

Soot Accumulation in Diesel Particulate Filters Using ULSD and B20 Biodiesel Fuel Blends

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Biodiesel Generated Particulate Matter

- Less PM by mass
- Different Composition
 - ⌘ Higher Organic Carbon Fraction
 - ⌘ Higher Oxygen Content
- Different Size Distribution
- Amorphous – irregular microstructure

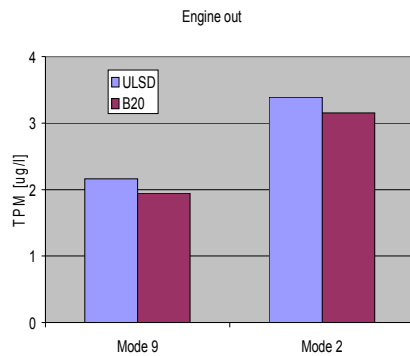


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Total Particulate Matter (TPM)

- Engine Out TPM decreases by 7-10% with B20 over ULSD.



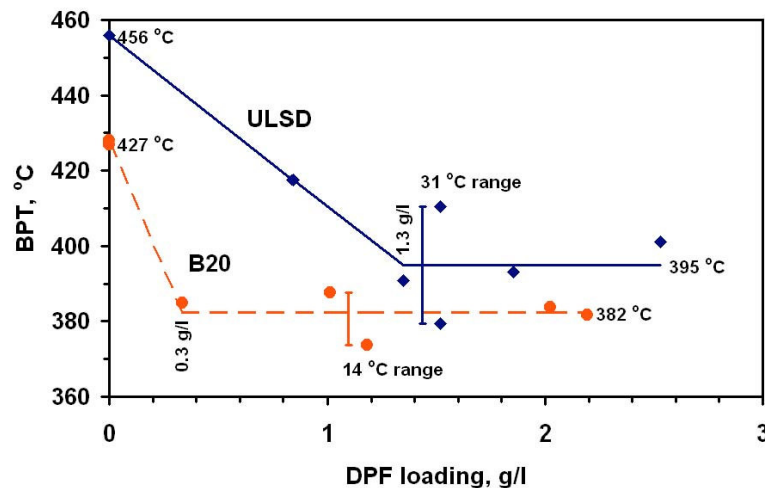
- All DPFs removed >99% of TPM by mass.
- No significant difference between fuels at DPF outlet.



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Balance Point Temperature Results



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DPFs and Biodiesel Emissions

Lower Balance Point Temperature
Attributed to:

- ⌘ More Reactive Chemical Composition
- ⌘ More Reactive Amorphous Microstructure



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Synopsis

- Studied emissions from the use of ULSD and B20 fuels
- Loaded DPFs for discrete times of 1, 2, 5 and 10 hours on an off-road heavy duty diesel engine
- Recorded pressure drop across filters and mass gained by filters
- Dissected filters and sampled channel walls
- Analyzed soot on channel walls at different stages of loading using Scanning Electron Microscopy



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Apparatus & Experimental Procedure

Engine and Fuels
DPF Specifications
Experimental Setup
Test Matrix
Filter Dissection and Sampling
Procedure



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Engine and Fuels

Engine:

- ❑ 3.9l four-cylinder turbocharged DI diesel engine – Tier 1 off-road specification

Fuels:

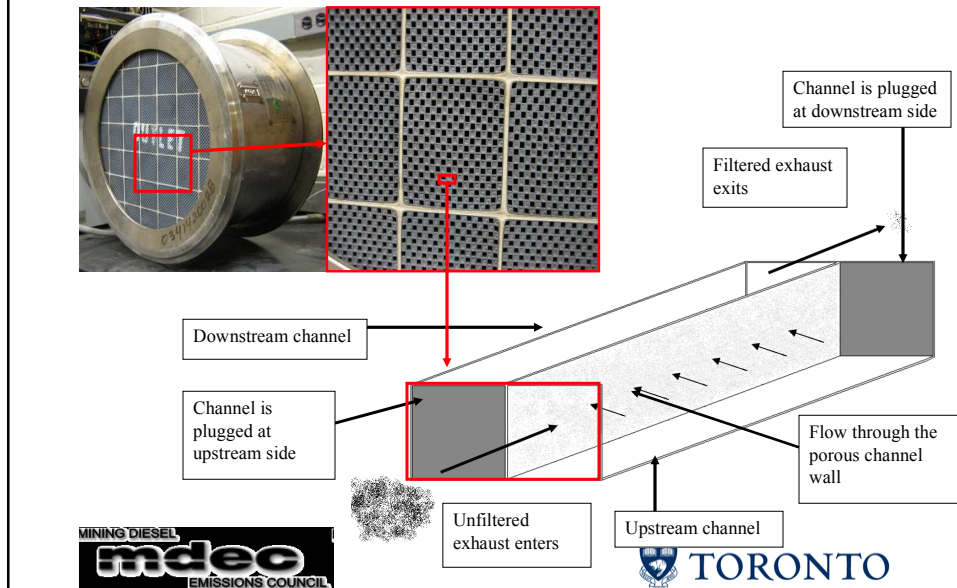
- ❑ ULSD – 2007 certification fuel
- ❑ B20 blend – 20% soy-based biodiesel in ULSD



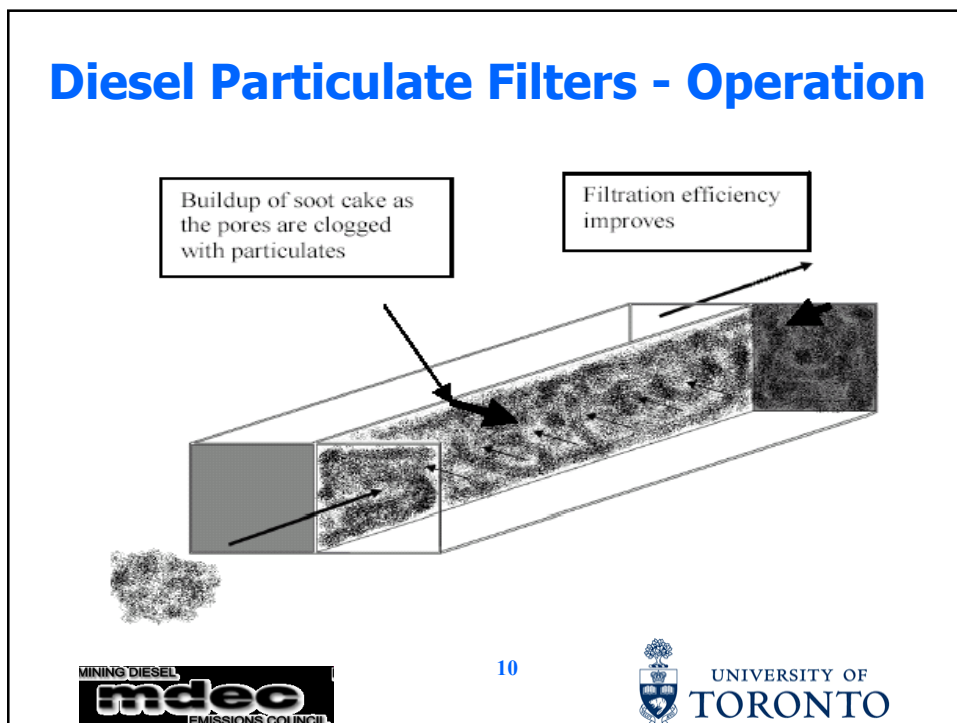
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Diesel Particulate Filters: Operation



