



## **Effect of injector deposits in engines on sprays and combustion**

**Roger Cracknell**

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Reserves: Our use of the term “reserves” in this presentation means SEC proved oil and gas reserves.

Resources: Our use of the term “resources” in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions.

Organic: Our use of the term Organic includes SEC proved oil and gas reserves excluding changes resulting from acquisitions, divestments and year-average pricing impact.

Resources plays: our use of the term ‘resources plays’ refers to tight, shale and coal bed methane oil and gas acreage.

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# Outline

- Introduction
- Diesel Injector fouling examples
- Gasoline DISI Fouling examples
- Summary

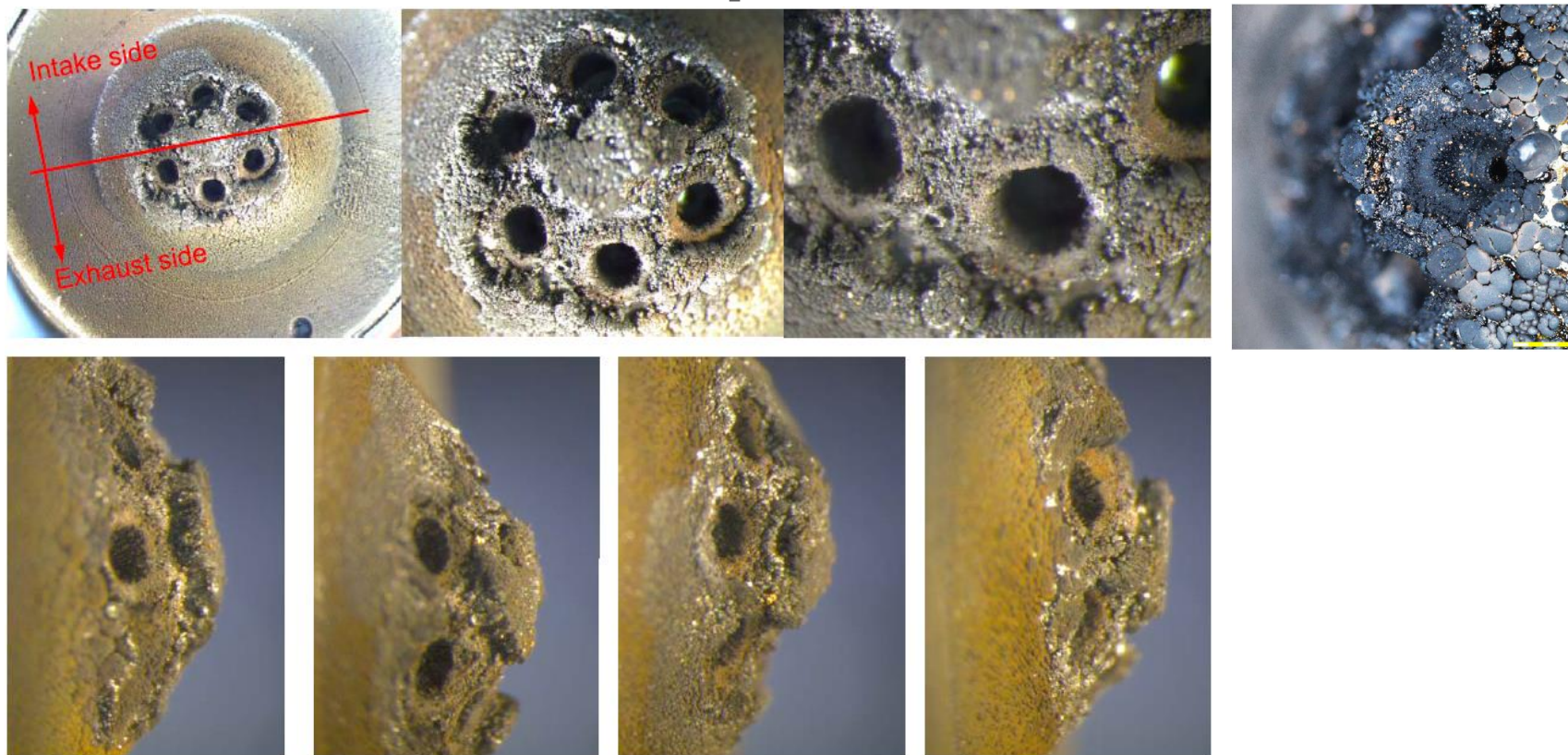
# Direct Injection in Diesel and Petrol Engines

