Effect of Fuels on Compression Ignition Engine Particle Number, Size Distribution and DPF Filtration Efficiency

SOUTHWEST RESEARCH INSTITUTE®

Venkata Lakkireddy, Imad Khalek, Gina Buffaloe

Presented by

Imad Khalek, PhD, Institute Engineer

CE-CERT OSAR, April 17-18, 2025

Objective

- To investigate how various fuels impact particle emissions from upstream and downstream of a diesel particulate filter (DPF) of a diesel engine using nonroad transient cycles (NRTC and NRSC)
  - This work was recently published: SAE Papers: 2025-01-8502 & 2025-01-8503

Test Fuels

- A DOE of 9 fuels were used.
  - 4 fuels were whole/ complete.
  - The other five were formulations of 50% of fuels, which will include RDE, B100 and RME.
- ULSD was used as a baseline reference fuel and was tested twice

Fuel or Formulation	Abbreviation
Diesel (ULSD)	ULSD
Soy-based biodiesel	B100
Rapeseed-based biodiesel	RME
Renewable Diesel	RDE
50% B100 and ULSD	B50
50% RME and ULSD	RM50
50% RDE and ULSD	R50
50% B100 and RDE	B50R50
50% RME and RDE	R50RM50

Particle number and mass measurements

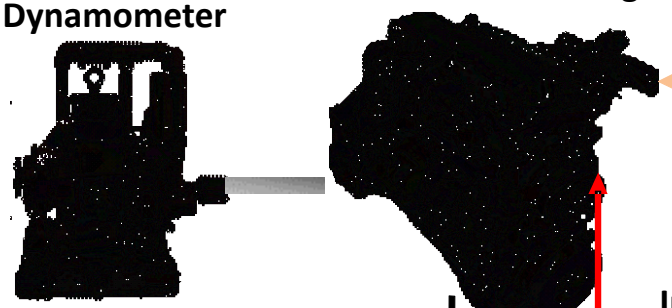
PM,PN measurement	Instrument	Location
Solid Particle Number	VPR (Dekati DEED 100 or ediluter Pro) with TSI CPC 3790, d50 23nm, TSI CPC 3750, d50 10 nm *(Euro VI/VII compliant, ISO 17025 calibrated)*	DPF In DPF Out
Solid Particle Size Distribution	TSI EEPS + Catalytic Stripper (not pictured)	DPF In DPF Out
Particulate Mass	Sierra BG3	DPF In DPF Out
Soot Mass Concentration	AVL Microsoot Sensor (*calibrated accdg to ICAO*)	DPF In

Experimental Setup

DPF-In Measurement Equipment
- Dekati ediluter + TSI CPC 3790, TSI CPC 3750
- TSI EEPS + catalytic stripper
- Sierra BG3
- AVL MSS

