# Effect of Biodiesel Blended Diesel Fuel (B20) on Retrofitted Diesel Particulate Filter Behavior

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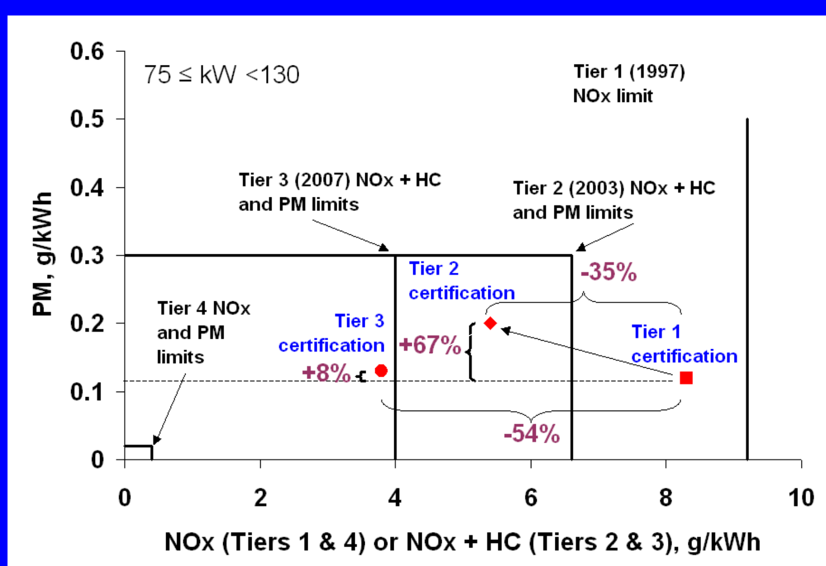
## Overview

- Introduction
- Review
- Project Summary
- Results
- Conclusions

# Introduction

- DPF retrofits are important for achieving significant PM reductions from existing equipment.
- Tighter emission standards do not always ensure significant PM reductions from one engine generation to the next.

# Introduction - Importance of Retrofits.



## Introduction - Goals of this research.

- An important aspect of any retrofitted DPF is the ability to passively (no operator interaction) keep it clean.
  - Balance point temperature (BPT)
    - exhaust gas temperature where rate of particulate accumulation = rate of particulate oxidation.
  - Over the longer term, it is important for the DPF to regenerate fully
    - avoid slow accumulation of difficult to oxidize particulate.
- What is the effect of biodiesel (B20)?

## Introduction - Goals of this research.

- This research wanted to answer the following questions:
  - What is the impact of the amount of soot accumulated on the DPF (soot loading) on Balance point temperature (BPT) of a passive filter?
  - How does B20 affect BPT and its dependence on soot loading?
  - Does B20 show an effect on the ability of a DPF to stay clean?

# Review

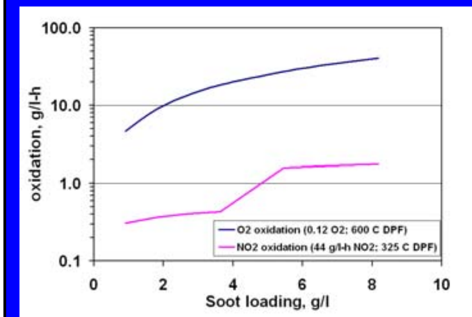
- DPF regeneration mechanisms
- Biodiesel & aftertreatment systems

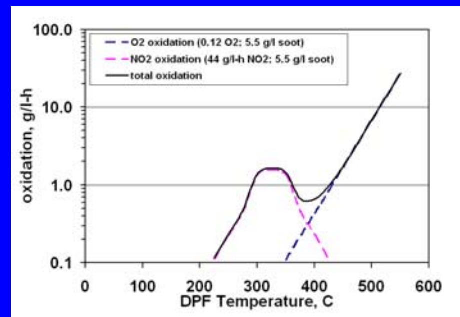
# Review-DPF regeneration mechanisms

| MECHANISM | GEOMETRIC REACTION CHARACTERISTICS | ACTIVE TEMPERATURE RANGE, deg.C | ACTIVATION ENERGY, KJ/MOLE | USEFUL FOR |
|---|---|---|---|---|
| OXIDATION BY NO2 | Proportional to NO2 available and soot layer thickness | 200 to 400 | 20 to 40 | Passive or engine management |
| CATALYTICALLY ENHANCED OXIDATION | Proportional to catalyst surface area | >300 deg.C | Depends on catalyst | Passive, engine management, or HC injection |
| DIRECT OXIDATION | Proportional to total soot present | > 450 deg.C | 95 to 170 | HC injection |