- Direct injection means that fuel is injected directly in to the combustion chamber and that the tip of the nozzle is exposed to combustion temperatures.
- Direct injection dominates nearly all diesel applications.
  - Trend towards higher fuel pressures ( up to 3000Bar) and smaller holes for better fuel atomisation.
- Direct injection becoming increasingly important for petrol vehicles

## Direct Injection Spark Ignition (DISI) or Gasoline Direct Injection

- Prediction by Bosch that a quarter of all petrol engines will be DI by 2020
- Increased knock resistance allows for higher compression ratio compared to port fuel engines
- Can enable lean burn combustion through stratified charge

# What do fouled DISI injectors look like?



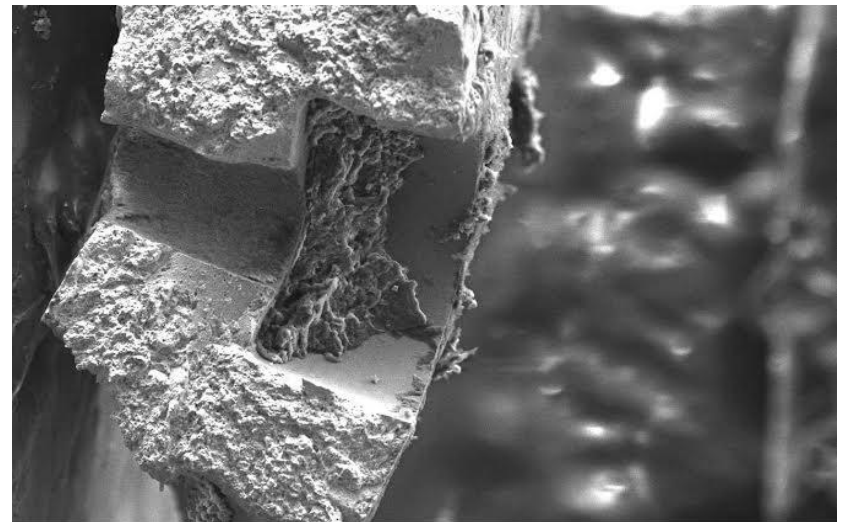
Conifer et al SAE 2017-01-0808



