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National Renewable Energy Laboratory

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DPF Performance with Biodiesel Blends

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CRADA Partners: Cummins
National Biodiesel Board

Project Objectives and Approach

How are DPFs impacted by blending with biodiesel?

Phase I CRADAs w/ Cummins & NBB (completed)

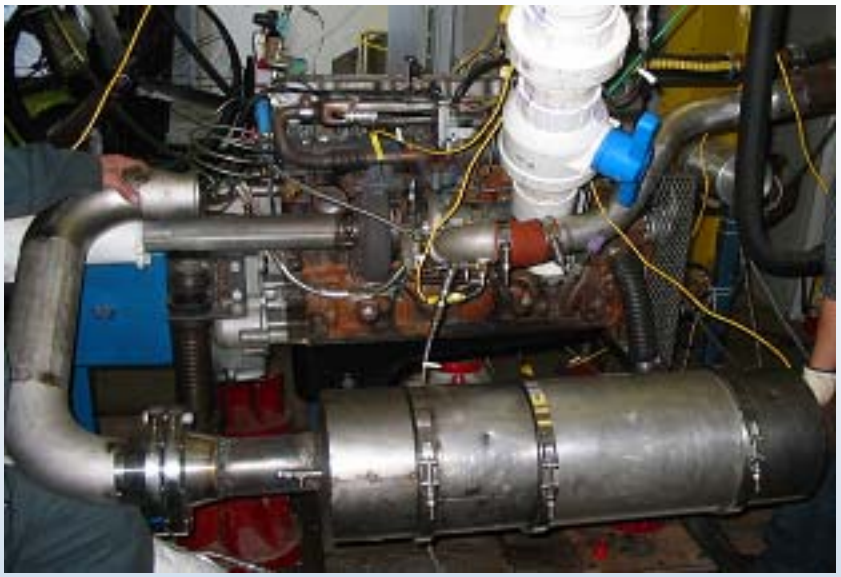
- **Transient testing** – Confirm operation of DPF with ULSD and B20 (HDT FTP)
- **Balance point temperature testing** – Understand how biodiesel blends impact temperature of soot oxidation on DPF (DECSE method)
- **Regeneration rate testing** – Understand how biodiesel blends may impact actively regenerated systems (Slope method)
- **Soot characterization** – Understand fundamental differences in biodiesel soot (Raman Spec, SEM-EDX, TGA)

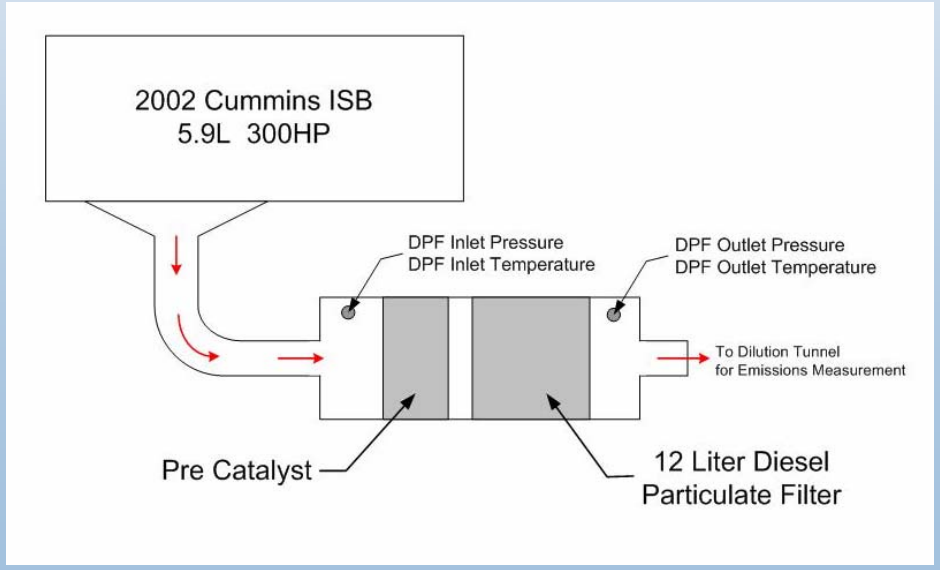
Phase II CRADA w/ NBB (FY07)

- **Moving to a 2007 compliant engine**
- **Transient testing with controlled exhaust temps** – Understanding of how DPF design criteria could be affected by biodiesel blends