Source: Bunting et al., DEER 2002

## Review-DPF regeneration mechanisms




Source: Wills 2007, US 2007/0056273

## Review-Biodiesel & Aftertreatment Systems

| | | |
|---|---|---|
| **Lower DPF BPT** | soot morphology | |
| **Catalyst deactivation** | may contain elements that can poison/deactivate catalysts | P - catalyst poison<br>K - deactivate vanadia SCR catalysts, destabilizing effect on refractory oxides in the washcoat, corrode cordierite catalyst substrates<br>Ca - affect SCR catalysts |
| **Increased DPF ash loading** | high allowable levels of inorganic impurities | more of a concern with high level blends |
| **Engine oil dilution** | especially when filter regeneration relies on post-injection of fuel in the cylinder | higher boiling temperature increases the likelihood of liquid fuel spray reaching the cylinder wall during late-cycle injection |
| **DPF regeneration reliability** | lower heating value means sufficient heat may not be generated to fully regenerate DPF | more of a concern with high level blends |
| **DPF soot loading estimate** | calculation of DPF soot mass less accurate | regeneration may not start when needed |

Source: DieselNet.com

## Project Summary

- 1997 Cummins B3.9 non-road engine. Meets US EPA Tier 1 emission standards for $75 \leq kW < 130$ engines.
- Fuels:
  - ultra low sulphur diesel (ULSD)
  - 20% by volume soy based biodiesel in ULSD (B20)
- DPF:
  - ECS filter with a low precious metal loading

## Project Summary

- Engine conditions:
  - ISO 8178 Mode 9, intermediate speed and 25% load used for DPF loading.
    - Low exhaust temperature – 236 $^{o}$C at DPF inlet
  - load and speed increased to ISO 8178 Mode 2, rated speed and 75% load
    - Final exhaust temperature ~> 450 $^{o}$C at DPF inlet

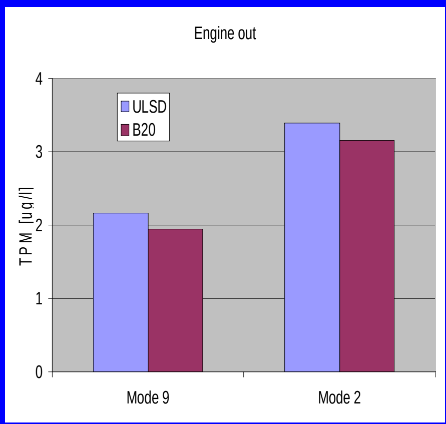
# Fuel Properties

| | ULSD | B100 |
|---|---|---|
| *Flash Point, °C* | 74.0 | 175.0 |
| *Distillation, 90% Recovered, °C* | 249.7 | 349.9 |
| *Kinematic Viscosity at 40 °C, mm2/s(cSt)* | 1.764 | 3.968 |
| *Sulfur, mg/kg* | <2.0 | <2.0 |
| *Cetane Number* | 49.8 | 54.6 |
| *Cloud Point, °C* | -67.2 | -1 |

B100 blended with the ULSD to give B20

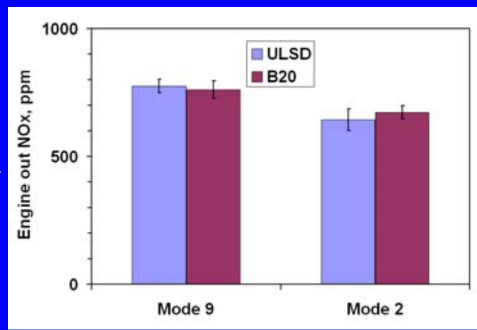
# Total Particulate Matter (TPM)

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



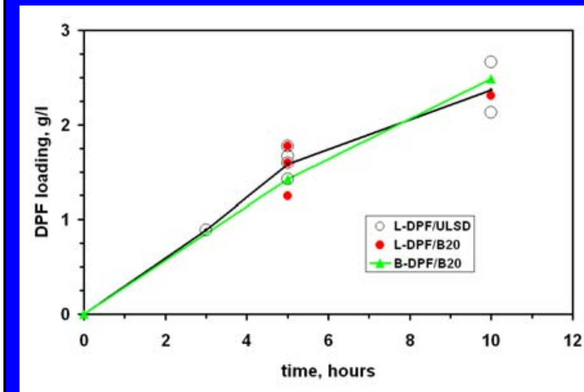
# Engine-out NOx

- Engine-out NOx emissions shows no statistically significant difference between B20 and ULSD.




