

# Ammonium Nitrate Nanoparticles from Ammonia Combustion in Engines and Burners

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# Ammonium Nitrate (NH<sub>4</sub>NO<sub>3</sub>) Formation

- Despite carbon free nature of NH<sub>3</sub>, its combustion forms NH<sub>4</sub>NO<sub>3</sub> particles [1]
- NH<sub>4</sub>NO<sub>3</sub> particles form when gaseous NH<sub>3</sub> reacts with nitrogen dioxide (NO<sub>2</sub>)
- Previously studied in diesel SCR systems, atmospheric inorganic aerosols, gas-phase NH<sub>3</sub>-NO<sub>2</sub> reactors [2-5]



- Important from emissions control aspect
- Ultrafine particles are a health hazard

[1] Patil, T., et al. ASME. J. Eng. Gas Turbines Power. October 2025

[2] N. Ottinger, et al., SAE (2018)

[2] Nova, et al. Catalysis Today (2006)

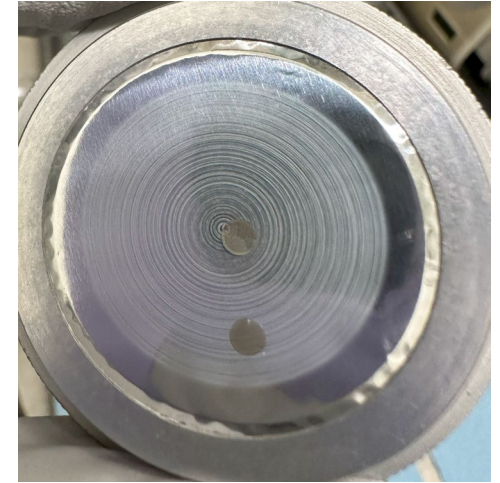
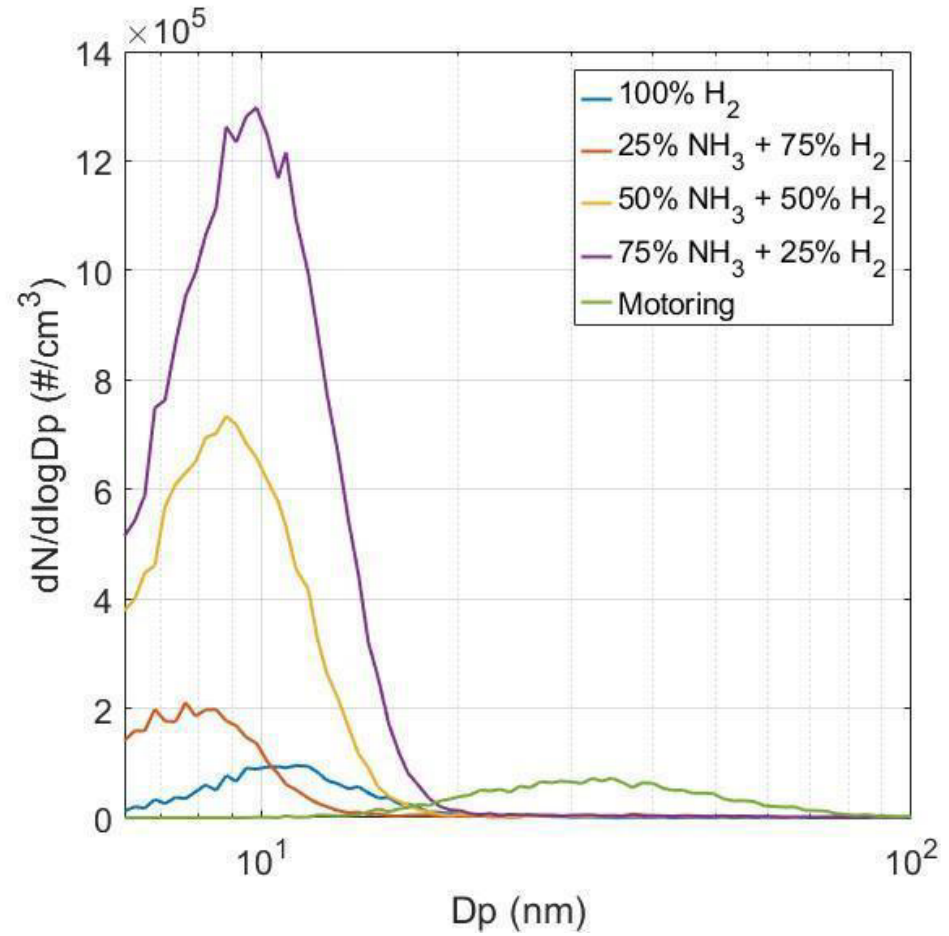
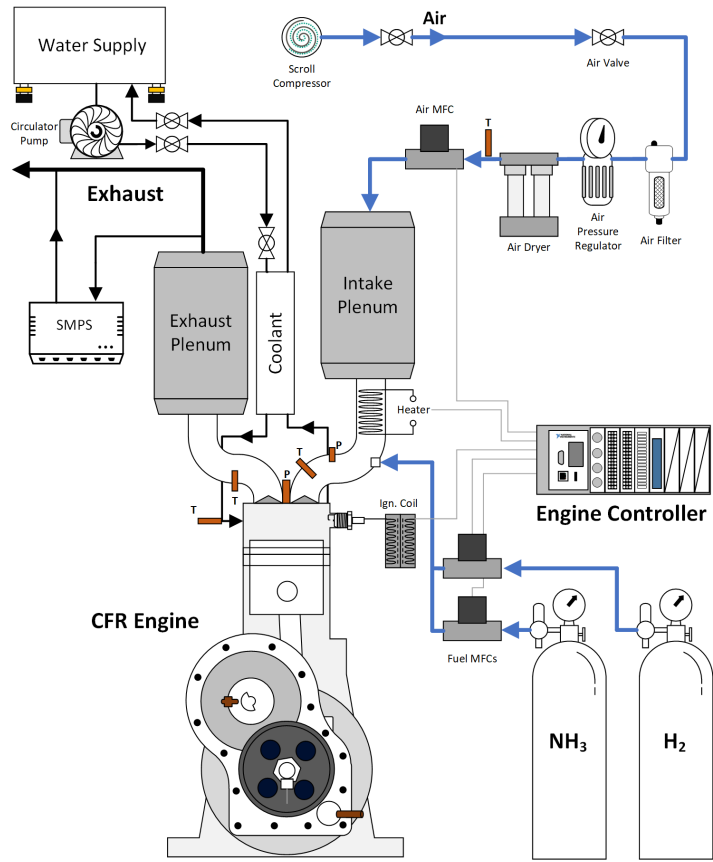
[3] A. S. Wexler and J. H. Seinfeld, Atmos. Environ. (1990)

