

## **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

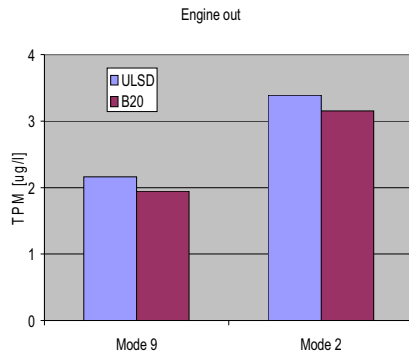


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## Total Particulate Matter (TPM)

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



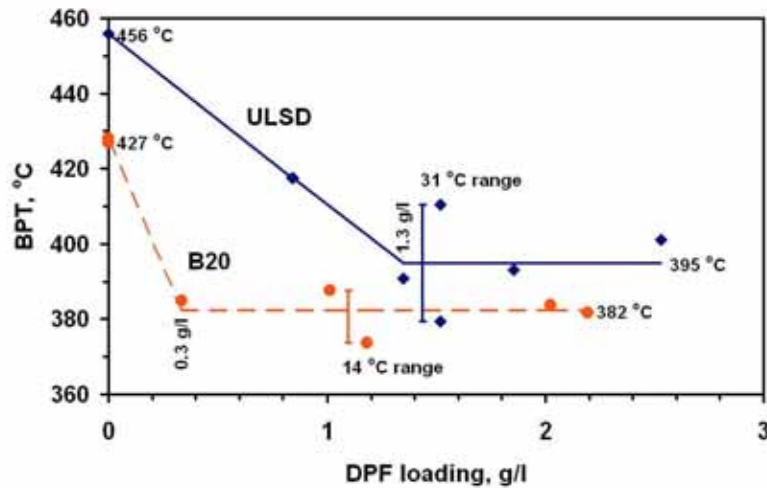
- All DPFs removed >99% of TPM by mass.
- No significant difference between fuels at DPF outlet.



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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:

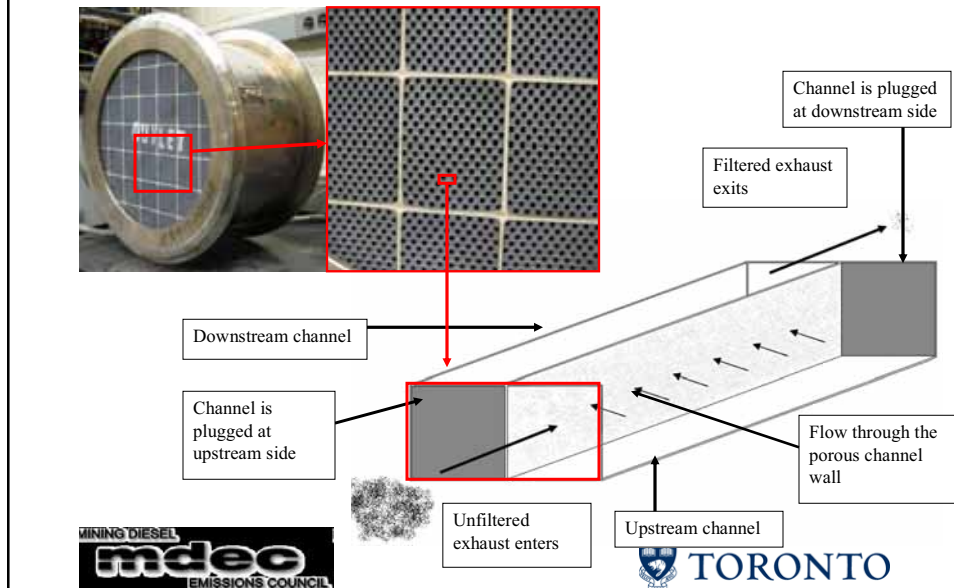
- ❑ ULSD – 2007 certification fuel
- ❑ B20 blend – 20% soy-based biodiesel in ULSD



