MariNH$_3$

Clean, green ammonia
engines for maritime

Fuel Spray Imaging

MariNH$_3$ Conference, 28 June 23

Prepared by: Agustin Valera-Medina
Anthony Giles

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  - Experimental plan
    - Fundamental sprays
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- Fundamental combustion activities
- Focus for next year of project

Premixed NH_3 - Air Flame

Non-premixed NH_3 - Air flame

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Previous Relevant Work Activities

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Previous work

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- Cardiff's ICE work using Ammonia began in 2015 (Siemens).
- Basic engine, with only limited modifications for Ammonia use.
- Fuel system comprised of series of pressure regulators together with MFC's to control / meter fuel to engine.
- Engine operated with basic carburettor.
- Ammonia running limited by fuel system and the effect of ambient conditions on its components.

Siemens Green Ammonia Demonstrator, STFC[4]

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Previous work

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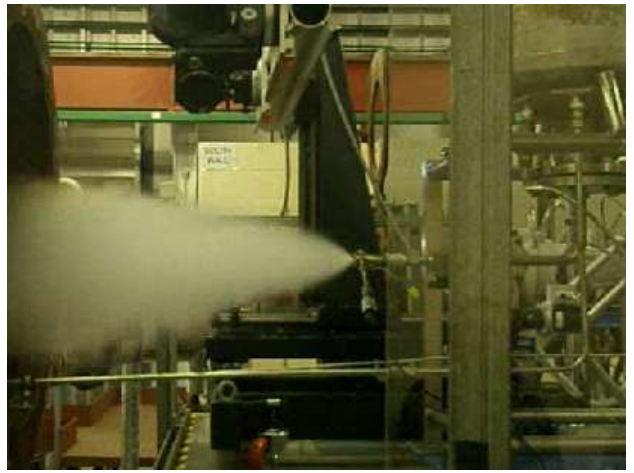
- Completed a variety of studies involving hazardous releases, involving a range of chemicals and scales.
- Worked with DNV led consortium on experiments involving “flashing” releases, developing empirical models.
- Recent experimental work with HSE led JIP relates to accidental releases and ignitability of “high flash-point” fuels.



Flashing Butane Release

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Previous work

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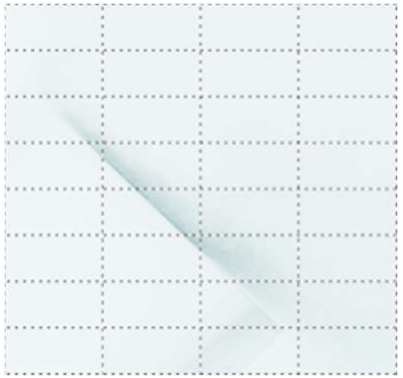
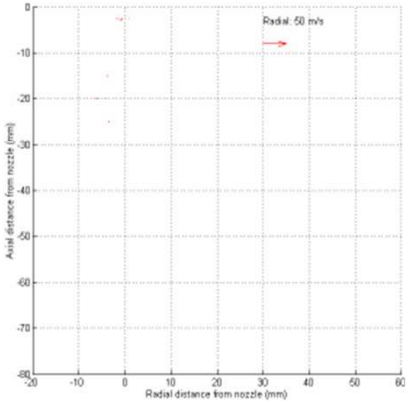
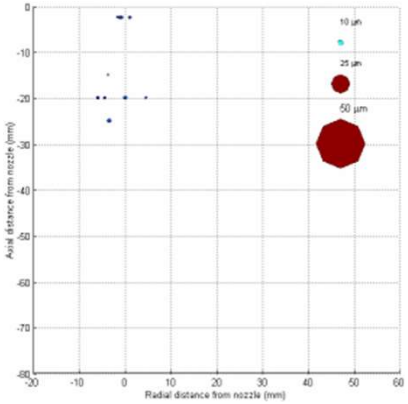
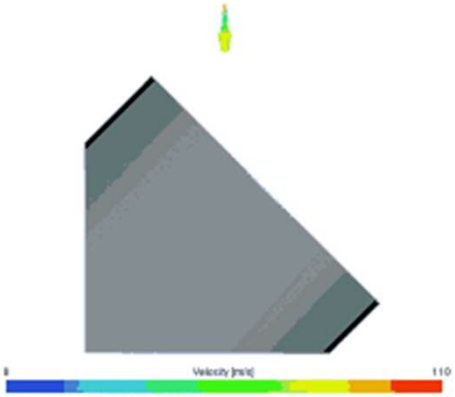
- Multiple PhD projects collaborating with Ricardo (and partners) to develop injector characterisation methods.

