

Affect of Biodiesel Blends on Advanced Aftertreatment Systems

Aaron Williams, Bob McCormick, Dan Pedersen,
John Ireland, Charlie King
National Renewable Energy Laboratory

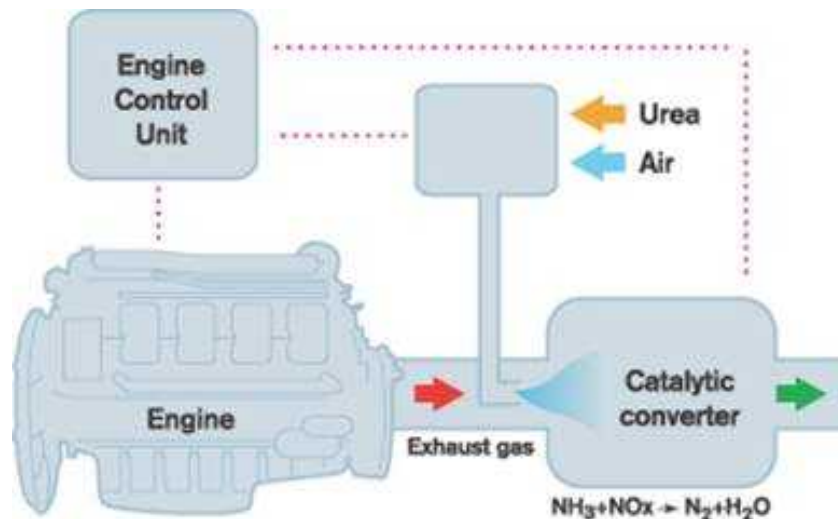
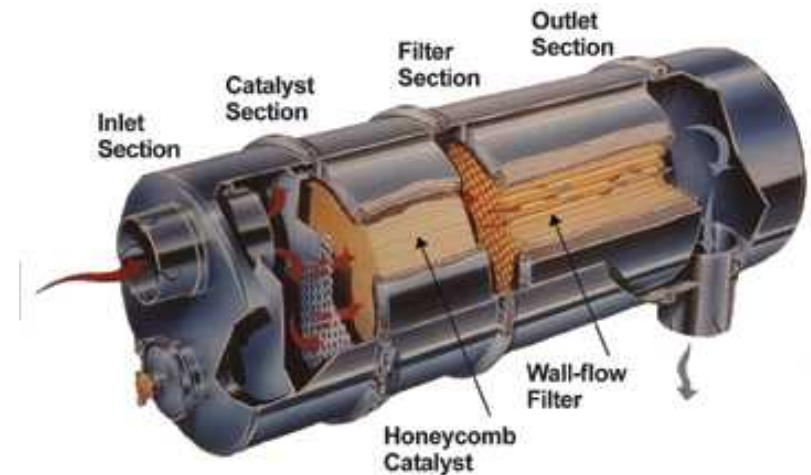
Howard L. Fang
Cummins, Inc.

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Advanced Aftertreatment Systems

Diesel Particulate Filters (DPF)

- Configurations – wall-flow, flow-through, porous, fibrous
- Materials – ceramic, metallic
- Control & Maintenance – passive, active

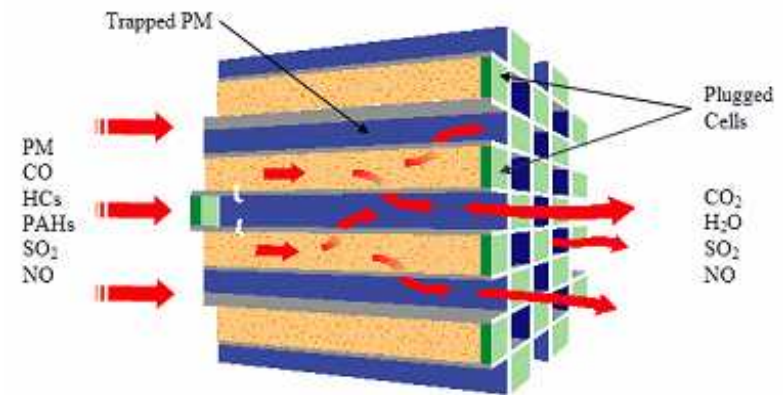


de-NO_x Systems

- Lean NO_x Catalyst (LNC)
- Lean NO_x Trap (LNT)
- Selective Catalytic Reduction (SCR)