[4] A. M. Mearns, et al., J. Chem. Tech. Biotech (1984)

[5] D. B. Kittelson, et al., J. Aerosol Science (2022)



# 2024 work from CFR engine with ammonia blended with hydrogen showed particles increased with increasing $\text{NH}_3$

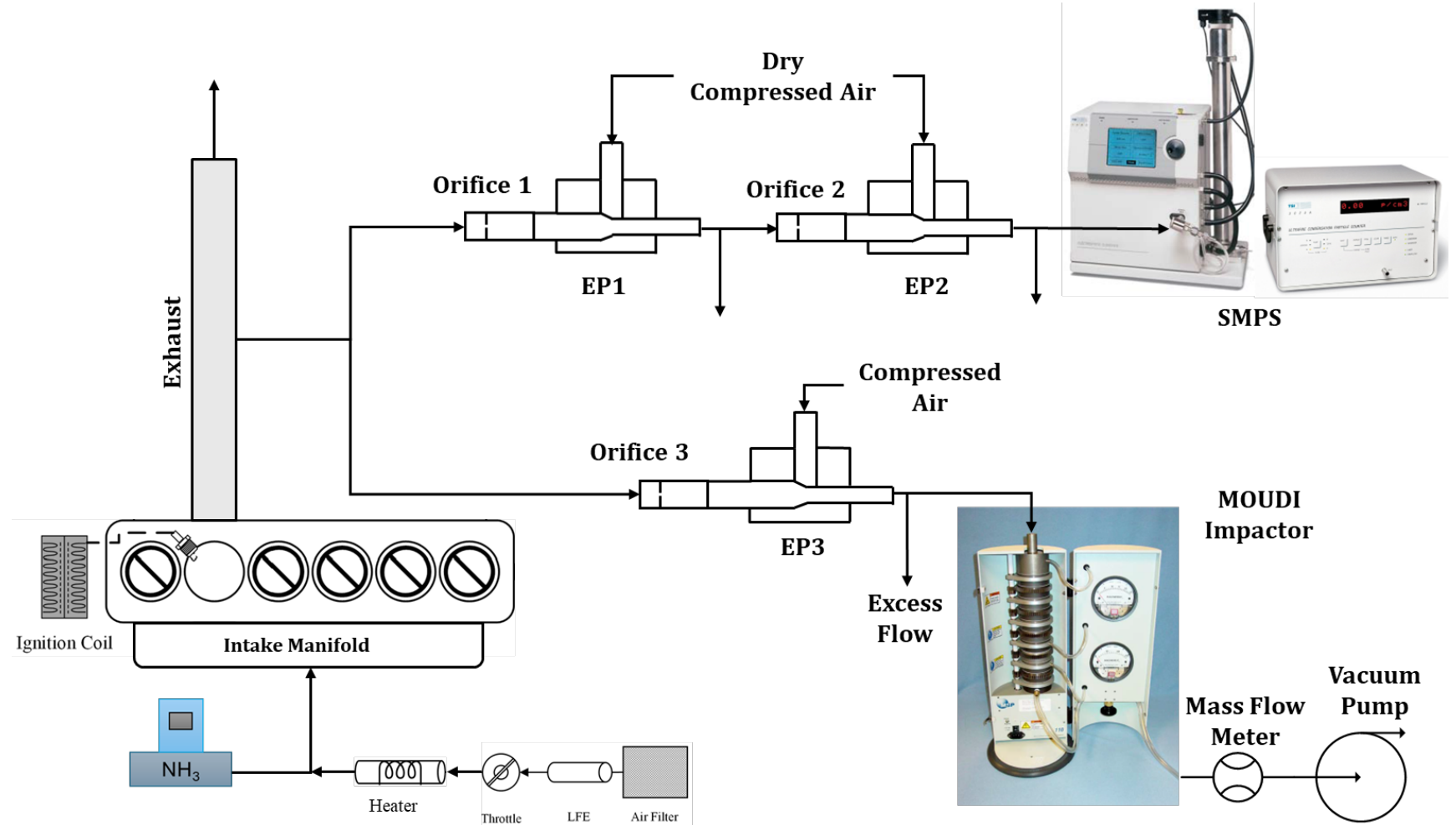
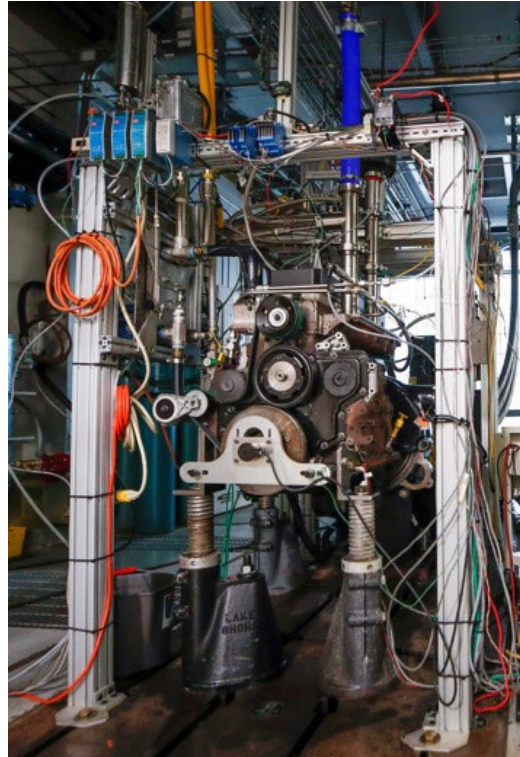