Experimental Configuration

- Cummins ISB 300
  - 2002 Engine, 2004 Certification
  - Cooled EGR, VGT
- Johnson Matthey CCRT
  - 12 Liter DPF
  - Passively Regenerated System
  - Pre Catalyst (NO_2 Production)
- Fuels: ULSD, B100, B20, B5

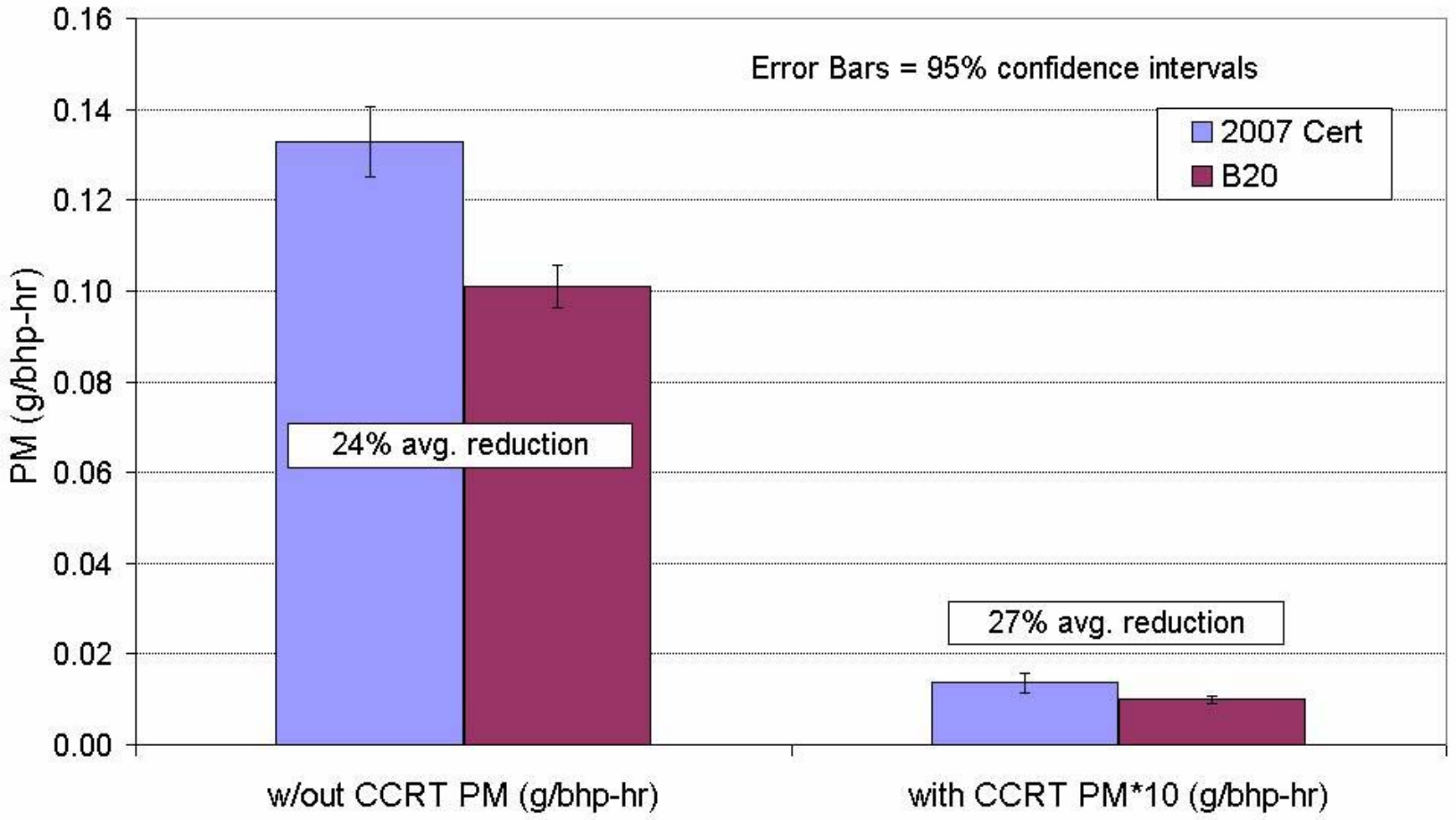




- ReFUEL Test Facility
  - 400 HP Dynamometer
  - Transient & Steady State Testing
- Cummins
  - Soot Characterization

