Ammonia Utilization in Internal Combustion Engines

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Ammonia to H2@Scale Utilization Panel

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University of Minnesota
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Ammonia IC Engine Overview

Compression Ignition

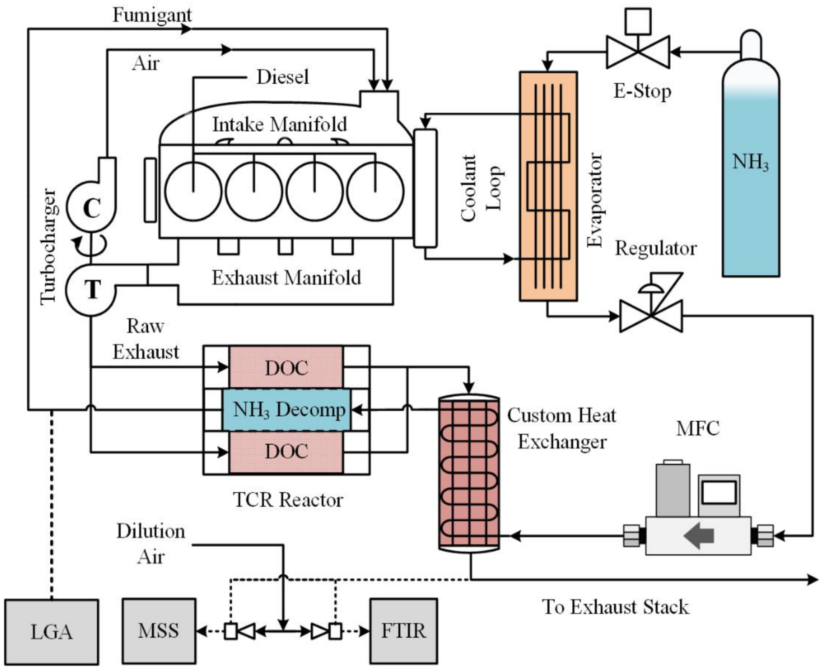
- 100% NH_3 requires high compression ratio (CR > 35:1)
- Dual-fuel strategies
- <10% Pilot diesel injection
- Multiple injection strategies for emissions reduction

Spark Ignition

- Laminar flame speed low for ammonia alone
- Blending with hydrocarbon fuel
- H_2-NH_3 blends from cracking are promising
- Reduced volumetric efficiency

- High NO_X and unburned ammonia emissions – N_2O
- Catalytic aftertreatment is expensive – benefit, unburned NH_3 as reductant for SCR for lean engines

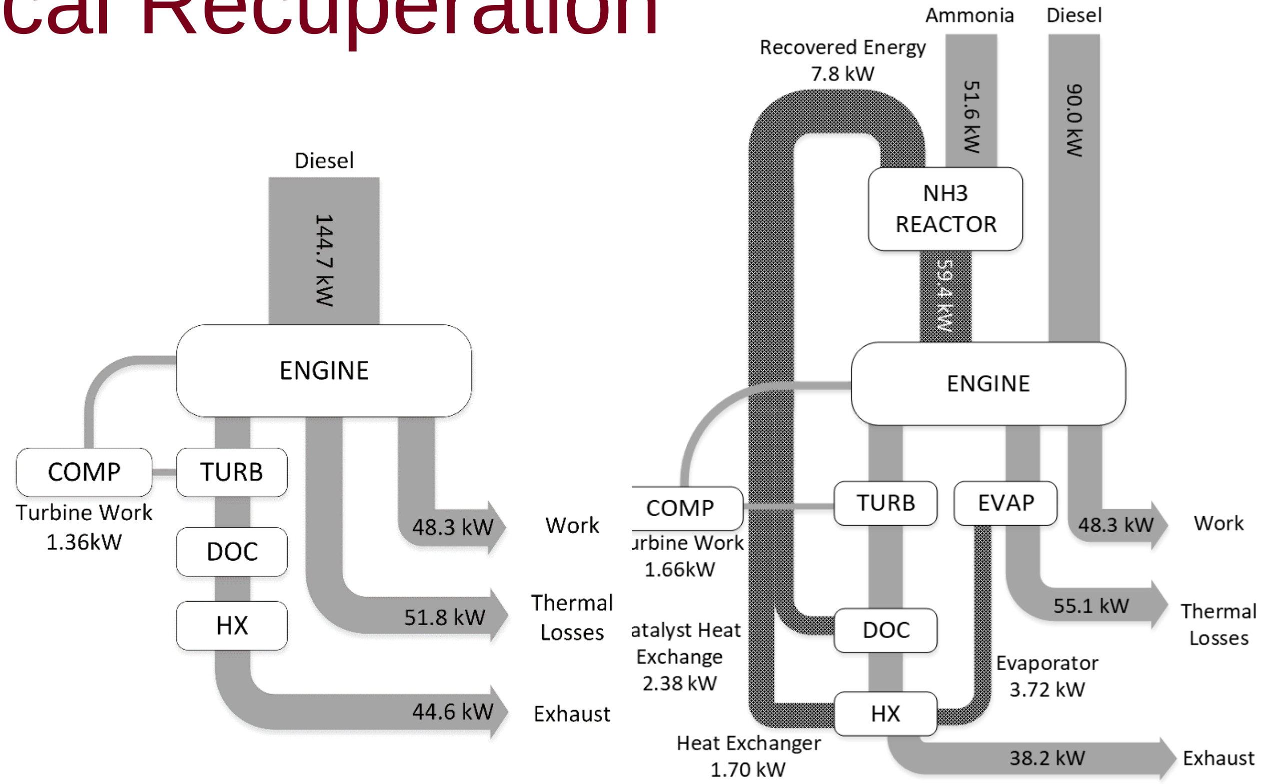
Case Study – H_2-Enhanced Dual Fuel Diesel Engine