# Results

# Soot loading



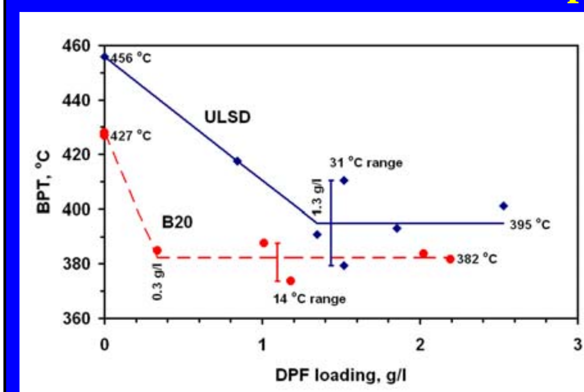

Soot loading rate is:

- Unaffected by fuel. Effect of fuel differences may be less important than variations.
- Unaffected by catalyst.

Loading at Mode 9 (236ºC exhaust temperature).

Low precious metal loaded DPF & uncatalysed DPF.

# Balance Point Temperature

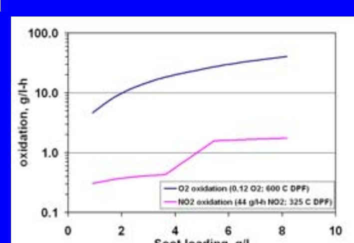



B20 impact on BPT:

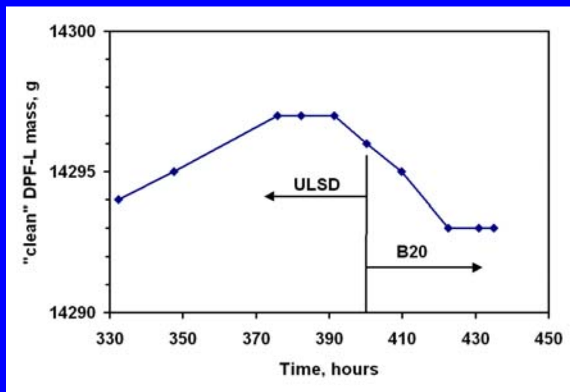
- ~13ºC lower.
- more consistent (14ºC vs. 31ºC range)
- less affected by soot loading.

Loading at Mode 9.

Low precious metal loaded DPF.



## Ability to Regenerate Fully




B20 showed improved ability to fully regenerate the DPF.

Loading at Mode 9.

Low precious metal loaded DPF.

## Conclusions

- After an initial decrease, BPT shows little impact from soot loading up to about 2.5 g/l soot. This is consistent with known nature of $NO_2$ oxidation mechanism.
- DPF catalyst showed no effect on soot accumulation at exhaust temperatures ~235$^{o}$C.

## Conclusions

- B20 showed:
  - ~13 °C lower BPT.
  - Less variability in BPT
  - Less impact from initial soot loading on BPT when oxidation was by $NO_2$.
  - Improved ability to fully regenerate the DPF
- DPF soot accumulation was not significantly affected by B20 in this study.

## Effect of biodiesel on aftertreatment systems

| | | |
|---|---|---|
| **Lower DPF BPT** | soot morphology | Less sensitive to soot loading. Lower variability. |
| **Catalyst deactivation** | may contain elements that can poison/deactivate catalysts | P - catalyst poison<br>K - deactivate vanadia SCR catalysts, destabilizing effect on refractory oxides in the washcoat, corrode cordierite catalyst substrates<br>Ca - affect SCR catalysts |
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| **Engine oil dilution** | especially when filter regeneration relies on post-injection of fuel in the cylinder | Higher boiling temperature increases the likelihood of liquid fuel spray reaching the cylinder wall during late-cycle injection. |
| **DPF regeneration reliability** | lower heating value means sufficient heat may not be generated to fully regenerate DPF | More of a concern with high level blends. May be partially offset by more complete regeneration. |
| **DPF soot loading estimate** | calculation of DPF soot mass less accurate | Regeneration may not start when needed. |

# Acknowledgments


- Partners:
  - Engine Control Systems Ltd.
- Sponsors:
  - E-Tech
  - NRCan
  - Auto21