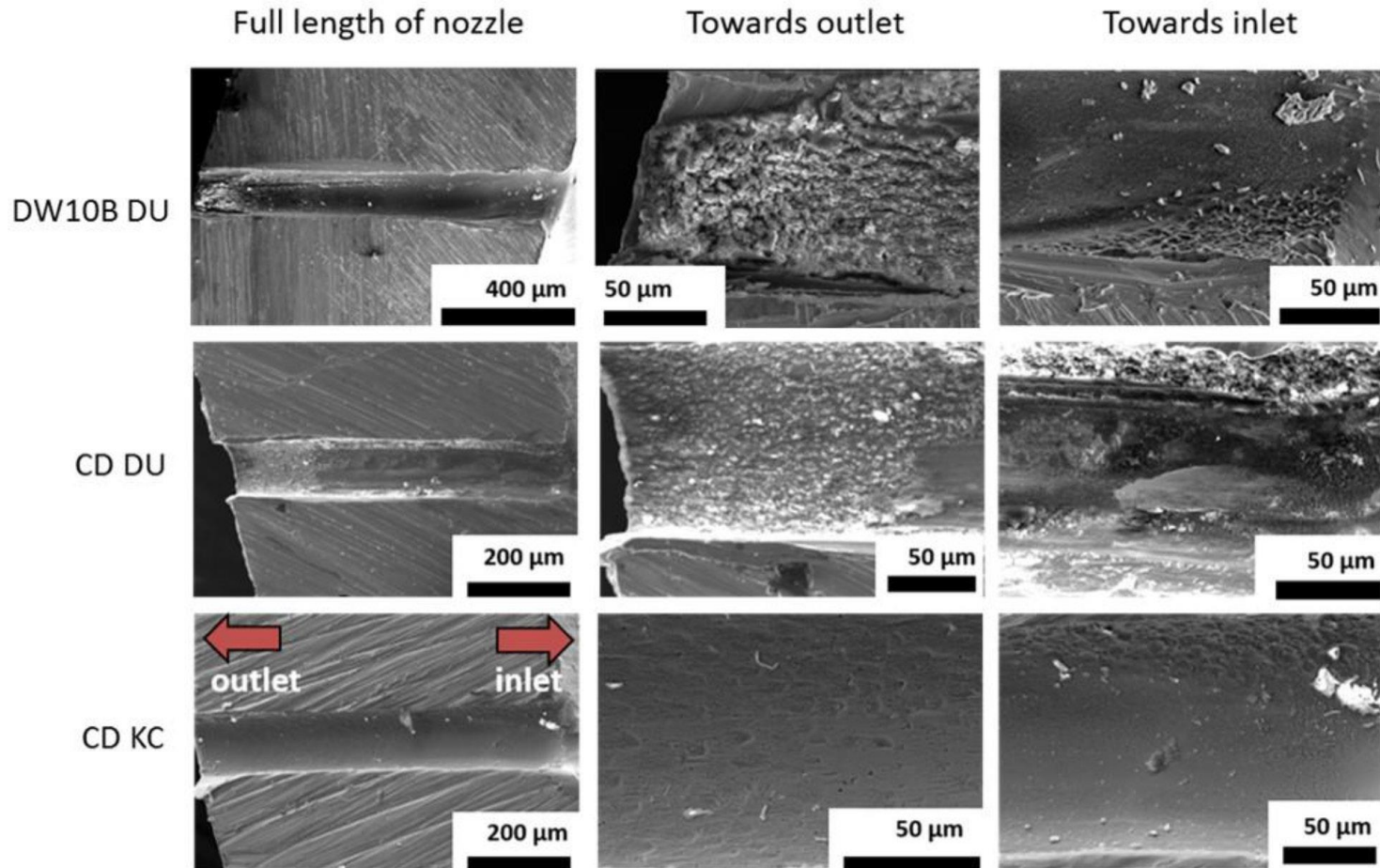
# Cracking of Fouled DISI Injectors



Dearn et al SAE 2014-01-0808



# Cracking of fouled Diesel injectors



Rounthwaite et al SAE 2017-01-0798

# Consequences of Injector Fouling

- Flow reduction, leading to power loss/ efficiency loss
- Fouled injector tips can produce fuel sprays with altered penetration depth, and cone angles
- A modified spray pattern can lead to greater fuel impingement on cylinder walls and piston crown plus sprays with larger droplets
- Adsorption of fuel by deposits leading to rich combustion and soot

**REDUCED POWER/EFFICIENCY**

**MORE EMISSIONS**



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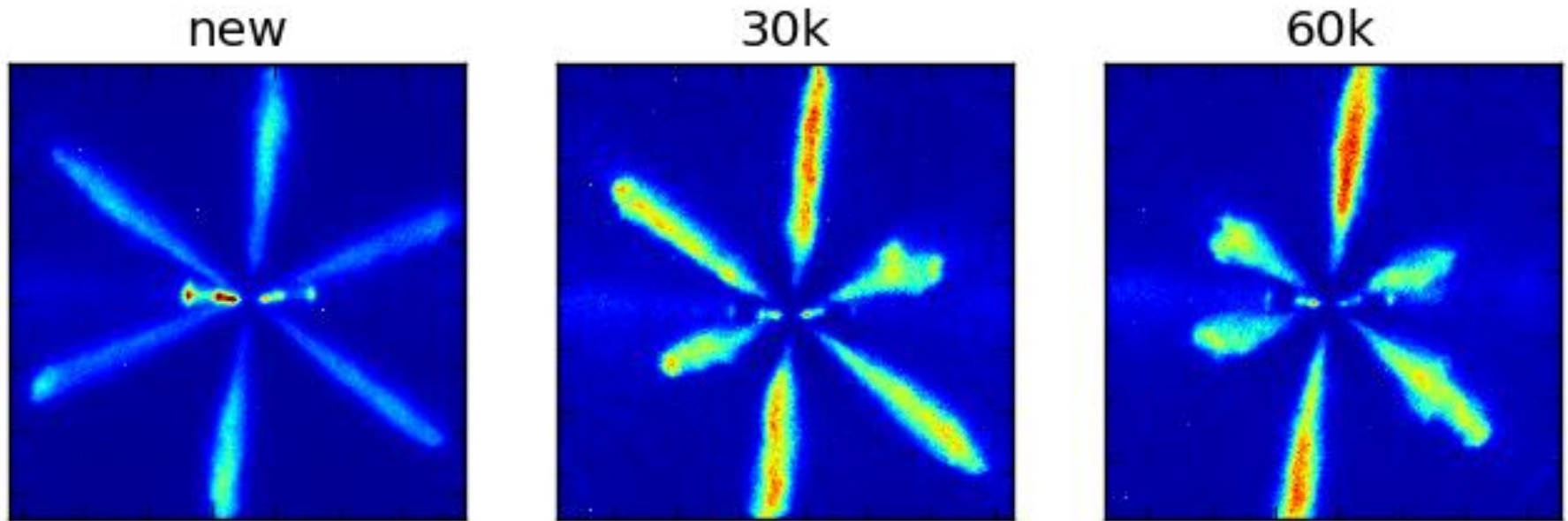
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# SHELL/BRUNEL STUDY - REAL WORLD DIESEL INJECTORS