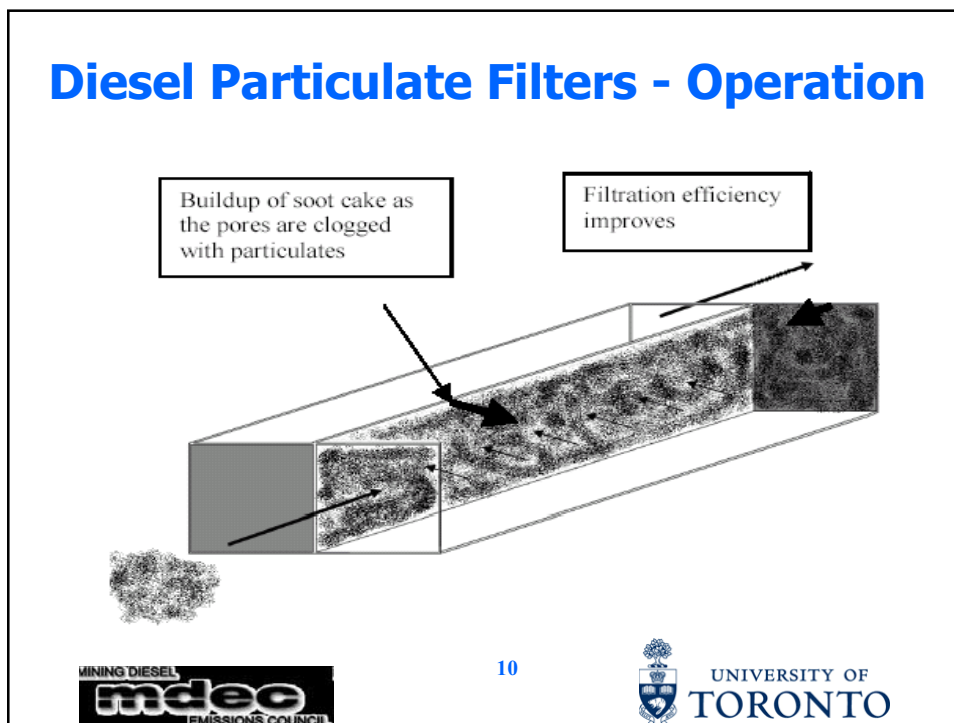
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## Diesel Particulate Filters: Operation



## Diesel Particulate Filters - Operation



## DPF Specifications

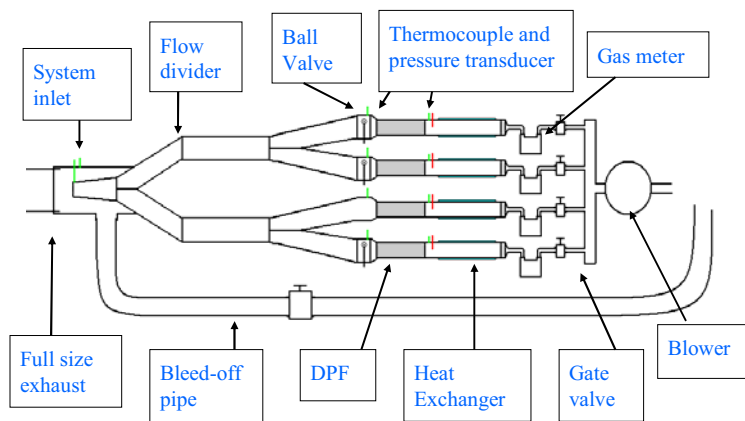
Material	Uncatalyzed Silicon Carbide (SiC)
Diameter	80mm
Length	130mm
Channel Density	150 cells/in <sup>2</sup>
Channel Size	1.6 x 1.6 mm
Channel Wall Thickness	0.5mm



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## Experimental Setup



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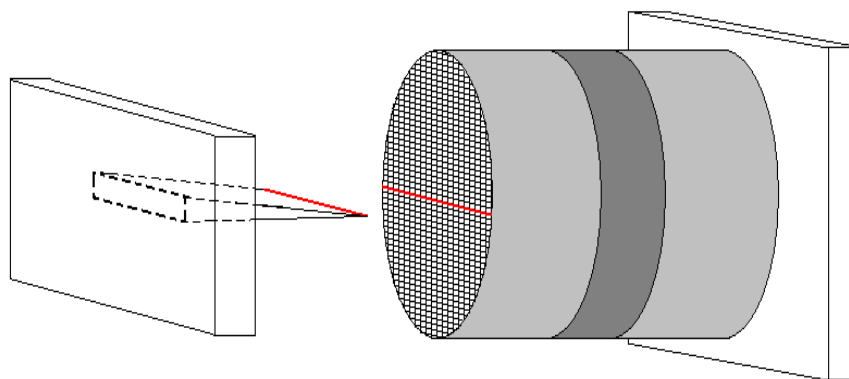


