The Effect of Biodiesel Fuel Blends on Diesel Particulate Filter Operation

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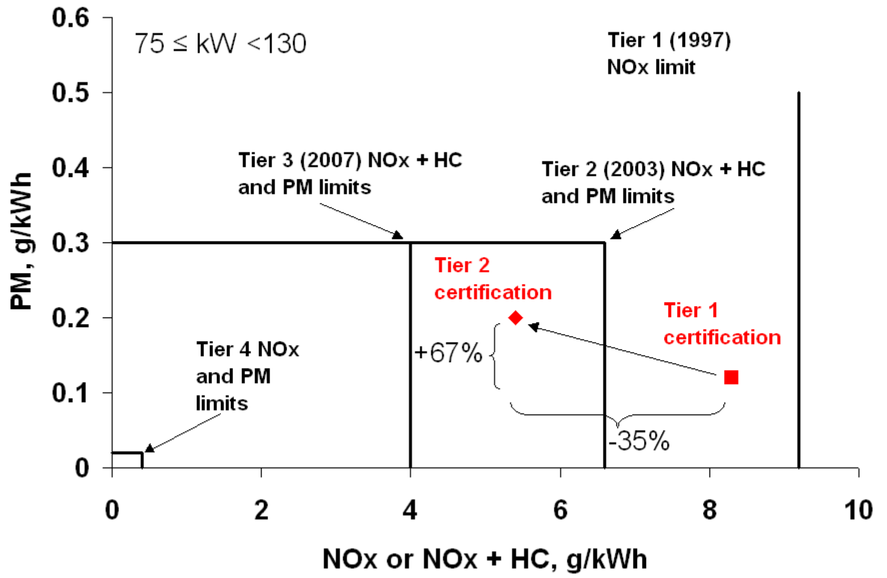
Project Summary

- Interested in the effect of retrofitting an existing non-road diesel engine with a Diesel particulate filter (DPF).
- Impact of biodiesel/diesel fuel blend (B20) on engines retrofitted with DPFs.

Importance of retrofits

- Diesel engines have a long life
- Engines meeting tighter emission standards may not always guarantee that all emissions are lower.

Retrofits to control PM are important because tighter emission standards do not always ensure that all emissions will be lowered.



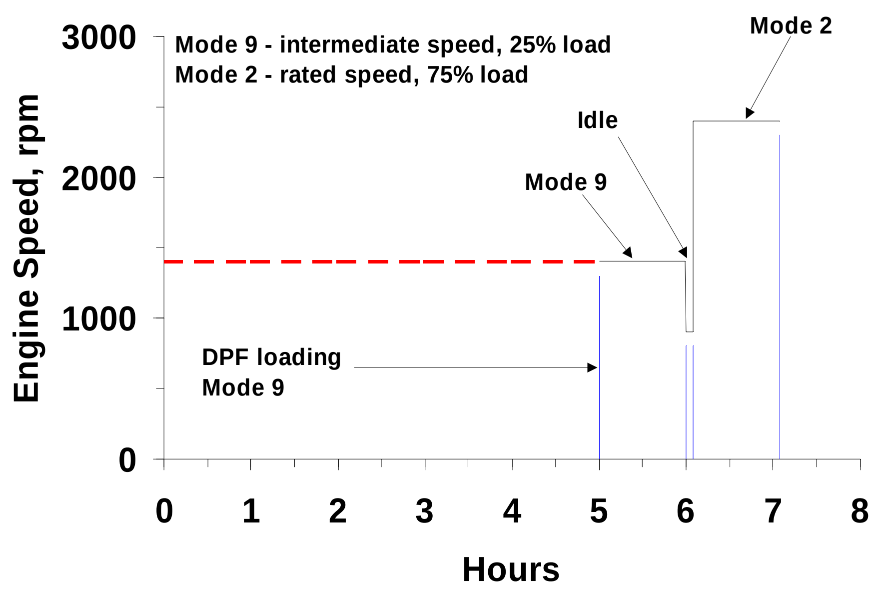
Project Summary

- 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)
- Three DPFs:
  - bare filter with no catalyst
  - filter with a low precious metal loading
  - filter with high precious metal loading

Project Summary

- Two engine conditions from ISO 8178 examined:
  - Mode 9, intermediate speed and 25% load.
    - Low exhaust temperature – 236 ^{o}C at DPF inlet
  - Mode 2, rated speed and 75% load
    - High exhaust temperature – 434 ^{o}C at DPF inlet

Test cycle



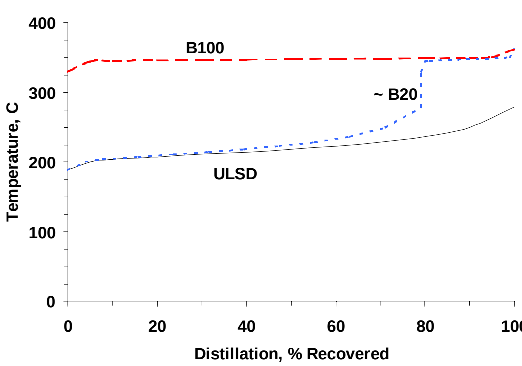
Measurements

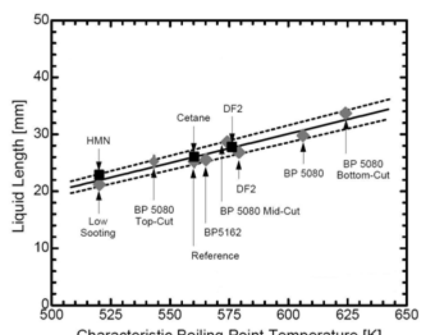
- Gaseous emissions:
  - engine out NO_x
  - DPF outlet NO, THC, O_2, CO_2
- Particulate emissions
  - Gravimetric TPM
  - OC/EC
  - Sulphate
  - CPC count
  - SMPS size distribution
  - Dekati 2 stage diluter, FPS-4000

