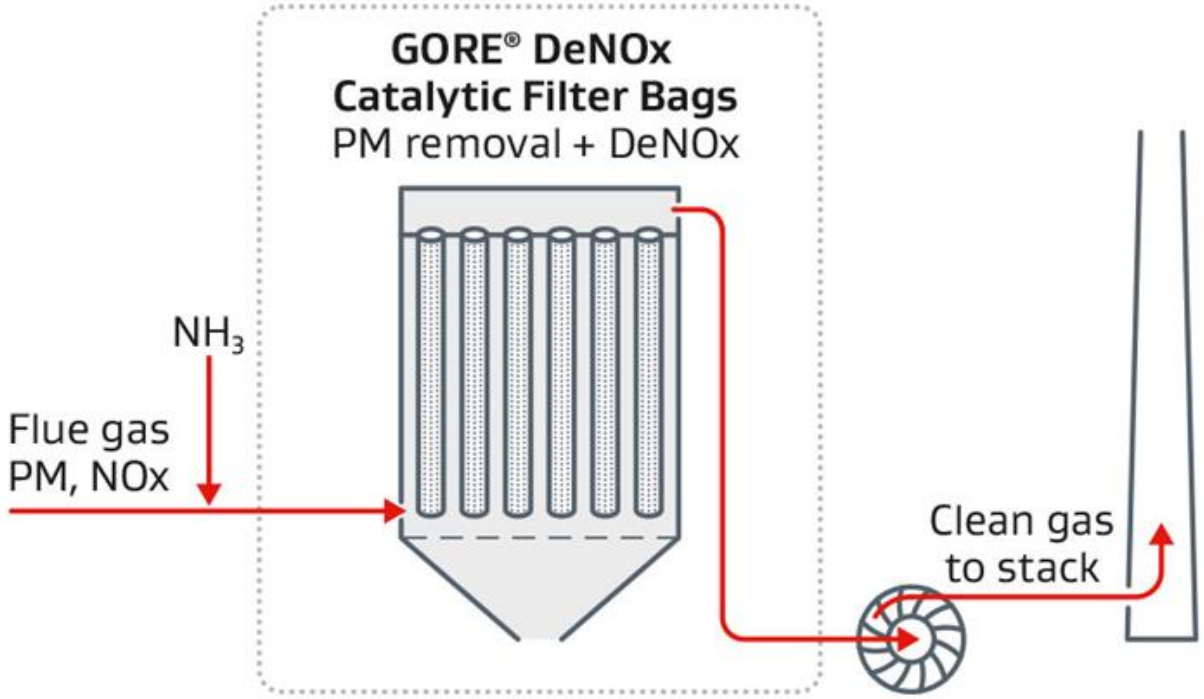


- Example performance chart. Actual performance could be higher or lower based on process conditions.
- Temperature in the chart is the average temperature of the baghouse.

Operational Requirements for GORE® DeNOx Filter Bags

- Existing or to be built baghouse
- NOx reduction efficiency requirements
- Average bag house temperatures: 180˚C to 250˚C
- NH_3 at the inlet of the baghouse
- Controlled SO_2 concentration in the baghouse

- Source of NOx does not matter
- Process conditions at the treatment location influences performance

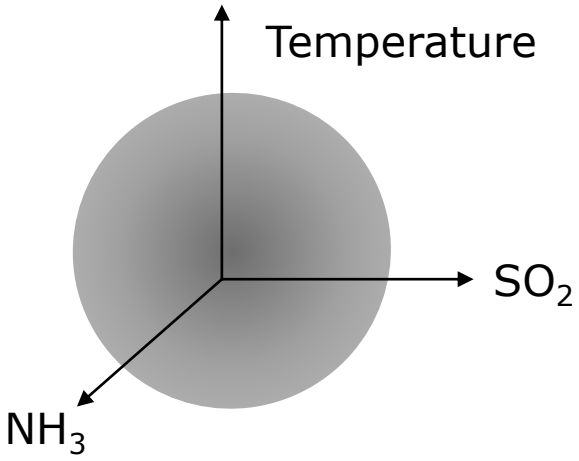


Undesired reactions and catalyst fouling

Ammonia salt formation on catalyst

Impact

- NOx reduction efficiency
- Catalytic bag-filter life



$$2\ SO_2 + O_2 \rightarrow 2\ SO_3$$

$$NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$$

$$2NH_3 + SO_3 + H_2O \rightarrow (NH_4)_2SO_4$$

Solution

- Implementation of optimized process conditions (ammonia, SO_2 and temperature)
  - Gore application support

Uniqueness & Distinctive Performances

Uniqueness

100 % PTFE-based construction

High catalyst loading

Catalyst is an integral part of the felt

Innovative composite felt structure

Unique micro-structure of PTFE membrane

Distinctive Performances

High temperature application
Absolute resistance to corrosive environment

High DeNOx efficiency in a single layer

No catalyst loss – durability of catalytic performance

Long mechanical life of bags

- High permeability - resistance tradeoff
  - Good flow and low differential pressure (DP)
- Effective and efficient cleanability
  - Maintenance of good flow and low DP

High efficiency for particulate matter capture

GORE® DeNOx Catalytic Filter Bag laminate - Technical data

Felt Content:	Staple: Polytetrafluoroethylene Scrim: Woven Polytetrafluoroethylene
Felt Construction:	Supported Needlefelt
Continuous Operating Temperature:	500°F (260°C) maximum
Maximum Surge Temperature:	525°F (274°C)
Acid Resistance:	Excellent
Alkali-Resistance:	Excellent
Weight:	39 oz/yd^2 (1320 g/m^2)
Air Permeability:	2.5 ft^3/ft^2/min @ 0.5 inch of water
Breaking Strength:	Machine direction: 120 lbs/2” wide sample (53 kg/5 cm) Cross-Machine direction: 130 lbs/2" wide sample (58 kg/5 cm)
Mullen Burst:	400 psi (28 kg/cm^2)
Thickness:	Minimum 0.072" (1.85 mm)
Thermal Stability:	Less than 2% shrinkage at 260°C after 2 hours (in cage)
Durability:	Excellent

All data expressed as minimum values. This specification is subject to change.
Please contact W. L. Gore & Associates, Inc. directly to confirm current information.

