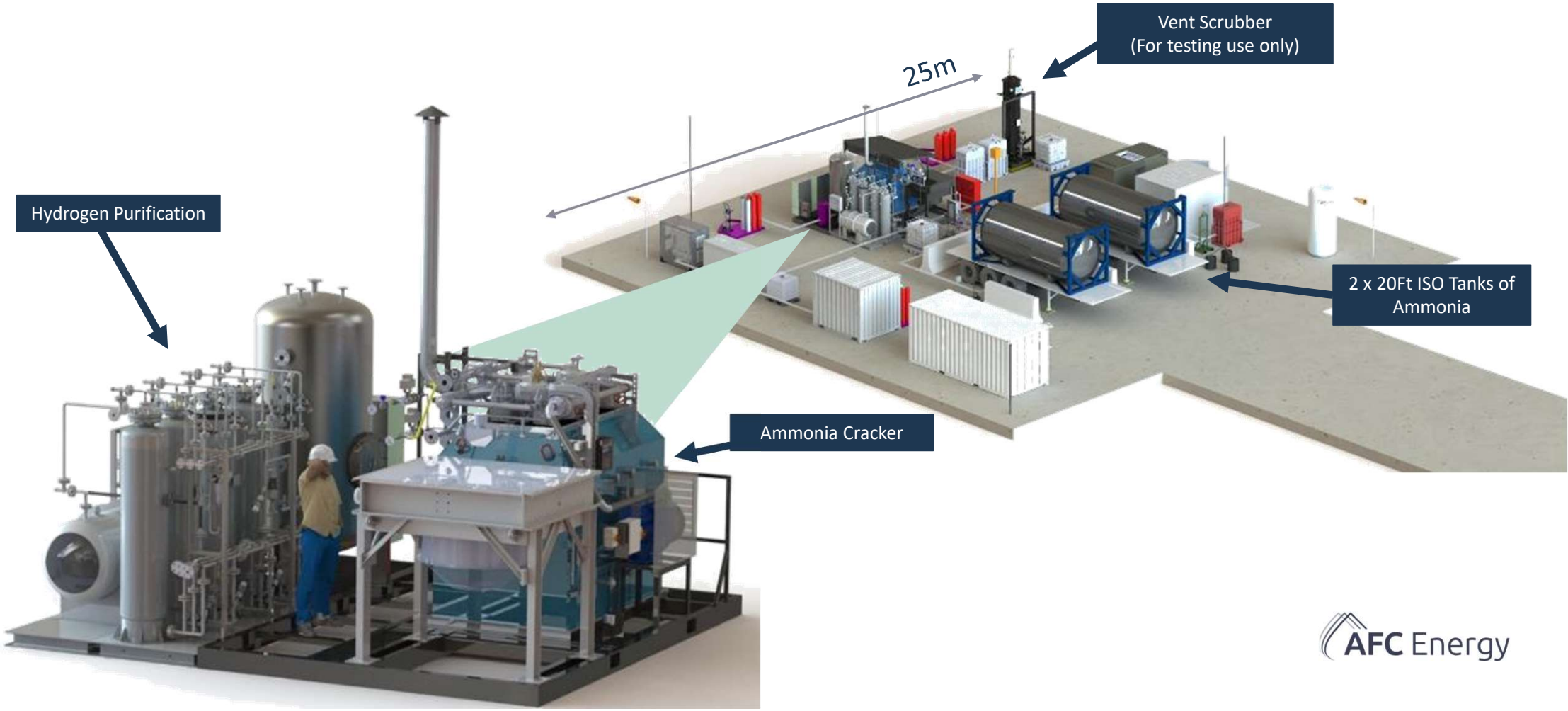
Compact UK Hydrogen Generation Facility



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Compact UK Hydrogen Generation Facility

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Integrated Ammonia Cracker & Fuel Cell System Concept

VARD™
a Fincantieri company

DNV

AiP AWARDED

2 x 600kW Ammonia Cracker & Fuel Cell
Marine Power Supply Concept Design

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Sounds good – but what's up?

Perfect

- Technology Works
- Projected High Fuel Efficiency

Imperfect

- Technology Maturity for Critical Applications
- Shock & Vibration
- Significant Investment ($/kW)
- Purification plant requires additional space
- Elongated time to market
- Challenging Certifications