- Collaborative research on GDi systems included in 2014 REF case study “Low-Carbon Engine Design Through Integrated Simulation-Validation”.









Injector Characterisation Process

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Spray Analysis

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Spray analysis - Activities

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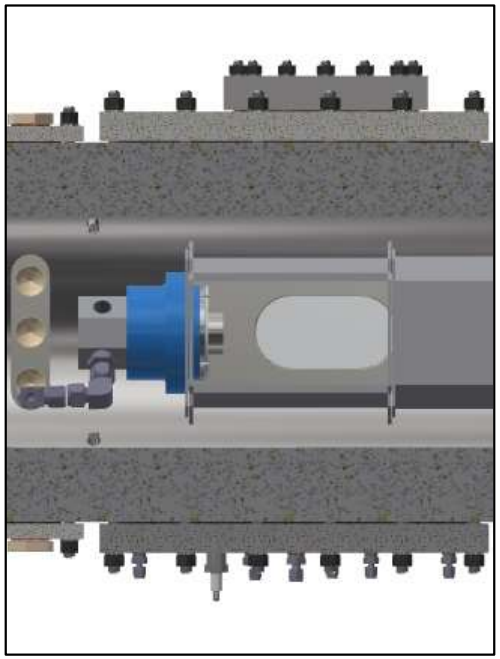
- Optical diagnostics of Ammonia fuel sprays
  - Designed modular staged combustor design to be used for analysis of spray into low flow (zero swirl) environment.
  - Liquid Ammonia fuel delivery system for spray work designed. Construction underway.
  - Procured new laser. PDA system has been serviced and upgraded.
  - Recommissioning of Injector PV underway.
  - Recent delay in work activities, injury.



Staged Combustor for Steady-State Ammonia Spray Studies

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Spray analysis - Plan

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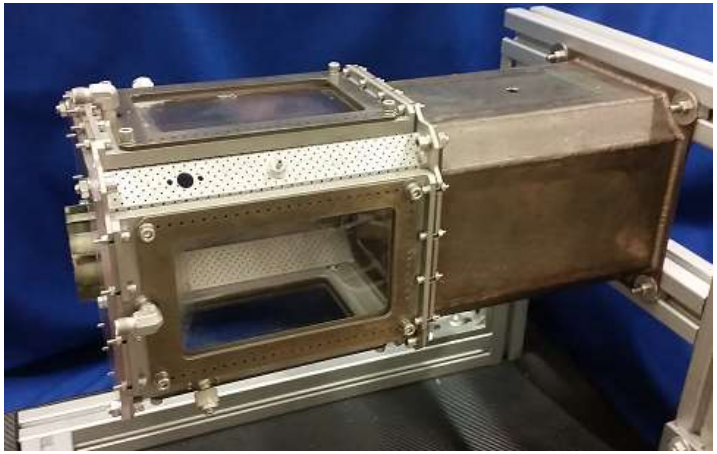
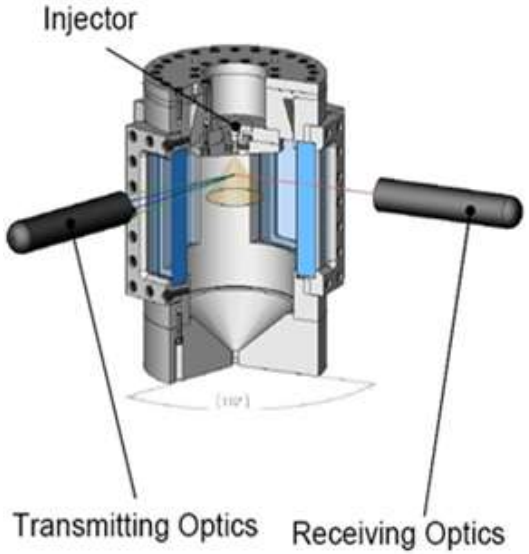
- Two separate experimental programs being undertaken
  - Fundamental Sprays
  - Automotive Injectors



New Staged Combustor



Injector Characterisation Vessel

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Spray analysis - Fundamental