Dynamometer

2015 ISB Diesel Engine



Intercooler

Exhaust

Turbo

Fuel

Exhaust

DPF

DOC

NO_x/O_2 Sensor

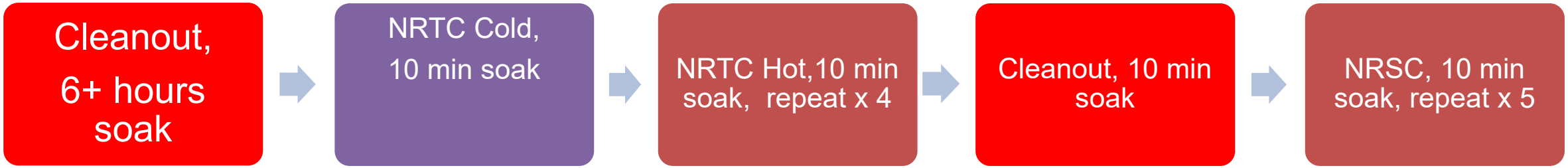
LFE

Conditioned Air

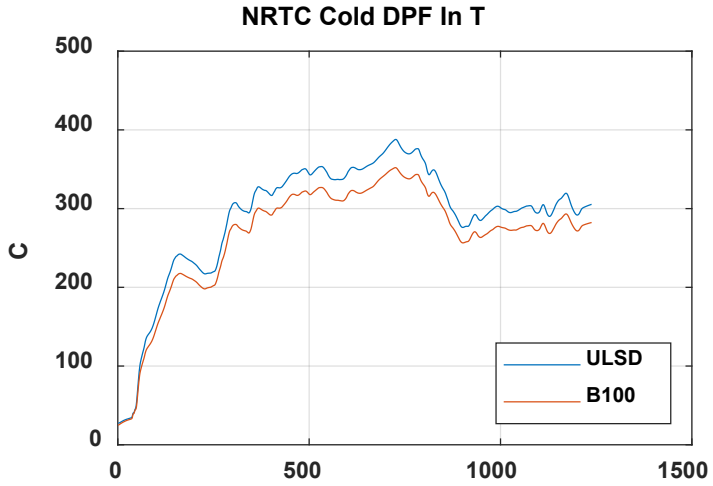
DPF-out Measurement Equipment
- Dekati DEED 100 + TSI CPC 3790, TSI CPC 3750
- TSI EEPS + catalytic stripper
- Sierra BG3

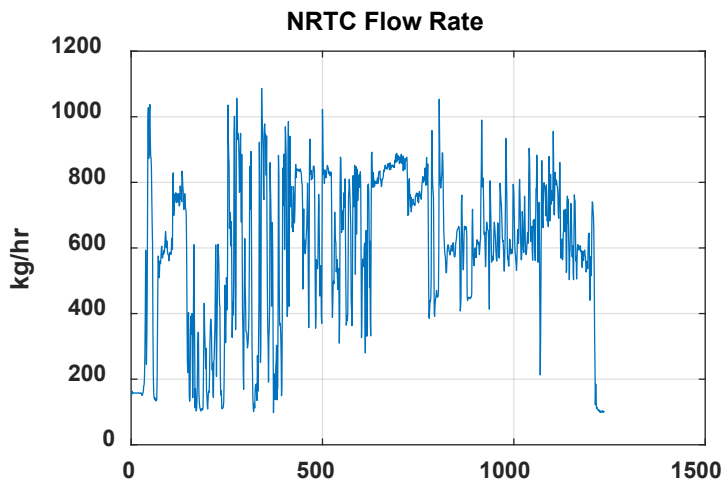
Test Cycle Sequence

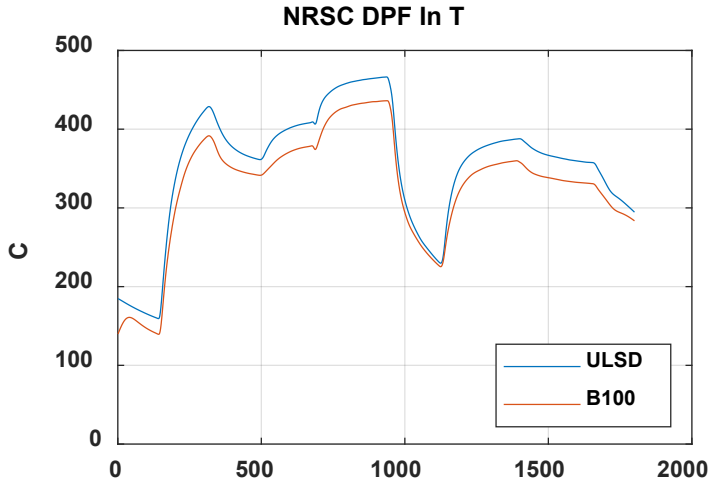
- Particle measurements were conducted during an NRTC/ NRSC sequence.
- A total of 10 cycles – 5 NRTC & 5 NRSC cycles each.
  - Each cycle (except NRTC cold) preceded by a 10 min soak.
  - DPF weights were measured after cleanouts and cycles to indicate soot loading on DPF