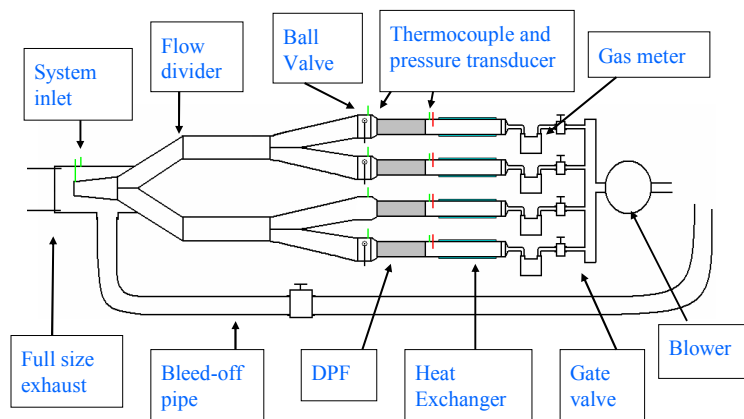
Diesel Particulate Filters - Operation



DPF Specifications

Material	Uncatalyzed Silicon Carbide (SiC)
Diameter	80mm
Length	130mm
Channel Density	150 cells/in ²
Channel Size	1.6 x 1.6 mm
Channel Wall Thickness	0.5mm

Experimental Setup

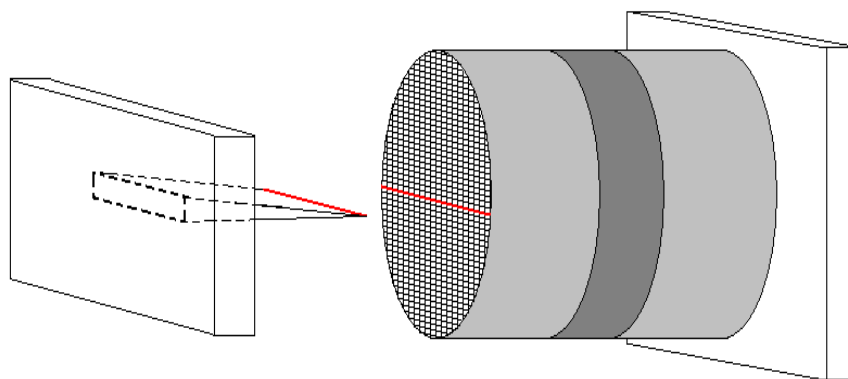


Test Matrix

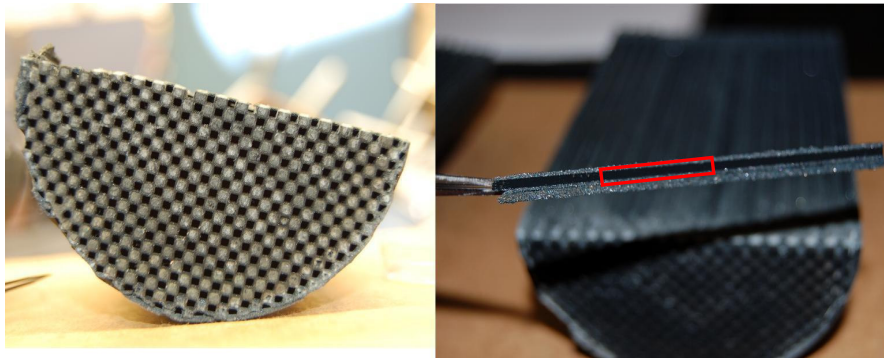
Loading Time (hrs)	ULSD	B20 Blend
0.5	x1	x0
1	x2	x3
2	x3	x3
5	x3	X3
10	x3	X3
<i>FMPS</i>	x3	X3

ISO Mode 9 used for loading
Uncatalyzed SiC Filters

Post-Trial Filter Dissection



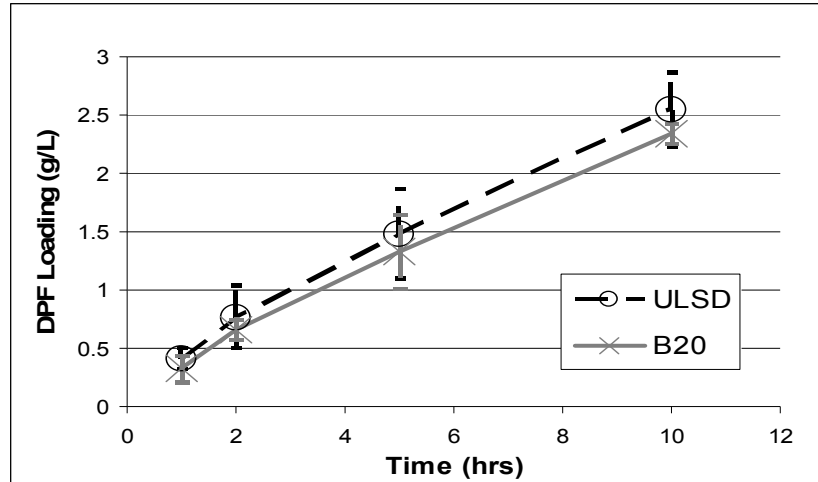
Filter Dissection and Channel Wall Sampling