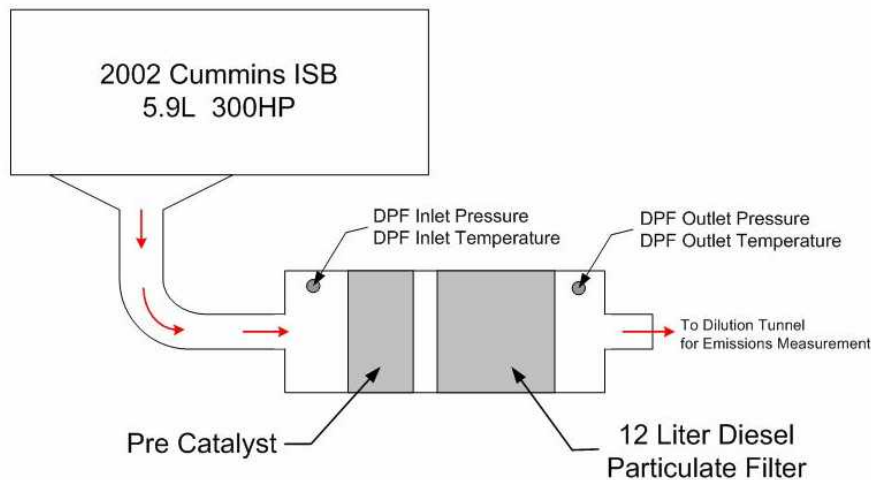
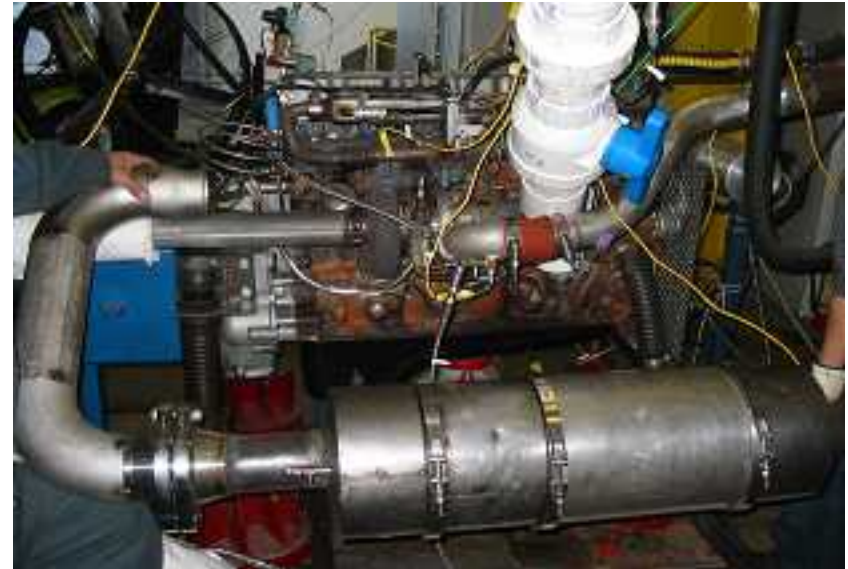
How are DPFs impacted by blending with biodiesel?

- **Balance point temperature testing** – Understand how biodiesel blends impact temperature of soot oxidation on DPF (DECSE method)
- **Regeneration rate testing** – Understand how biodiesel blends may impact rate of filter regeneration (Slope method)
- **Soot characterization** – Understand fundamental differences in biodiesel soot (Raman Spec, SEM-EDX, TGA)



Experimental Setup

- Cummins ISB 300
 - 2002 Engine, 2004 Certification
 - Cooled EGR, VGT
- Johnson Matthey CCRT
 - 12 Liter DPF
 - Passively Regenerated System
 - Pre Catalyst (NO₂ Production)
- Fuels: ULSD, B100, B20, B5

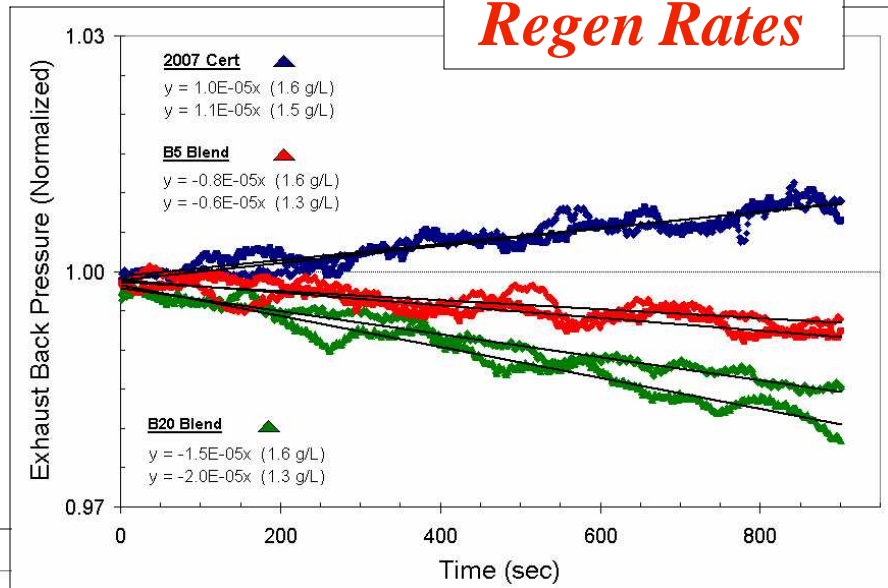


- ReFUEL Test Facility
 - 400 HP Dynamometer
 - Transient & Steady State Testing
- Cummins
 - Soot Characterization