ADVANTAGES OF GORE TECHNOLOGY OVER OTHER SOLUTIONS

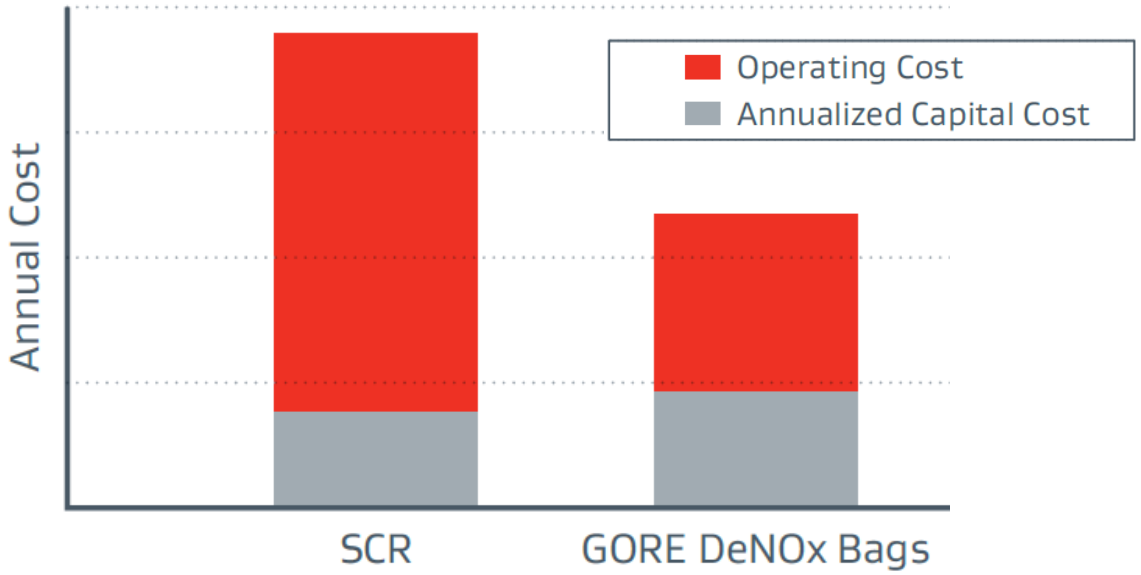
Advantages of GORE® DeNOx Filter Bags over conventional SCR

GORE DeNOx technology with filtration in a single unit

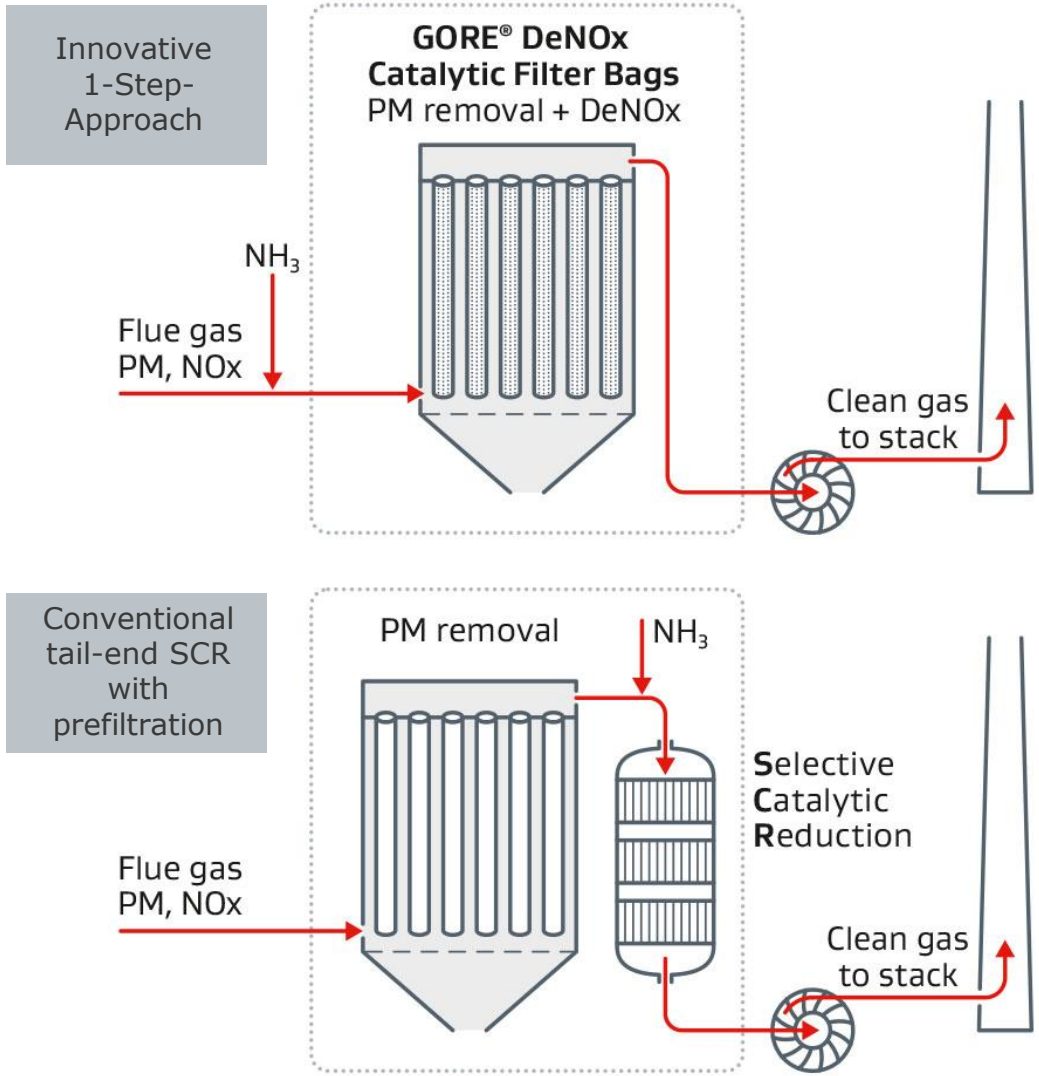
- Less capital investments
- Easy and quick implementation of technology in the existing system
  - No capital equipment - utilizes existing baghouse
  - No system modification
  - Minimal or no process modification
  - No major shut down required
  - No need to deal with space constraints
- Less operating cost
  - Less maintenance
  - Not required to reheat flue gas to a high temperature
  - Easy to maintain low pressure drop
  - Long bag life

Advantages of GORE® DeNOx Filter Bags over conventional SCR

Lower Total Cost of Ownership



- Calculation based on WTE application in China; larger TCO advantage in Western countries due to much higher capital cost for SCR
- Reheating requirement of flue gas in SCR is the biggest contributor for operating cost advantage



Unique Performance of GORE® DeNOx Catalytic Filter Bags

- High performance GORE ePTFE membrane for efficient particulate filtration:
  - Reliable PM emission compliance in demanding environments
  - Prevent toxic heavy metal emission
  - Efficient bag cleaning enables longer cleaning cycles
  - Low dP
  - Longer bag life

- Innovative PTFE-Catalyst composite for exceptional catalytic filtration performance:
  - Achieve NOx reduction efficiency >90%
  - Prevent catalyst shedding: Catalyst particles permanently held within the microscopic structure of the PTFE matrix
  - Prevent mechanical strength loss caused by acid attack in process upsetting situations
  - Avoid poisoning from alkaline metals
  - Providing greater access of flue gas to catalyst active sites