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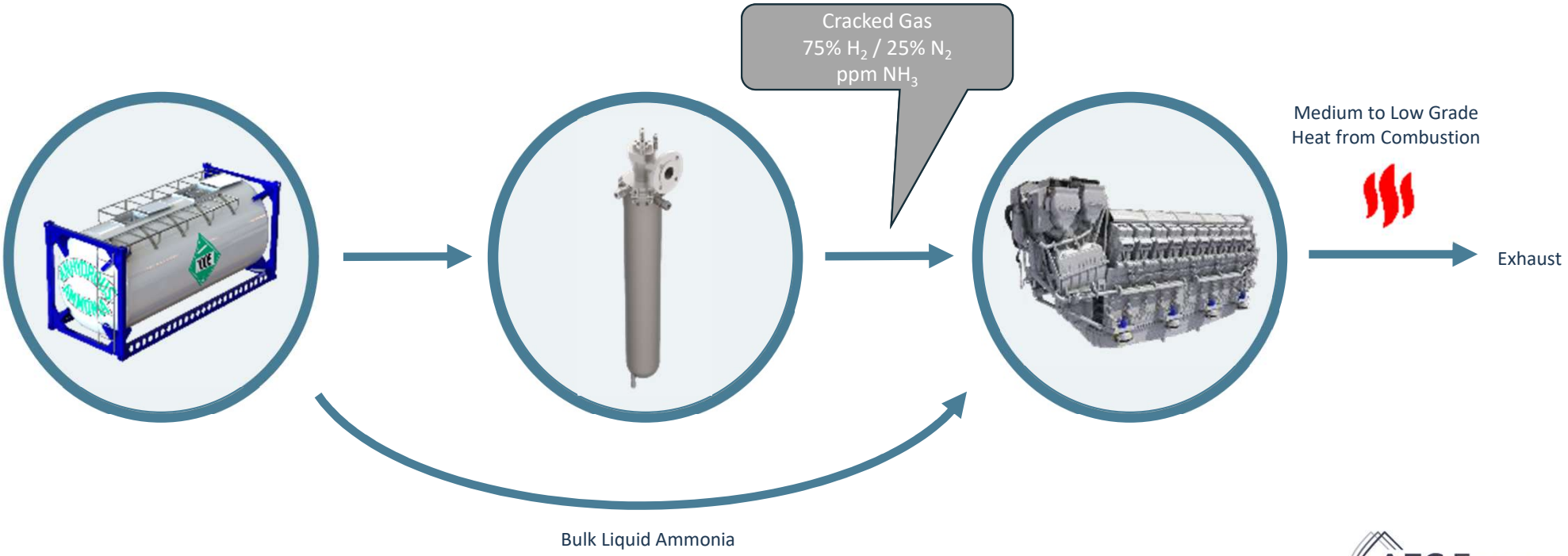
Ammonia Cracking for Internal Combustion Engines

If you can make a pilot fuel (Hydrogen from cracked gas) to improve the combustion attributes of bulk ammonia, does it matter if you don't purify the gas?



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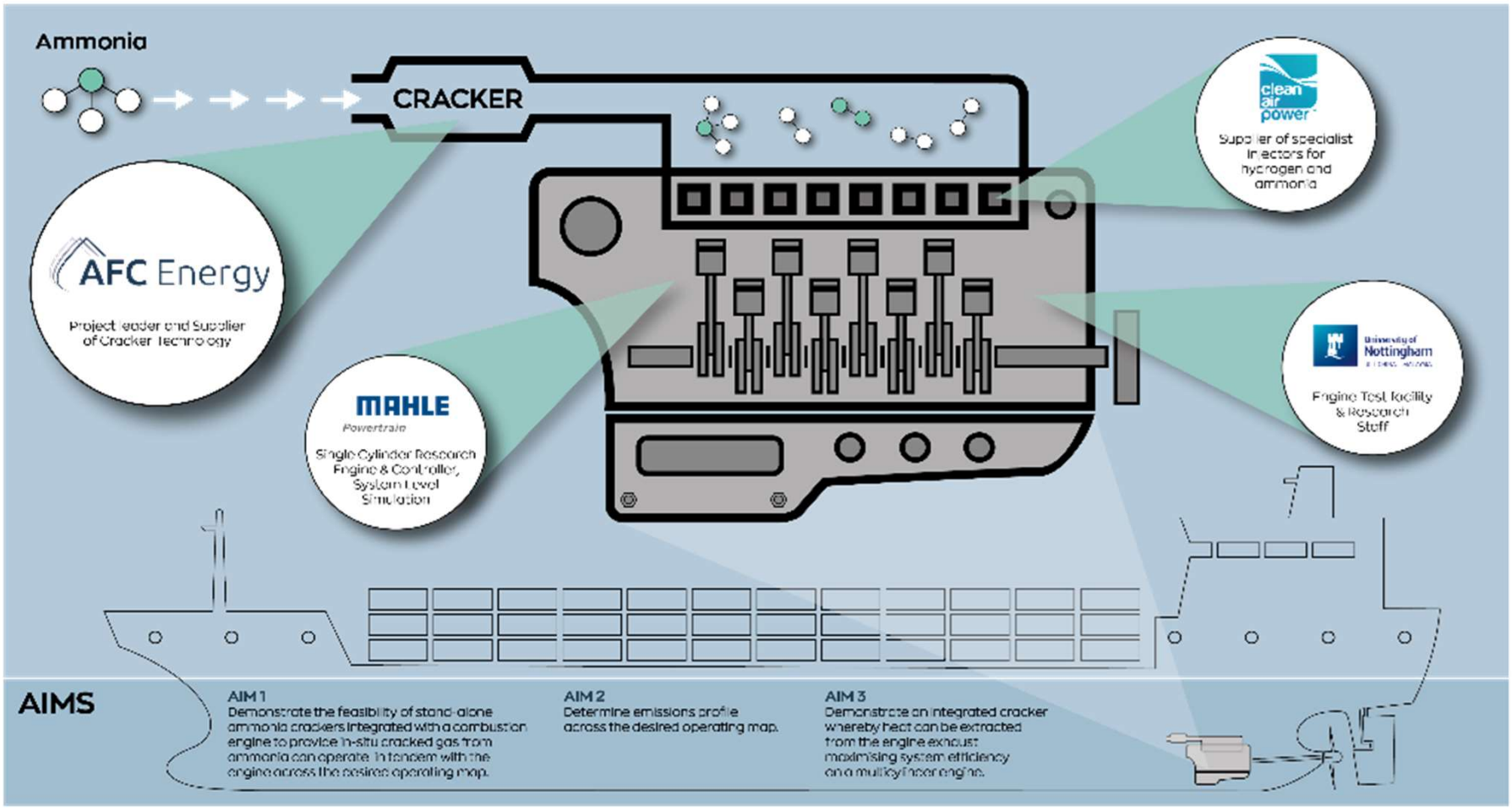
Project ENTICE

