

Strategies for testing renewable fuels & blends safely in an open combustion system



12 April 2026

Safe combustion test with NH_3 ...

... in an open combustion chamber (boiler)

Agenda:

- Alfa Laval introduction
- NH_3 as a fuel in a boiler (open combustion)
 - Combustion theory
 - First practical combustion test
- Safety measures considered
 - on boiler
 - on NH_3 plant installation
- Safe ammonia test in an open combustion system
 - Learnings so far
 - Hard lessons obtained

Introducing Alfa Laval

Alfa Laval at a glance

Founded in

1883

140 years of experience in
engineering and innovation

Employees

23,600+

Operating in over
100 countries

Key technologies

3

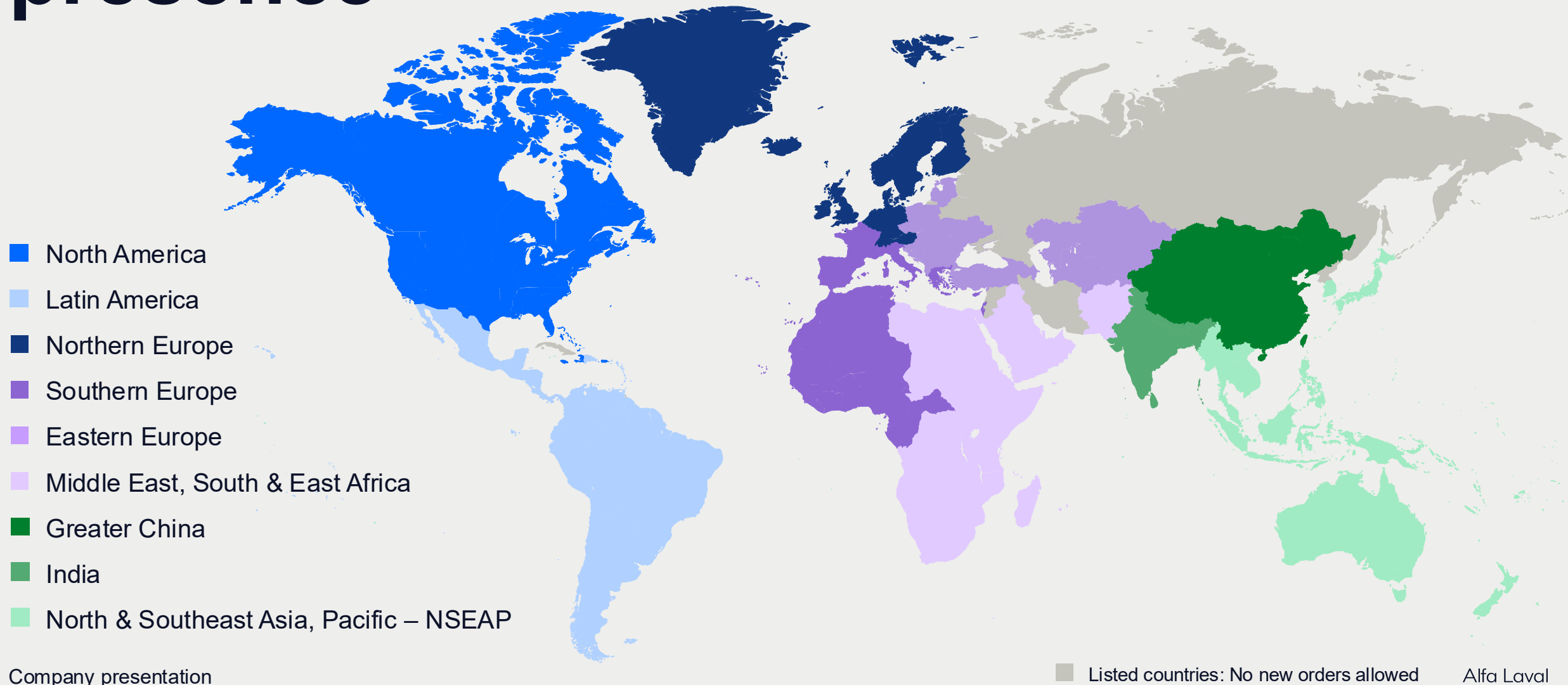
- Heat transfer
- Separation
- Fluid handling

Patents

4,500+

Continuous
investment in R&D

A strong local presence



Business divisions & key technologies

Key technologies

Our key technologies are adapted to each business unit and offered separately or combined into optimized solutions.