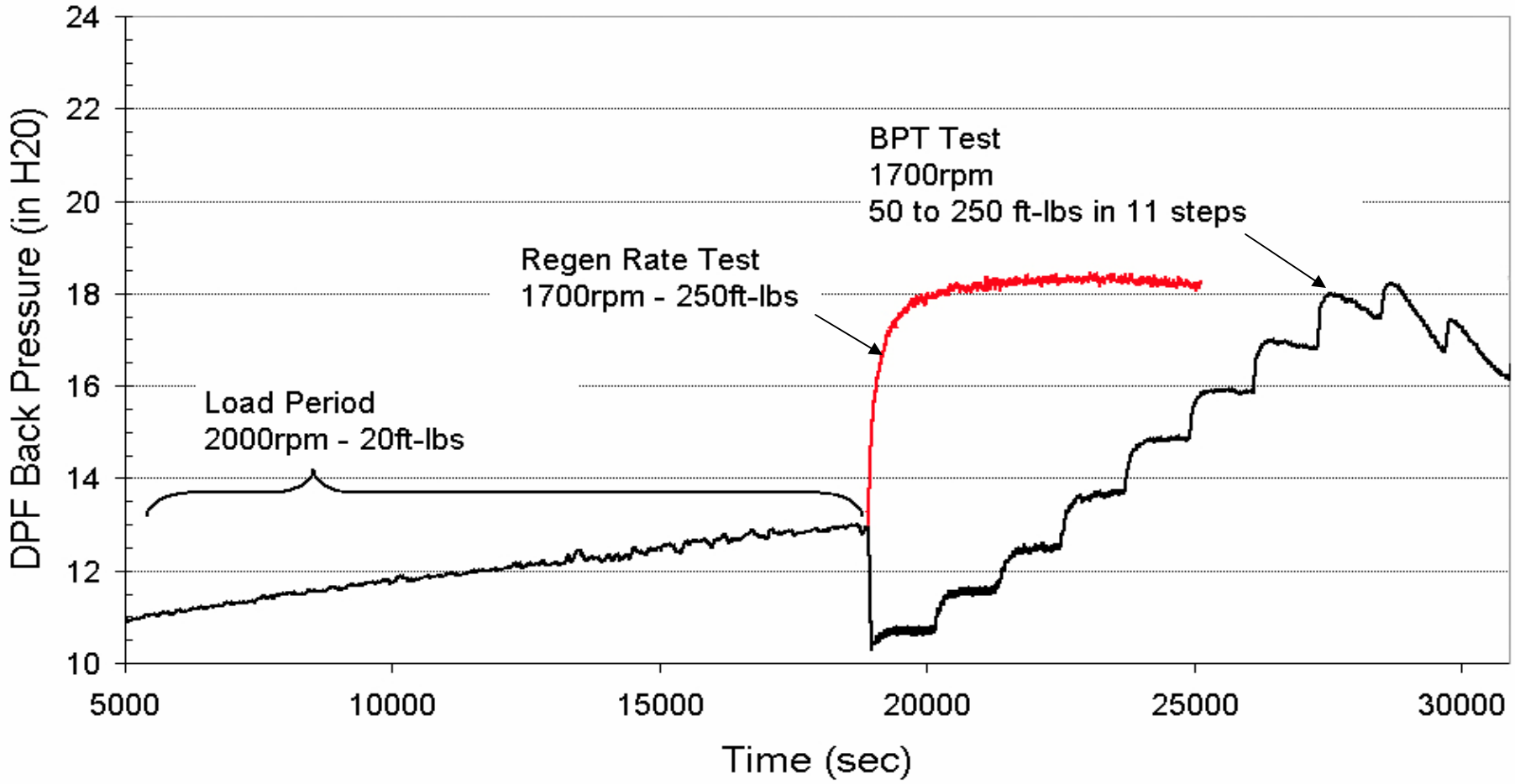
Heavy Duty Transient (HDT) Test Results

- Installation of DPF (base fuel):
  –97% CO, –99% THC, –99% PM, +1% BSFC
- B20 results in 24% PM reduction w/o DPF, 27% reduction w/ DPF