ENhanced Ammonia Cracking To Improve Engine Combustion and Emissions



Ammonia to power

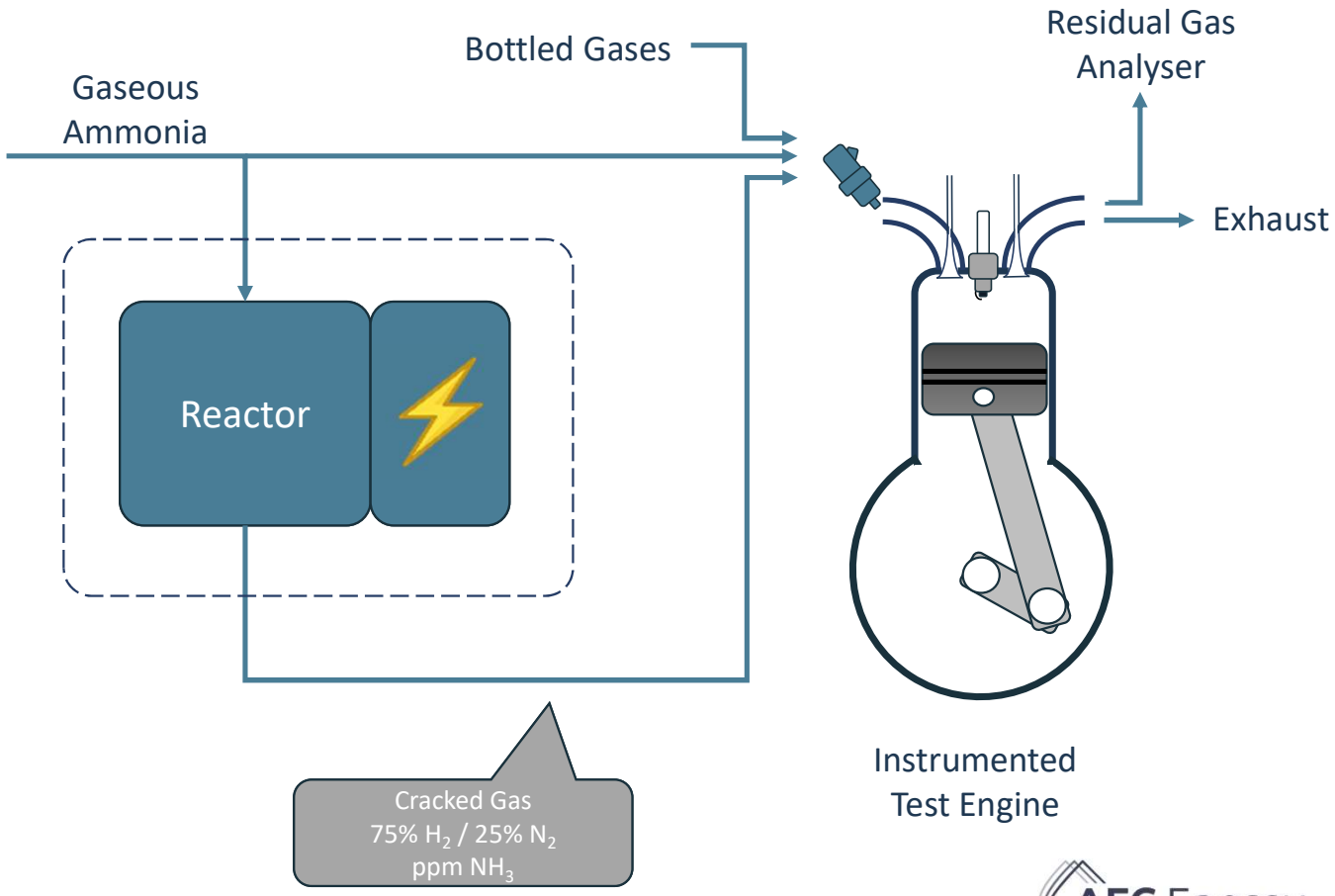
This project is part of the **Clean Maritime Demonstration Competition Round 4 (CMDC4)**, funded by the UK Department for Transport (DfT) and delivered by Innovate UK. CMDC4 is part of the Department's UK Upgrading Effort for Reducing Emissions (UKUPDATE) programme, which aims to focus on developing the technology necessary to decarbonise the UK domestic maritime sector.