## Test Matrix

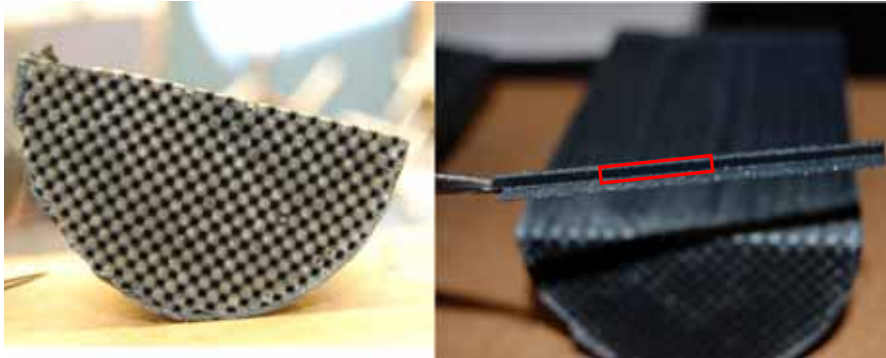
Loading Time (hrs)	ULSD	B20 Blend
0.5	x1	x0
1	x2	x3
2	x3	x3
5	x3	X3
10	x3	X3
<i>FMPS</i>	x3	X3

ISO Mode 9 used for loading  
Uncatalyzed SiC Filters

## Post-Trial Filter Dissection



## Filter Dissection and Channel Wall Sampling

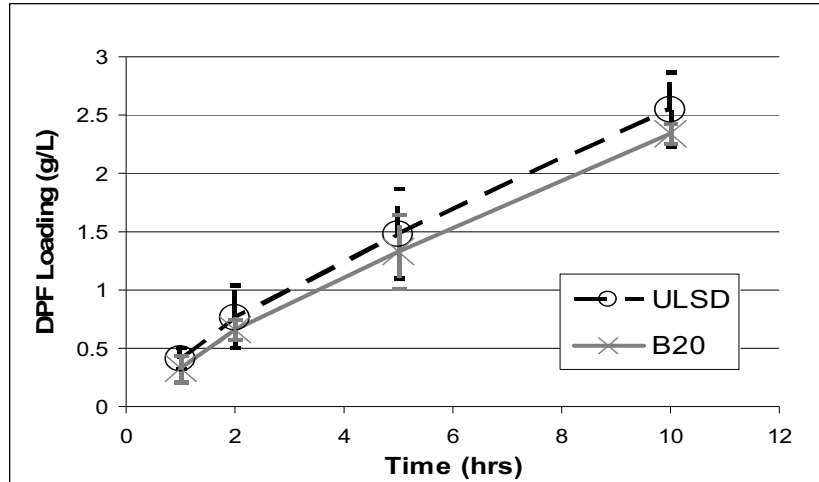


## Analysis and Results

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



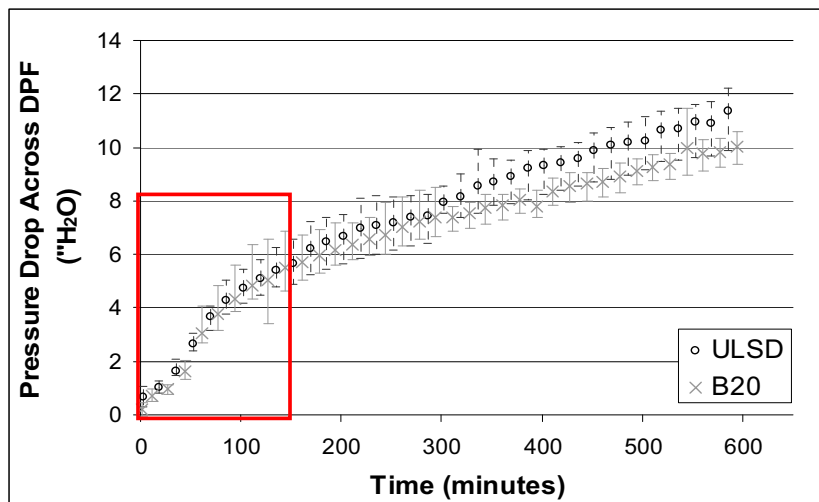
### Fuel Effect on Trial Data: Mass Accumulation