- Injectors fouled during real world driving on UK roads.
- Shell arranged for injectors (still fully functional) to be replaced at a dealership during service interval
- Same make and model of car/injector:
  - New injectors
  - 30K miles
  - 60K miles
  - 90K miles
- Study focusses on differences in transient spray pattern.



# PENETRATION DIFFERENCES BETWEEN ORIFICES IN OLD DIESEL INJECTORS



Constant Volume Chamber

- Images taken 135µs after SOI
- Clear deterioration of spray pattern after 60K miles

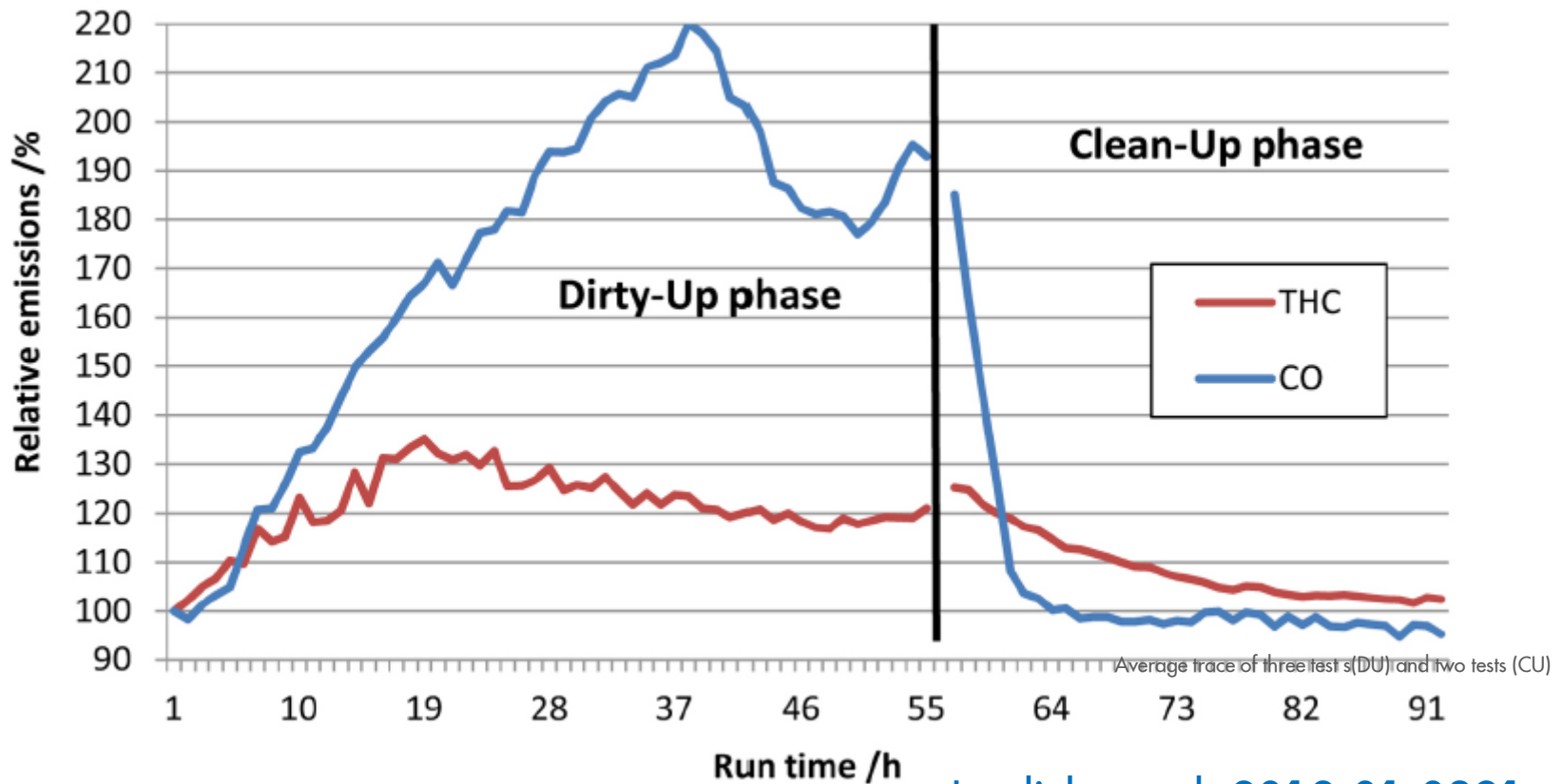
R. F. Cracknell, R. Wardle, R. Pos, L. Ganippa; Effect of diesel 3RD INTERNATIONAL ENGINE CONGRESS 2016 ,  
Baden Baden