#cleanmaritime #innovateUK #UKUPDATE #MaritimeUPDATE #EnhancedEngineering #TeamEnergy #ammonia #ammoniaenergy #marinepowertrain #cleanairpower #MarineNH3 @afcenergy @cleanairpower @mahlepowertrain @MarineNH3

Innovate UK

In-situ Laboratory testing of Ammonia Cracking Technology

- 400cc Single Cylinder four-stroke test engine with multi-fuel capability
- Small Laboratory Ammonia Cracker, Fully Electrically heated & instrumented
- Ability to change gas flow and mixture (with other diluent gases)
- Downstream monitoring of NH_3 slip and NOx



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In-situ Laboratory testing of Ammonia Cracking Technology

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Cracker Simulation Tests

Aim : To understand how the nitrogen produced from the ammonia decomposition impacts in the combustion in engine, tests were carried out using bottled gas to simulate a cracker product being injected at the intake manifold

Test Methodology : The tests were carried out a set point with a constant hydrogen-ammonia ratio (20%-80% Energy fraction) at Air fuel Equivalence ratio (λ) of 1.2. Nitrogen was then injected into the engine until the combustion became unstable determined by CoV of IMEPn (≥3%).

Test Conditions

Engine Load in IMEPn [bar]	6
Engine Speed [rpm]	1400
Spark Timing [CAD BTDC]	MBT
Engine Temperature	90^0C
Air Fuel Equivalence ratio (λ)	1.2

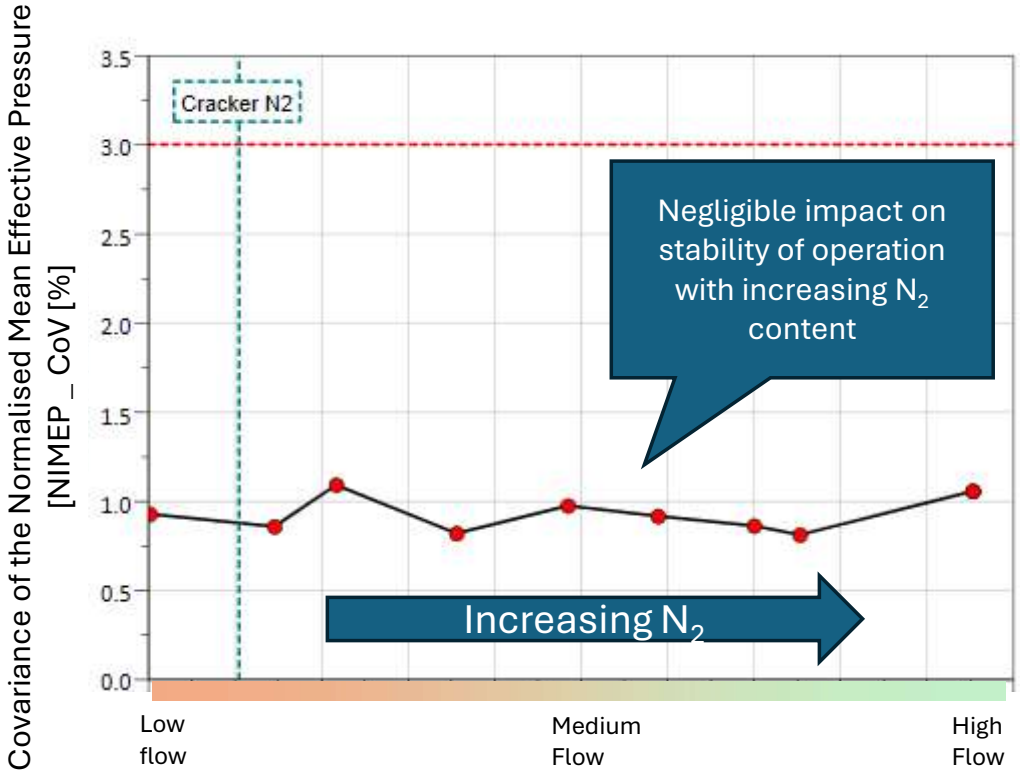
→ Lower load is more prone to show un-stability from nitrogen dilution