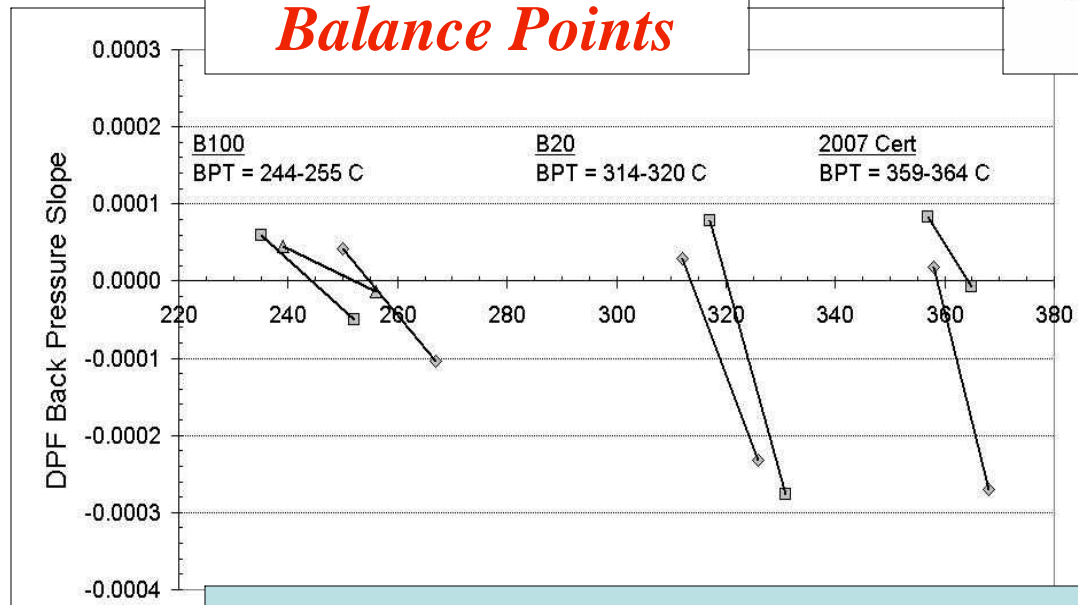
DPF Balance Point Temperature & Regeneration Rate

- DPF Regeneration Rate increases with increasing biodiesel content
- Even at 5% blend levels biodiesel PM measurably oxidizes more quickly