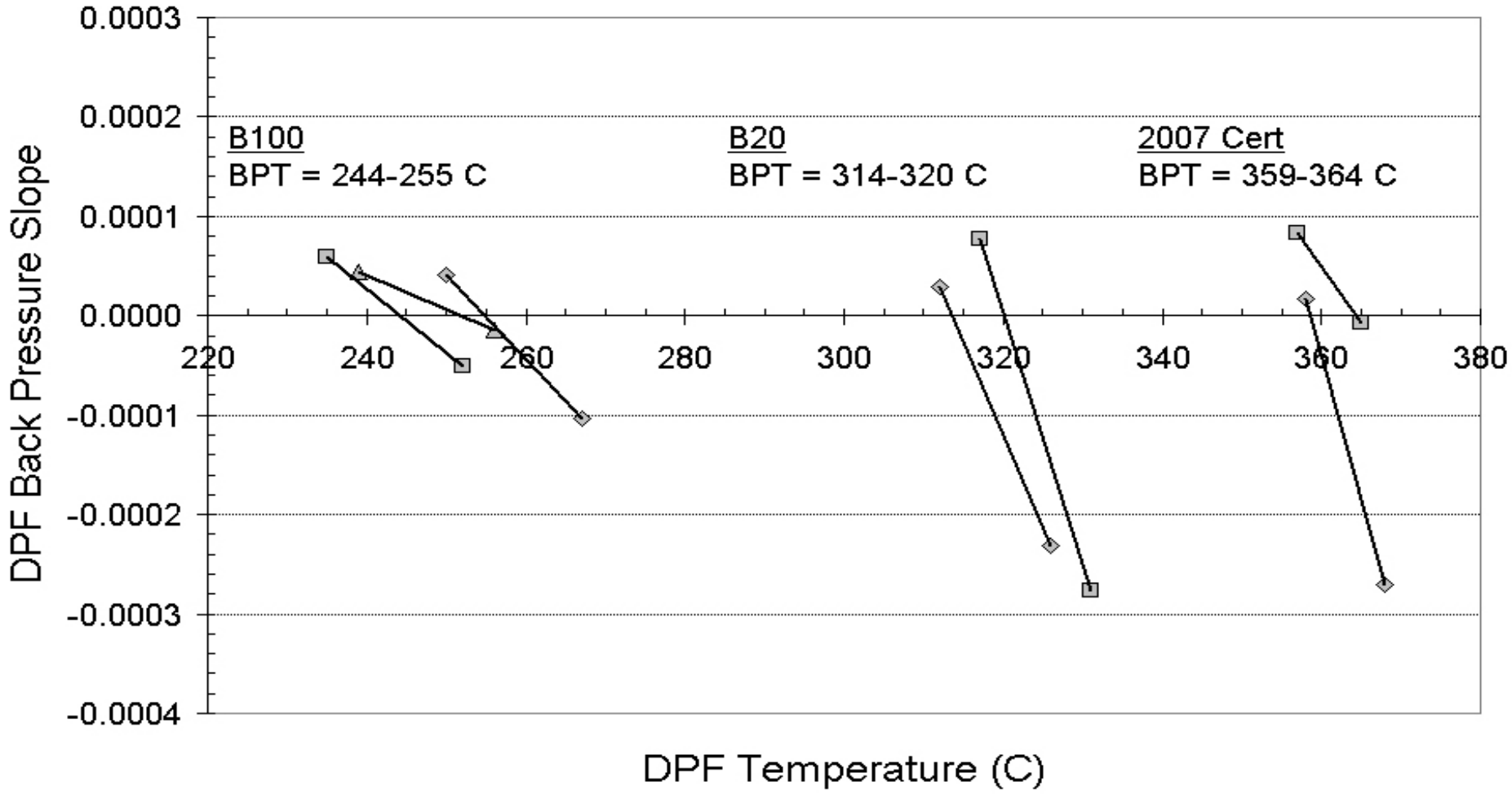
BPT and Regen Rate Test Procedures

- Balance Point Temperature (BPT) – DPF temperature where rate of PM collection equals rate of PM oxidation
- BPT is determined by monitoring DPF back pressure
- Regeneration Rate Test – simulates active regeneration strategy