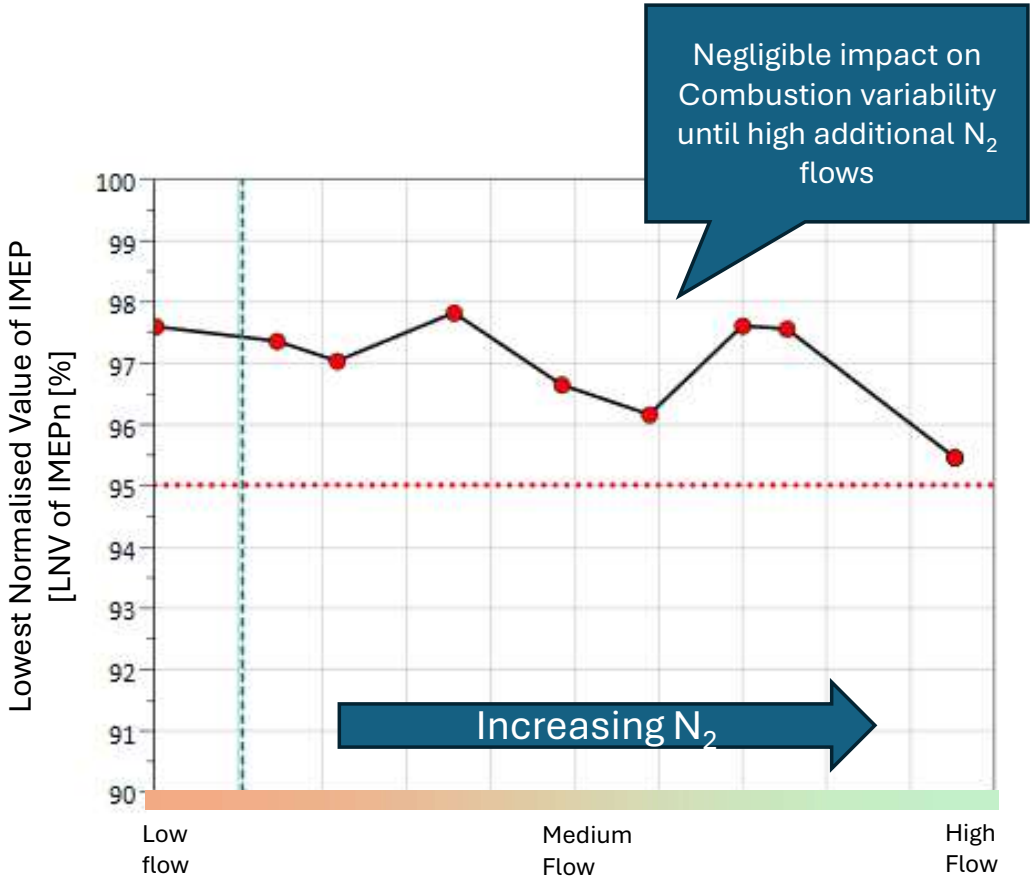
→ Maximum Brake Torque

→ Operating at 1.2 results in NH_3/NOx ratio (Alpha Ratio) to be 1, suitable for SCR