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### General Loading Trends from Trial Data: Pressure Drop Across Filters

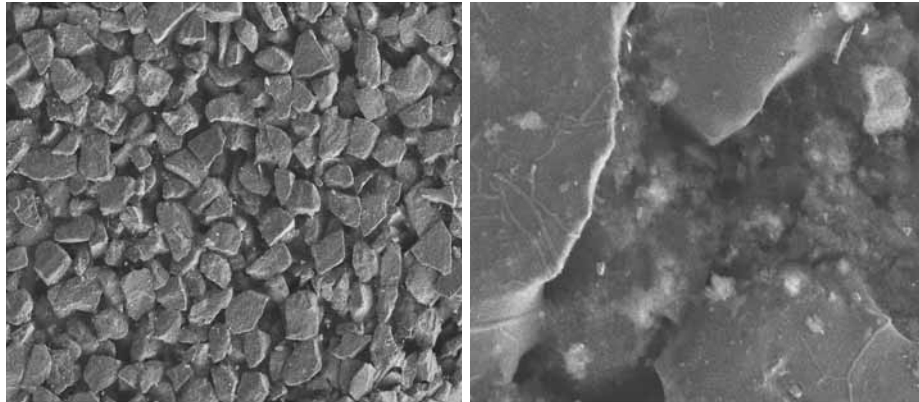


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## General Loading Trends from Scanning Electron Microscopy

2 Hour Loading

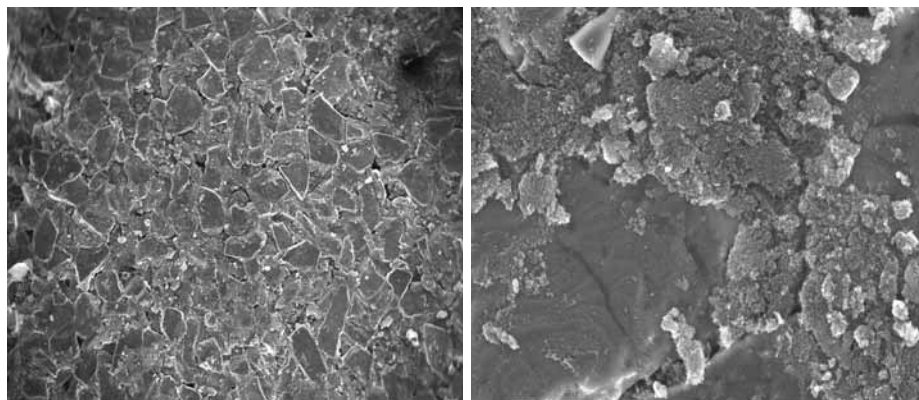


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## General Loading Trends from Scanning Electron Microscopy

5 Hour Loading

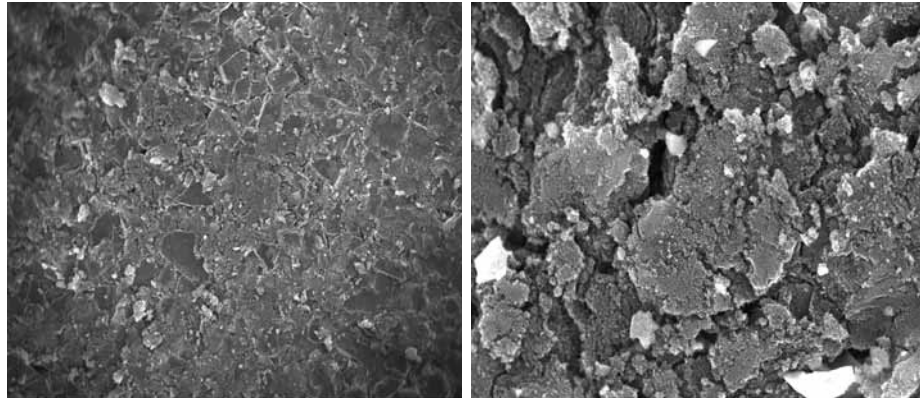


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## General Loading Trends from Scanning Electron Microscopy