Regen Rates



Balance Points

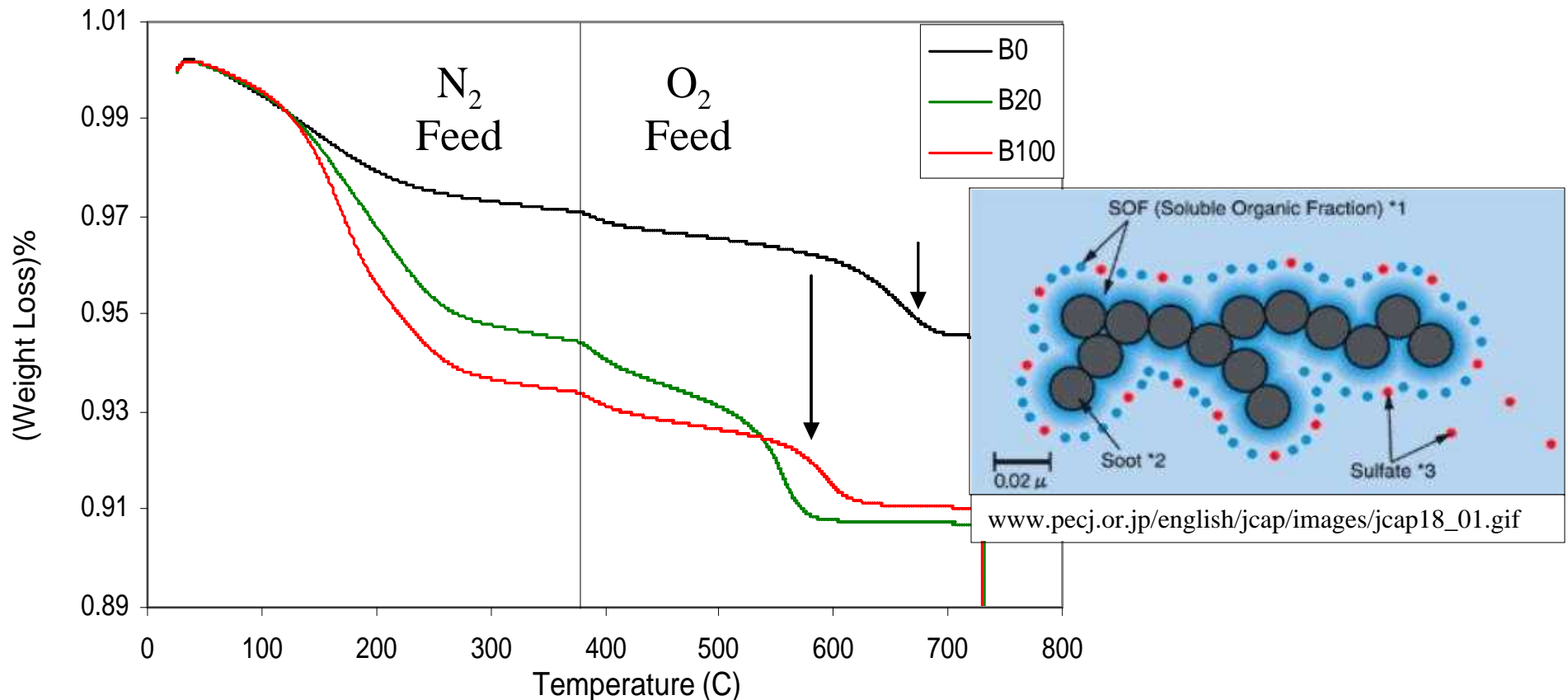


- BPT – DPF temp where soot load rate is equal to soot regeneration rate
- BPT with B20 and B100 is lower than 2007 Cert by 45 °C and 112 °C

Effect of Biodiesel Blends on DPF Performance:
<http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/40015.pdf>

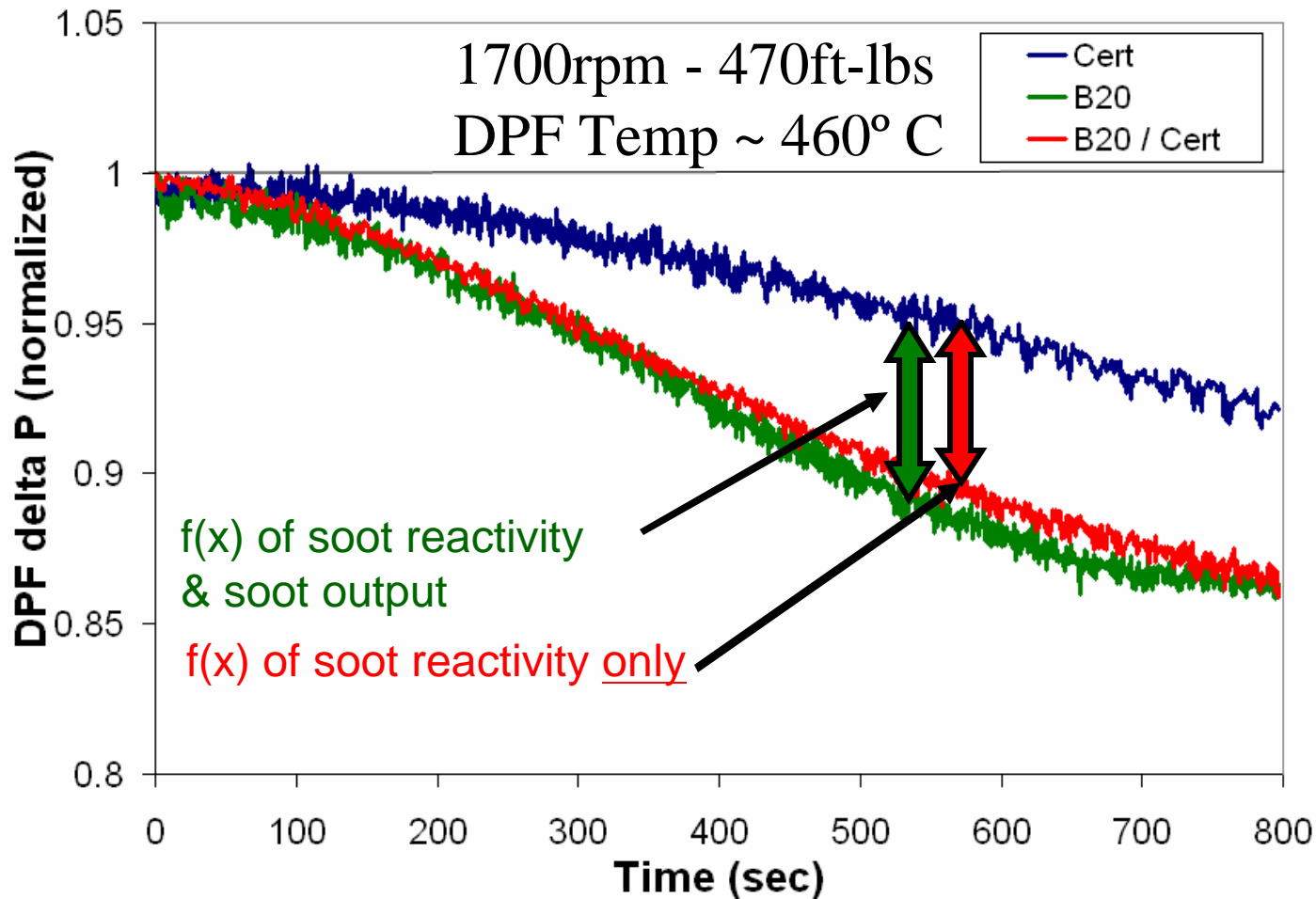
Soot Characterization

- Lower combustion temperature for biodiesel soot – (TGA)
- Higher disordered carbon content for B100 soot – G/D Carbon Ratio (Raman Spec)
 $G/D_{ULSD} = .836$ $G/D_{B100} = .586$
- Higher oxygen content for B100 soot – Carbon/Oxygen Ratio (SEM-EDX)
 $C/O_{ULSD} = 25.34$ $C/O_{B100} = 20.34$



Regeneration Rate Test Results

- Increased regeneration rate is a function of increased soot reactivity and lower soot output with biodiesel
- Further testing decouples the dependence on soot reactivity vs soot output



Does Biodiesel's DPF benefits translate to real-world performance?