Hypothesis: Ammonia may be formed in ammonia combustion exhaust



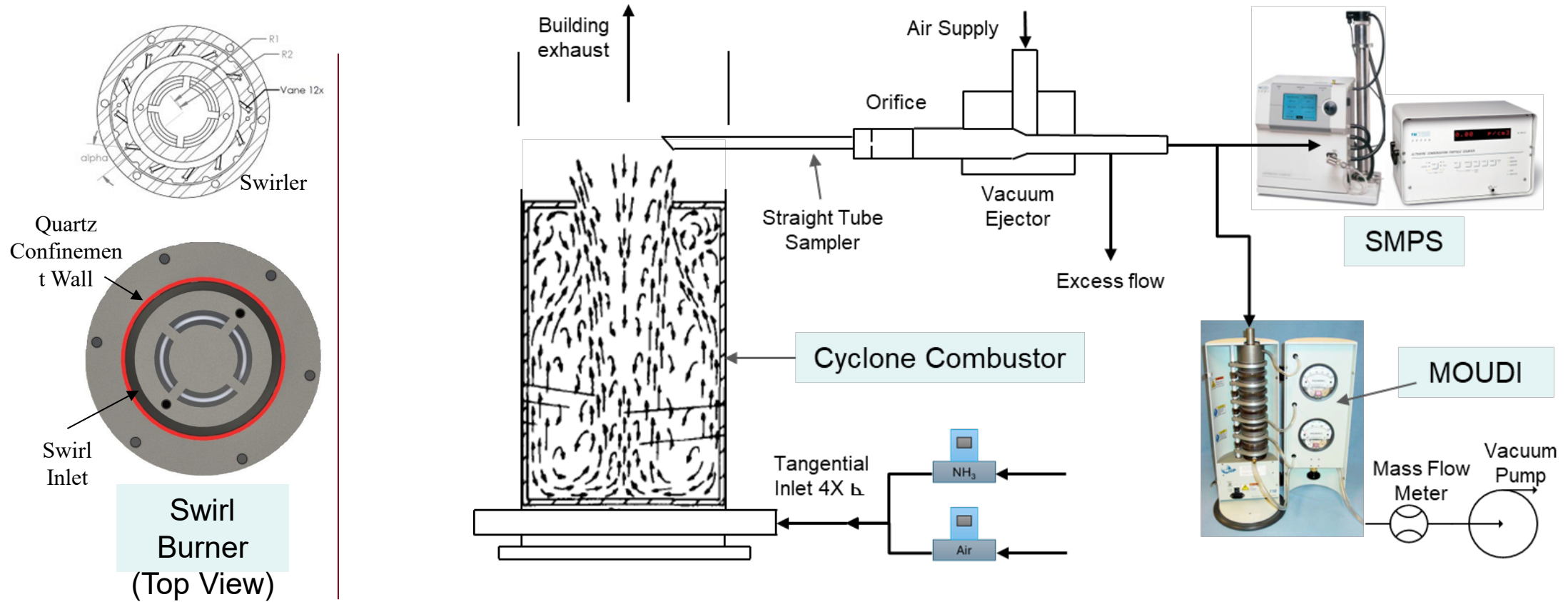
# Experimental: Engine, turbulent burners, laminar flames