Cracker Simulation – Preliminary Results

Combustion variability with additional Nitrogen





Cracker Simulation – Preliminary Results

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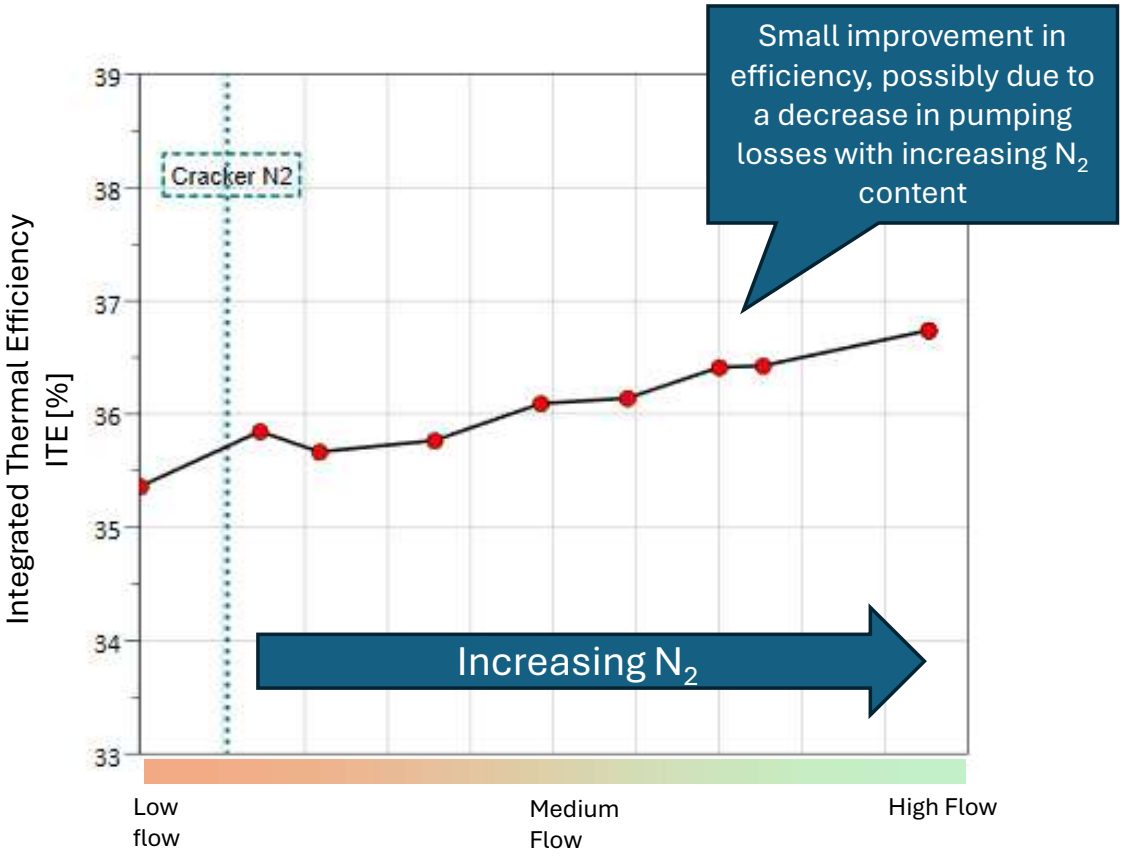
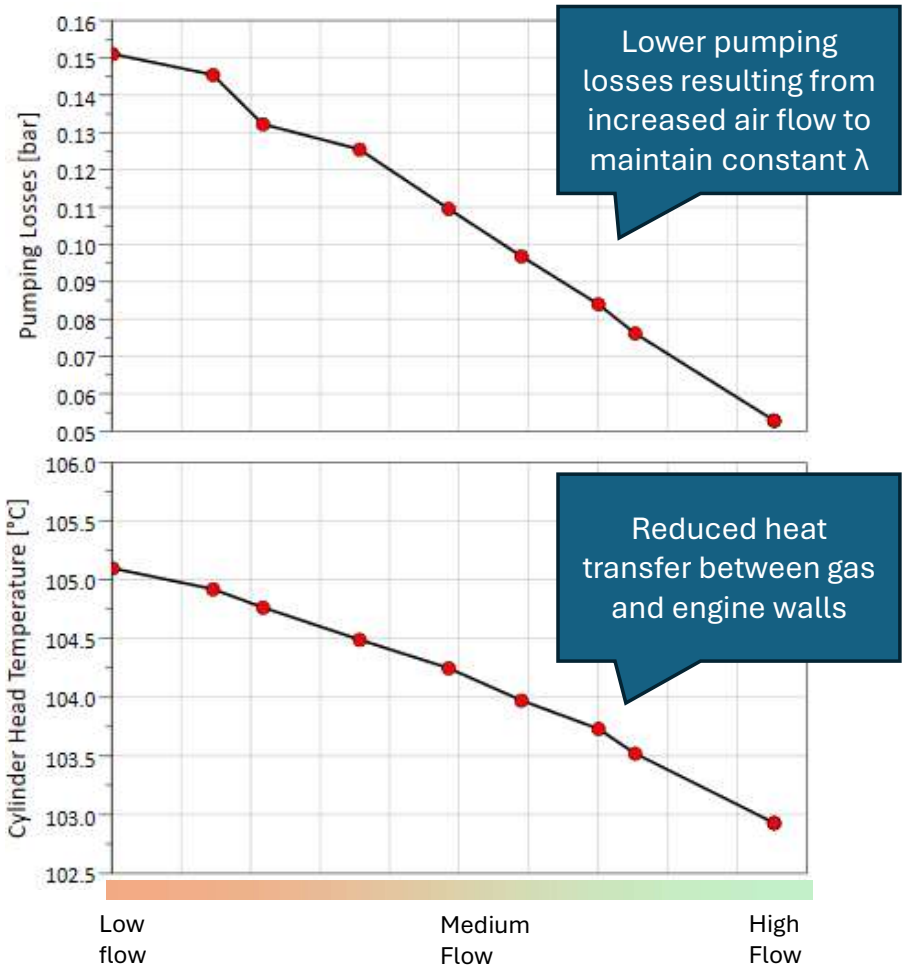
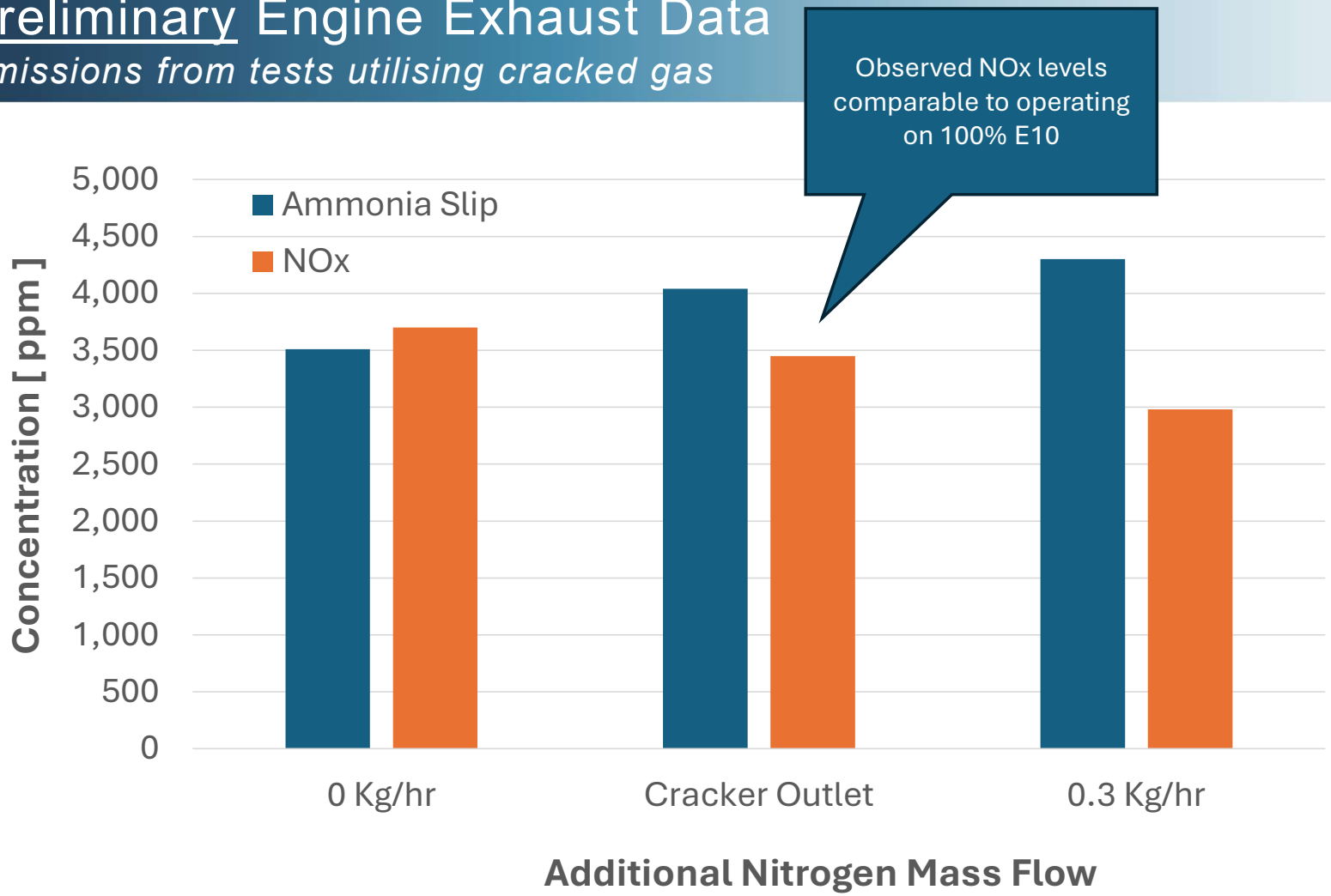