PROVEN TECHNOLOGY -

REFERENCES & CASE HISTORIES

Proven technology in commercial applications

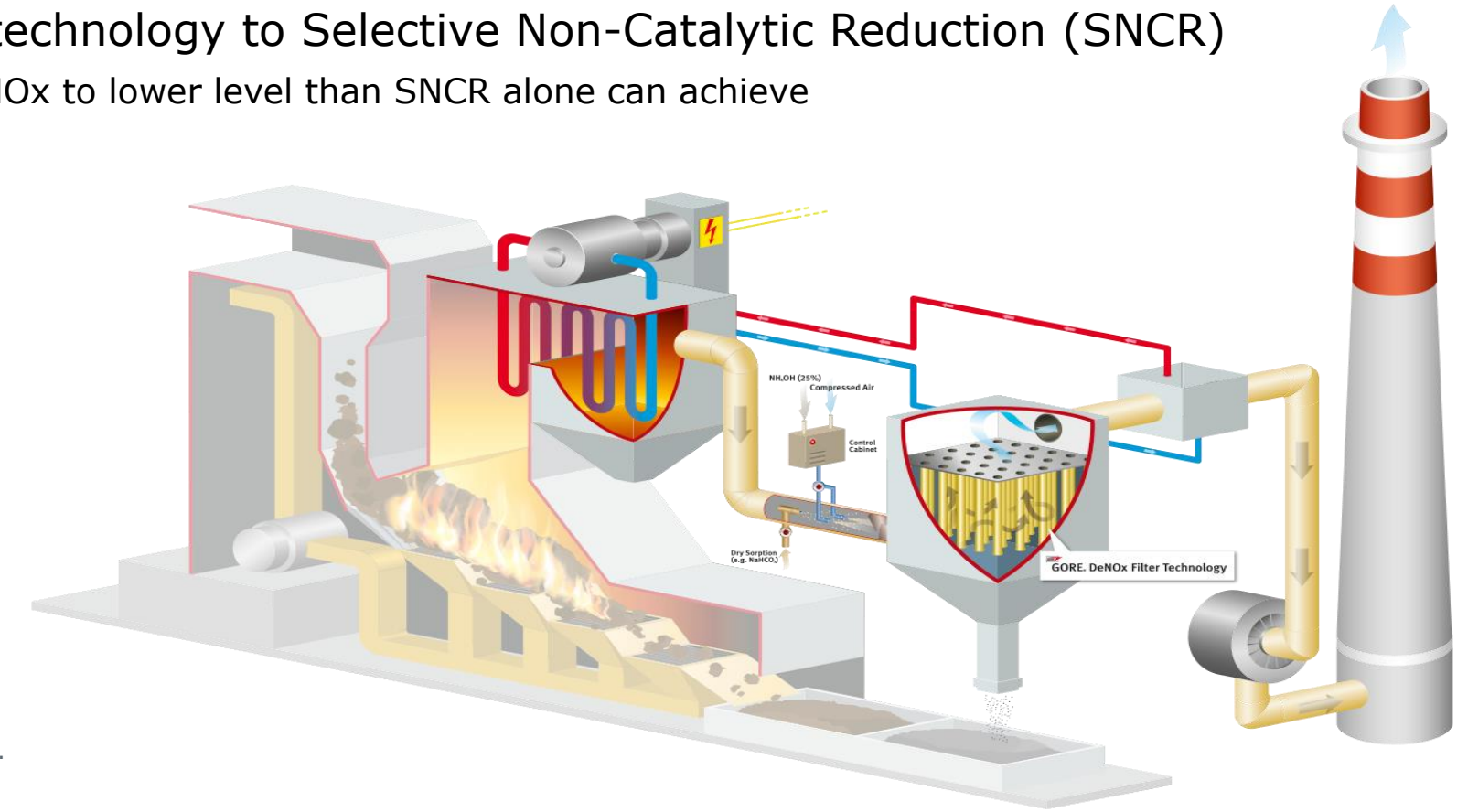
- 6 MSW incineration plants
  - 4 plants in France (total of 8 lines, all active)
  - 2 plants in Italy (Total of 3 lines, 1 active)
- 2 HWI installation
  - 2 plants in China (Total of 3 lines)
- 1 Sinter plant in steel manufacturing in China
  - 2 lines
- Upcoming installation in Europe
  - 1 Optical fiber manufacturing plant in Germany (1 line)
- Successful demonstration in other segments
  - 2 Lime plants (1 in Italy and 1 in US)
  - 1 Cement (Germany)
  - 1 Chemical (Germany)