## Engine Experiments



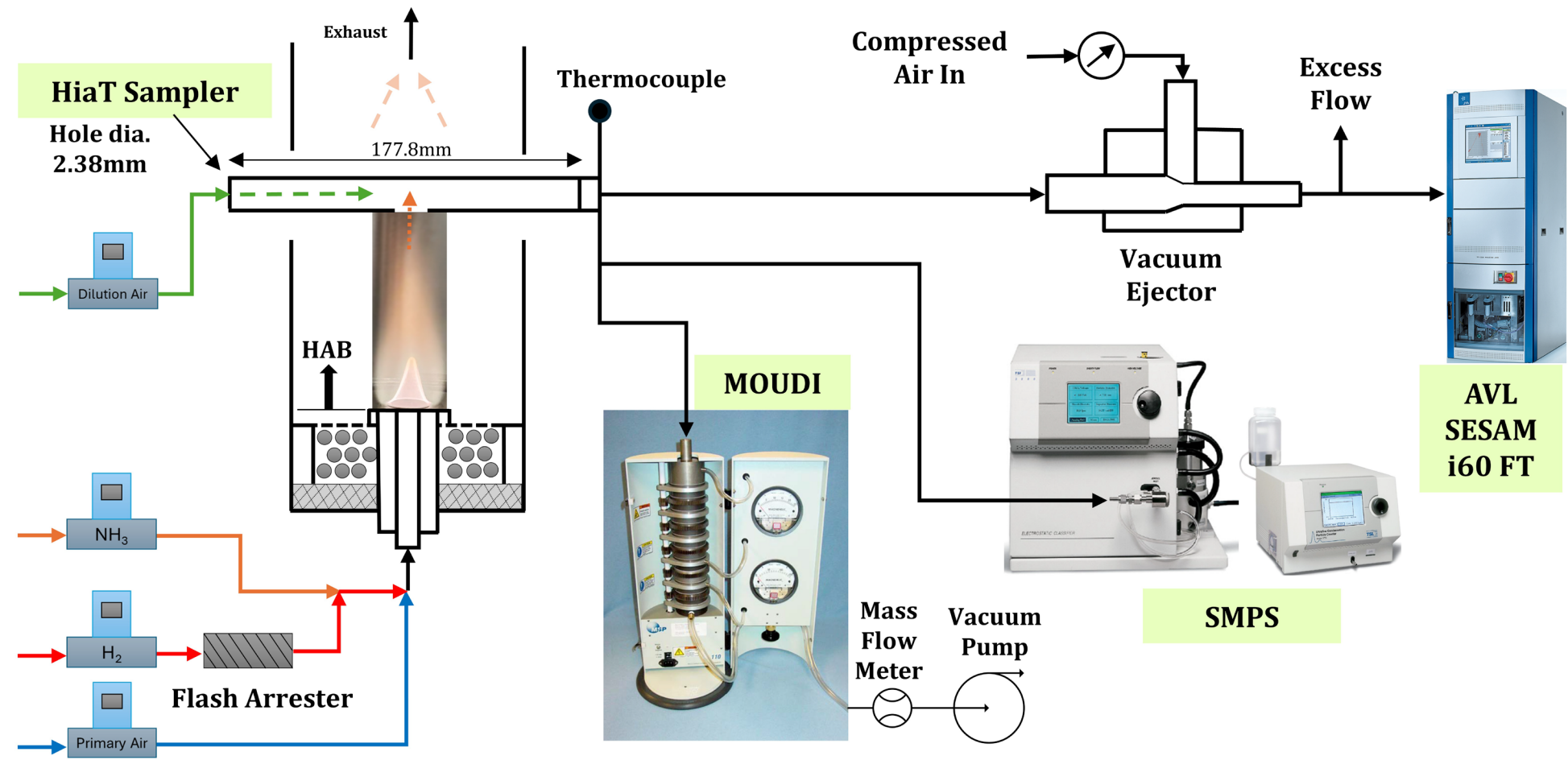
# Experimental: Engine, turbulent burners, laminar flames

## Turbulent Burner Experiments



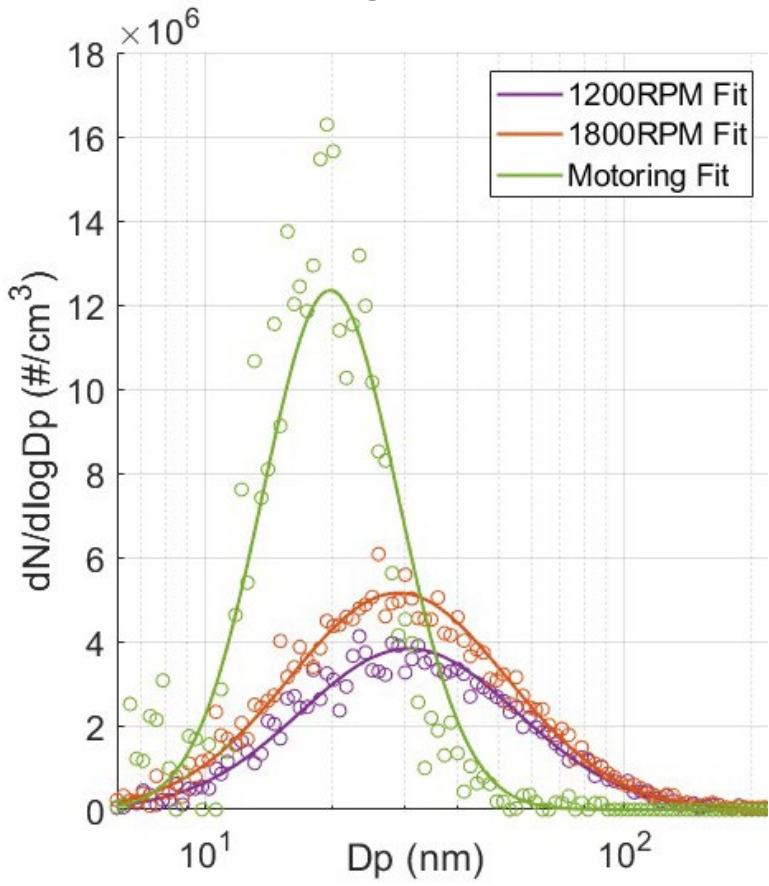
# Experimental: Engine, turbulent burners, laminar flames