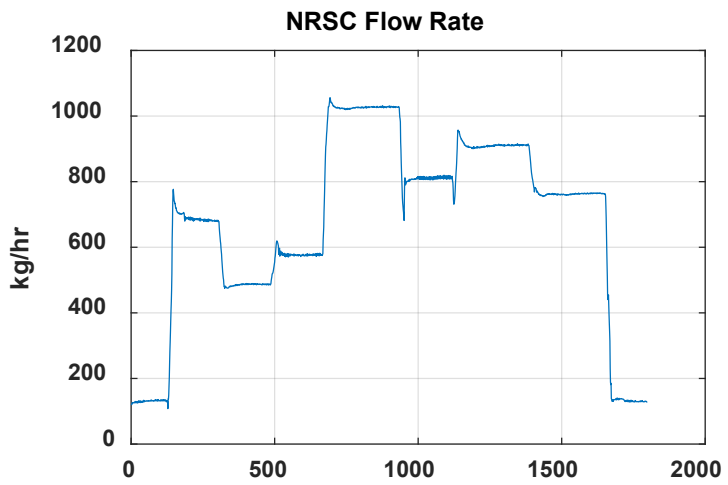


DPF-In Temperature and Exhaust Flow Rate





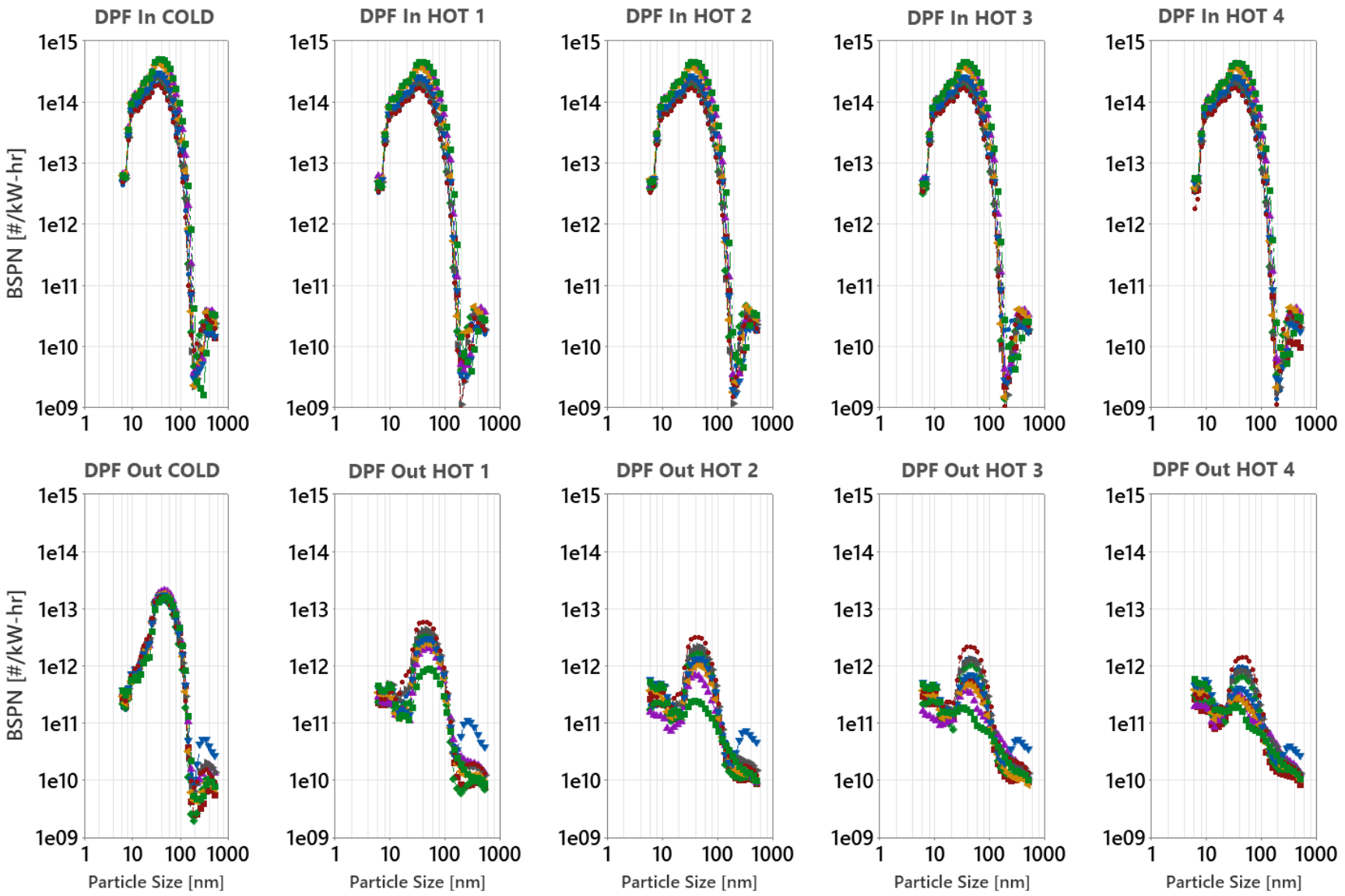




NRTC Number-Weighted Size Distribution (DPF-IN & DPF-Out)