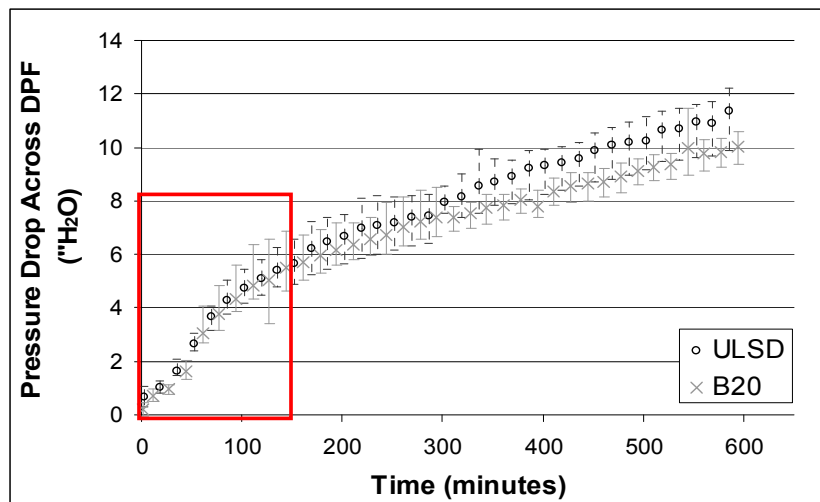
Analysis and Results

- Trial Data
 - ≡ Mass Accumulation
 - ≡ Pressure Drop Across Filters
- Post-Trial Analysis
 - Scanning Electron Microscopy