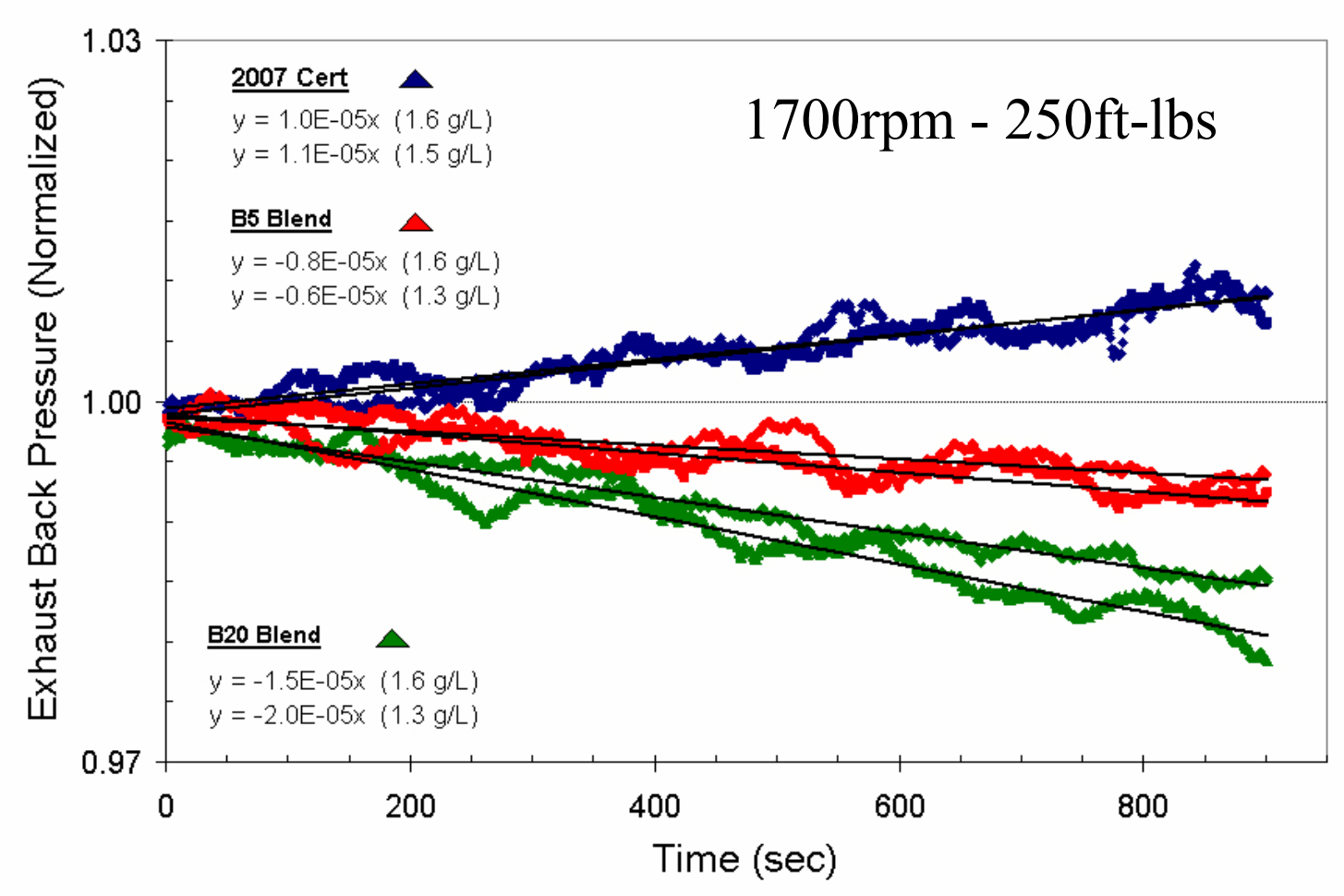
Balance Point Temperature Test Results

- Repeatability of test method shown with multiple repeats for each test fuel
- BPT determined by linear curve fit between two points nearest zero slope
- BPT with B20 and B100 is lower than 2007 Cert by 45 ºC and 112 º C



Regeneration Rate Test Results

- Regeneration rate increases with increasing biodiesel content
- Even at 5% blend levels biodiesel PM measurably oxidizes more quickly
- 2007 Cert has positive regen rate slope, consistent with findings from BPT tests