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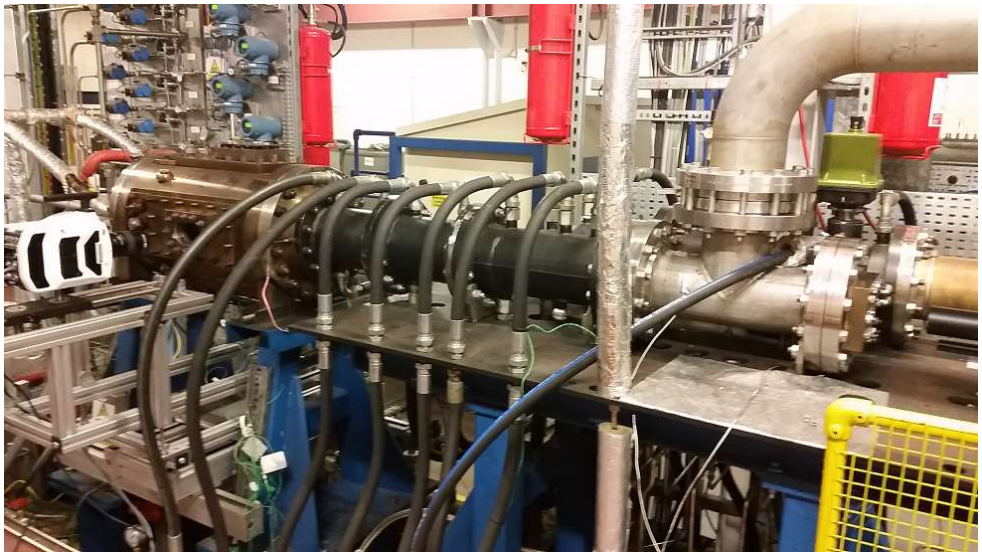
- Experiments will utilise HPCR and a newly developed Generic Staged Combustor.



Rig for Steady-State Ammonia Spray Studies

- Typical operation:
  - < 9 bar absolute
  - < 250 g/s air flow
  - < 575 K inlet temp
- Fuel delivery system utilises Bronkhorst pressure controller to control driving pressure of 20l bladder accumulator.
- Plain orifices of 0.2, 0.3 and 0.4mm diameter will deliver between 0.4 and 5 g/s of Ammonia.

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Spray analysis - Fundamental

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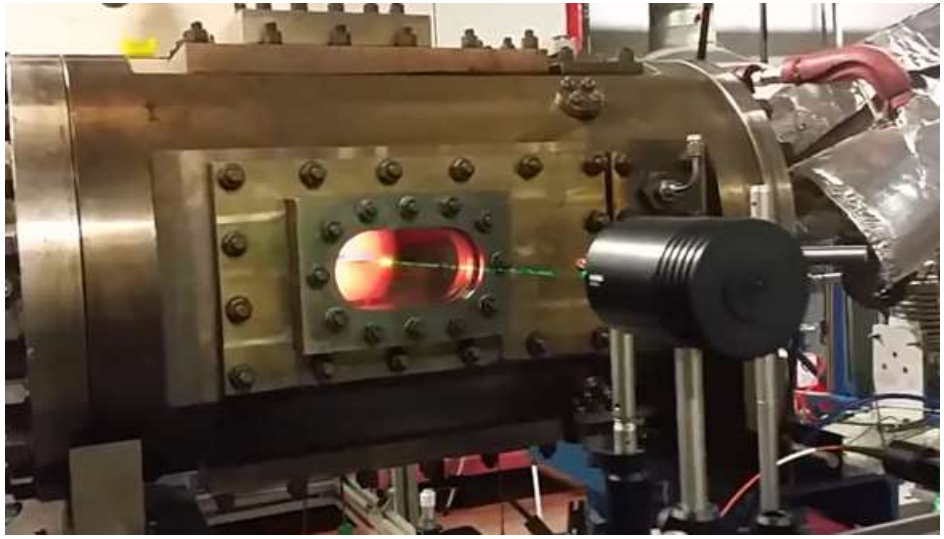
- Multitude of diagnostic options available for spray visualization, velocity and droplet sizing.
- Backlit or laser sheet illuminated high-speed imaging.
- LDA or high-speed PIV velocity field measurement.
- Malvern Spraytech, Dantec IPI / ILIDS for droplet sizing.
- NH_3 PLIF for vaporization analysis.



Optical Access for Variety of Characterisation Techniques

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Spray analysis - Fundamental

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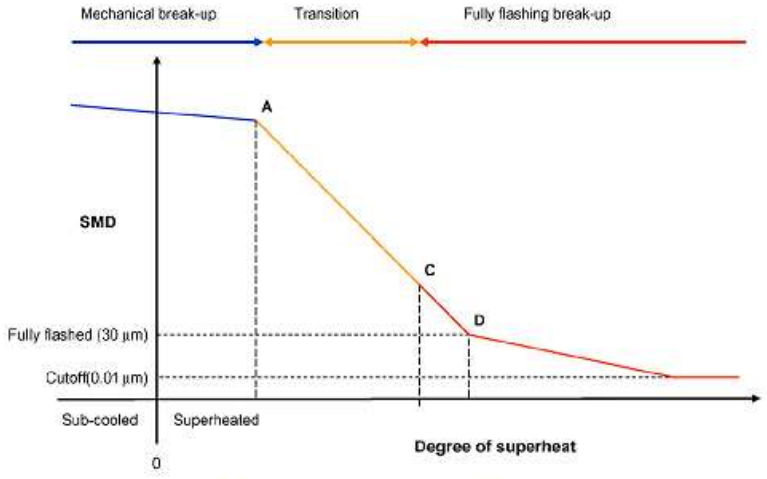
- Processes involved in formation of Ammonia sprays has similarities to that of hazardous releases of superheated flashing liquids.