Fuel Properties

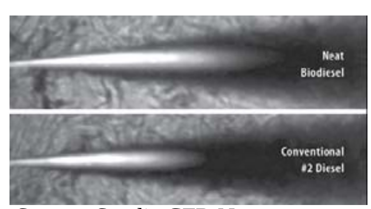
	ULSD	B100
Flash Point, °C	74.0	175.0
Distillation, 90% Recovered, °C	249.7	349.9
Kinematic Viscosity at 40 °C, mm2/s(cSt)	1.764	3.968
Sulfur, mg/kg	<2.0	<2.0
Cetane Number	49.8	54.6
Cloud Point, °C	-67.2	-1

Fuel Distillation Characteristics





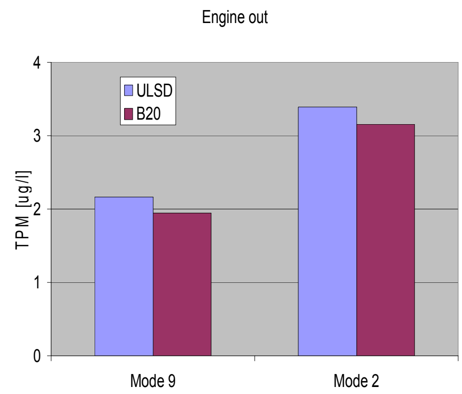
Source: SAE 980809



Source: Sandia CFR News

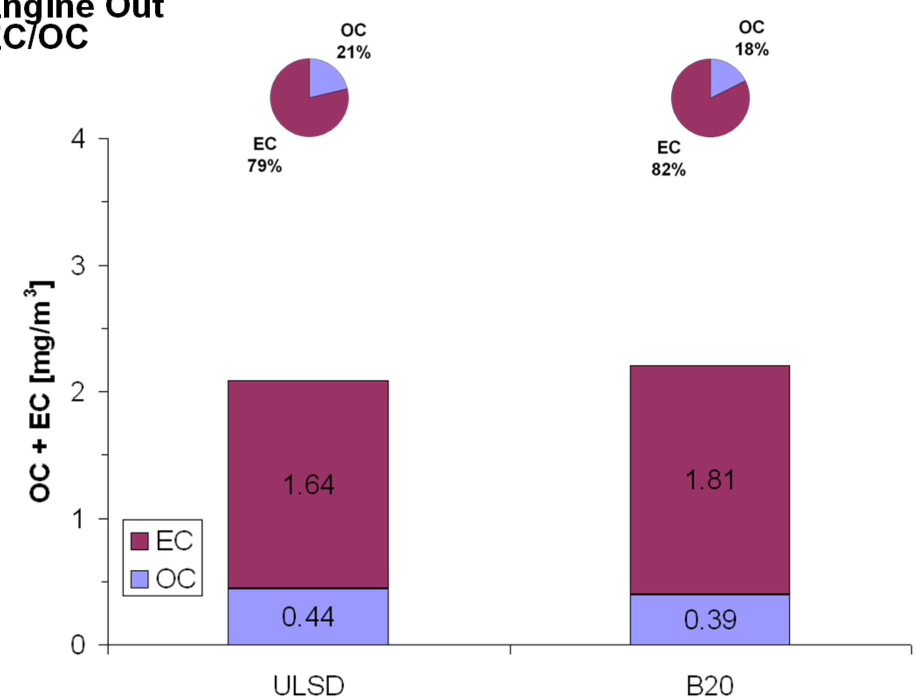
Total Particulate Matter (TPM)

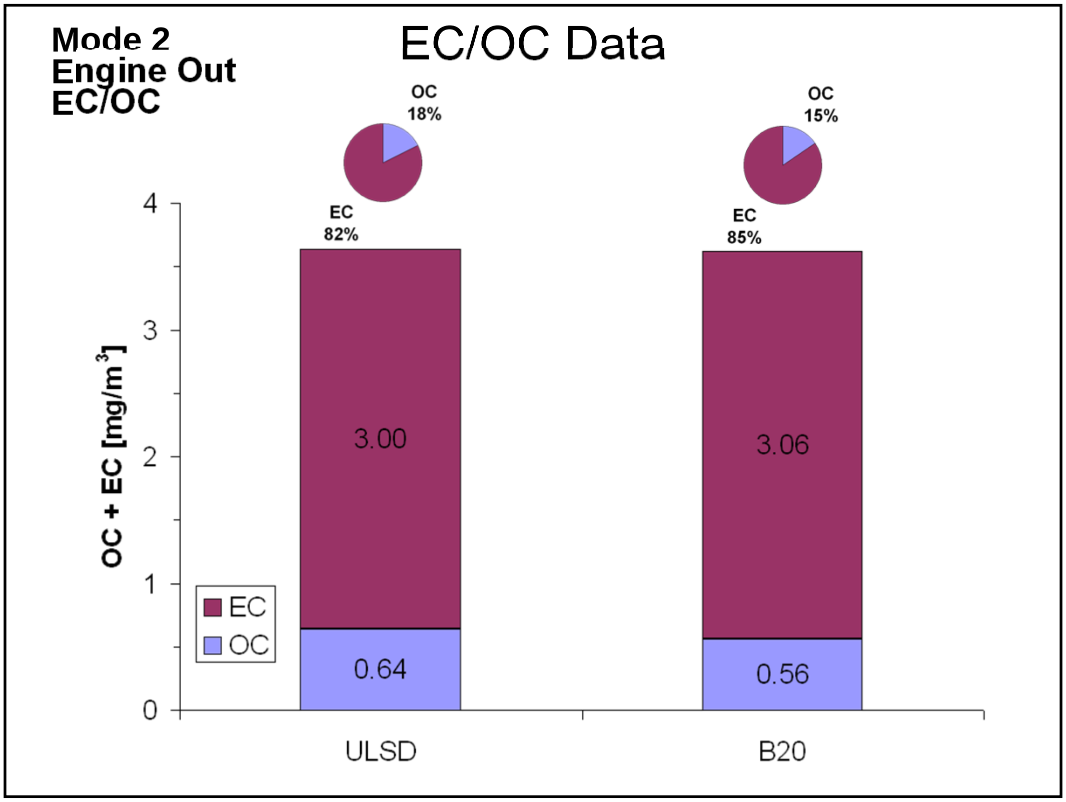
- Engine Out TPM deceases by 7-10% with B20 over ULSD.
- All DPFs removed > 99% of TPM by mass.
- No significant difference between fuels at DPF outlet.