Conduct Vehicle Testing on Chassis Dynamometer

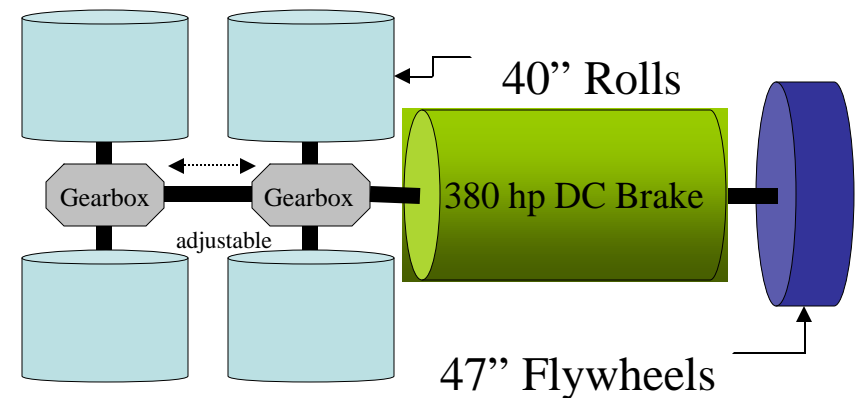
Test Vehicle

- International Class 8 Truck
- 2007 Cummins ISX
- 20 Liter DPF – actively regenerated system

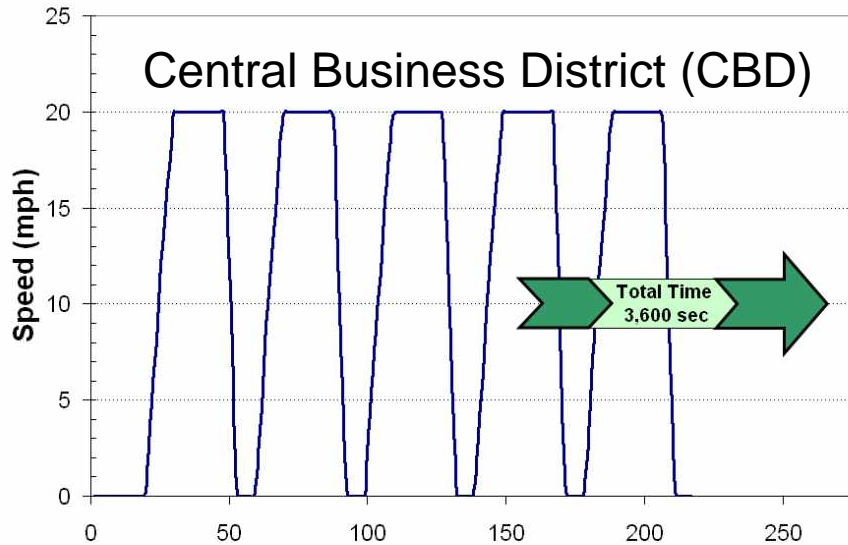


Chassis Dynamometer

- Test Range: 8,000–80,000 lb (Class 3-8)
- Twin 40" rolls (adjustable wheelbase)
- 380 hp DC motor
- Road Load and Inertia Simulation

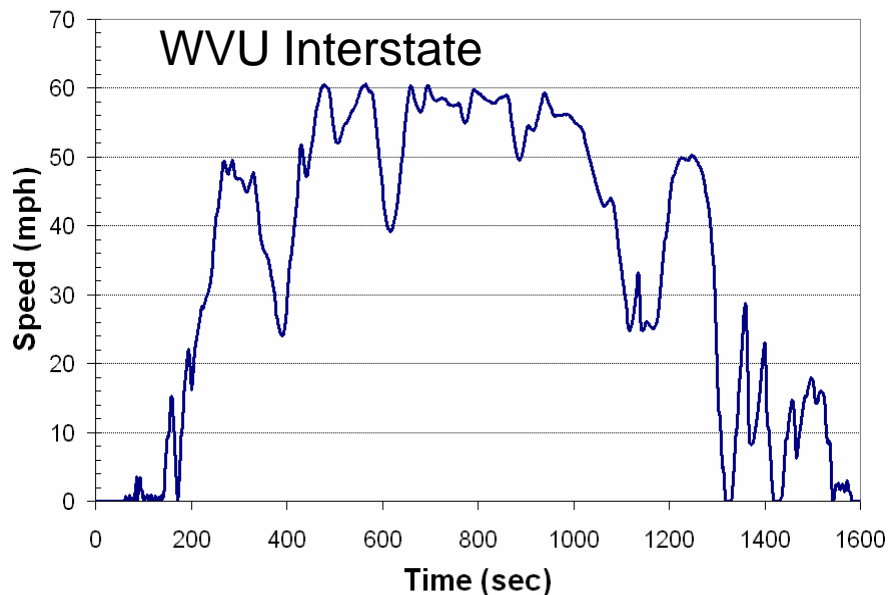


How does B20 impact DPF load and regeneration during vehicle operation?