GORE® DeNOx Catalytic Filter Bag technology in waste incineration process

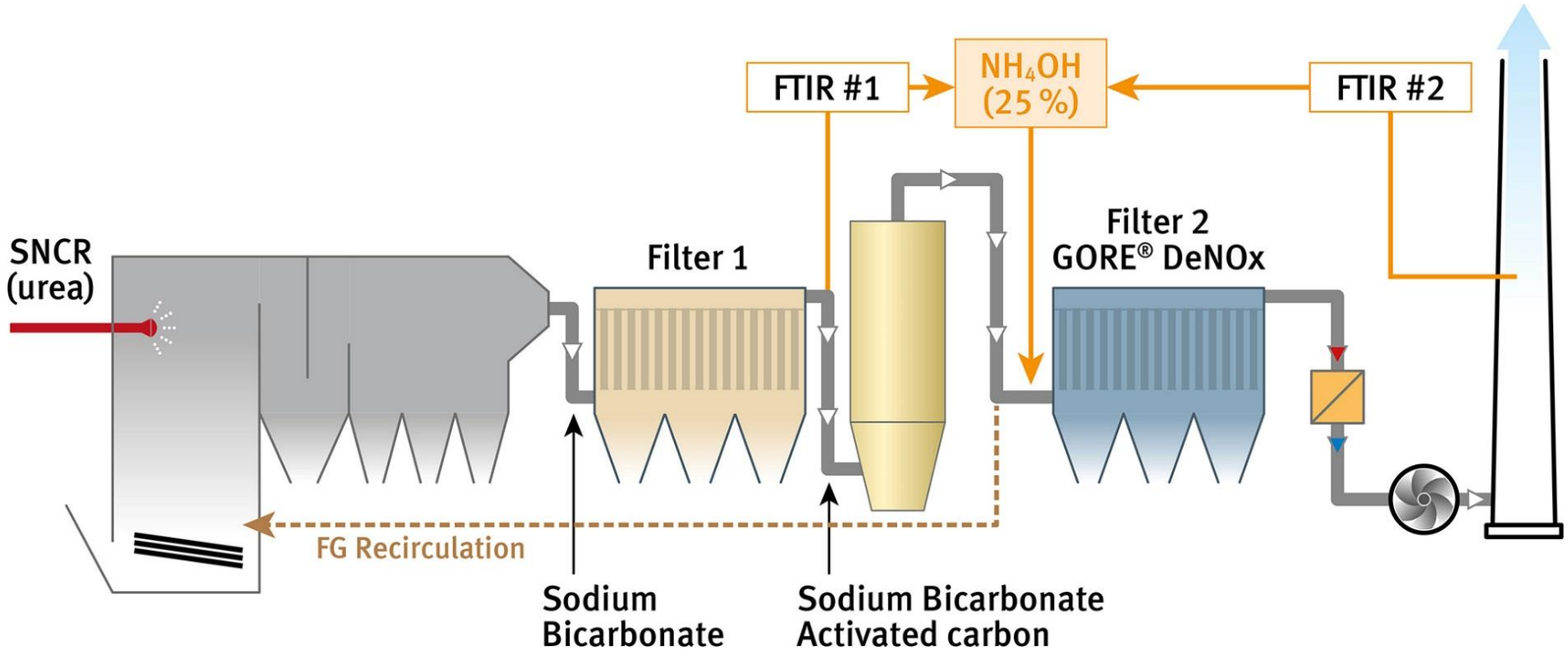
- Standalone unit reduce NOx

OR

- Complementary technology to Selective Non-Catalytic Reduction (SNCR)
  - Capable to reduce NOx to lower level than SNCR alone can achieve