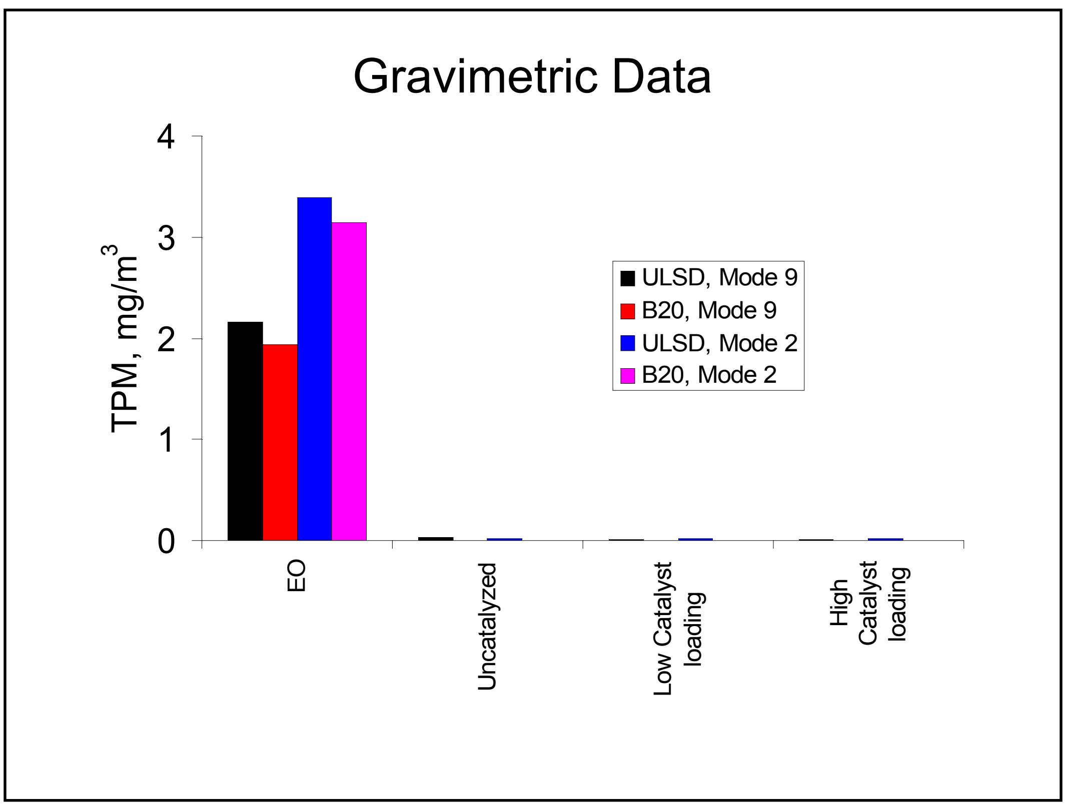


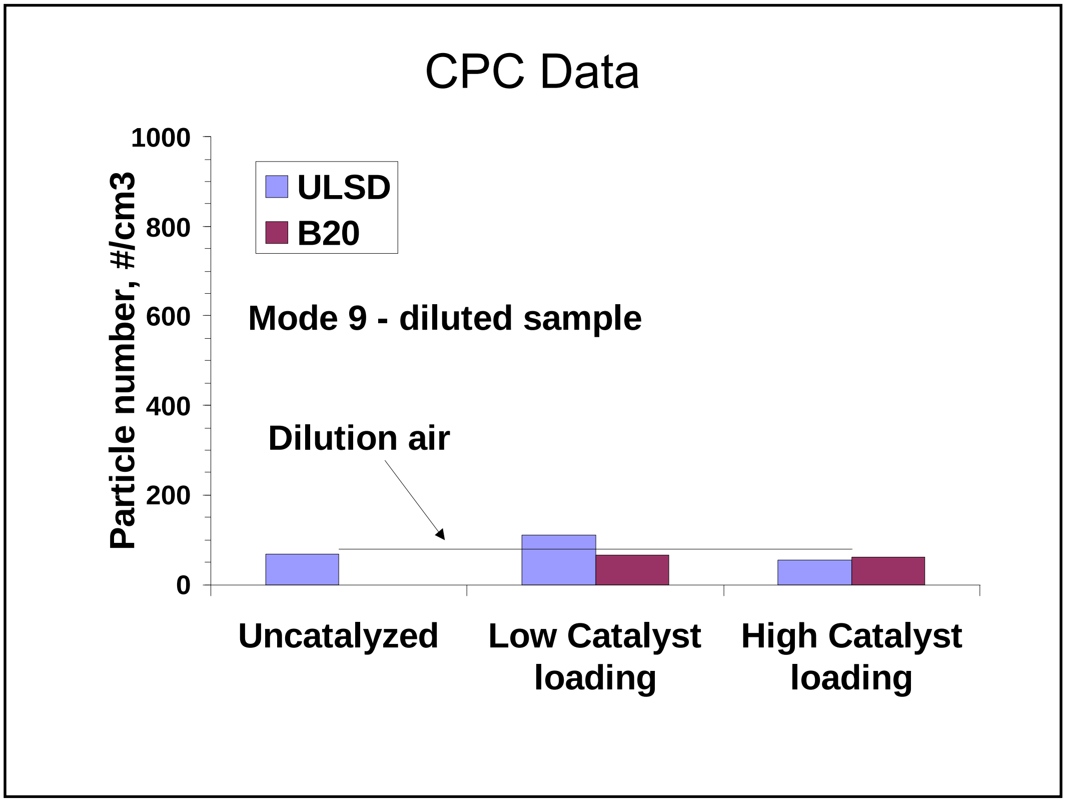
Mode 9
Engine Out
EC/OC