Filter Loading – Operate under low speed & light load conditions

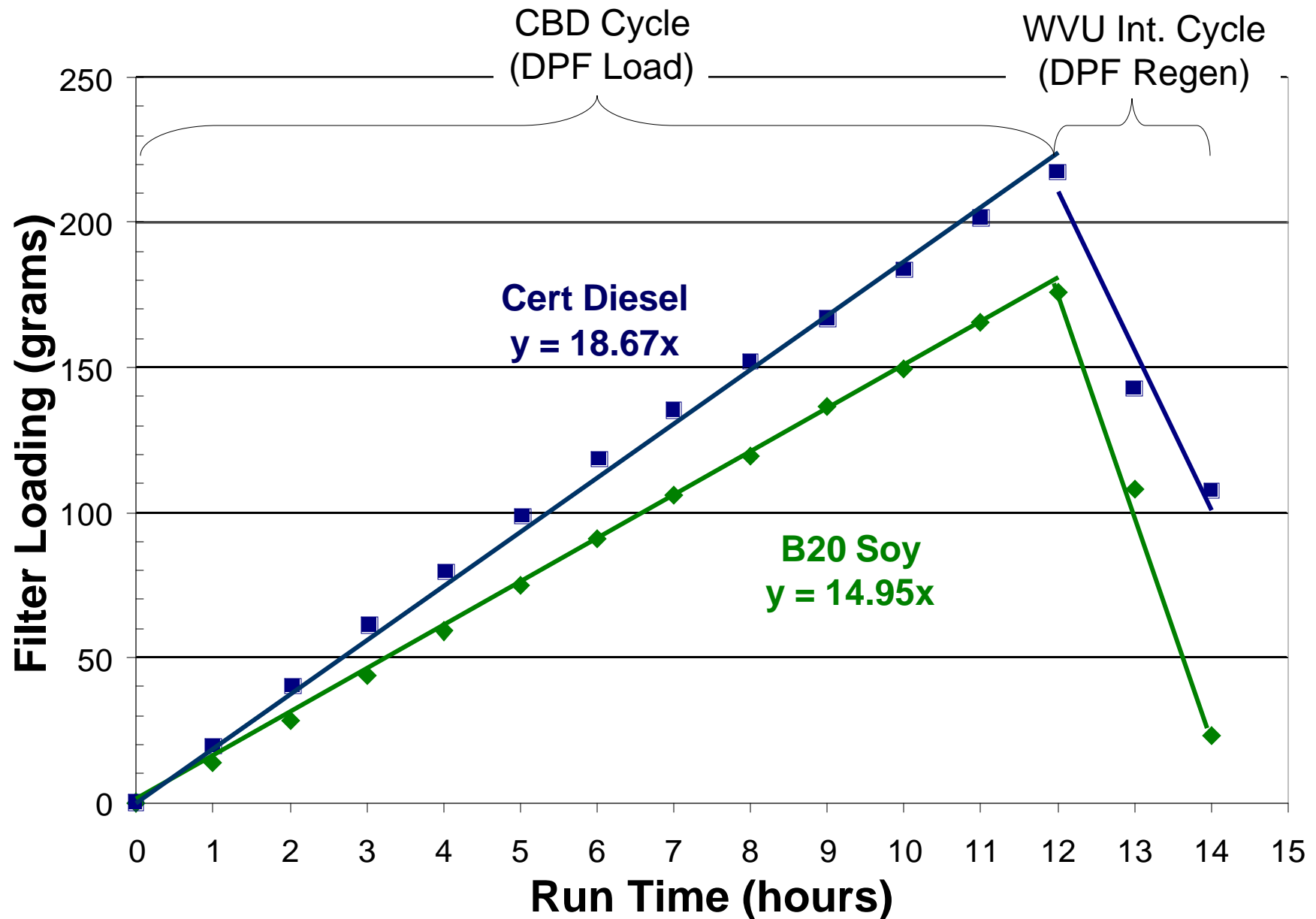
- Cycle Time = 1 hour
- Max Speed = 20 mph
- Vehicle Inertia = 28,000 lbs
- Avg Exhaust Temp = 225 C
- DPF Regeneration Opportunity = “Low”



Filter Regen – Operate under high speed & high load conditions

- Cycle Time = 26 min
- Max Speed = 60 mph
- Vehicle Inertia = 64,000 lbs
- Avg Exhaust Temp = 365 C
- DPF Regeneration Opportunity = “High”