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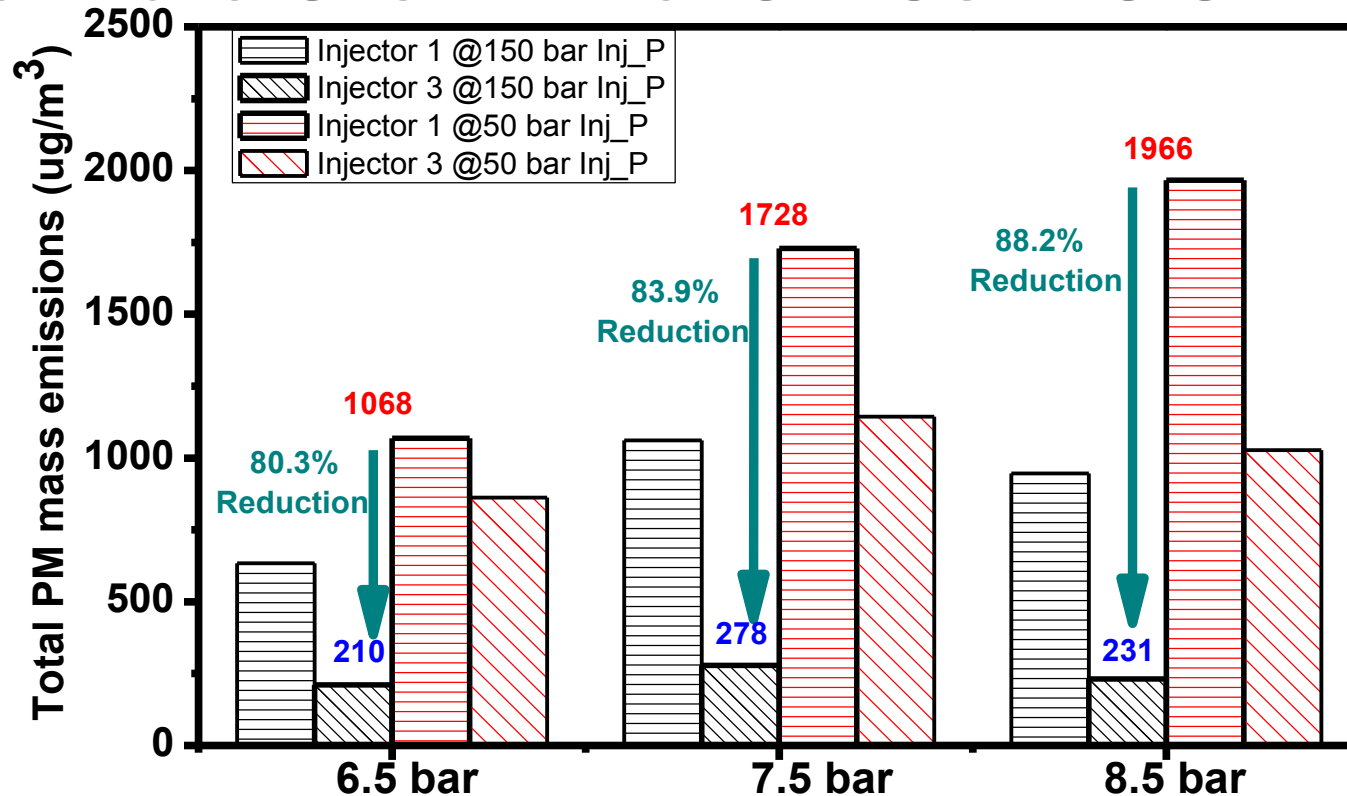
# CO AND THC EMISSIONS INCREASE WITH FOULED INJECTORS