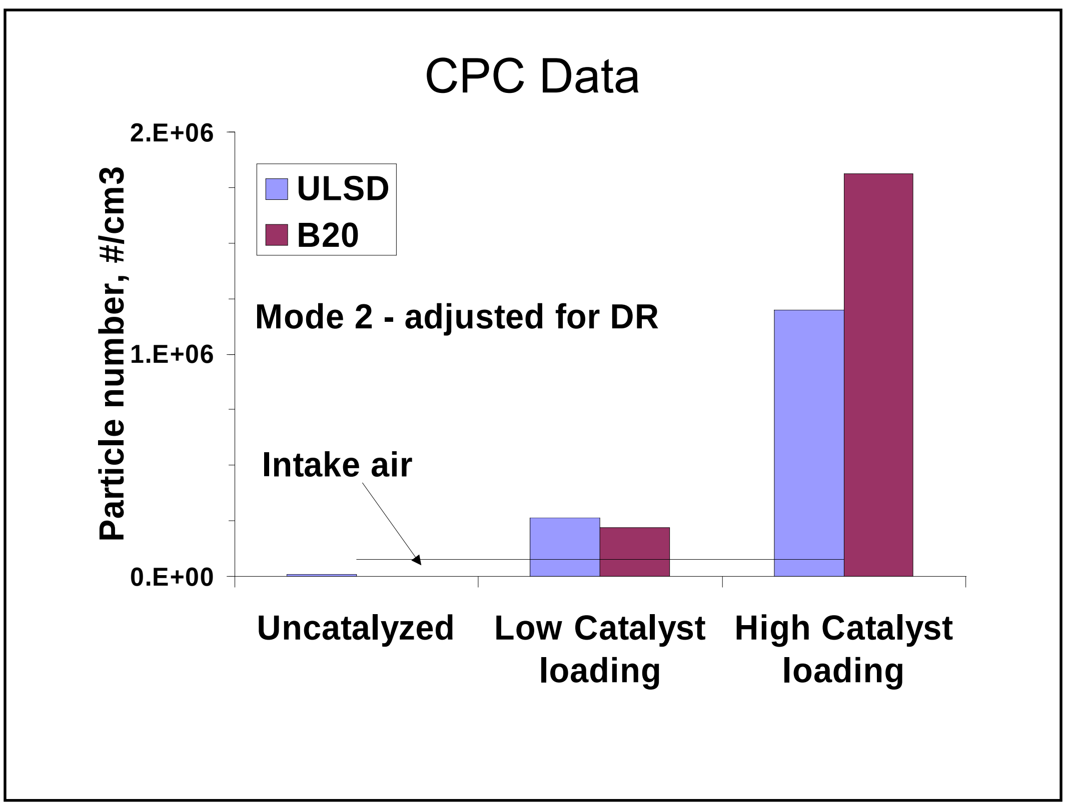
EC/OC Data

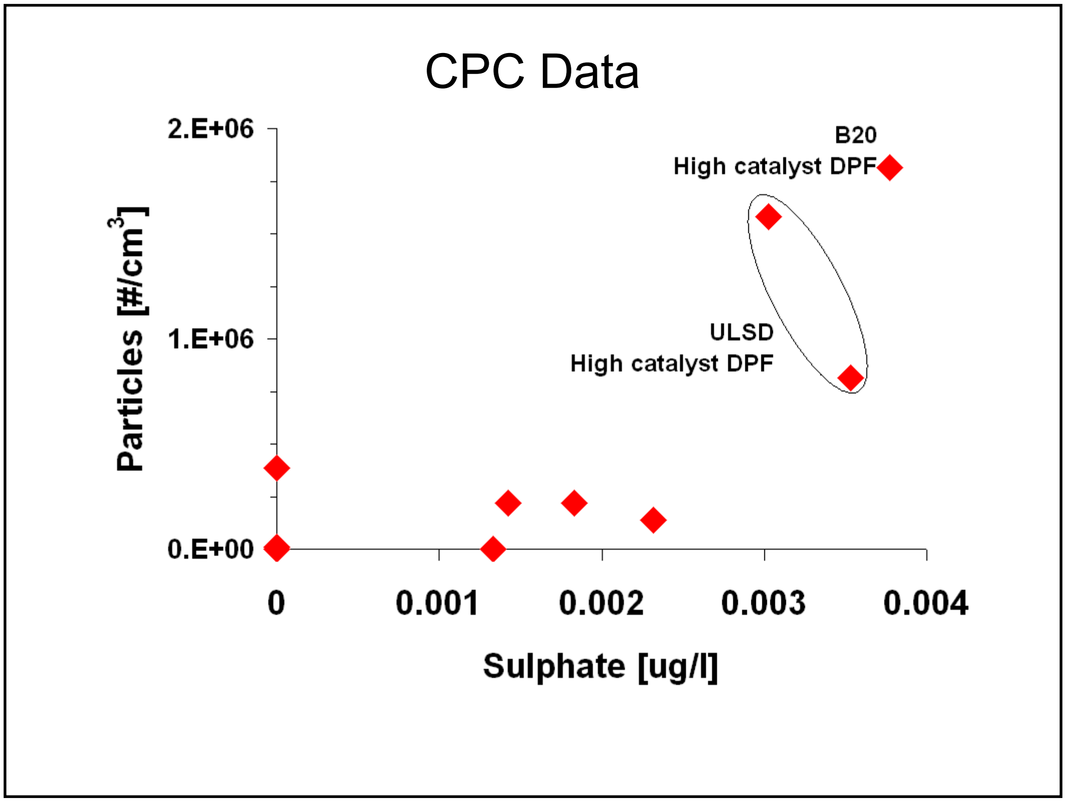


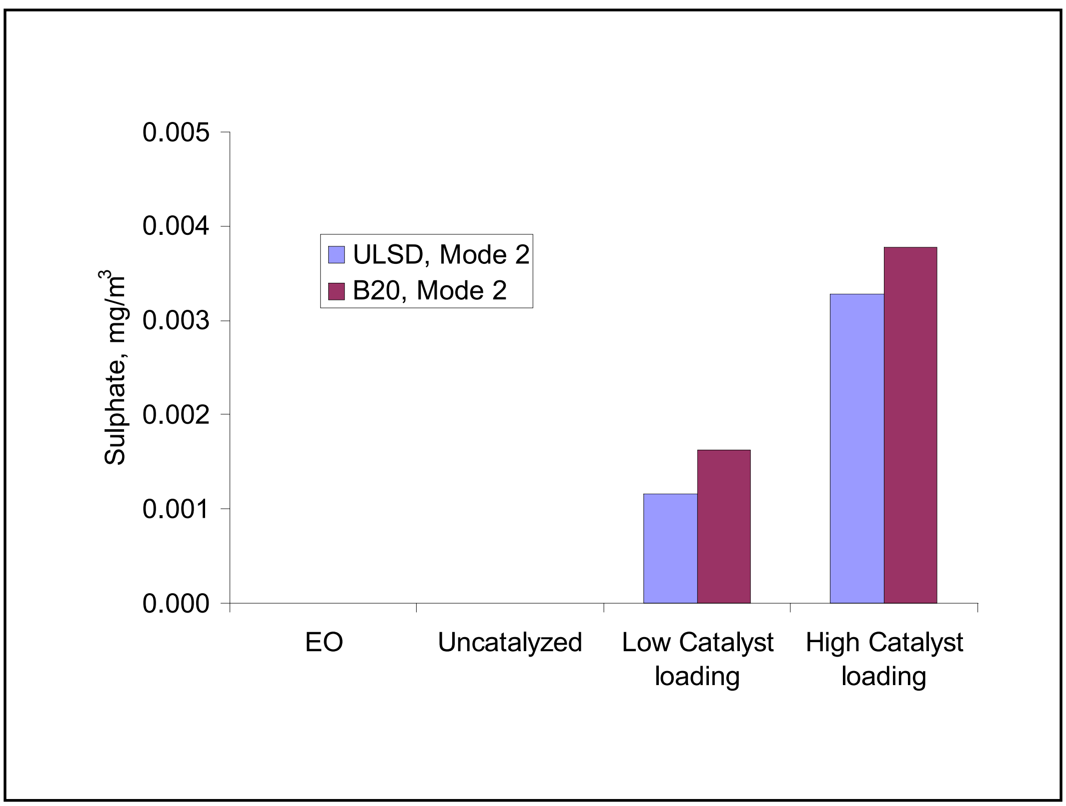

Mode 2
Engine Out
EC/OC
EC/OC Data
OC
18%
EC
82%
OC
15%
EC
85%
OC + EC [mg/m3]
4
3
2
1
0
EC
OC
3.00
0.64
3.06
0.56
ULSD
B20