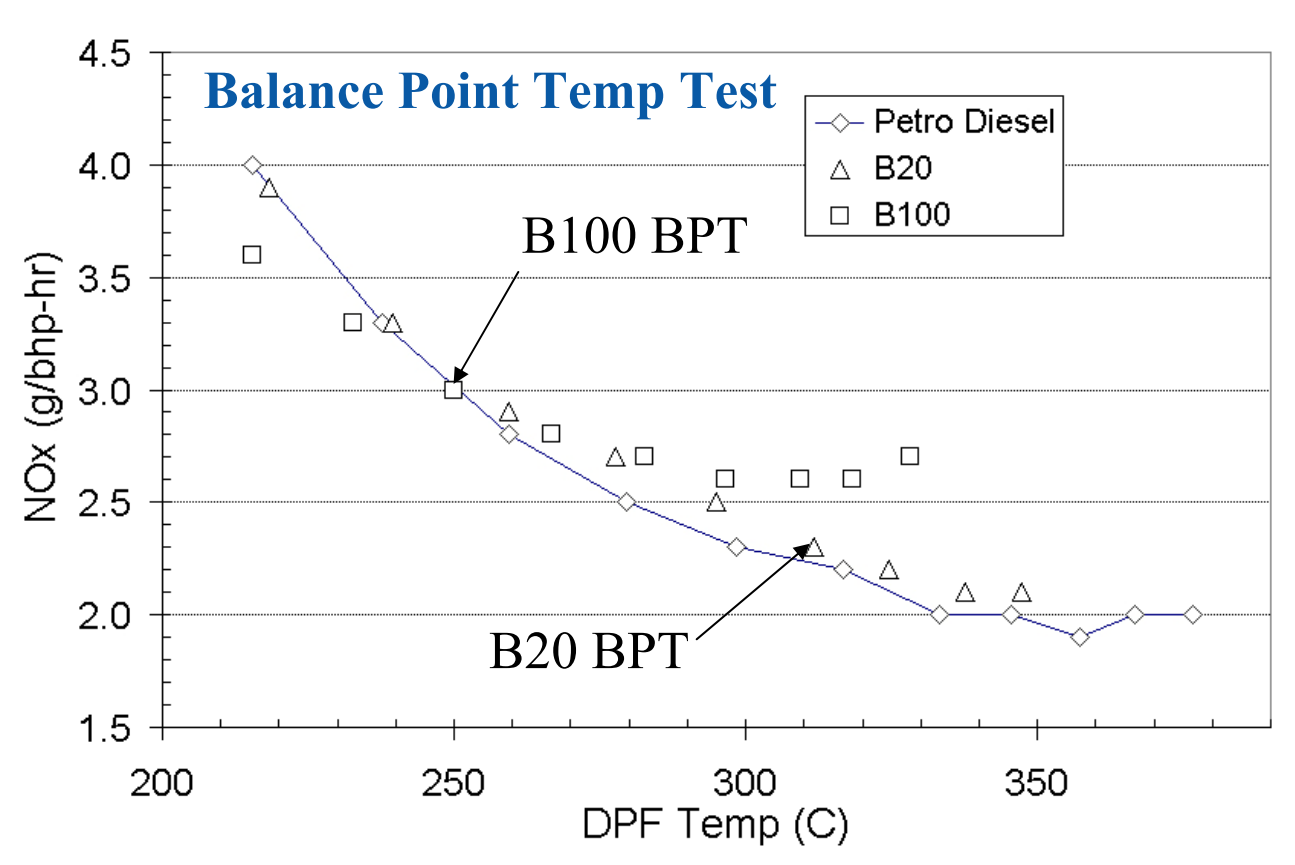
Availability of NOx for Soot Regeneration

- Catalyzed DPF's use NO_2 to oxidize soot
- There is no evidence to higher availability of NOx from biodiesel fuels

Regeneration Rate Test

ULSD = 2.01 g/bhp-hr
B5 = 1.97 g/bhp-hr
B20 = 2.15 g/bhp-hr

} No statistical difference (at alpha = 0.05)