Kane, S. P., Zarling, D., and Northrop, W. F., ASME ICEF 2019. https://doi.org/10.1115/ICEF2019-7241

Thermochemical Recuperation

- 3.5 kW less input fuel for ammonia case due to thermochemical recuperation.
- 34.1% BTE vs. 33.3% for diesel baseline – 2.4% improvement



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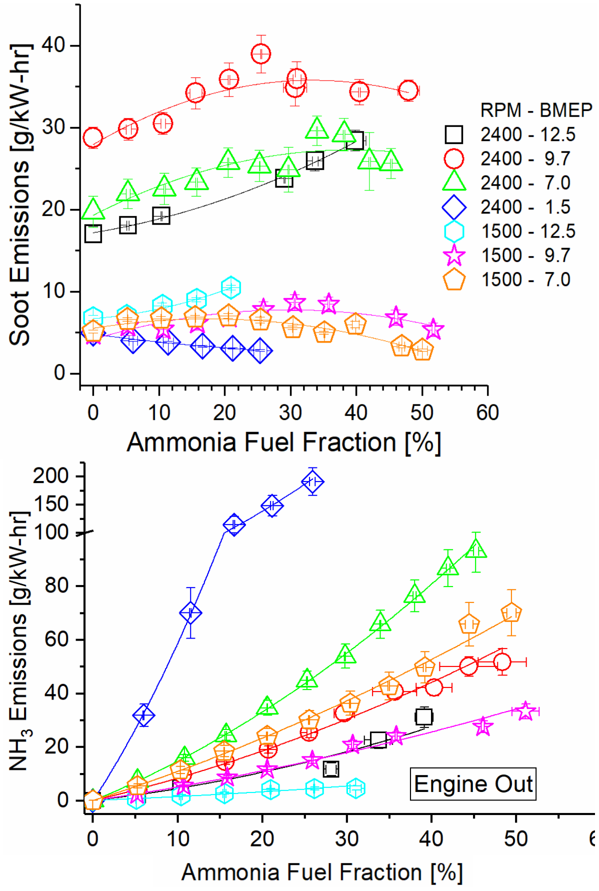
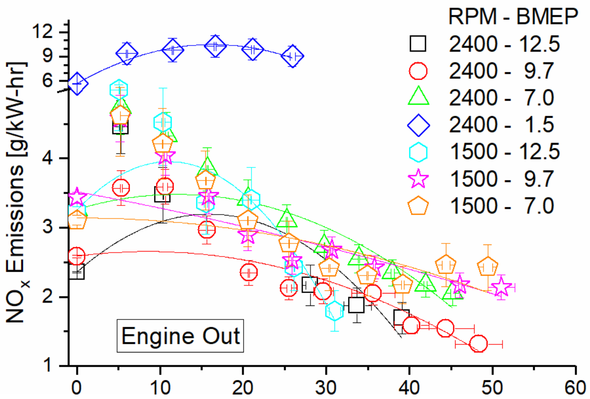
Dual-Fuel Diesel Emissions

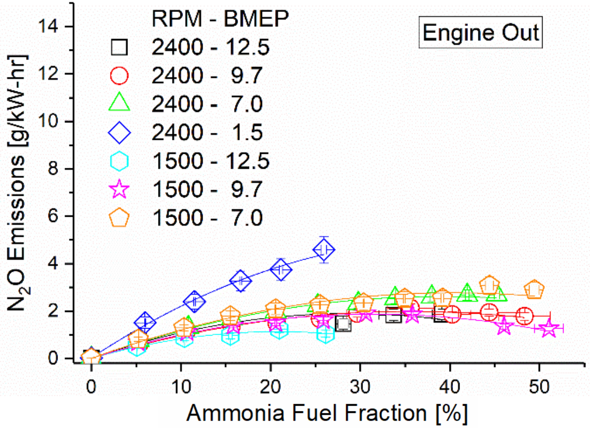
- Soot emissions increase at high speed due to oxygen displacement and lower temperature combustion temperatures
- Unburned NH_3 highest increase for for high-speed low load case – slow kinetics at low combustion temperature



Dual-Fuel Diesel Emissions

- Engine-out NO_X decreases at high ammonia fuel fraction
- N_2O emissions order of magnitude higher than diesel baseline
- Oxidation catalyst produces NO_X, N_2O due to unburned NH_3 oxidation (not shown in plots)





IC Engine R&D Topics

- NH_3 low reactivity and flame speed must be enhanced
- Fundamental combustion studies for refining chemical mechanisms and NH_3 flames
- Alternative ignition systems for SI
- Closed cycle liquid injection to reduce volumetric losses
- Nitrogen oxides and unburned NH_3 aftertreatment
- Thermochemical recuperation to increase engine efficiency and provide H_2 source – 100% NH_3 engine
- Non-PM based catalysts
- Soot and nitrogen-derived particle emissions from ammonia engine combustion

Ammonia-H_2 Counterflow Flame at UMN MERL

Thank You!

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