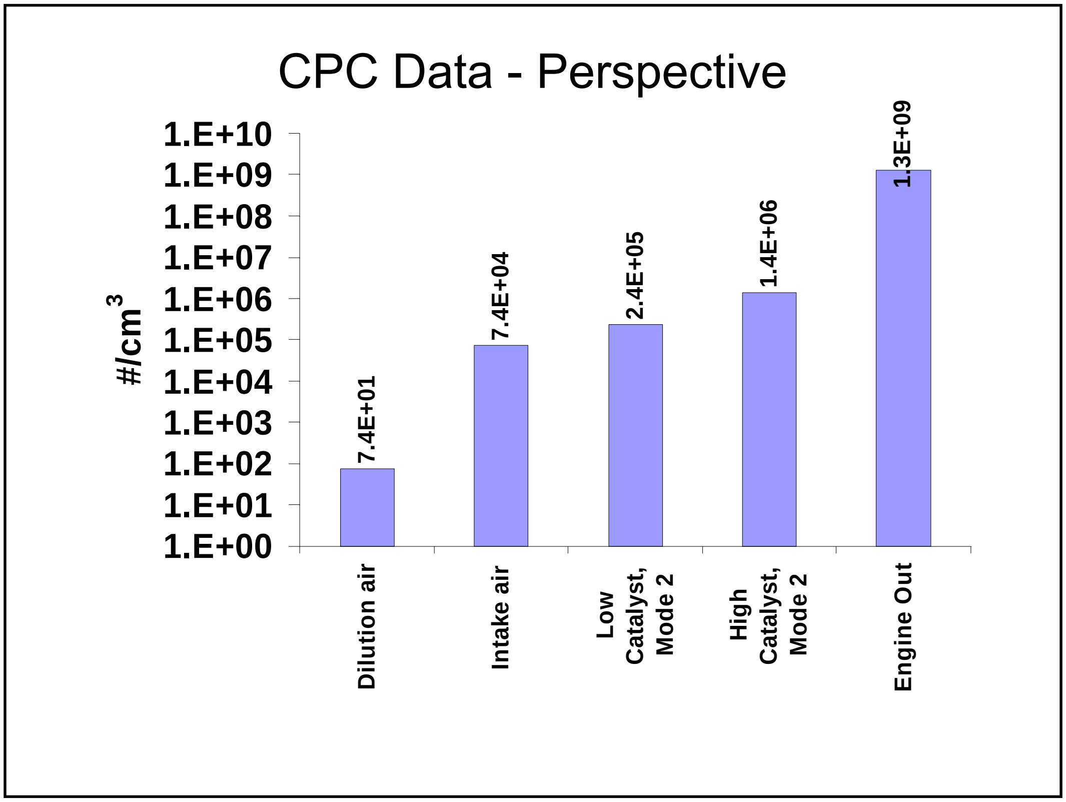

Gravimetric Data
TPM, mg/m3
4
3
2
1
0
ULSD, Mode 9
B20, Mode 9
ULSD, Mode 2
B20, Mode 2
EO
Uncatalyzed
Low Catalyst loading
High Catalyst loading

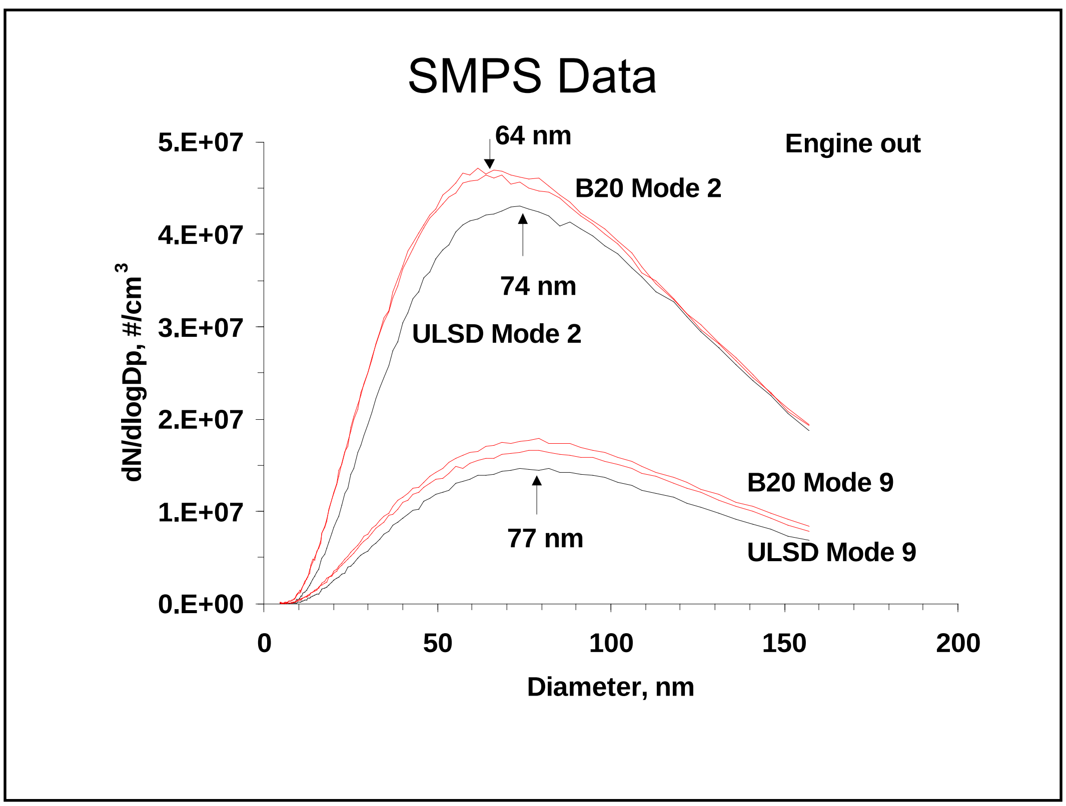

CPC Data
1000
800
600
400
200
0
Particle number, #/cm3
ULSD
B20
Mode 9 - diluted sample
Dilution air
Uncatalyzed
Low Catalyst loading
High Catalyst loading