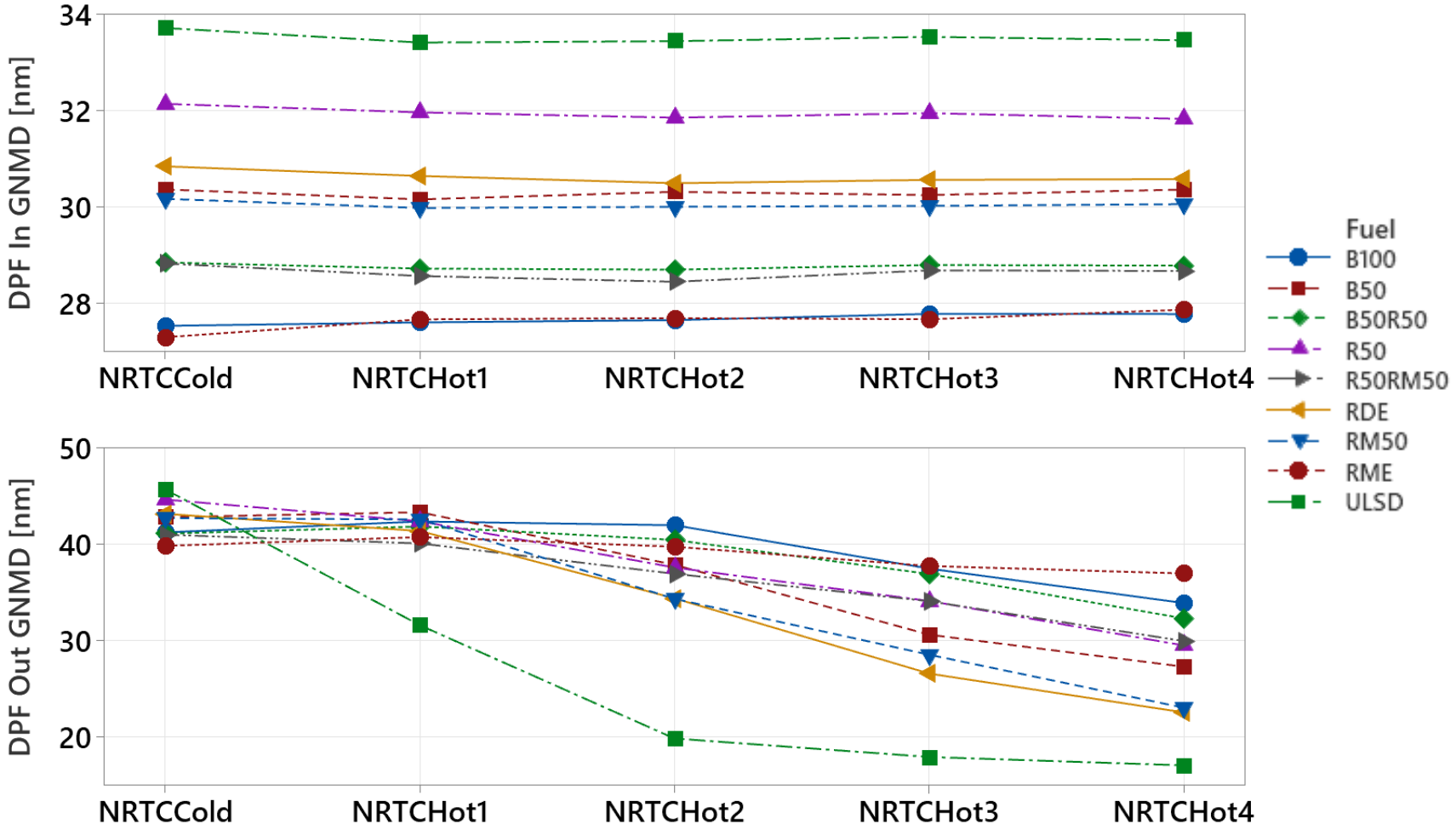
DPF-IN

DPF-Out