Heat transfer

Separation

Fluid handling

Company presentation

Alfa Laval

The three divisions

Energy Division

Delivers solutions that improve energy efficiency across data centers, renewables, HVAC, and power and process industries, petrochemicals and power generation.



Company presentation

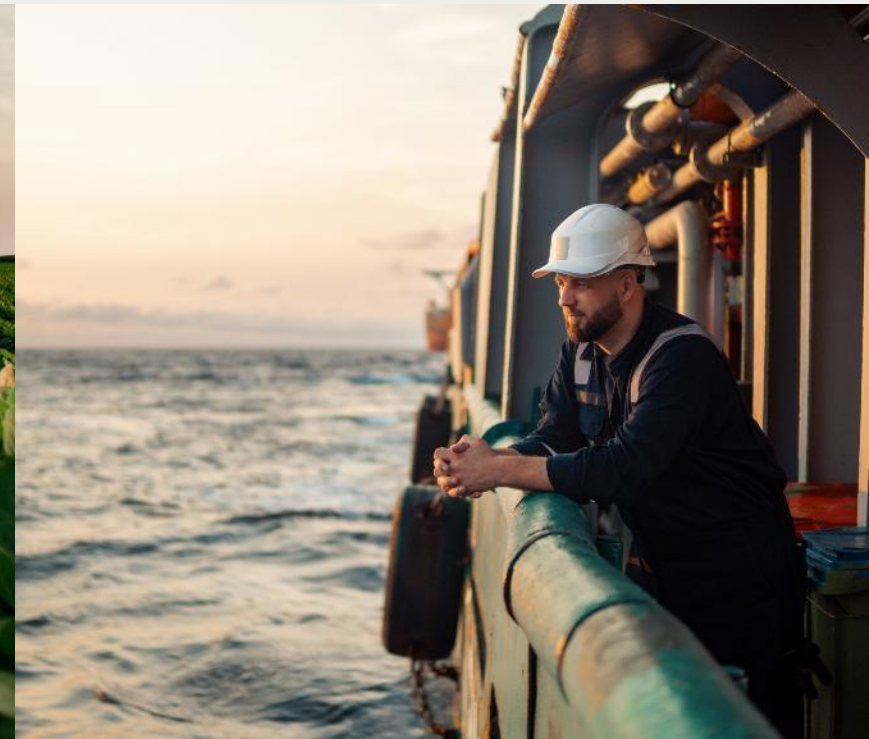
Food & Pharma Division

Provides fluid handling, heat transfer, and processing solutions for food, beverage, pharma, and water industries—helping customers do more with fewer resources.



Ocean Division

Specializes in solutions for shipping customers incl. shipping companies, shipbuilding, engine manufacturers and offshore industries.



Where are we going?

The world is facing some **big challenges**

These include rising demand for:

Energy efficiency



Life essentials (food, water and medicine)



Shipping transformation



Alfa Laval film: Leading the transition



NH_3 as a fuel in a boiler (open combustion)

Combustion theory
First practical combustion test

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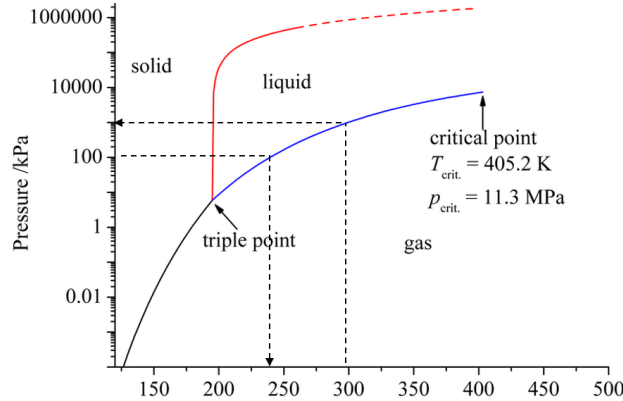


NH₃ as a fuel in a boiler (open combustion)