Fuel Effect on Trial Data: Mass Accumulation

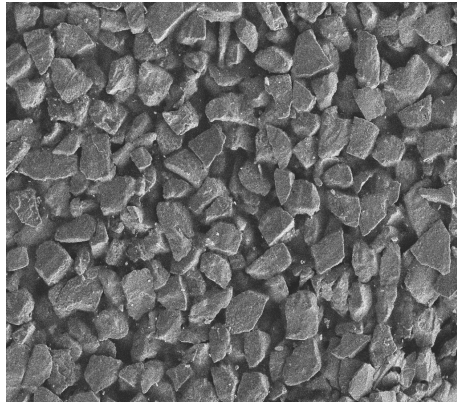


General Loading Trends from Trial Data: Pressure Drop Across Filters

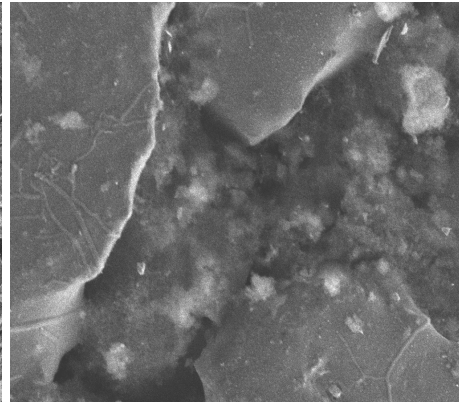


General Loading Trends from Scanning Electron Microscopy

2 Hour Loading



600µm



50µm



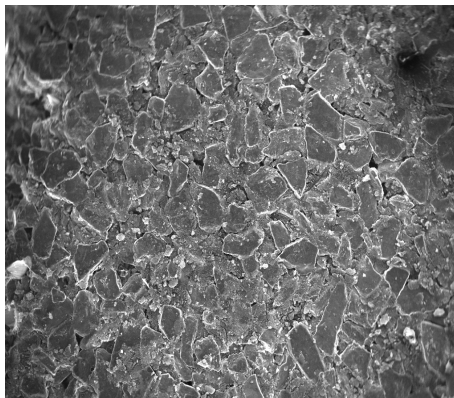
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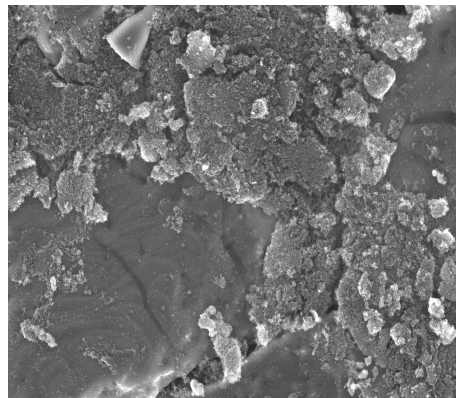
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General Loading Trends from Scanning Electron Microscopy

5 Hour Loading



600µm



50µm



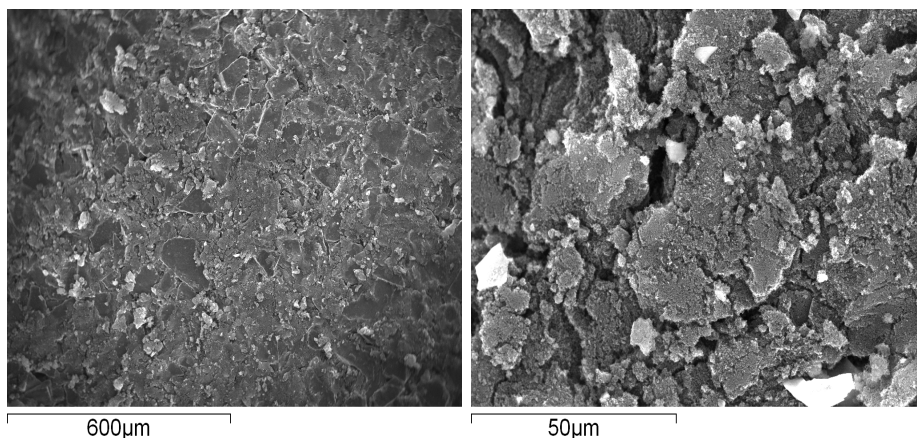
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General Loading Trends from Scanning Electron Microscopy

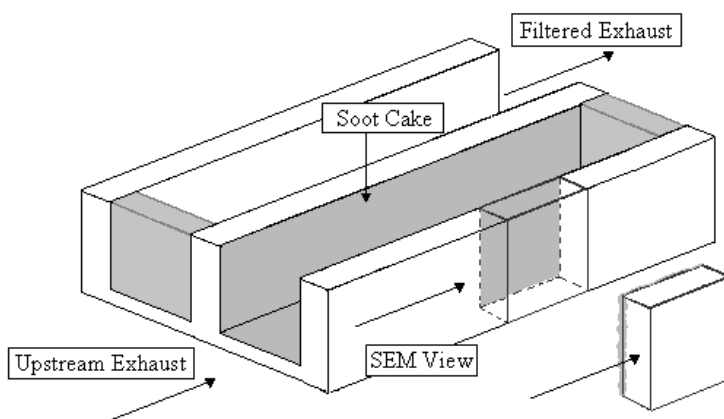
10 Hour Loading



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General Loading Trends from Cross Sectional SEM Images