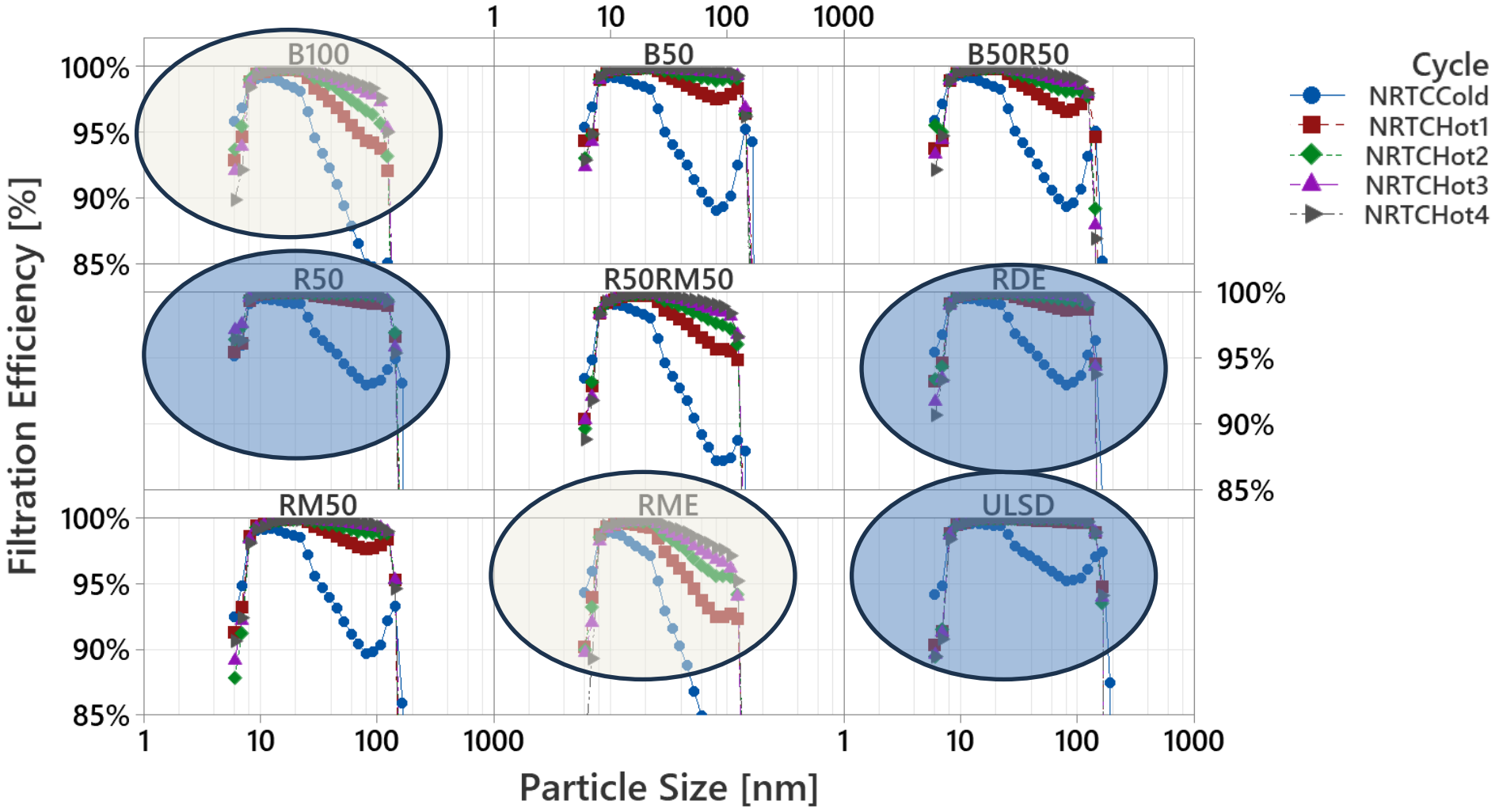
Geometric Number Mean Diameter (GNMD) for NRTC