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NH₃ combustion theory

- Hazards:
 - Corrosive
 - Toxic
 - Environmental
- Low flashpoint Fuel
 - 1Bar(100kpa) => -33°C
 - 25°C => 9.9Bar(990kpa)



Fuel	NH ₃	H ₂	CH ₄	C ₃ H ₈
Boiling temperature at 1 atm (°C)	-33.4	-253	-161	-42.1
Condensation pressure at 25 °C (atm)	9.90	N/A	9.40	50.0
Lower heating value, LHV (MJ/kg)	18.6	N/A	50.0	46.4
Flammability limit (Equivalence ratio)	0.63~1.40	0.10~7.1	0.50~1.7	0.51~2.5
Adiabatic flame temperature (°C)	1800	2110	1950	2000
Maximum laminar burning velocity (m/s)	0.07	2.91	0.37	0.43
Minimum auto ignition temperature (°C)	650	520	630	450



- Ammonia is flammable from 16-28% Vol. Conc. – Increasing range with temperature
- Corresponding to stoichiometric Fuel to Oxygen ratio of 1:0.7 to 1:1.8

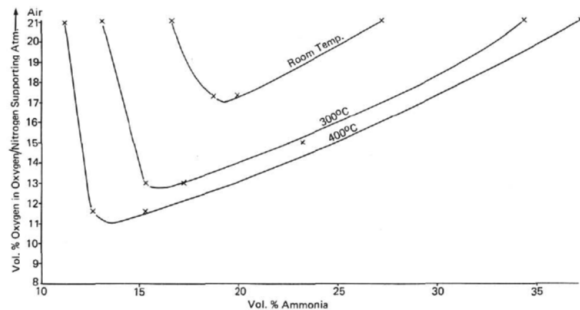
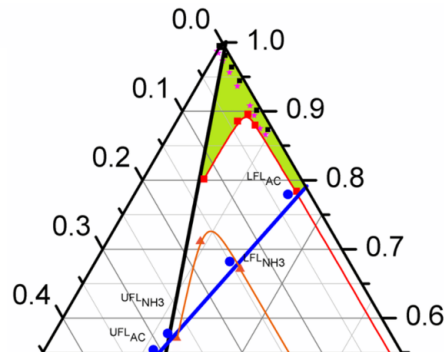


FIG. 2 FLAMMABLE LIMITS AMMONIA – AIR – NITROGEN MIXTURES : AMMONIA VS OXYGEN CONTENT OF SUPPORTING ATMOSPHERE



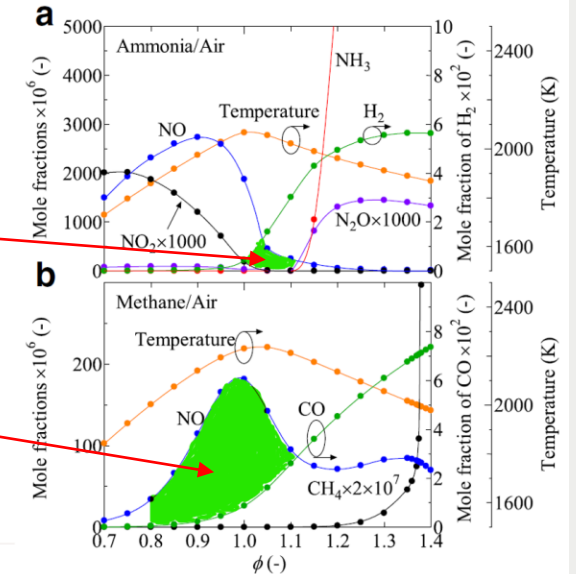
Combustion Properties

- Combustion properties comparison between Methane & Ammonia at different stoichiometric mixing ratios.