Joedicke et al 2012-01-0391



# DISI INJECTORS – EFFECT OF FOULING ON PM

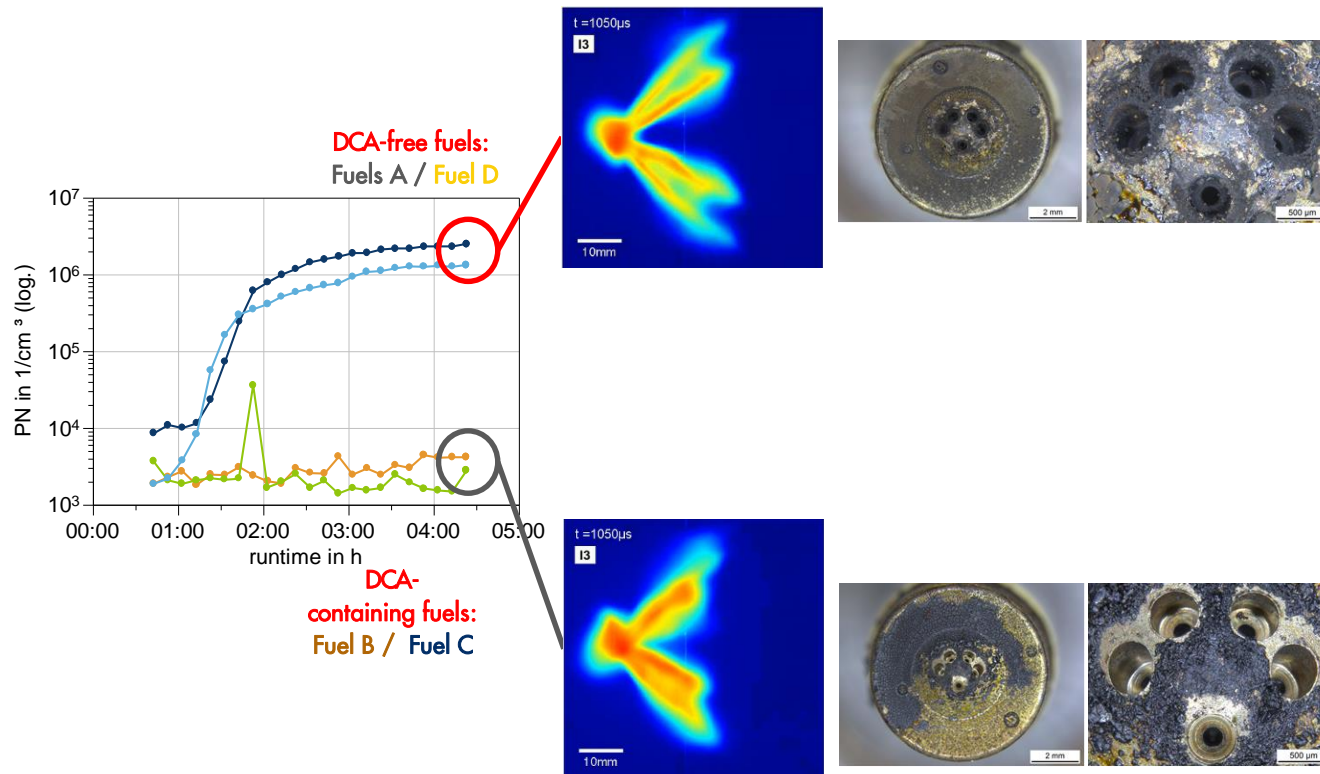


Injector 1 = fouled injector with 8.5% flow rate loss  
 Injector 3 = new injector

Impact of fuel and injection system on particle emissions from a GDI engine  
 Wang et al Applied Energy, Volume 132, 1 November 2014, Pages 178-191



# Test Results: Correlation between PMPN Emissions, Injector Fouling and Spray Characteristics



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**REDUCED POWER/EFFICIENCY**

**MORE EMISSIONS**

- Can be mitigated through Deposit Control Additives

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# Questions and Answers

Q&A