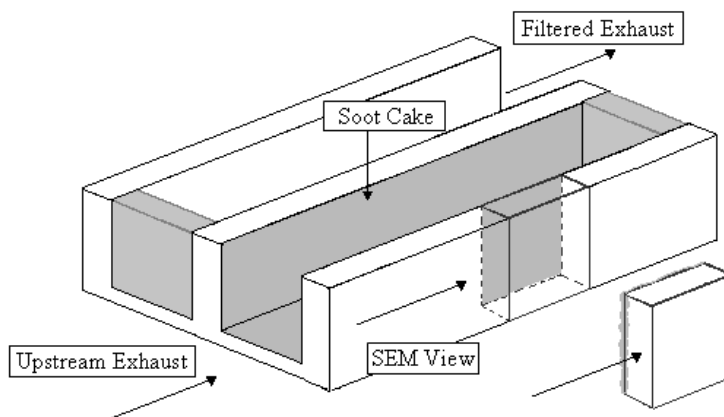
10 Hour Loading



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## General Loading Trends from Cross Sectional SEM Images



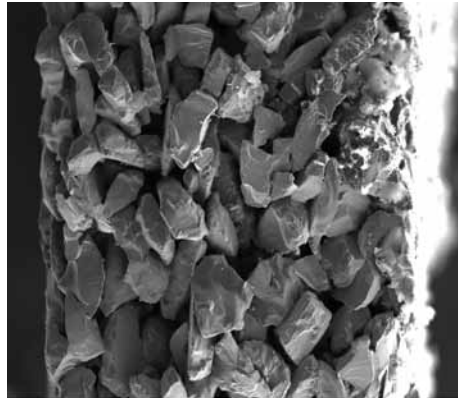
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## General Loading Trends from Cross Sectional SEM Images

10 Hour Loading – B20

10 Hour Loading – ULSD



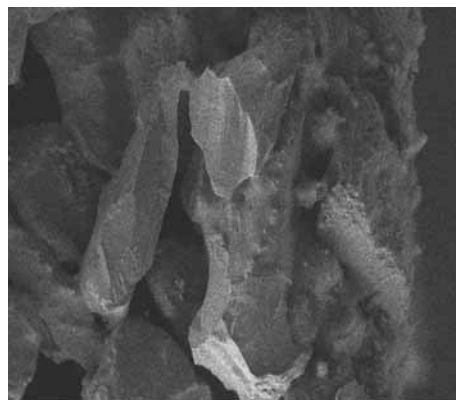
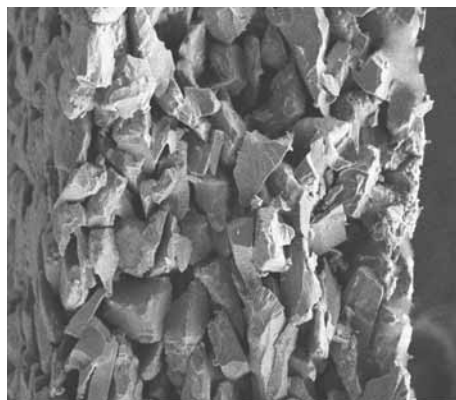
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## General Loading Trends from Cross Sectional SEM Images

2 Hour Loading – B20

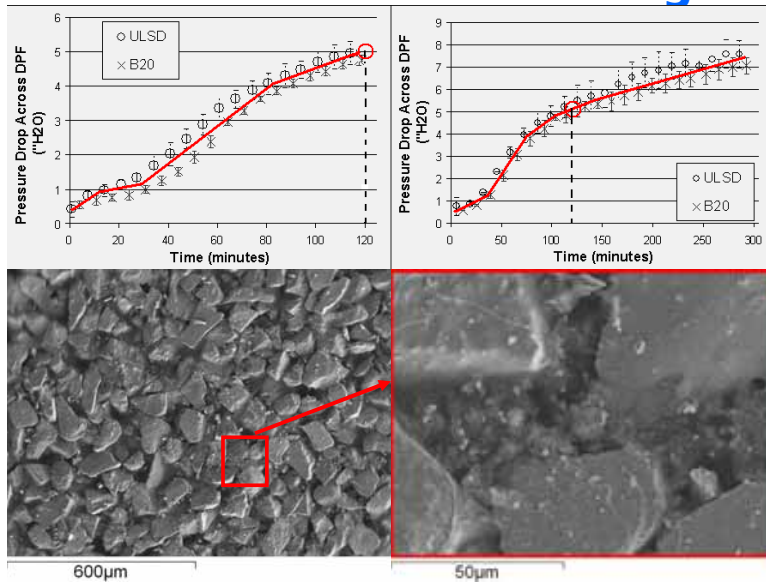
10 Hour Loading – ULSD



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## Discussion of General Loading Trends