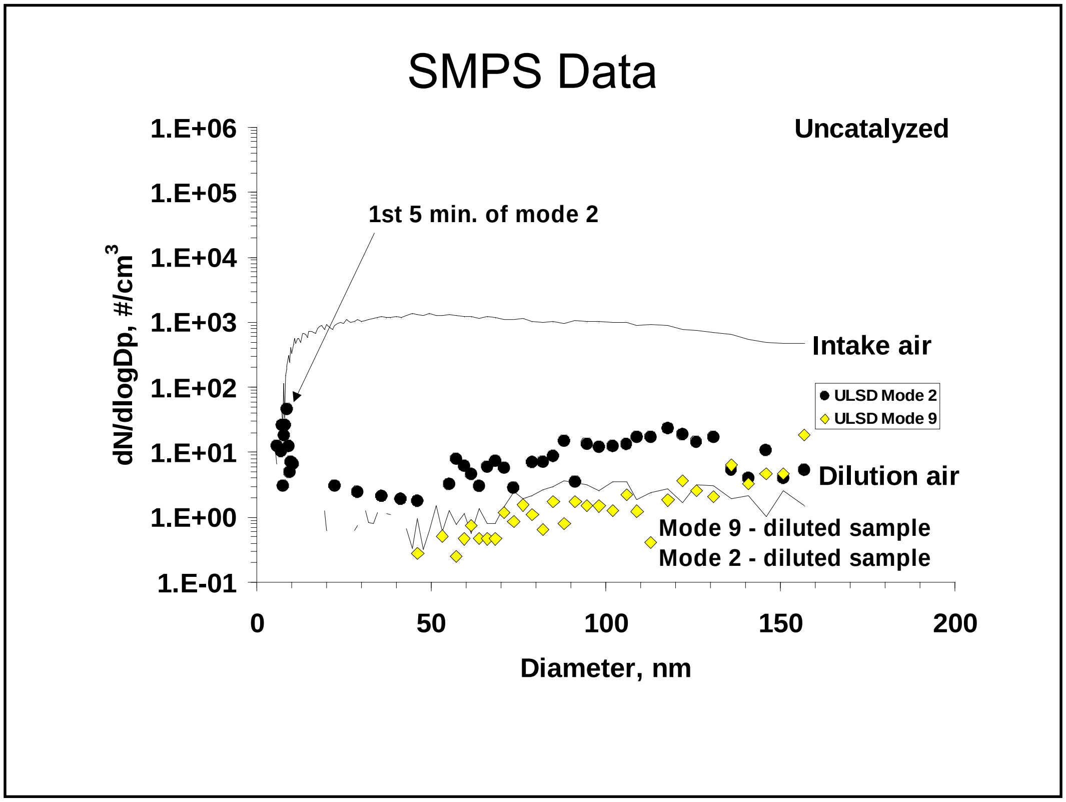

CPC Data
2.E+06
1.E+06
0.E+00
Particle number, #/cm3
ULSD
B20
Mode 2 - adjusted for DR
Intake air
Uncatalyzed
Low Catalyst loading
High Catalyst loading

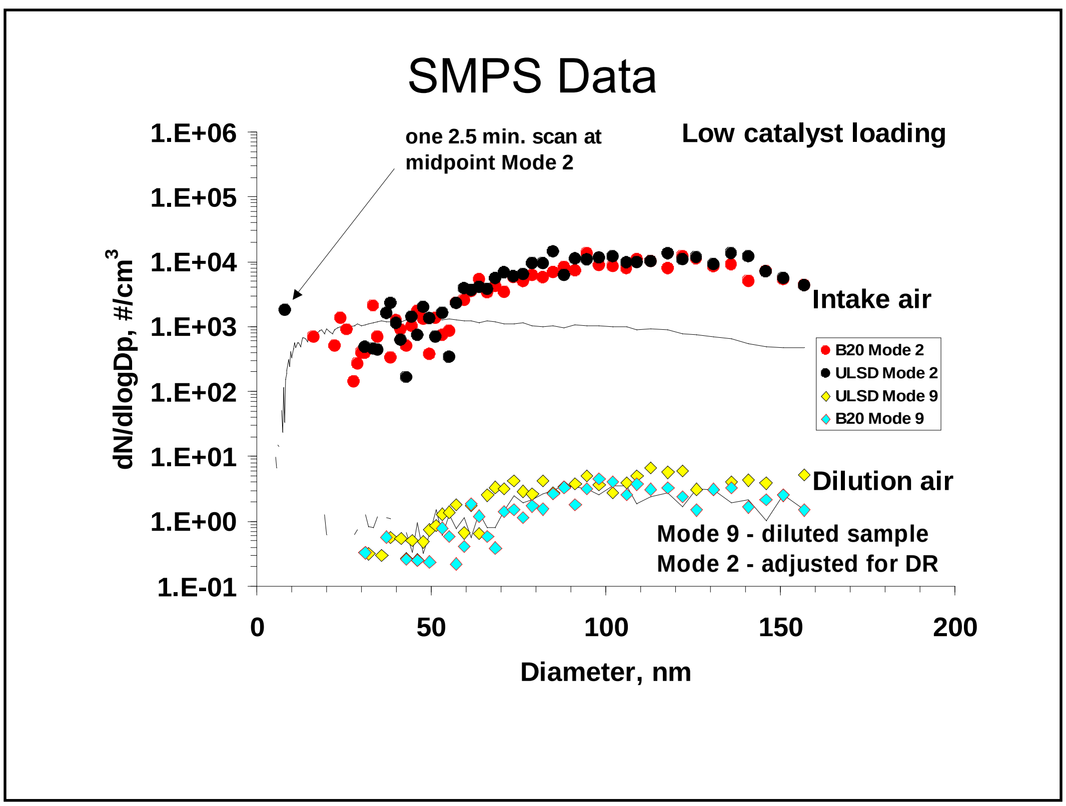

CPC Data
2.E+06
1.E+06
0.E+00
Particles [#/cm3]
B20
High catalyst DPF
ULSD
High catalyst DPF
0
0.001
0.002
0.003
0.004
Sulphate [ug/l]


0.005
0.004
0.003
0.002
0.001
0.000
Sulphate, mg/m3
ULSD, Mode 2
B20, Mode 2
EO
Uncatalyzed
Low Catalyst loading
High Catalyst loading