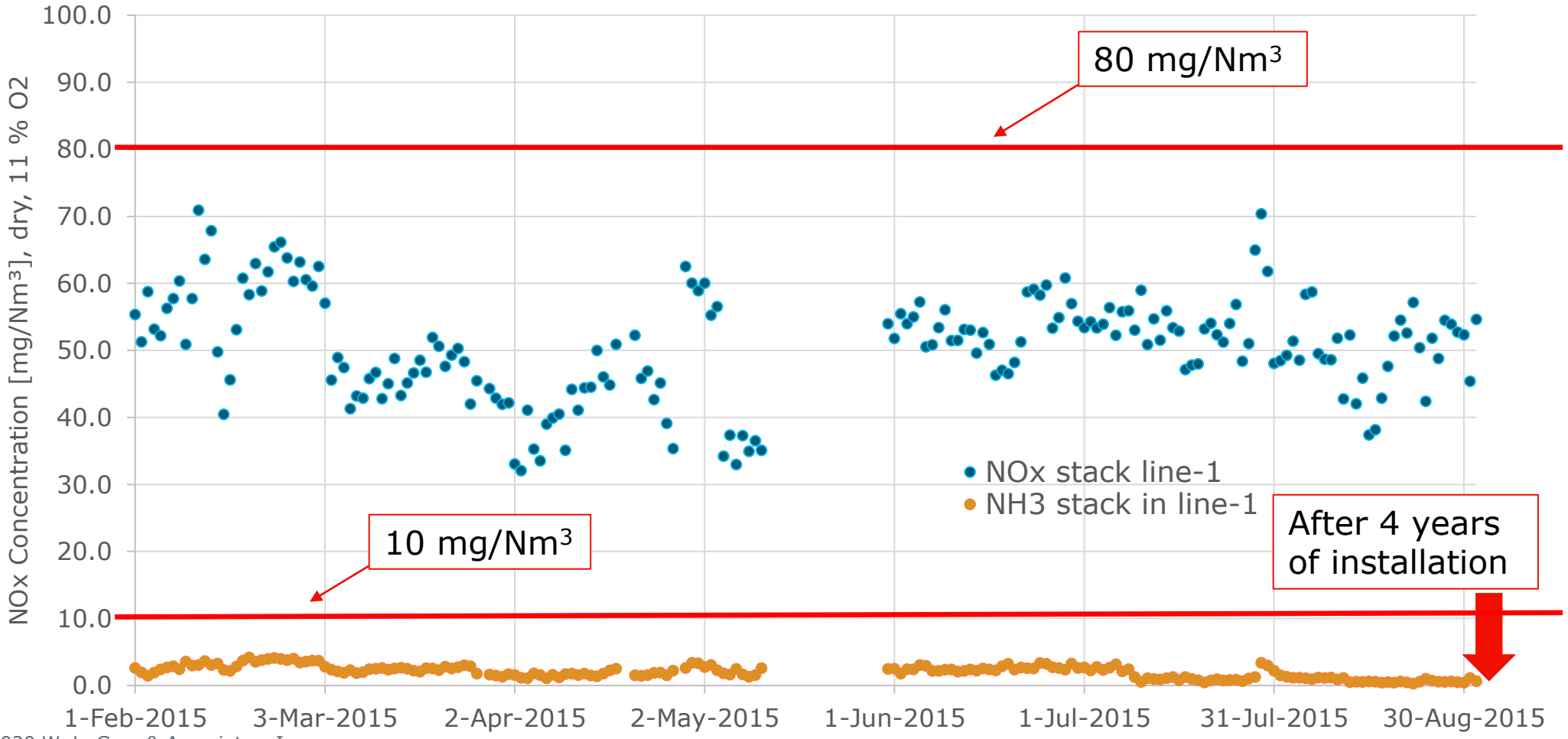
Municipal waste incinerator in Italy



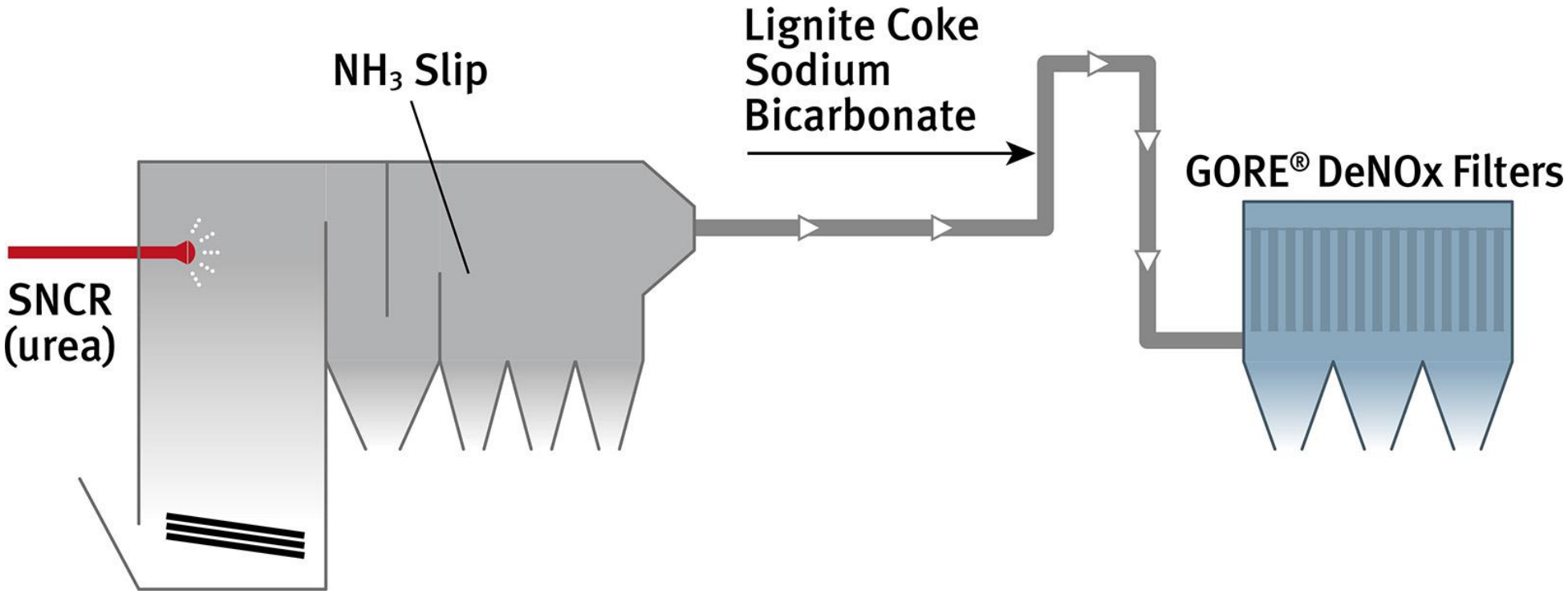
- Installed in September 2011, still running well
- GORE® DeNOx Catalytic Filter Bags installed in line 1

Reliable compliance for NOx & Ammonia Emission

Municipal waste incinerator in Italy - NOx & ammonia emission (GORE DeNOx Filter Bags Gen-1, daily averages)



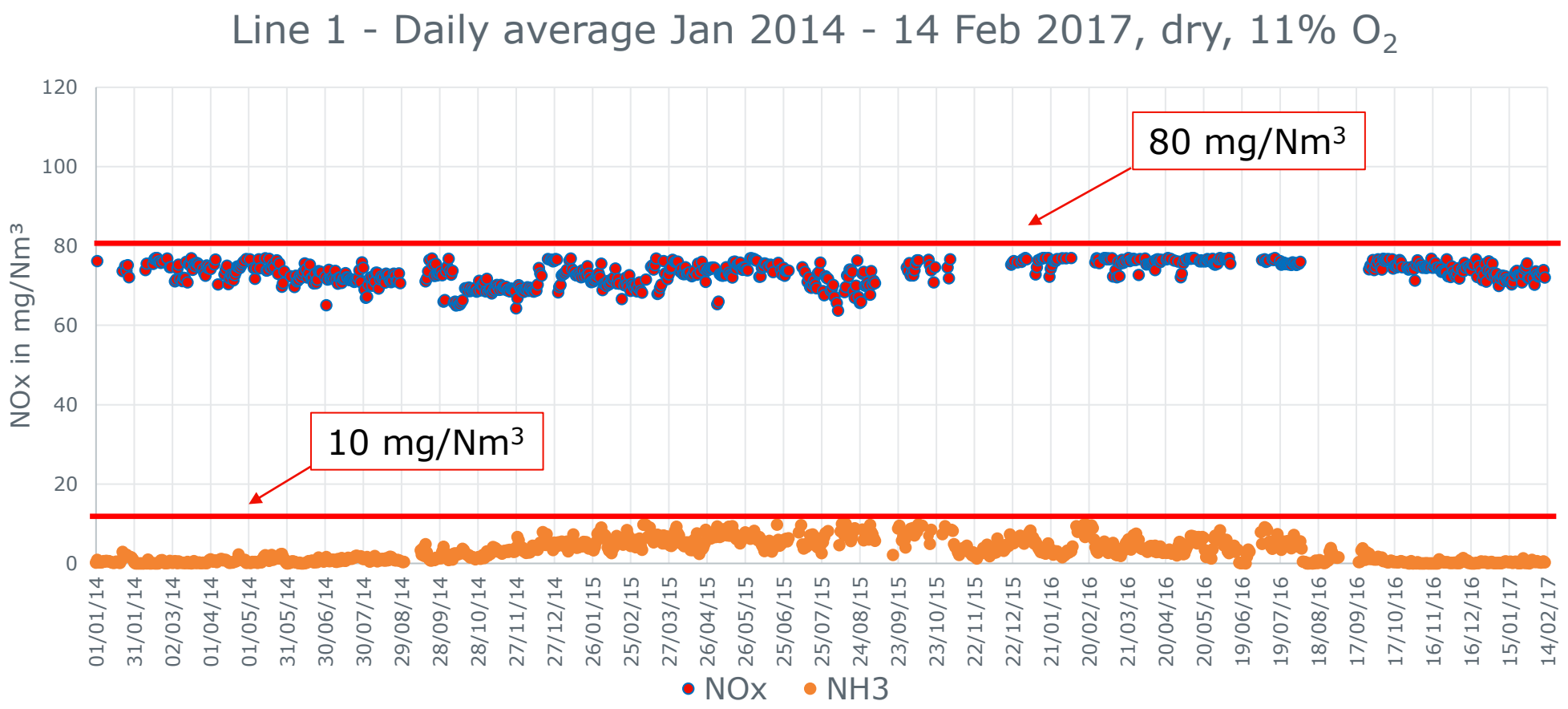
Municipal waste incinerator in France



- 2 incineration lines using GORE® DeNOx Catalytic Filter Bags
- Use of ammonia slip from SNCR

Reliable compliance for NOx & Ammonia Emission

Municipal waste incinerator in France - NOx & ammonia emission at stack (GORE DeNOx Filter Bags Gen-1, daily averages)