- DPF-in GNMD was highest for ULSD and Lowest for the 100% biofuels. RDE GNMD was in between the two fuels.
- DPF-Out GNMD was the highest for NRTC Cold and progressively went down for hots. The biggest drop was observed for ULSD followed by RDE

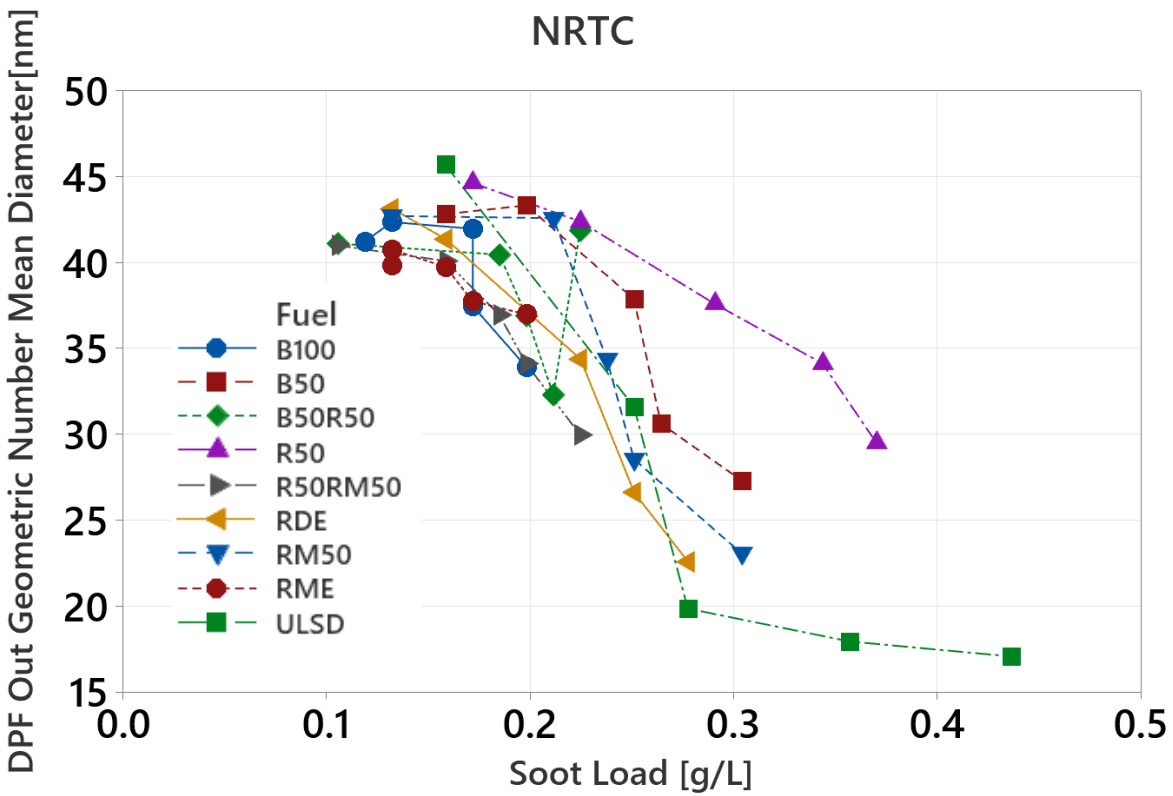


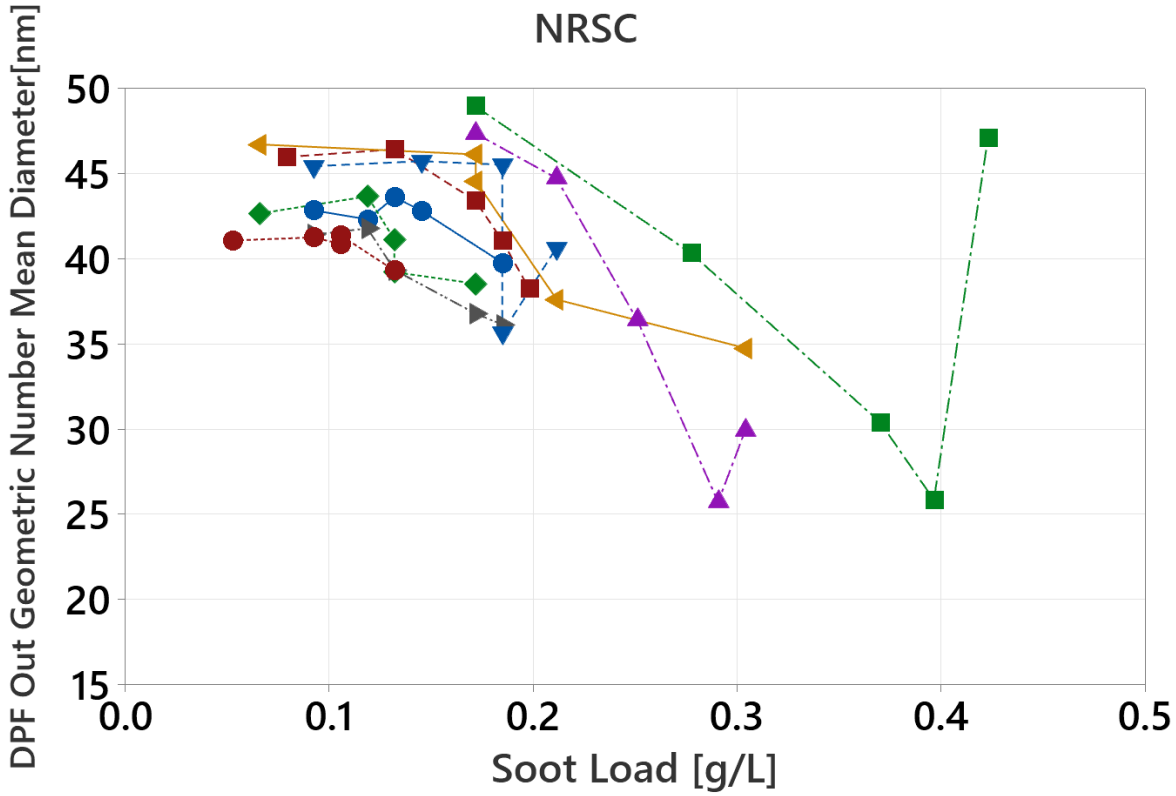
Filtration Efficiency for NRTCs

- Efficiency was lowest for ~100 nm particles (Filtration Theory)
- Efficiency was highest for ULSD and lowest for Biofuels