Sweet spot NH₃

Sweet spot CH₄

Copy from : Science & Technology of ammonia Combustion



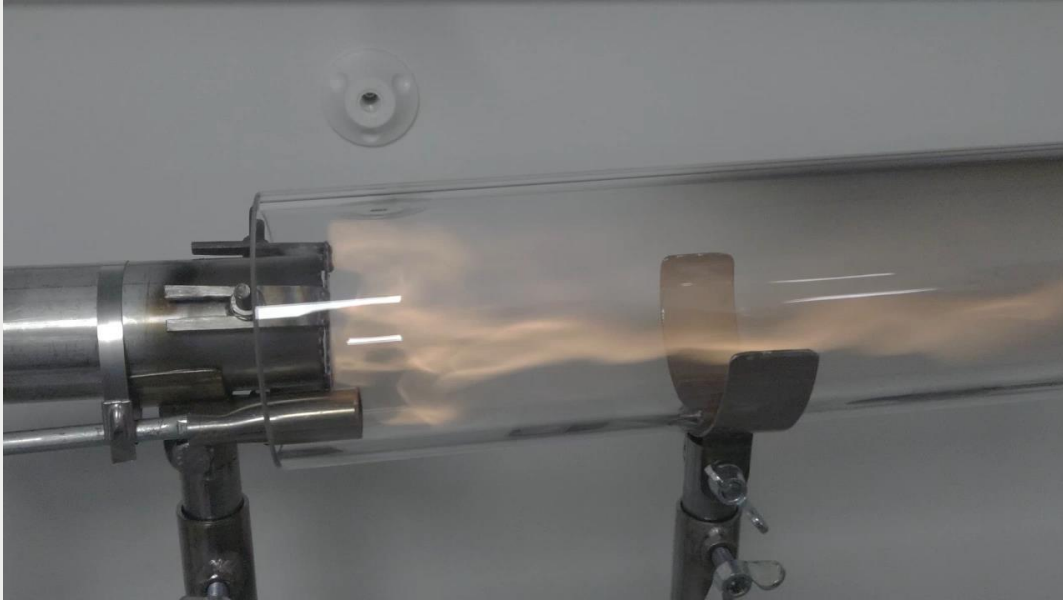
- Paper study conclusions so far...
 - Ammonia burns slowly, thermal output is expected to decrease significantly on existing equipment
 - Poor Burning characteristics (Difficult to ignite & NO_x/N₂O/NH₃-slip issues)
 - Extra air needed, lower flame temperature: Poor boiler performance
- Recommendations:
 - Preheat ammonia to increase flame temperature and flame velocity
 - Gas phase combustion like NG
 - Preheat Combustion Air if possible?
 - Work with excess air of "0%" (+/- 5%) N₂O or NH₃ slip?
 - Support flame may be needed for ignition or alternative flame enhancement

NH₃ as a fuel in a boiler (open combustion)

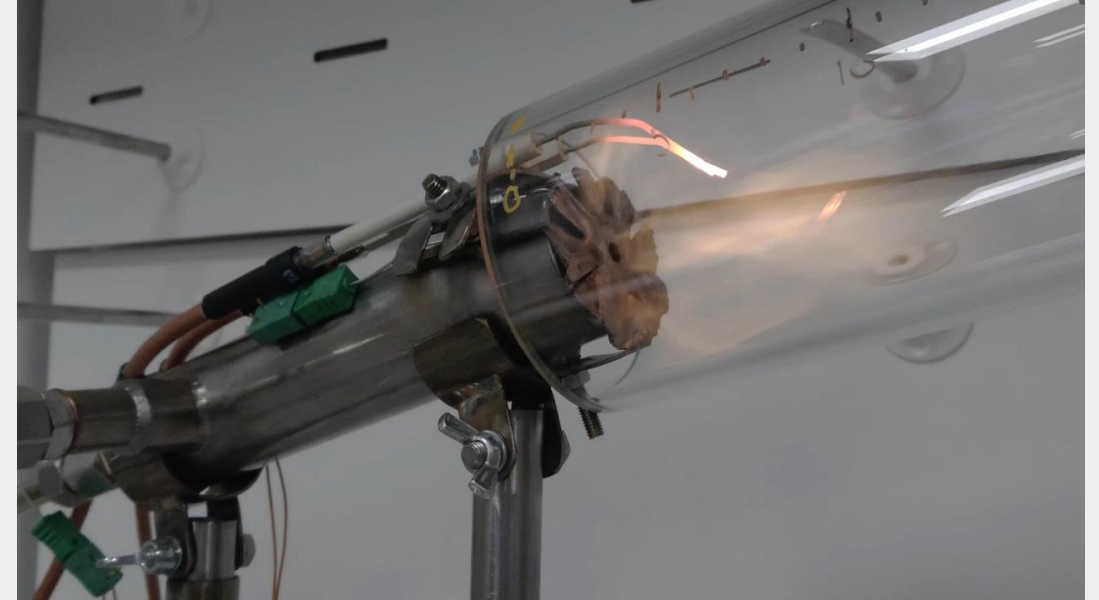
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NH₃ first practical combustion test