## Laminar Flame Experiments

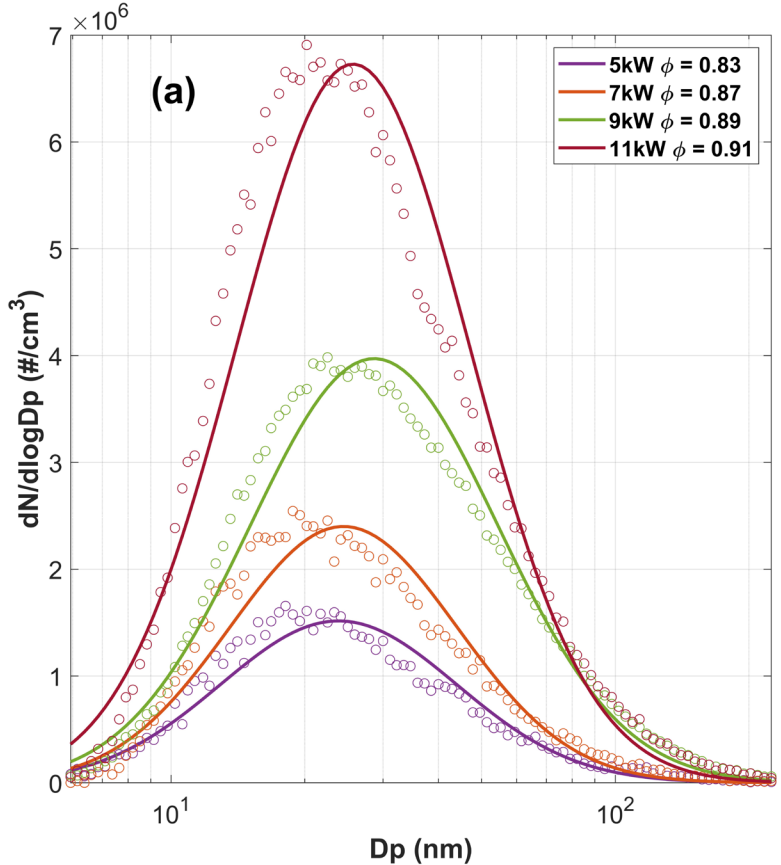


# In all three platforms, SMPS results show nanoparticles with GMD of 10-30 nm

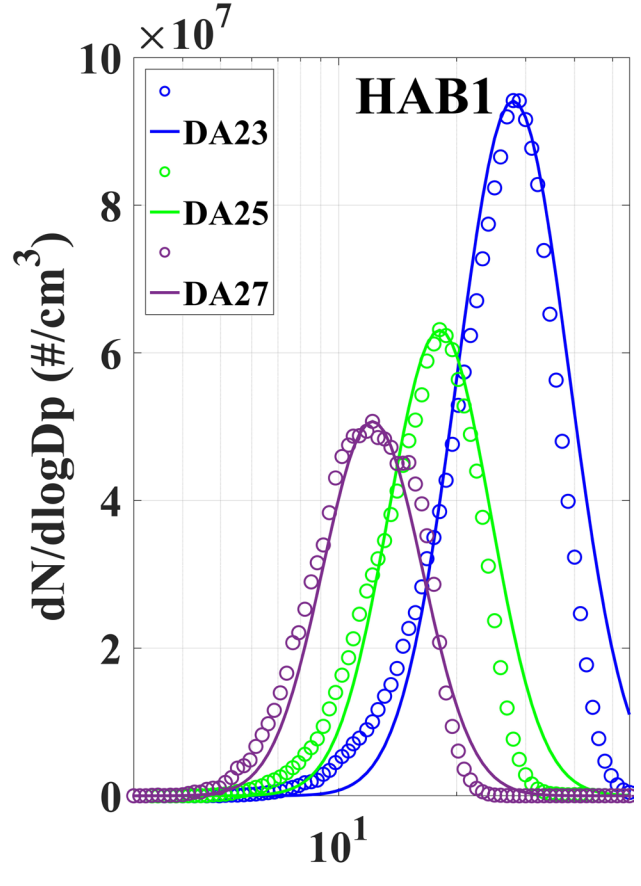
### Engine



### Swirl Burner

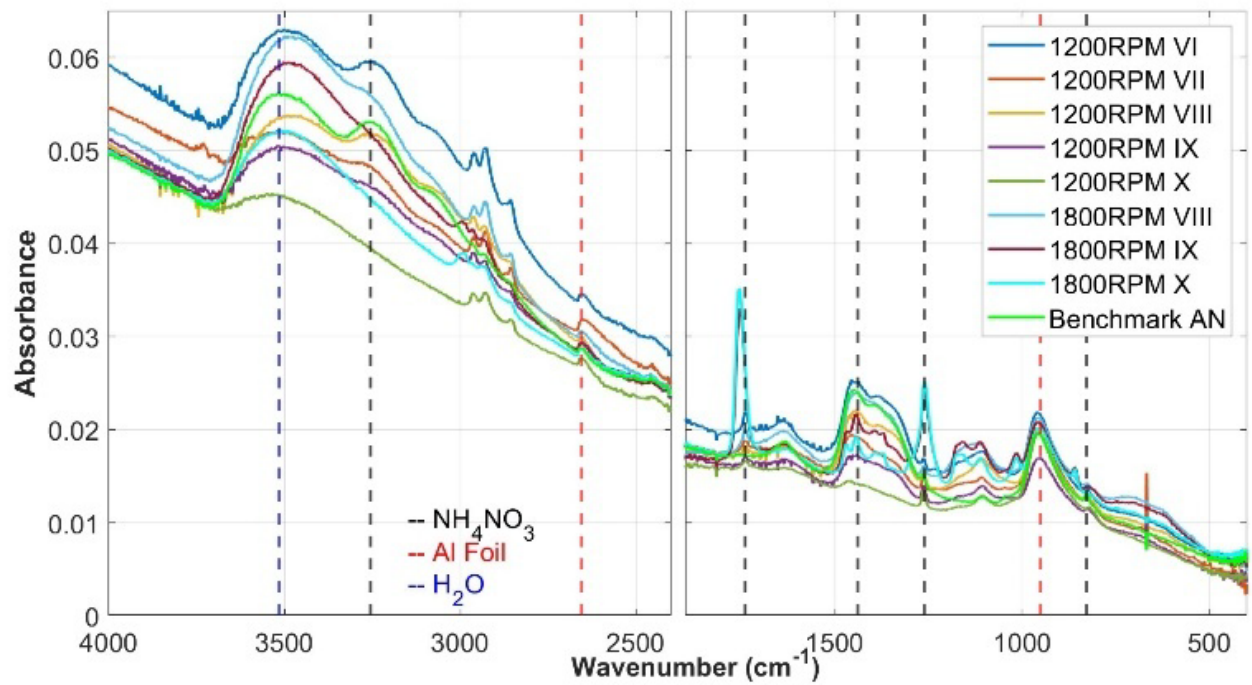