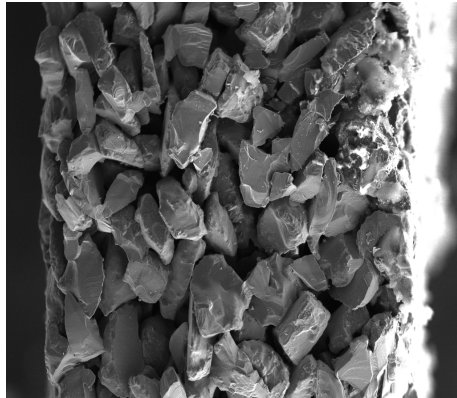
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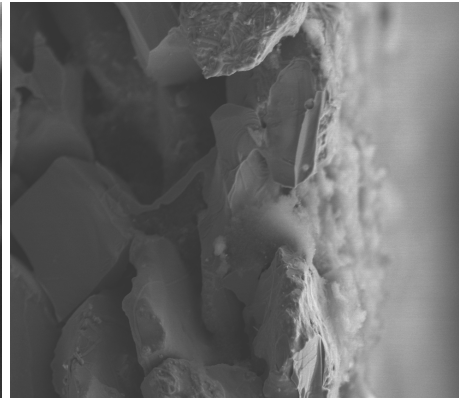
General Loading Trends from Cross Sectional SEM Images

10 Hour Loading – B20

10 Hour Loading – ULSD



300µm



100µm



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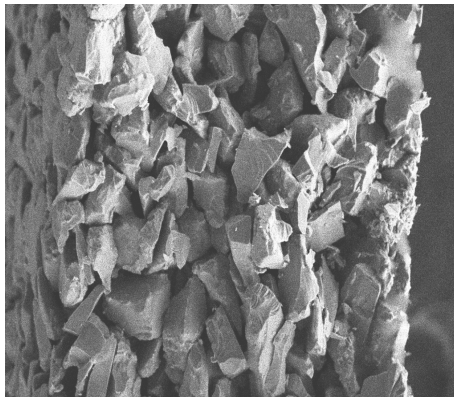


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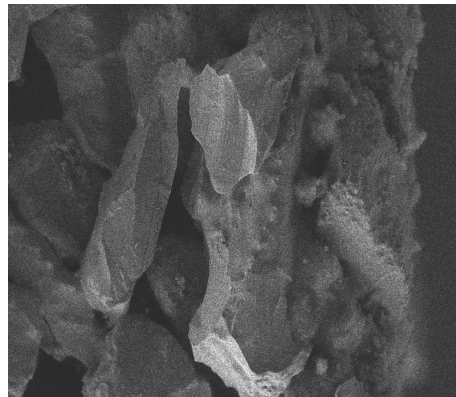
General Loading Trends from Cross Sectional SEM Images

2 Hour Loading – B20

10 Hour Loading – ULSD



300µm



100µm

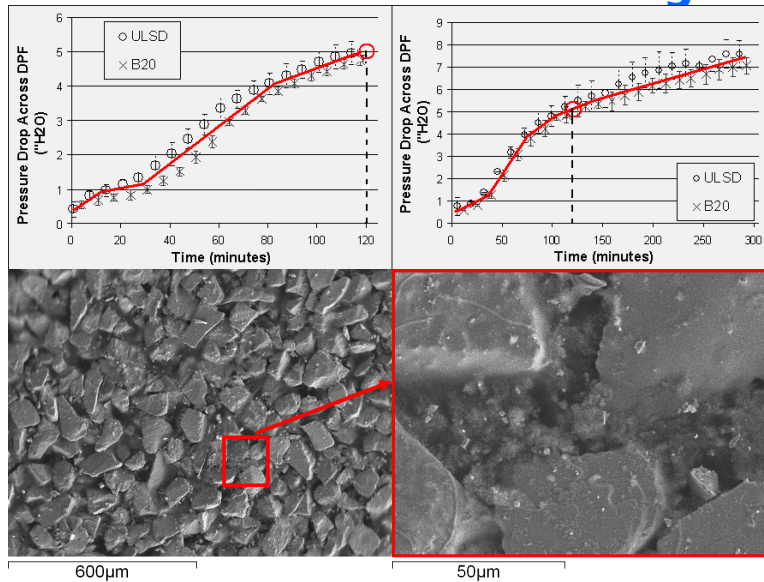


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Discussion of General Loading Trends