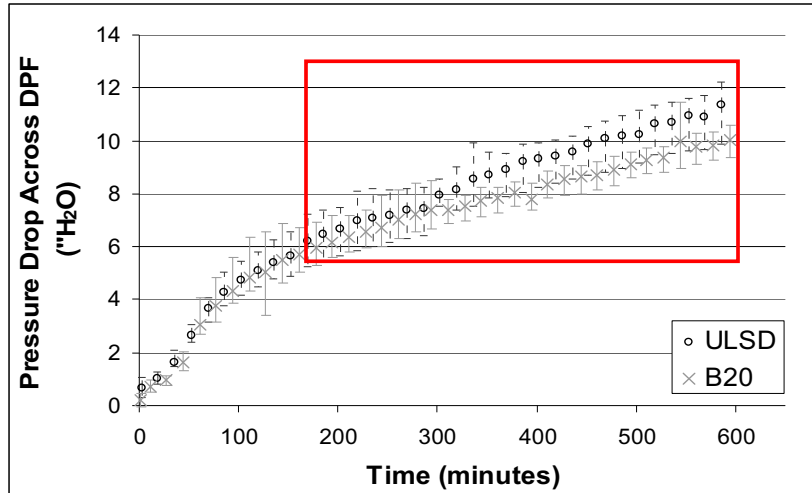


## Discussion of General Loading Trends

### 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



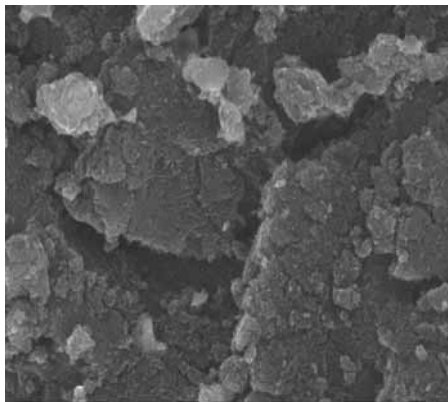
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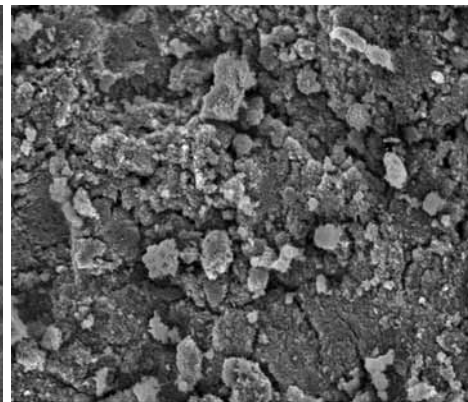
### Fuel Effect on SEM Images: Soot Cake Features