### Laminar Flame

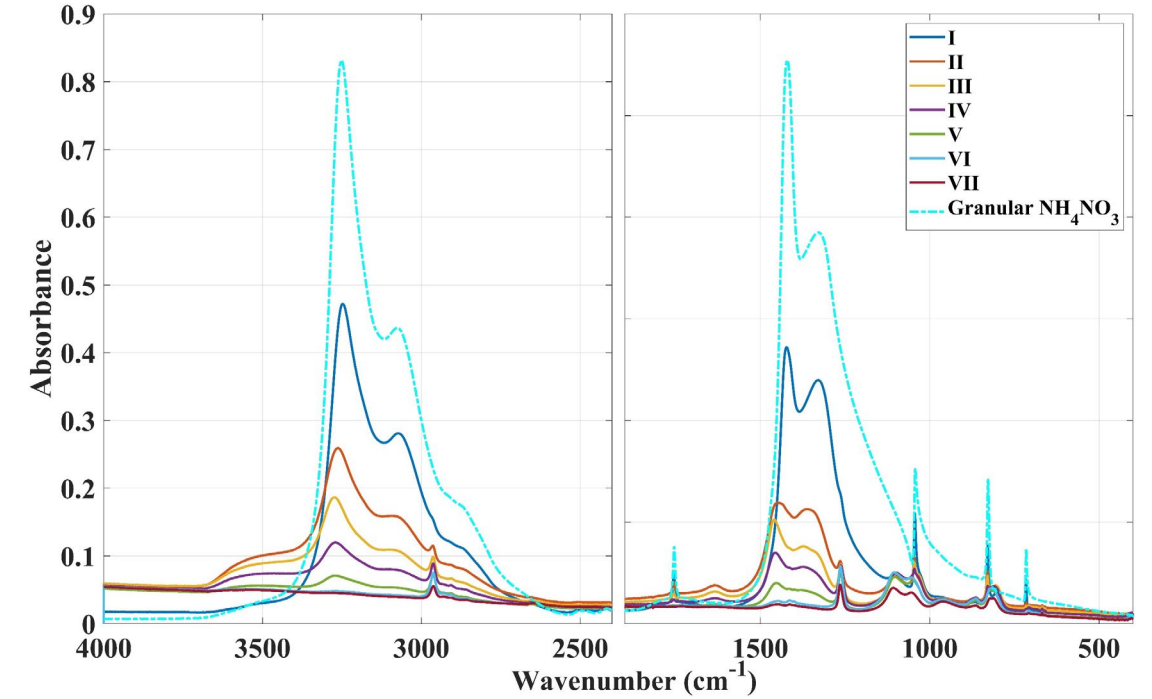


# Evidence points to ammonium nitrate

## Engine



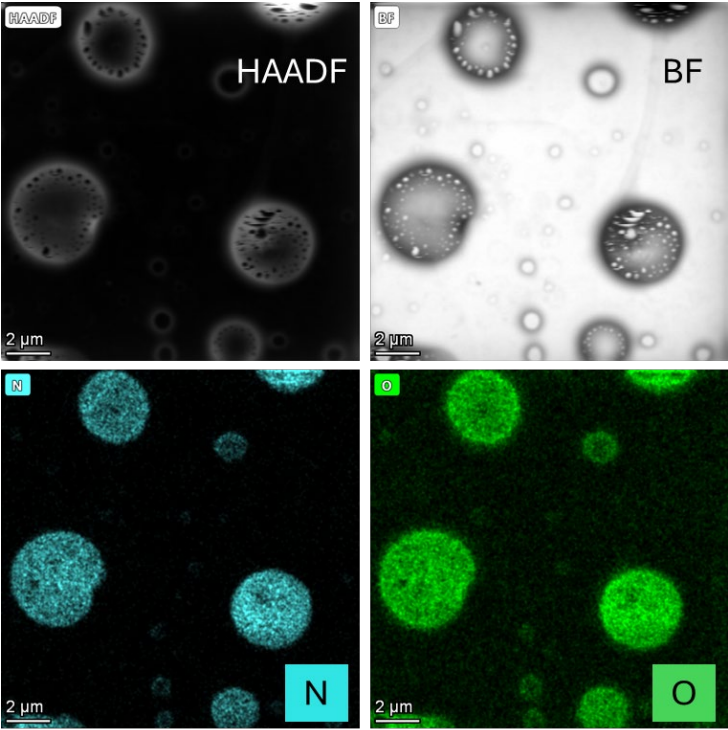
## Laminar Flame



ATR-FTIR spectra for particles at different engine conditions and stages I-VII of the MOUDI compared with known granular  $\text{NH}_4\text{NO}_3$