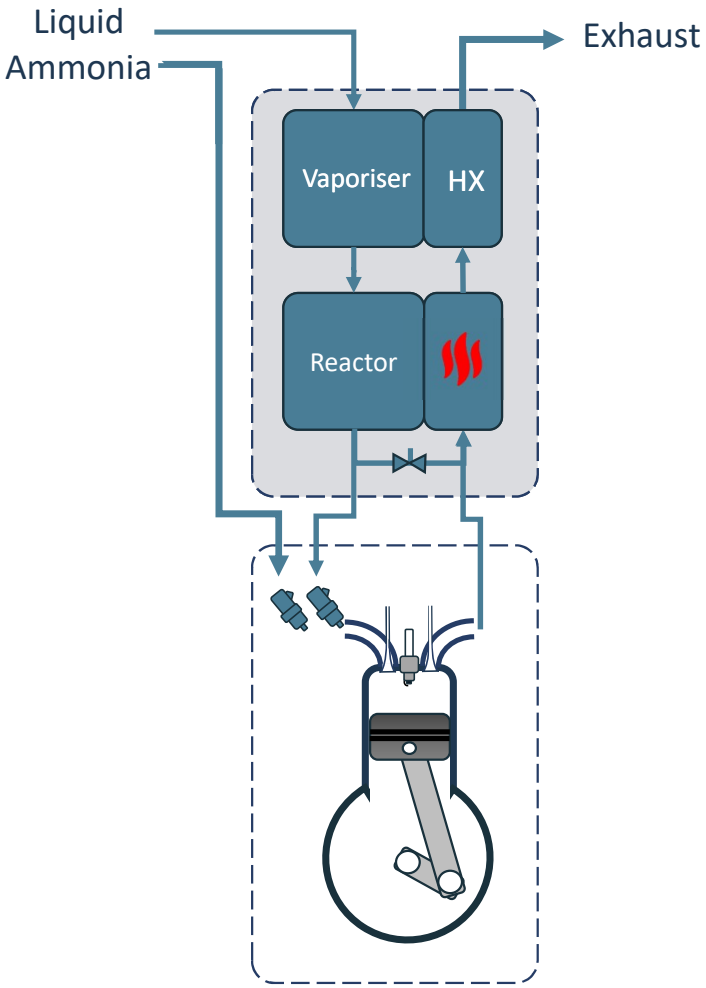
Preliminary Engine Exhaust Data

Emissions from tests utilising cracked gas

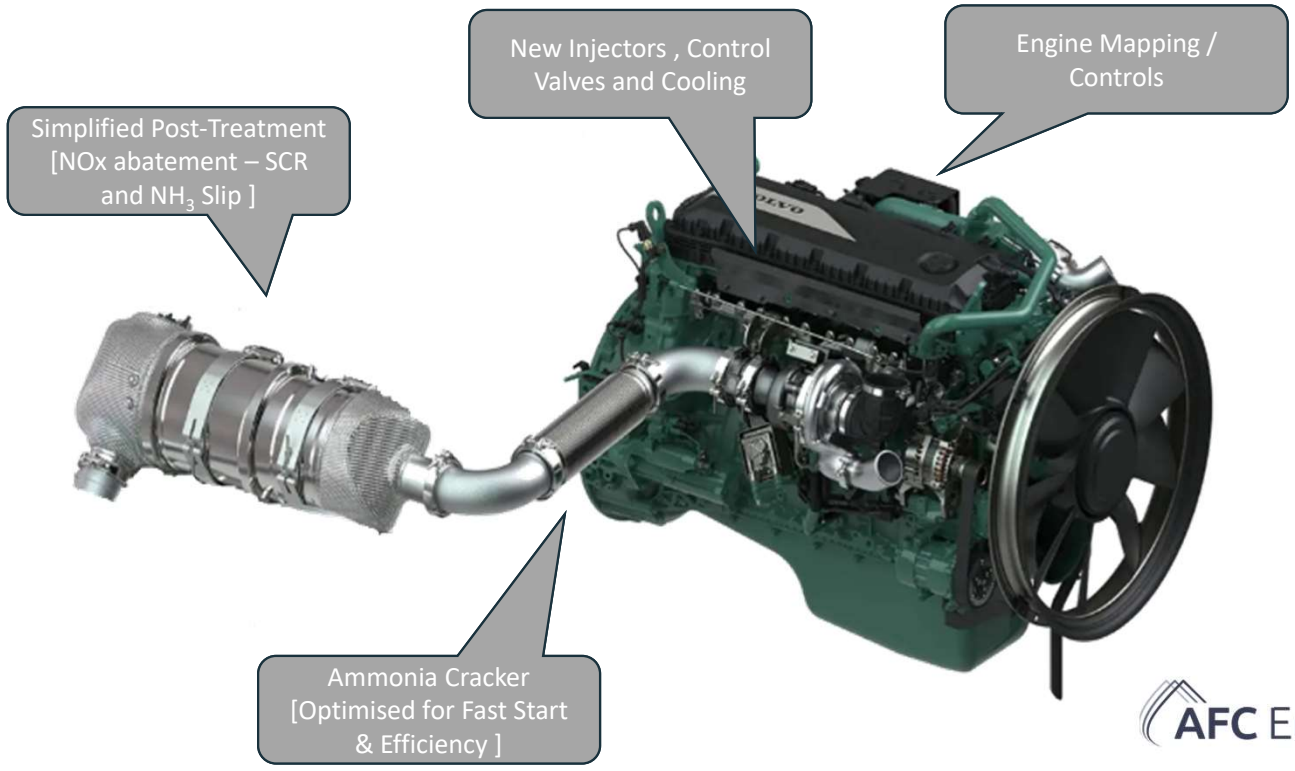


- In-situ tests conducted at 1400rpm, 6 bar IMEP and Lambda 1.2
- Full mapping (Pressure / Flow) exercise to take place

Progression to Multi-cylinder Engines



Subsequent cracker design to maximise utilisation of waste heat from a multi-cylinder engine, sized to generate sufficient hydrogen on demand and fast response time



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Small but Mighty ?

- Supplementary Hydrogen has been observed to improve the performance of both SI and dual fuel operation
- An on-board Ammonia cracker can generate the required hydrogen on-demand supporting a single fuel inventory.
- A test engine has been shown to operate with impure hydrogen, suggesting that purification would not be necessary
- The ammonia cracker can now be made smaller and thus more responsive to load changes; unlocking retro-fit of large marine and stationary engines.

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Clean, green ammonia engines for maritime

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