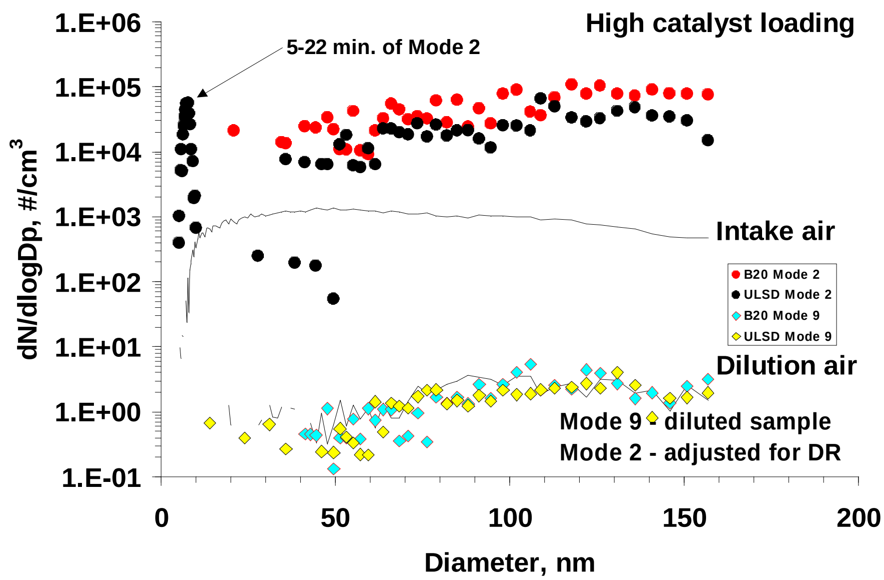

CPC Data - Perspective
#/cm3
1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
7.4E+01
7.4E+04
2.4E+05
1.4E+06
1.3E+09
Dilution air
Intake air
Low Catalyst, Mode 2
High Catalyst, Mode 2
Engine Out


SMPS Data
dN/dlogDp, #/cm3
5.E+07
4.E+07
3.E+07
2.E+07
1.E+07
0.E+00
0
50
100
150
200
Diameter, nm
64 nm
Engine out
B20 Mode 2
74 nm
ULSD Mode 2
B20 Mode 9
77 nm
ULSD Mode 9


SMPS Data
Uncatalyzed
1st 5 min. of mode 2
Intake air
ULSD Mode 2
ULSD Mode 9
Dilution air
Mode 9 - diluted sample
Mode 2 - diluted sample
dN/dlogDp, #/cm3
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
0
50
100
150
200
Diameter, nm

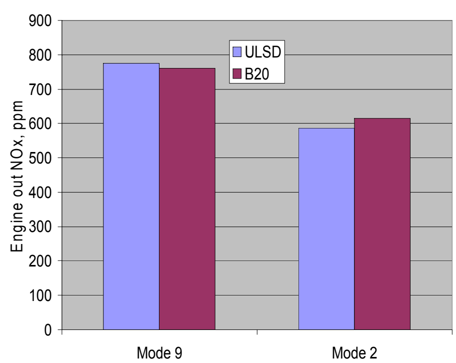

SMPS Data
one 2.5 min. scan at midpoint Mode 2
Low catalyst loading
Intake air
B20 Mode 2
ULSD Mode 2
ULSD Mode 9
B20 Mode 9
Dilution air
Mode 9 - diluted sample
Mode 2 - adjusted for DR
dN/dlogDp, #/cm3
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
0
50
100
150
200
Diameter, nm

SMPS Data



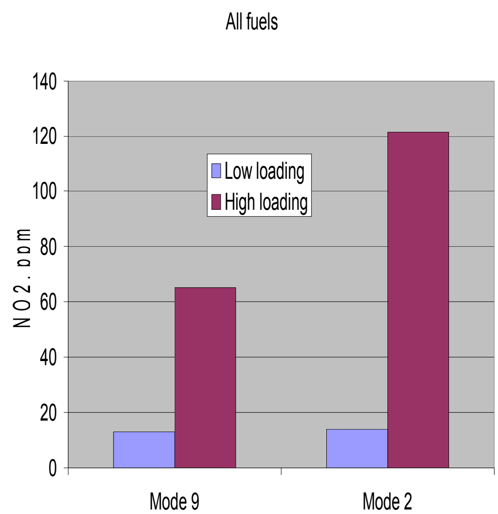
Engine-out NO_x Emissions

- Fuel effect on engine-out NO_x emissions not statistically significant.
  - Mode 9 difference SS only to 50% confidence
  - Mode 2 difference SS only to 75% confidence



NO to NO_2 conversion in the DPF

- DPF with low precious metal loading increased NO_2 by ~13 ppm.
- DPF with high precious metal loading increased NO_2 by 65-120 ppm.
- No discernable fuel effect.



Conclusions

- Engine out gravimetric TPM deceases by 7-10% with B20 over ULSD.
- No distinguishable differences in TPM between fuels at DPF outlet.
- All DPFs removed:
  - > 99% of TPM by mass.
  - > ~99.9% by particle count
- Small increase in DPF-out sulphate emissions with B20 at Mode 2.

Conclusions

- DPF-out particle number emissions at Mode 9 with the catalysed DPFs and at Mode 9 and 2 with the uncatalysed DPF were indistinguishable from dilution air.
- DPF-out particle number emissions at Mode 2 increased with catalyst precious metal loading
  - increase in smaller particles was greater
- Higher particle number emissions at Mode 2 correlated with sulphate emissions.

Conclusions

- Some fuel effect at DPF-out in Mode 2
  - ULSD some <10 nm particle emissions with all DPFs
  - B20 more > 20 nm particles with high precious metal loaded filter.

Conclusions

- NOx differences were not statistically significant
- Catalyst precious metal loading had a significant impact on Mode 2 NO_2 emissions.

Acknowledgments

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