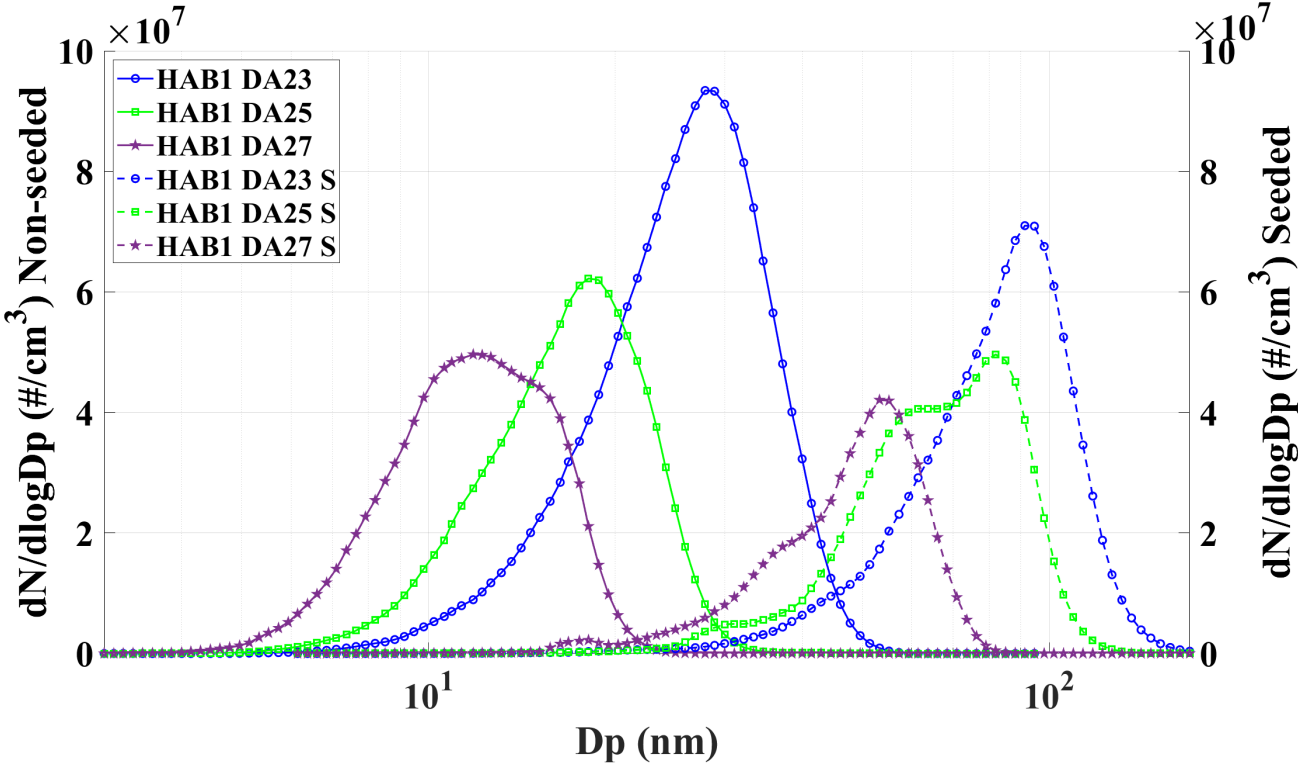


Though ash is a nucleation site for AN nanoparticle formation, it appears to nucleate homogeneously



TEM of unseeded  $\text{NH}_4\text{NO}_3$  particles

Laminar Flame



30 nm  $\text{TiO}_2$ -seeded flame measurements compared with unseeded



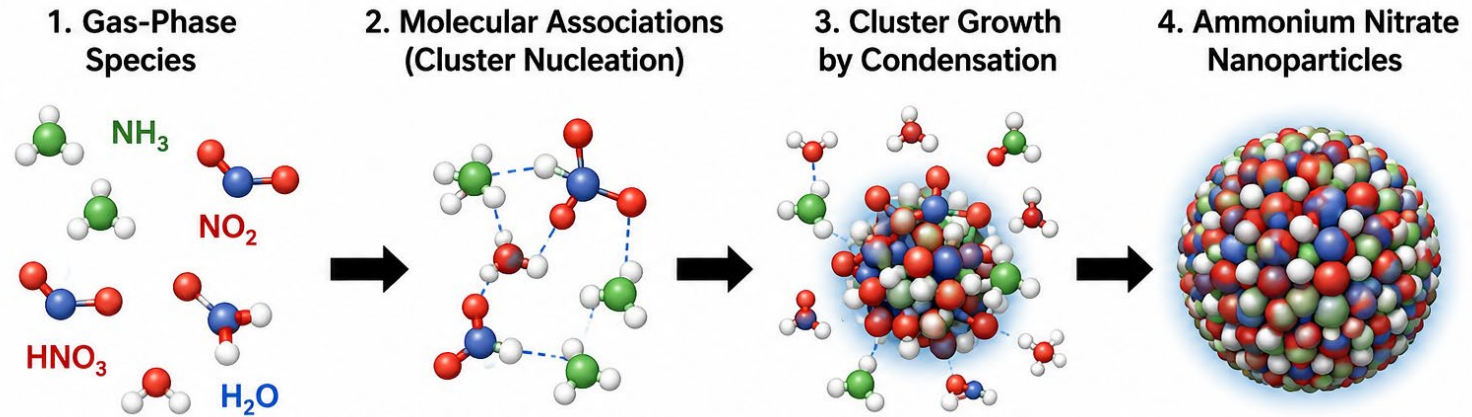
# Ammonia combustion is low-carbon, but future systems must also address emissions of ammonium nitrate nanoparticles