Tri-linear curve for Sauter Mean Diameter as function of superheat.

Witlox B, Bowen P - https://doi.org/10.1016/j.jhazmat.2006.06.126

- Recent work involving flashing Ammonia spray visualization needs to be compared to empirical models from literature for large scale releases.
- Aim of fundamental spray work is to quantify current, and where required develop new, empirical models for use in CFD etc.

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Spray analysis - Automotive

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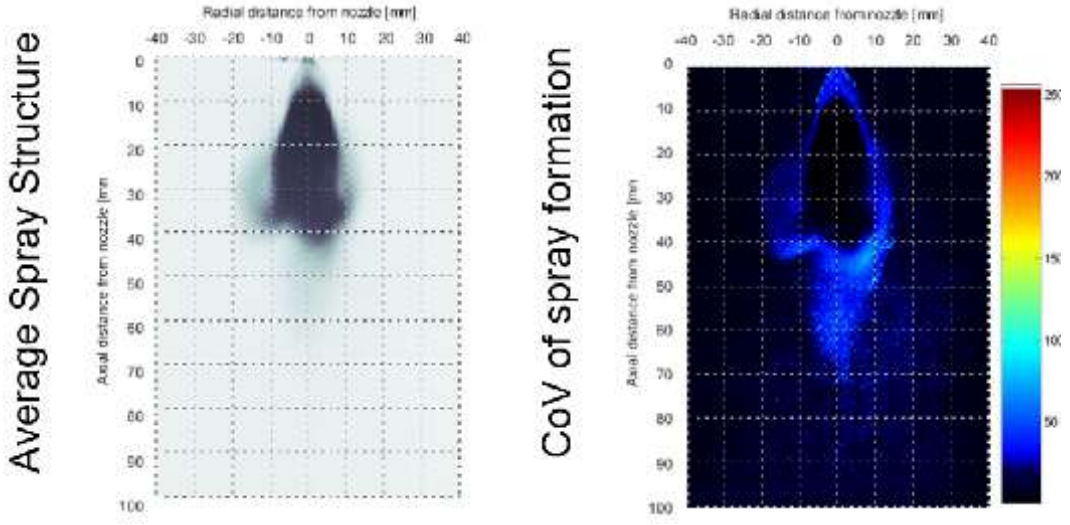
- Experiments to be carried out in re-commissioned spray pressure chamber. Previously rated to pressure of 15 barg at a temperature of up to 150 deg C.
- Mass flux of NH_3 to be measured over range of operational conditions.
- Imaging with backlit or laser sheet illumination will allow analysis of tempora spray structure.
- PDA used to interrogate spray “quality”.



Transient Injector Visualisation and Analysis

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Spray analysis - Automotive

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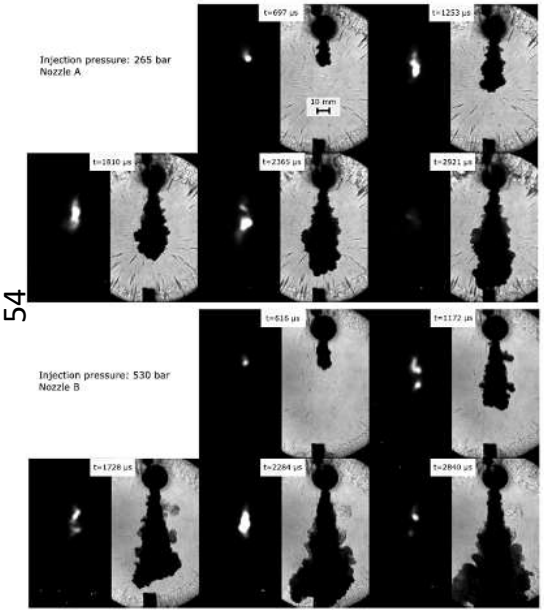
- Great deal of recent work involving spray visualisation of Ammonia injection, primarily using modified diesel injectors.