Soot Load & Regeneration Rate for Cert & B20



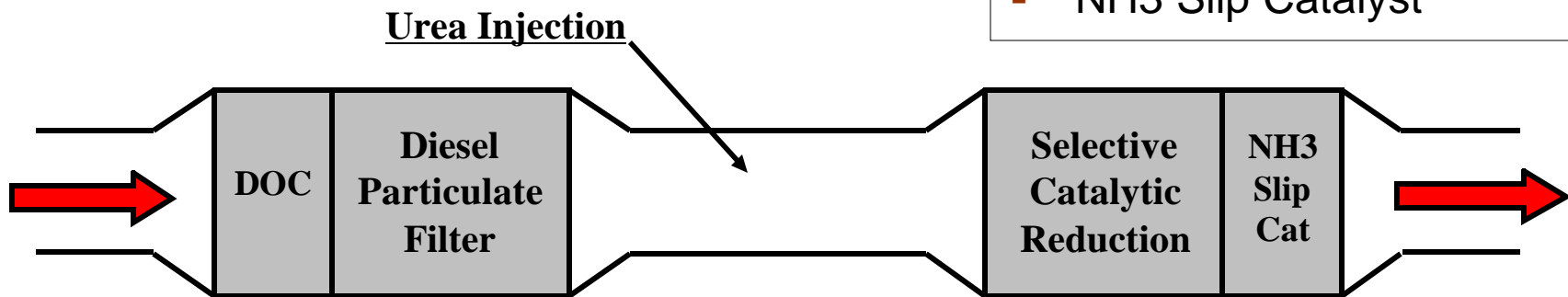
How are SCRs impacted by blending with biodiesel?

- Compare SCR catalyst performance with different fuels
 - Measure NOx conversion efficiency, exhaust temp and space velocity impacts
 - Steady-state modal tests and Transient tests
- Test hypothesis of HC mask effect on SCR catalyst performance
 - Does fuel significantly impact exhaust HC composition entering SCR
 - Measure NOx conversion efficiency after 50 hours of low temp operation



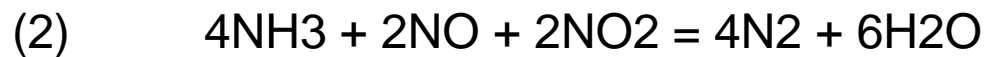
de-NOx Aftertreatment

- JM Zeolite SCR (15.5 Liters)
- Urea Injection (air assisted)
- NH3 Slip Catalyst



SCR Dependence on NO₂:NO_x and Temperature

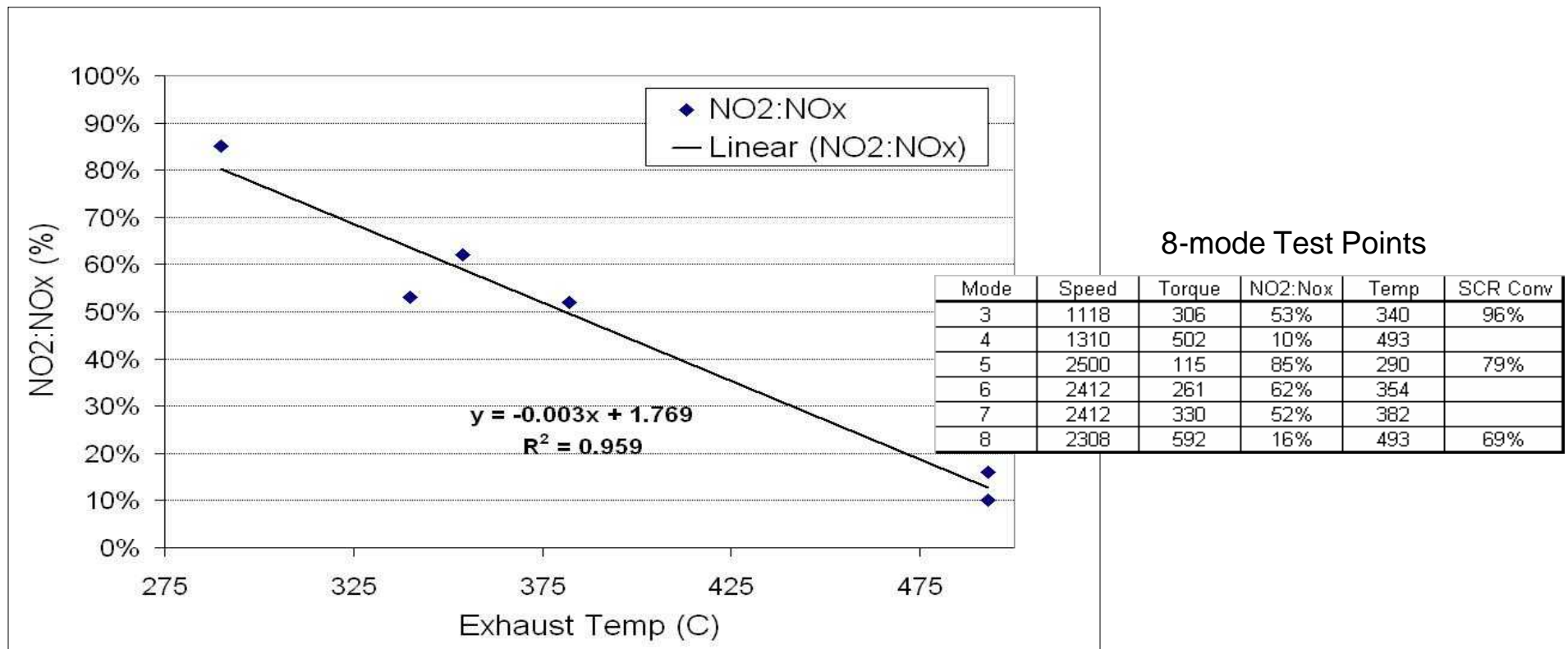
- Temperature and NO₂:NO_x can influence SCR NO_x conversion efficiency
- Three primary reactions dominate NO_x reduction by ammonia