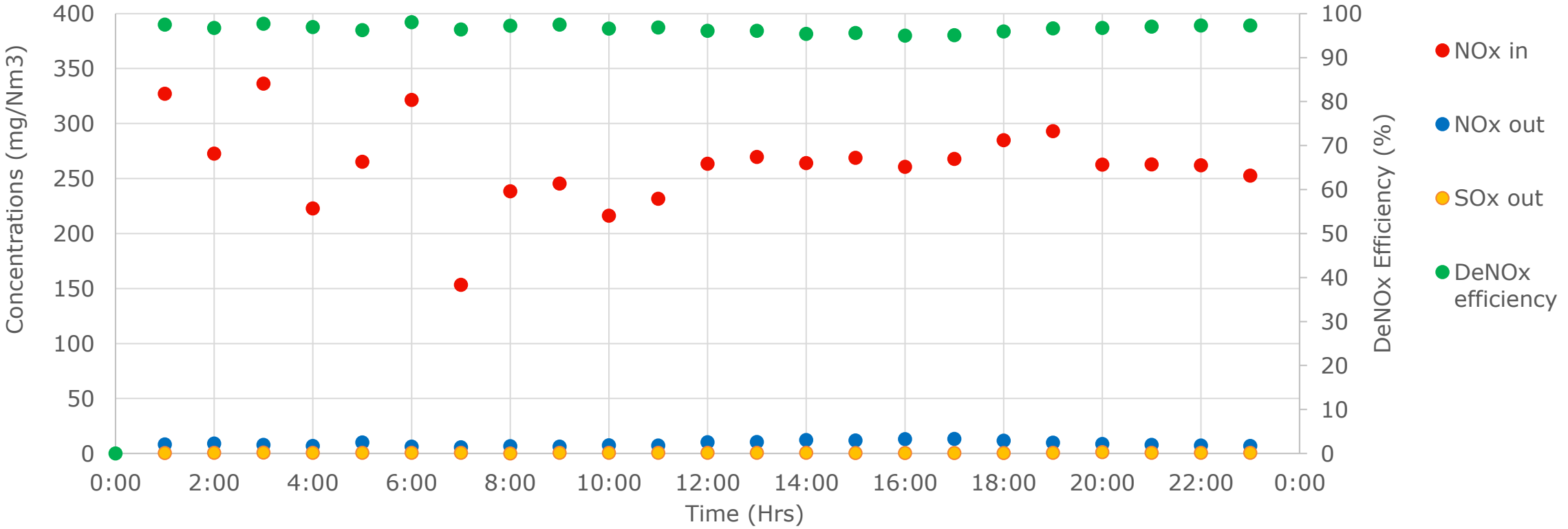
Flow rate: 35,000 Nm^3/hr, SO_2: < 5 mg/Nm^3, Temperature: 200°C, ACR: 0.92 m/min

Sinter plant in steel manufacturing

- Combined flue gas flow rate of 1.8 million Nm^3/hr
- Two lines comprising 18,000 filter bags
  - Gore DeNOx Catalytic Filter Bags Gen-2

Sinter plant in steel manufacturing

GORE DeNOx Filter Bags Gen-2



Inlet NOx: 200 to 400 mg/Nm^3
Outlet NOx: ≈ 10 mg/Nm^3
Average efficiency: ≈ 96%

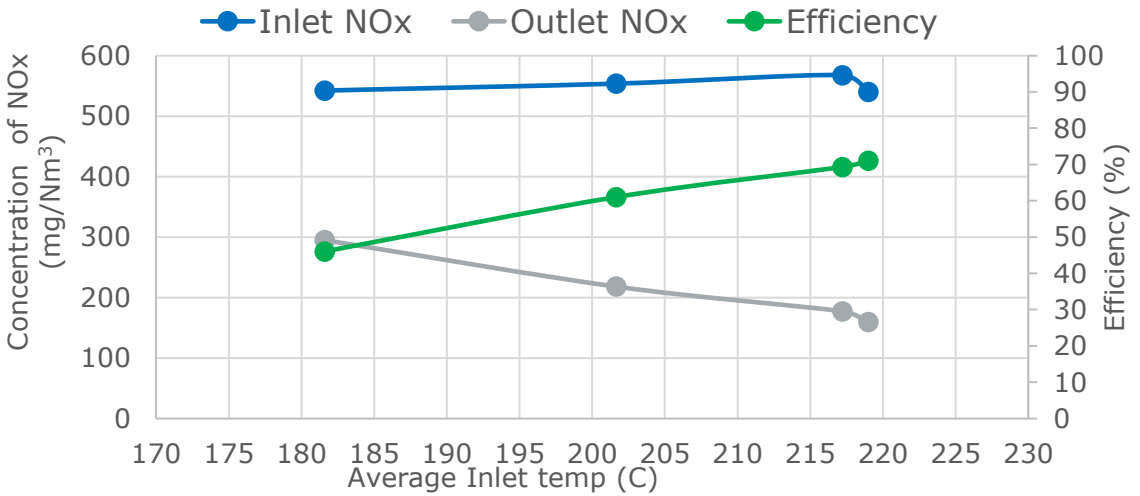
Inlet SOx: 125 to 25 mg/Nm^3
Outlet SOx: ≈ 2 mg/Nm^3
Average efficiency: ≈ 97%

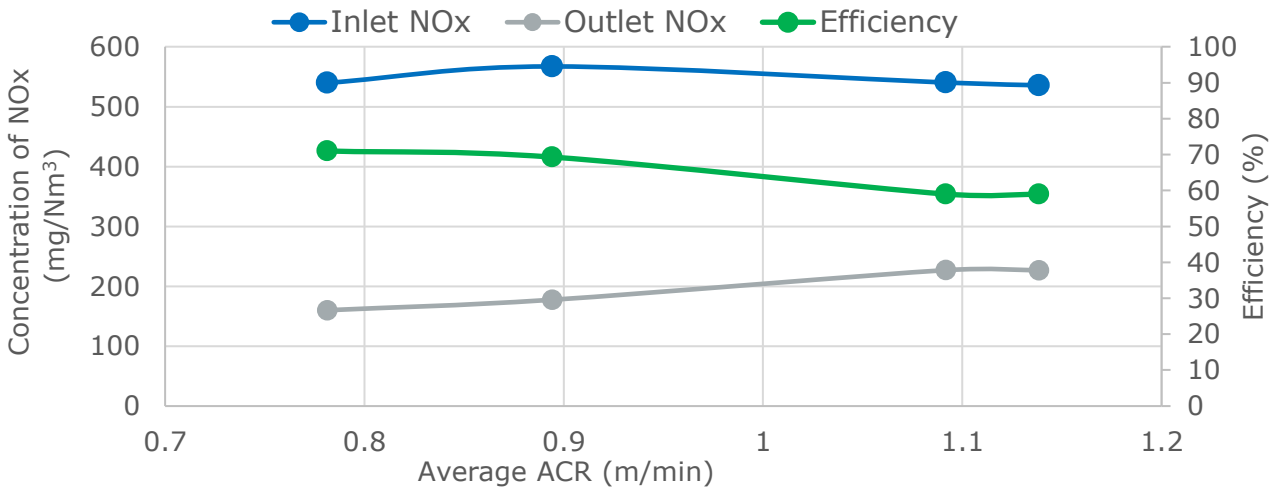
Average Temp: 230°C
Average ACR: 0.9 m/min
F-F DP: 0.7 kPa

Slip-stream trial in a lime plant

GORE® DeNOx Catalytic Filter Bags were tested for NOx reduction in lime calcination process

Slip-stream trial in a lime plant with GORE DeNOx Filter Bags (Gen-1)





- Average flow rate: 969 m^3/min (886 m^3/min – 1094 m^3/min)
- Average ACR: 0.85 m/min (0.78 m/min – 0.96 m/min)