- Research Status: AN particles can form homogeneously
  - Formed in exhaust, during cooling, and during dilution, like SOC in diesels

- Proposed chemical nucleation pathway:

- $\text{NH}_3$  drives particle concentration
- $\text{NO}_2$  contributes to cluster formation
- Water vapor promotes growth through condensation

## Gas-Phase Cluster Formation and Growth

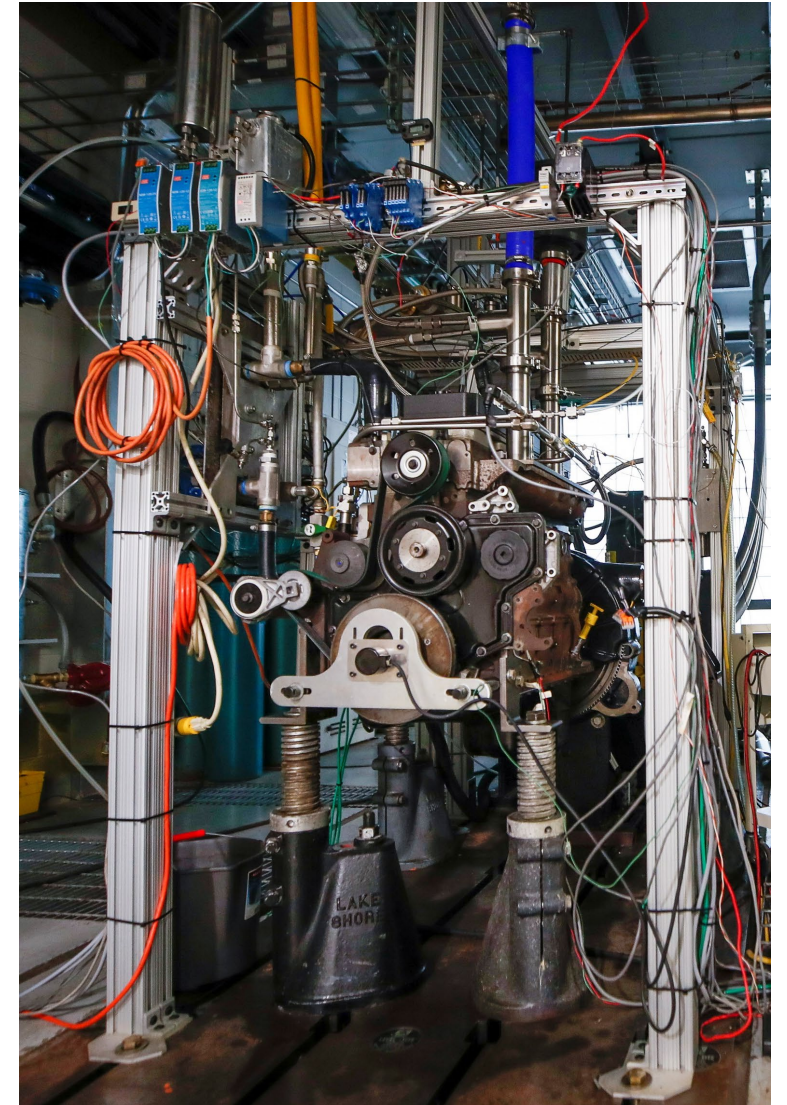


- Nucleation -> exhaust temp., dilution, water vapor,  $\text{NH}_3$ ,  $\text{NO}_2$ , and nuclei
- Future work: flat flame and tubular reactor studies to explore kinetic pathways

# Thank You

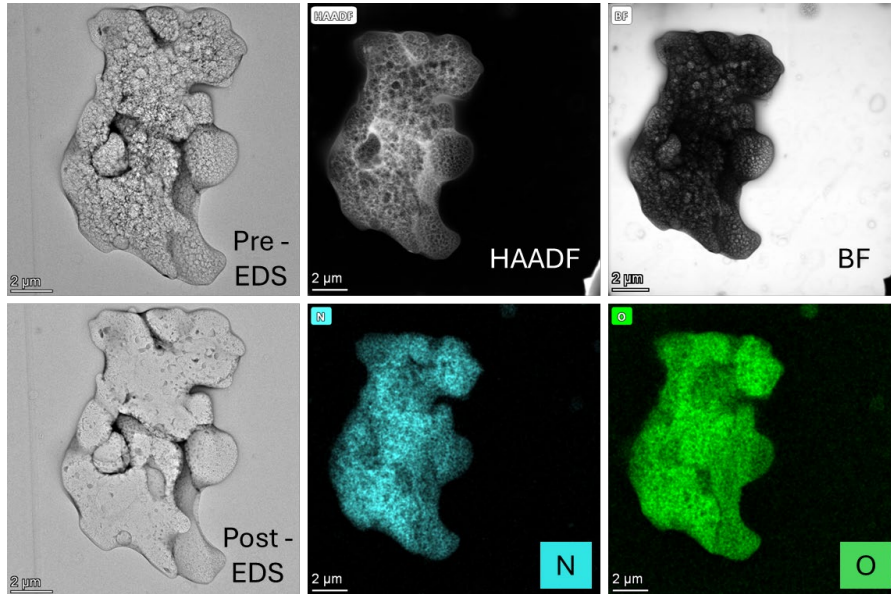
## **Prof. Will Northrop**

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# Extra TEM Images

Laminar Flame



TEM of unseeded  $\text{NH}_4\text{NO}_3$  particles pre- and post-EDS

Engine

ENGINE SPEED -  
MOUDI STAGE

1200-Filter