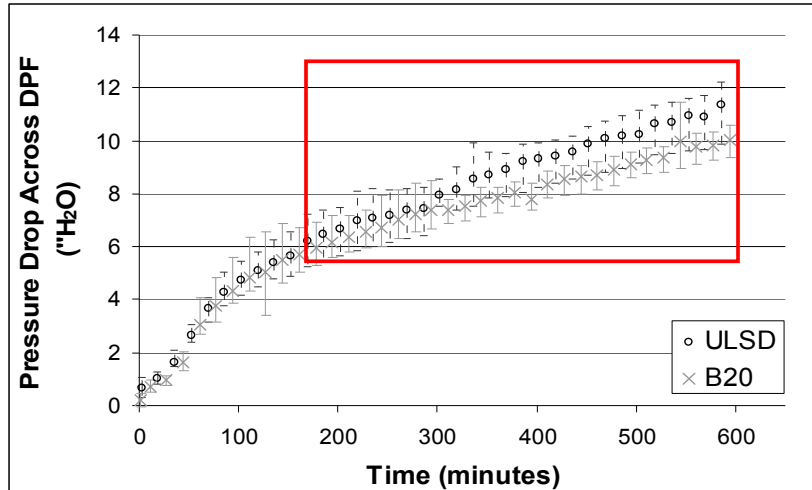


Discussion of General Loading Trends

Increasing Particulate Loading Showed:

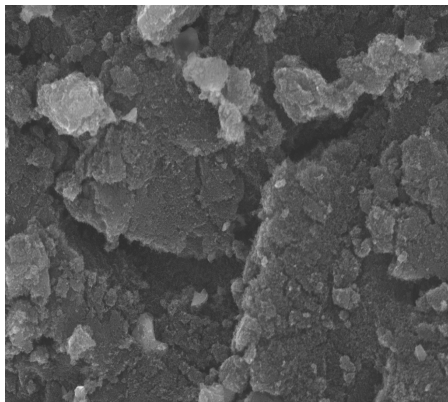
- ⇒ The initial non-linear portion of the pressure drop curve to be the result of the formation of a pore-bridge, clogging wall pores
- ⇒ The pore-bridge to be a shallow feature limited to the first $\frac{1}{4}$ of the depth of the channel wall
- ⇒ The growth of the soot cake is associated with the linear portion of the pressure drop curve

Fuel Effect on Trial Data: Pressure Drop Across Filters



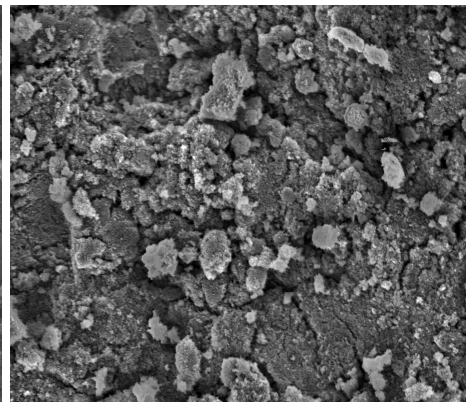
Fuel Effect on SEM Images: Soot Cake Features

10 Hour Loading – ULSD



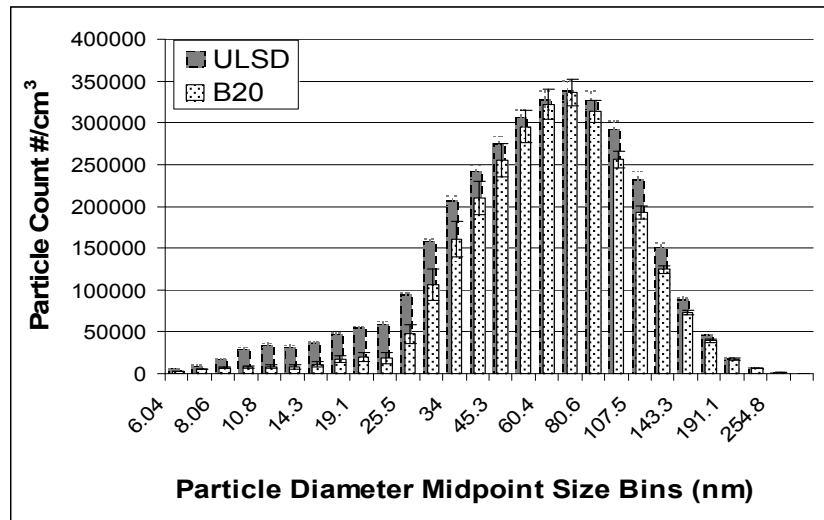
50µm

10 Hour Loading – B20



50µm

Fuel Effect on Trial Data: Particulate Size and Number Distribution



Discussion of Fuel Effect on DPF Loading

Use of B20 led to:

- ⌘ A particle size distribution with fewer nanoparticles (engine out)
- ⌘ Lower pressure drop across filters
- ⌘ Decreased particulate accumulation by mass (not S.S.)
- ⌘ A soot cake with more surface features consisting of smaller particulate clusters (SEM)
- ⌘ Evidence of a more amorphous soot cake (Raman Spectra)

Conclusions

Methodology

- ⇒ Fracturing technique shows great potential for further analysis of soot cakes on substrates

DPF Functionality

- ⇒ Results support hypothesis of increased reactivity of B20 generated PM
- ⇒ No significant graphitization of soot cake



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Thanks to Don Debelak and Liqtech NA for providing the SiC substrates



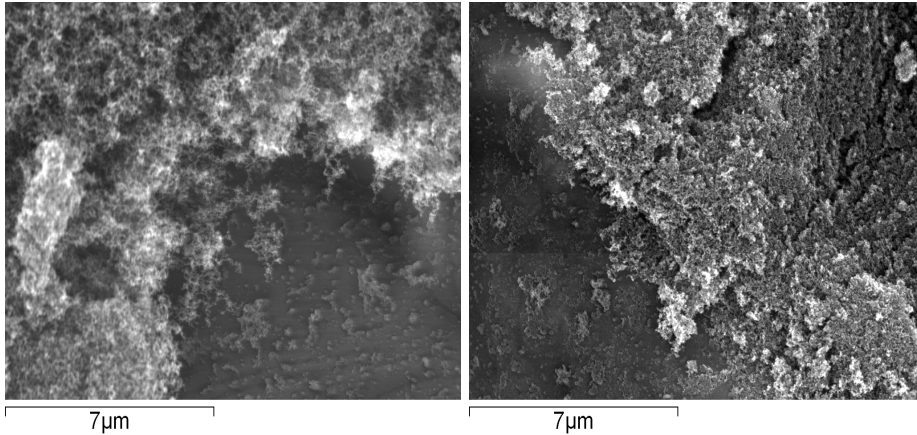
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General Loading Trends from High Magnification SEM: Cake Density

5 Hour Loading – ULSD

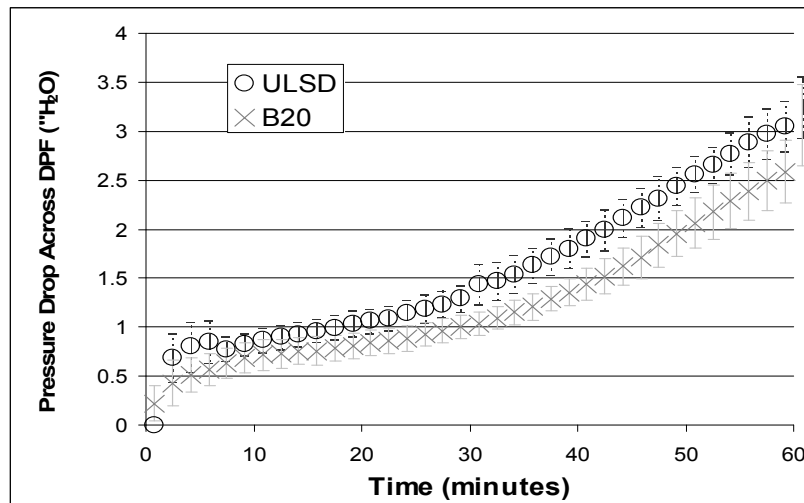
10 Hour Loading – B20



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Fuel Effect on Trial Data: Pressure Drop Across Filters



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