- Average constant temperature : 218.2°C (217.2°C – 219°C)

Average SO_2: 3.5 mg/Nm^3

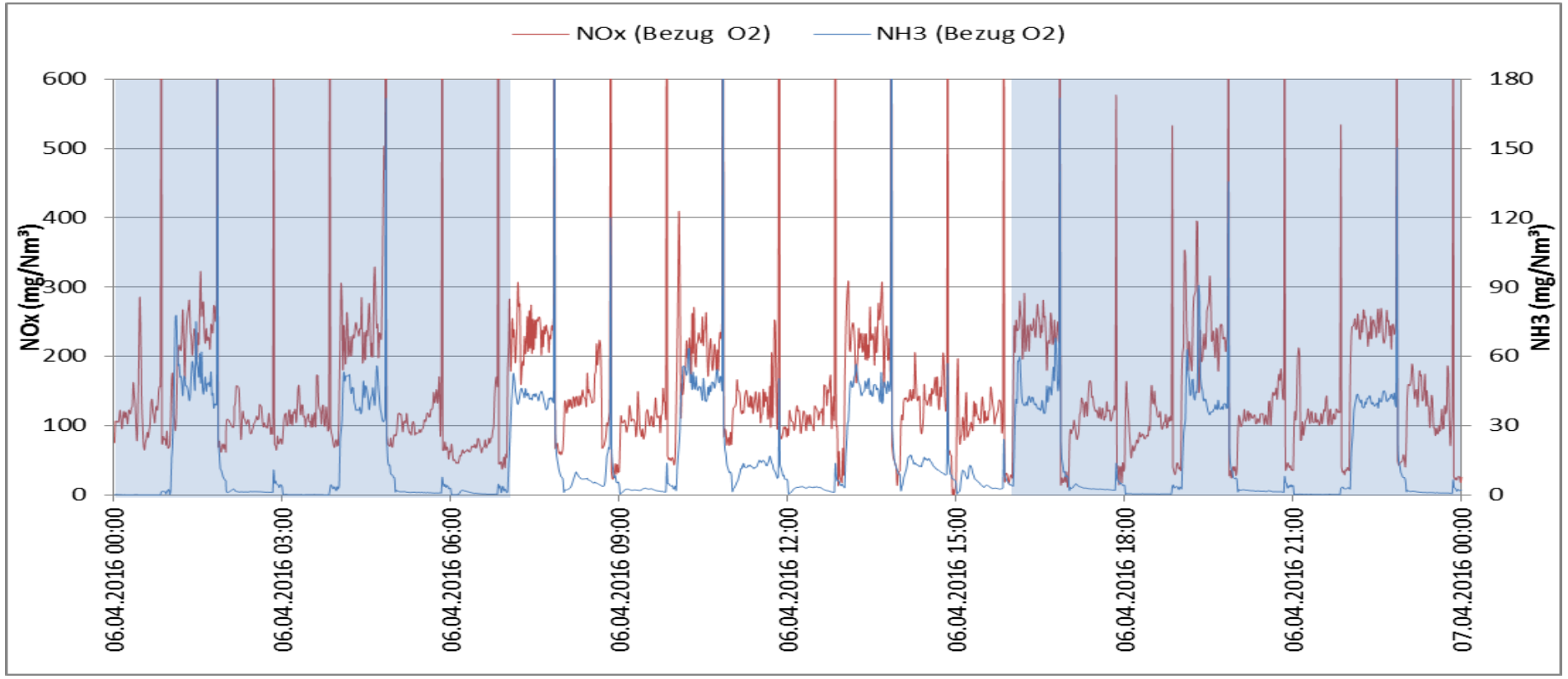
NOx destruction efficiency showed dependency on temperature and ACR

>72% NOx reduction efficiency at around 218˚C and around 0.85 m/min ACR

Slip-stream trial in cement plant

- SNCR is used in kiln to reduce NOx
- NH_3 slip in the process higher than permissible limit of 30 mg/Nm^3
- GORE® DeNOx Catalytic Filter Bags were tested for NH_3 slip reduction

Slip-stream trial in cement plant with GORE DeNOx Filter Bags (Gen-1)

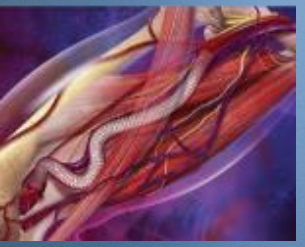


- Significant reduction of ammonia slip (below 5 mg/Nm^3)
- Around 50% reduction of NOx emission as an added benefit

GORE DELIVERS ON THE PROMISE

A company providing innovation
with integrity

Fabrics that protect and perform under many conditions



Dedication to performance

supported by technical expertise

Products and process solutions that **perform**

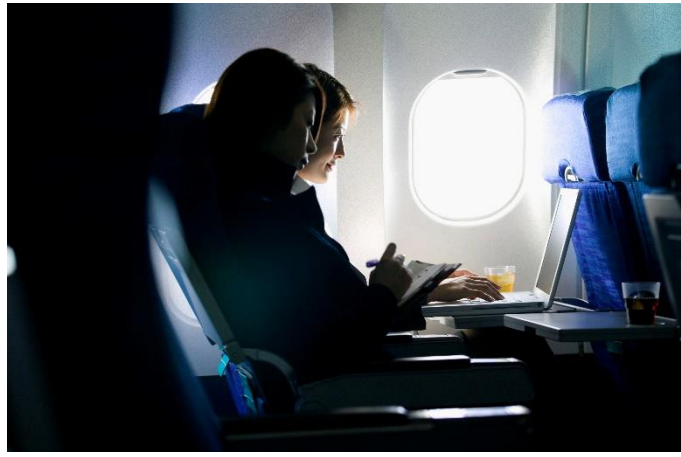
consistently and reliably in the most demanding environments


Technology
is at the heart
of what we do

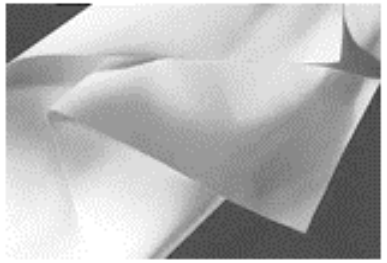
Commitment to fitness for use

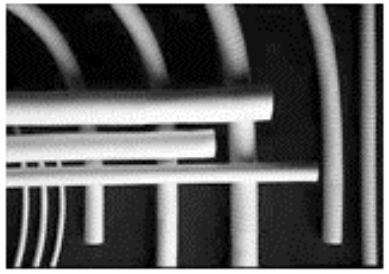
Our Products:

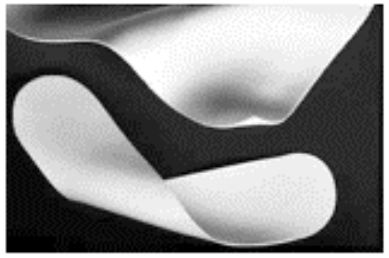
- Do what we say they will do — the first time and every time
- Adhere to our standards of high quality and product integrity
- Are derived from a comprehensive understanding of our customers' needs and end-use applications



Fluoropolymer Expertise as a Common Link







FORMS

Tapes

Membranes

Tubes

Fibers

Sheets

Rods

STRUCTURES

Geometries

Thin/Thick

High Density/
Low Density

Asymmetric

Oriented

Treated
Surface

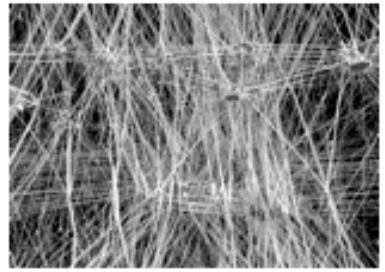
Filled

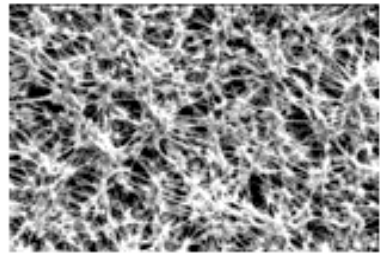
Laminated

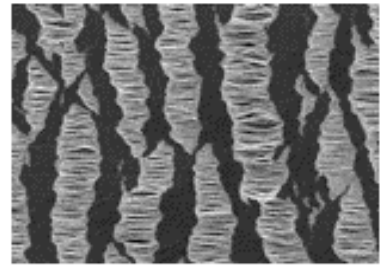
Coated

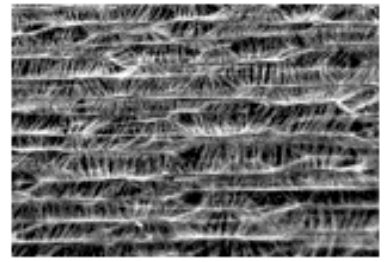
Imbibed

MODIFICATIONS









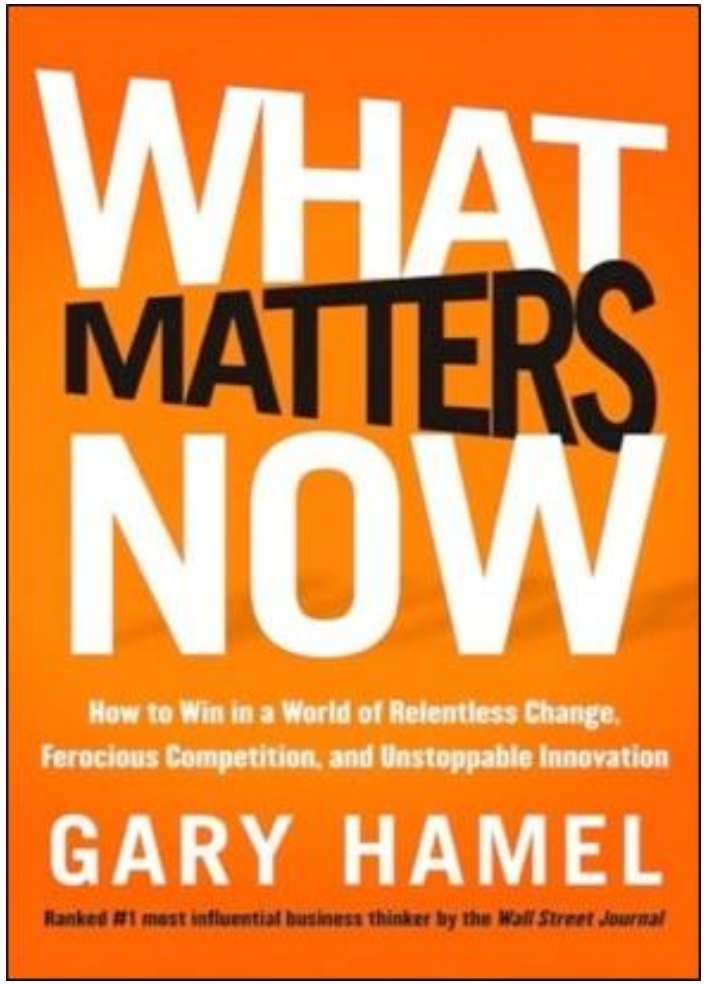
Bringing dreams to reality

- Founded in 1958
- $3.7 billion+ in annual revenues
- Approximately 10,500 Associates
- Privately held

Where It All Began

Bill and Vieve Gore

Recognized for culture and innovation



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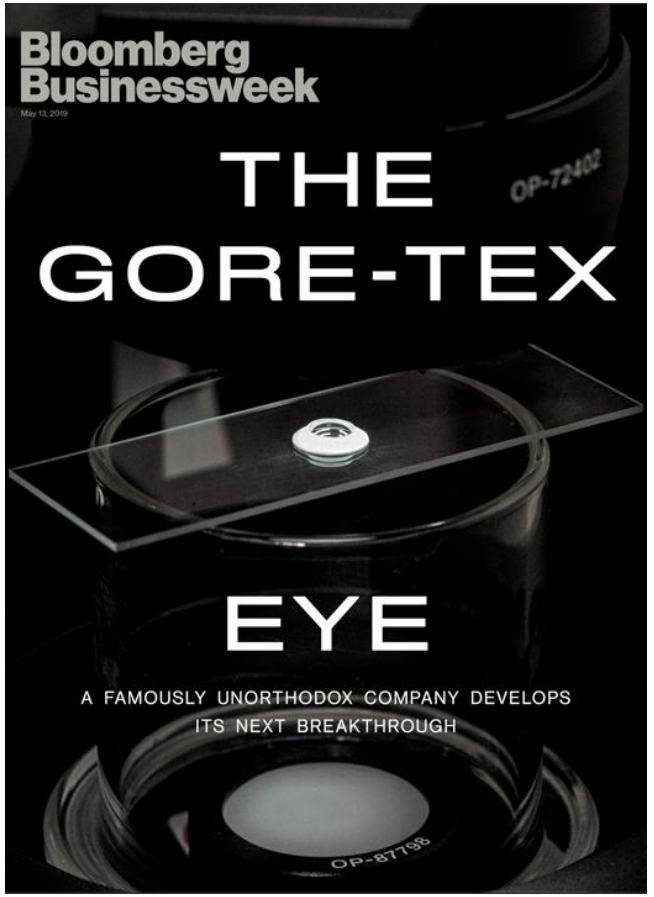

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A GLOBAL ENTERPRISE

WITH A DIVERSE RANGE OF PRODUCTS

THANK YOU

Together, improving life