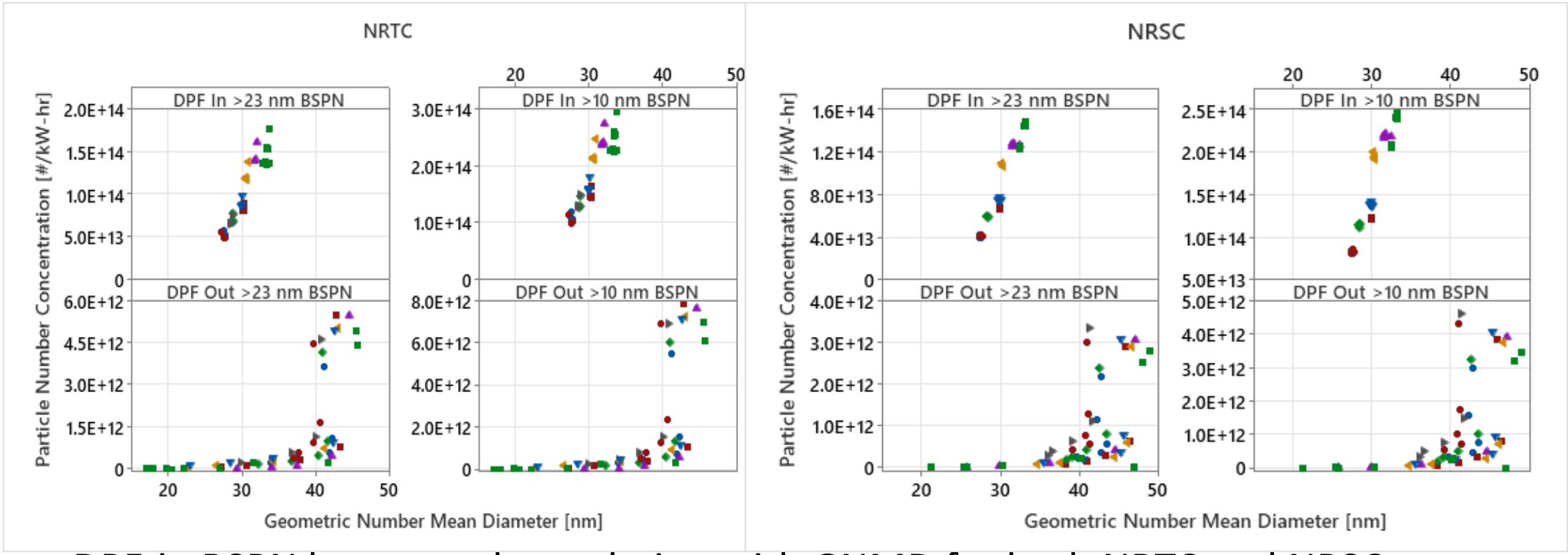
DPF-Out GNMD vs Soot Loading





- DPF-Out GNMD decreases with soot loading, as filtration moves from deep bed filtration to interception due to soot caking
- ULSD has the highest soot loading and B100 has the lowest

Solid Particle Number vs. GNMD



- DPF-in BSPN has a good correlation with GNMD for both NRTC and NRSC
- For DPF-Out, data did not fit a good correlation
- For DPF-In, ULSD showed the highest PN and B100 showed the lowest. This trend was reversed at the DPF-Out due to improved efficiency with soot loading for ULSD

Summary

- Diesel engine with DPF was tested with 9 fuels for 5 NRTC and 5 NRSC. For each fuel, a similar but different degreened DPF was used
- Solid particle Size distribution in the range from 5.6 nm to 560 nm was measured simultaneously at DPF-IN and DPF-Out locations
- Filtration Efficiency was highest for ULSD and lowest for biofuels. It improved drastically with soot loading on the DPF.
- **DPF-IN:**
  - PN was highest with ULSD and lowest with biofuels
  - GNMD was highest with ULSD and lowest for biofuels
- **DPF-Out**
  - PN was highest for B100 and lowest with ULSD (Opposite to DPF-IN)
  - GNMD went down with the increase of soot loading. It was the lowest for ULSD

Conclusions

- This work showed that the DPF is a dynamic system that results in different filtration efficiencies as a function of soot loading
- Although the use of biofuels and renewable fuels may be beneficial in terms of reduced soot loading, leading to reduced backpressure and less frequent regeneration of the DPF, it may lead to increased particle emissions at the DPF-OUT, compared to ULSD
  - Careful design of the DPF is needed to maintain the emissions performance target, taking into consideration the potential use of different fuels on an engine platform

Acknowledgements

- NGK Automotive Ceramics USA, Inc
  - Project sponsorship
- SwRI staff who contributed
  - with engine operation support,
  - emissions equipment installation and operation,
  - and department management for additional funding