10 Hour Loading – ULSD

10 Hour Loading – B20



50µm

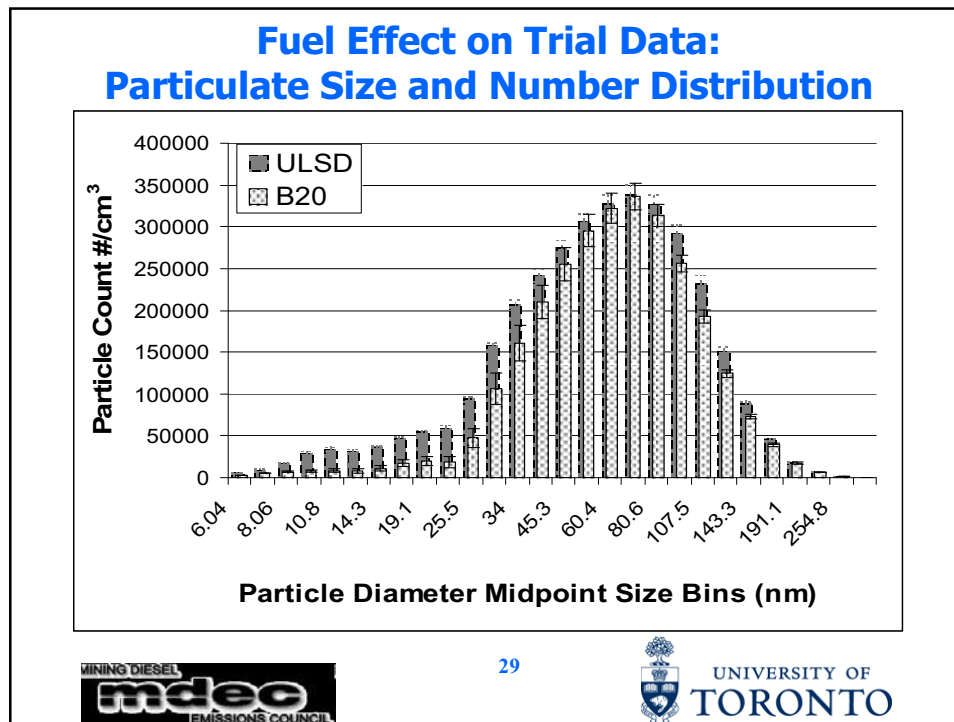


50µm



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## 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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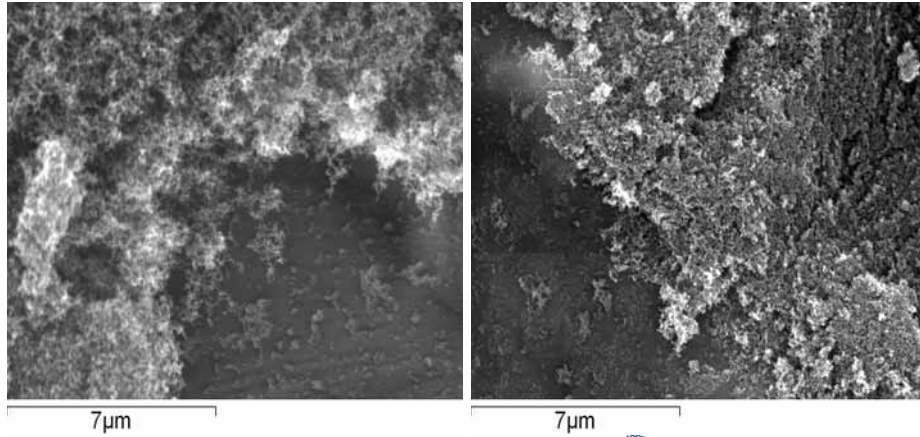




## General Loading Trends from High Magnification SEM: Cake Density

5 Hour Loading – ULSD

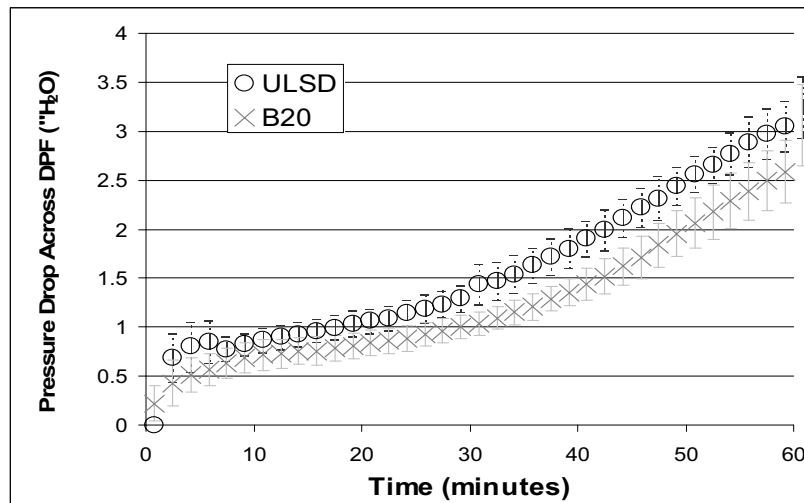
10 Hour Loading – B20



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## Fuel Effect on Trial Data: Pressure Drop Across Filters



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