Sattelmayer T. et al - https://doi.org/10.1016/j.fuel.2022.1264

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- Published data so far is generally limited to analysis of spray shape, penetration etc.
- Important effects, such as temperature effects of evaporation have only been reported through modelling.

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Fundamental Combustion Activities

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Fundamental combustion

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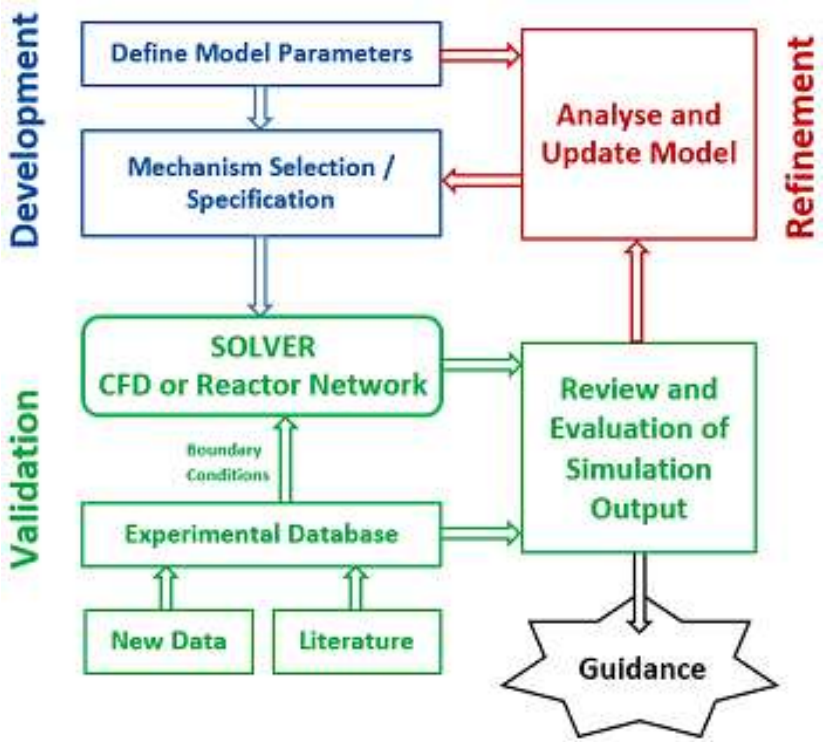
- Fundamental Combustion (WP6)
  - Preparation of optical rigs for fundamental analyses of Laminar Burning Speed of various blends (Ongoing).
  - Analyses of available Reaction Mechanisms used for ammonia/hydrogen combustion blends to evaluate their performance vs NOx emissions (Ongoing).
  - Results - Nakamura and Glarborg good under lean conditions, Wang good under rich conditions.



Methodology for Mechanism Development

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Fundamental combustion

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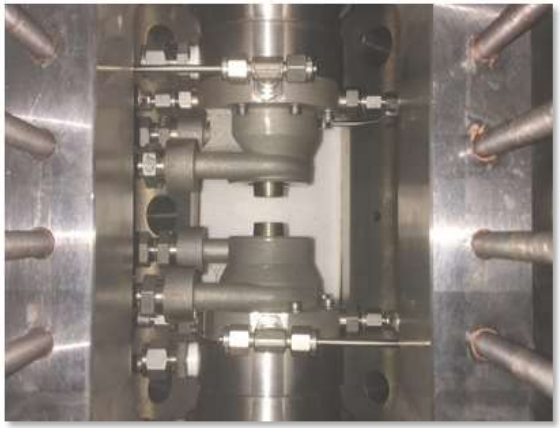
- A pressurized counter flow burner will be used to evaluate use of Ammonia with variety of pilot fuels.
- Typical operation:
  - < 9 bar absolute
  - < 25 g/s air flow per burner
  - < 433 K inlet temp
- 3D printed components used for temperature conditioning appear porous, have failed pressure test. Have been redesigned and manufactured by conventional methods.



Counter-Flow Burner

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Fundamental combustion

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CVB / Cloud Chamber

- Alternative rigs are available, and may be used to evaluate two-phase combustion. Expected to be difficult to obtain S_L for Ammonia mists.
- Vapour pressure curve for Ammonia results in unsuitability for formation of monodisperse droplets via use of cloud chamber.
- After initial quantification of automotive injectors for Ammonia sprays, may be able to come back to this.

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Focus for Next Year of Project

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Focus for next year…..

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- Finish “resurrection” of automotive injector PV and commission new PDA system.
- Finish assembly of liquid fuel delivery system, undertake initial investigations of fundamental ammonia sprays.
- Commission pressurized counter-flow burner with assistance of CDT student.

Counter-Flow Burner

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