Combustion with pilot burner



Combustion with spark ignition and swirl



Test Specification

- Pre-prototype burner installed in a vented cabinet
- Combustion air from compressor installation.
- Ammonia from bottle.
- Possibility to heat ammonia and combustion air
- NH₃ sensor installed besides cabinet
- Burner is calculated to be app. 4 kW

Input to design for scaled-up 1.7 MW burner

NH₃ as a fuel in a boiler (open combustion)

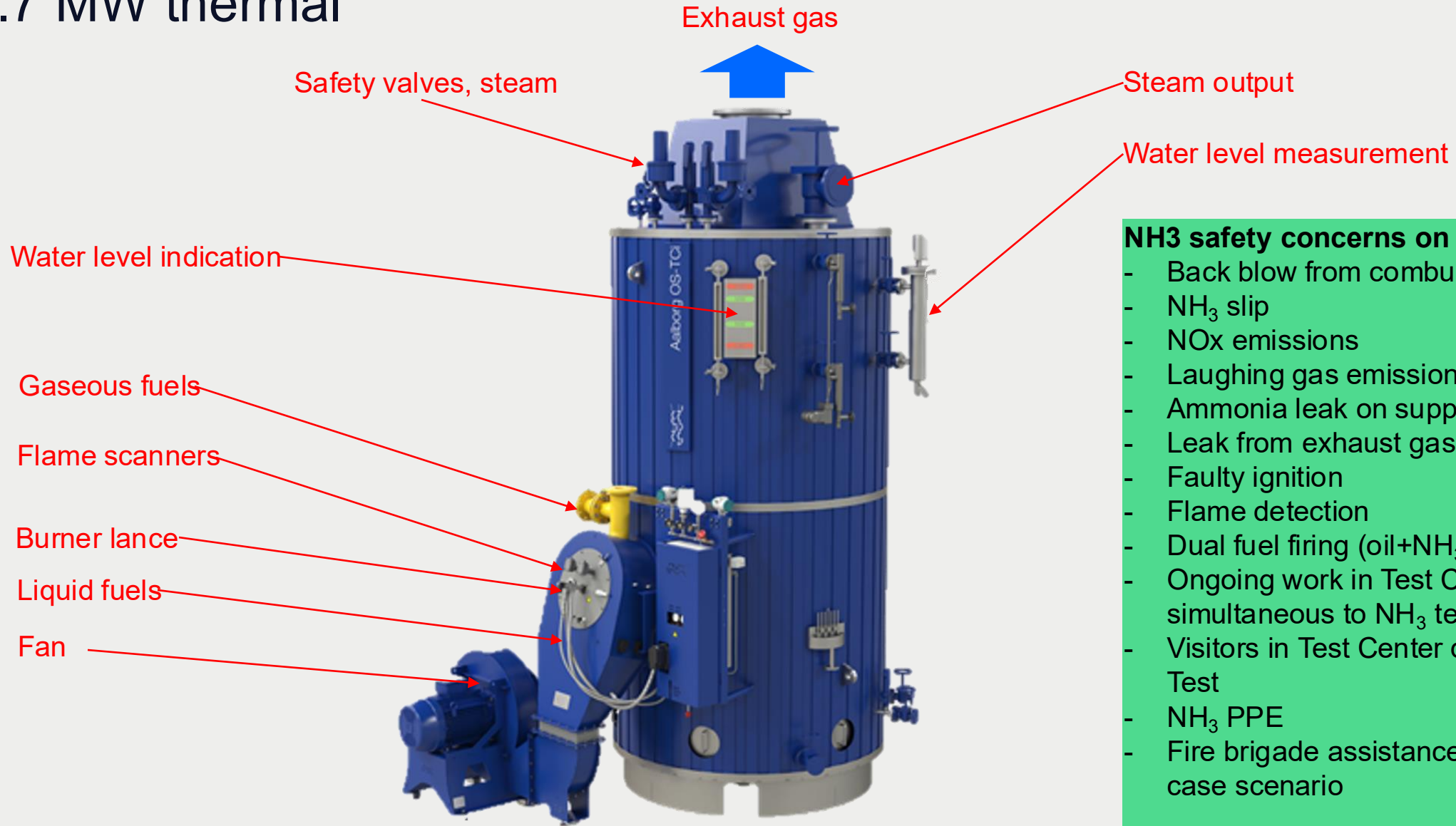
Safety measures considered...