fastest

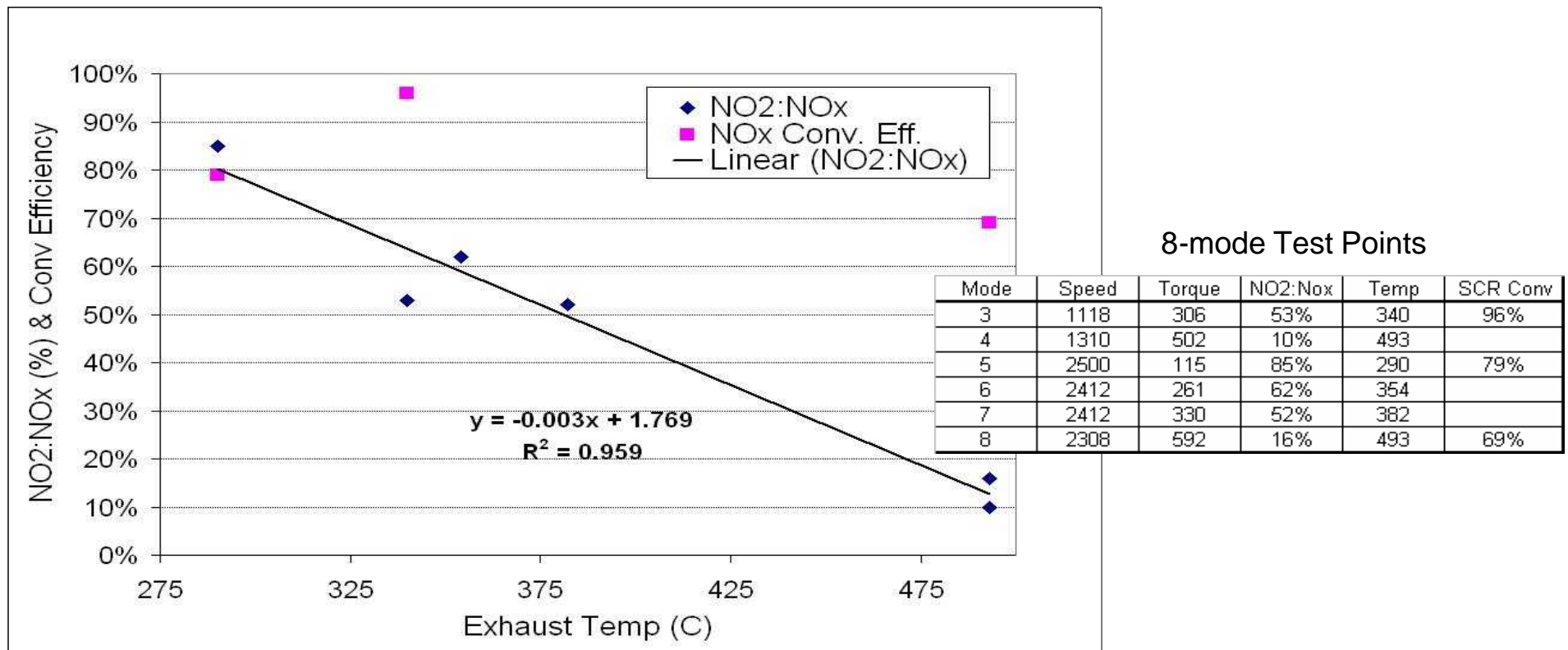


slowest



SCR Dependence on NO₂:NO_x and Temperature

- Data shows strong correlation between NO₂:NO_x and DPF temperature
- Data thus far shows that NO₂:NO_x dominates
 - (96% reduction with NO₂:NO_x=53%)
- What is biodiesel's impact on temperature and NO₂:NO_x and does it affect conversion efficiency
- How does DPF load impact NO₂:NO_x and does this affect conversion efficiency
 - High temps show very low NO₂, NO₂ may be consumed by loaded DPF
 - Is this different for clean DPF?



Summary

Selective Catalytic Reduction

- NOx reduction is a strong function of NO₂:NOx
- Impact of Biodiesel on NO₂:NOx and SCR performance is still uncertain
- Impact of DPF loading on NO₂:NOx and SCR performance is still uncertain

Diesel Particulate Filter

- Biodiesel creates lower BPT and Regeneration Rate
- Biodiesel soot is more reactive
- Benefits also observed in vehicle testing
- Fuel economy impacts for active systems still uncertain

Thank You

- US Dept of Energy (OFCVT)
- Cummins Inc.
- National Biodiesel Board
- National Biodiesel Conference Sponsors