- ... on boiler
- ... on NH₃ plant installation
- ... for test personal / visitors

OS-TCi 2 t steam/h multifuel boiler

1.7 MW thermal

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NH₃ safety concerns on boiler system

- Back blow from combustion chamber
- NH₃ slip
- NO_x emissions
- Laughing gas emissions
- Ammonia leak on supply system
- Leak from exhaust gas system
- Faulty ignition
- Flame detection
- Dual fuel firing (oil+NH₃)
- Ongoing work in Test Center simultaneous to NH₃ test
- Visitors in Test Center during NH₃ Test
- NH₃ PPE
- Fire brigade assistance in worst case scenario

Safety measures considered on NH₃ plant installation

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NH₃ as a fuel – demands from authorities, legislation and others

Legislation and Authorities

- **Danish Working Environment Authority (Arbejdstilsynet):** Oversees occupational safety, including ammonia handling and storage.
- **Danish Environmental Protection Agency (Miljøstyrelsen):** Regulates environmental impact, emissions, and chemical safety.
- **Local Fire Authorities:** Oversee fire safety and emergency preparedness.

Other key stakeholders

- **QHSE department**
Safety setup / evaluation
Environmental reporting
Emergency response plan

Key Requirements

- **Risk Assessment & Permits:**
A comprehensive risk assessment (APV) must be conducted, identifying hazards, exposure, and mitigation measures.
3. Party approval
- **Permit Application:**
Installations require environmental permits, including notification to the authorities.
Follow Danish legislation
Max. 5 m³ liquid NH₃
- **Design & Construction:** Must comply with EN 378 (Refrigerating systems and heat pumps – Safety and environmental requirements) and DS/EN 60079 (explosive atmospheres, if relevant).
3. Party approval
- **Pressure Equipment:** Must meet the Pressure Equipment Directive (PED) and Danish executive orders on pressure vessels.

Environmental Protection

- **Containment:** Secondary containment to prevent spills from the installation.
Follow criterias from
- **Reporting:** Immediate reporting of any significant leaks or accidents to authorities.
local environmental authority

Safety Measures

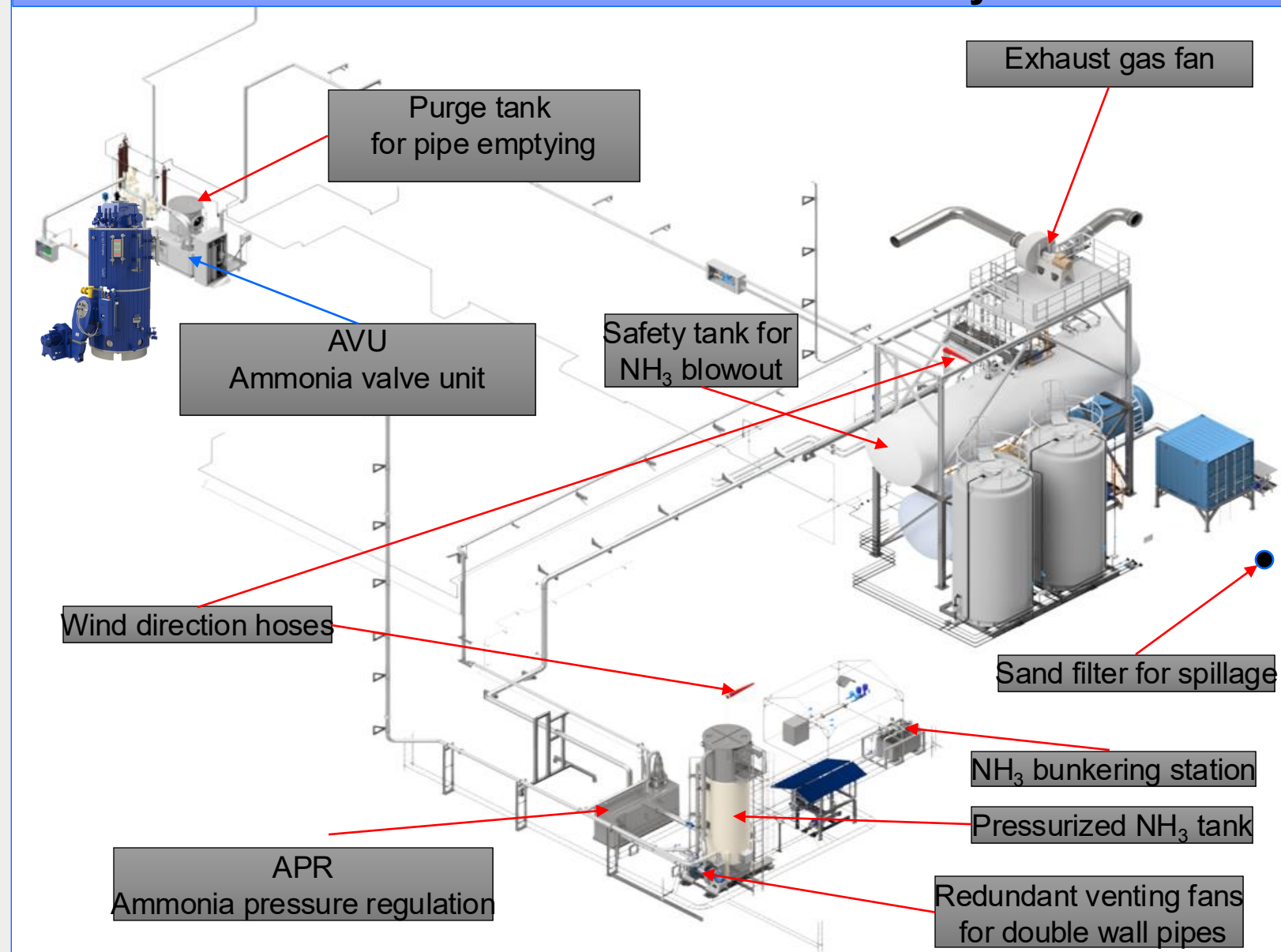
- **Leak Detection:** Installation of ammonia detectors and alarm systems is mandatory.
- **Ventilation:** Adequate ventilation to prevent accumulation of gas.
3. Party design approval
Redundent critical components
- **Emergency Measures:** Doubled walled installations.
Agree on emergency plans with firebrigade
Adapt PPE to fit NH₃ needs
- **Personal Protective Equipment (PPE):** Availability and use of suitable PPE for workers.

Training & Documentation

- **Staff Training:** Key personnel must be trained in ammonia handling, emergency response, and use of PPE.
Involve QHSE
Approval by local environmental authority
- **Documentation:** Maintenance logs, inspection records, and safety data sheets (SDS) must be kept up to date.

Double walled ammonia distribution system

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NH_3 as a fuel in a boiler (open combustion)

Safe ammonia test in an open combustion system

- Learnings so far
- Hard lessons obtained

Safe ammonia test in an open combustion system

Learnings so far...

- Run multiple risk workshops involving people with different competences to get different viewpoints
- Address all-risk found even if they are having a low risk factor (have a plan for them as well)
- Involve authorities in safety evaluation (if possible)
- Involve 3. party approval body early in process
- Communicate the safety setup to stakeholders frequently.
- Plan commissioning of plant in details preferably avoiding non-commissioning people at workplace during commissioning

Best learning...

... You can always find one risk more!

Risk Analysis				
Probability	High	3	6	9
	Medium	2	4	6
	Low	1	2	3
		Low	Medium	High
		Impact		

Hard lessons obtained...

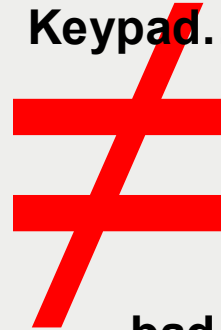
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PPE chemical suit with air

Gloves



Gloves
&
Keypad...



... bad
combo

Access controlled environment



Keypad with touch buttons



Thank you!