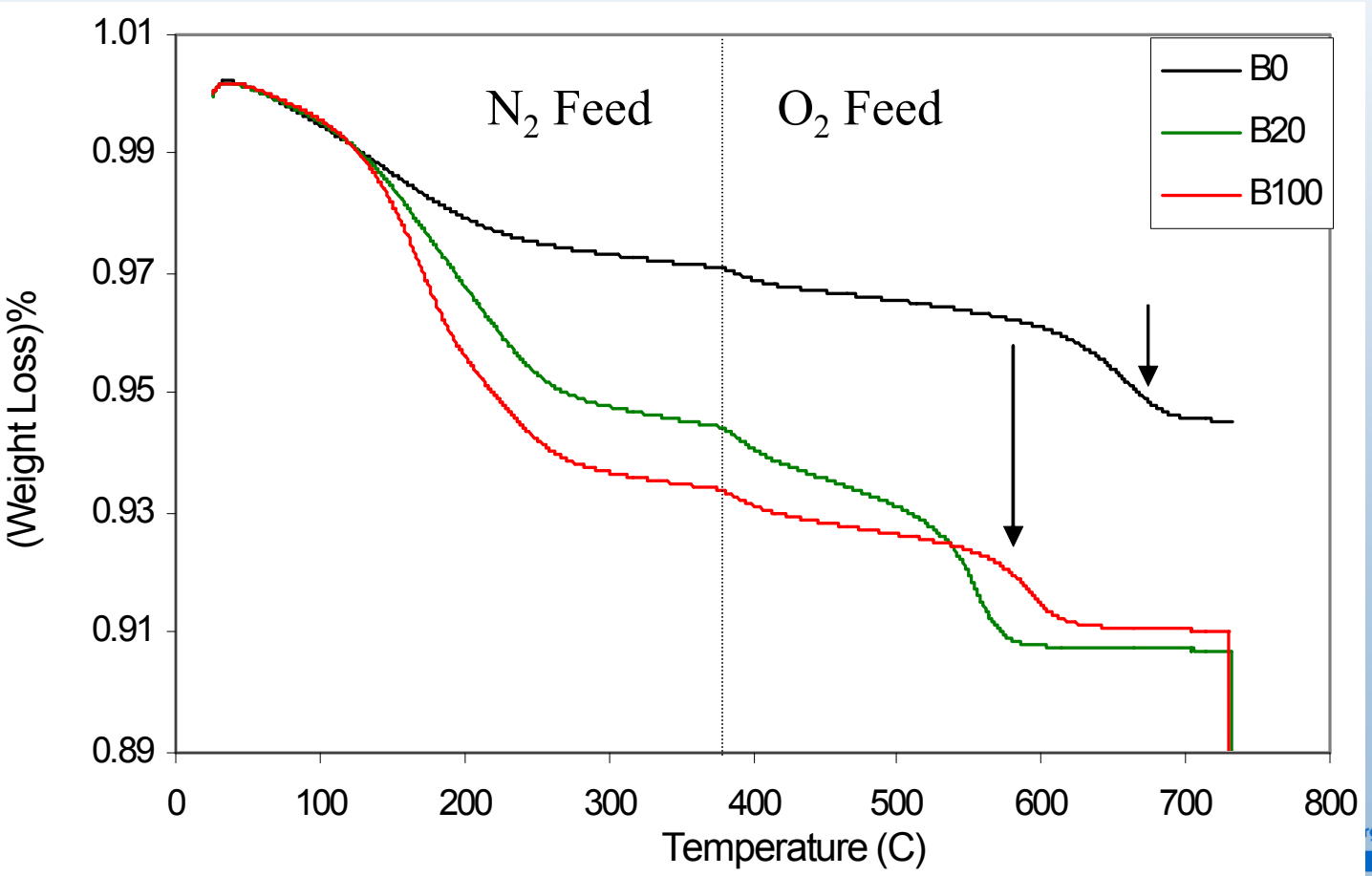


Soot Characterization – Industrial Collaboration w/ Cummins

- 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)

  $C/O_{ULSD} = 25.34$ $C/O_{B100} = 20.34$



Biodiesel DPF Summary

- B20 vs. ULSD Transient test results
  - Both fuels < 0.01 g/bhp-hr PM with CCRT installed
  - PM reduction from B20 vs. ULSD still measurable with CCRT installed
    27% reduction with CCRT vs. 24% reduction without CCRT
- BPT and Regeneration Rate Testing shows measurable differences with increasing biodiesel blends
  - BPT decreased by 45 ºC with B20 and 112 ºC with B100
  - Significant differences in regeneration rate with blend levels as low as 5%
- Soot Characterization
  - TGA confirms higher reactivity of biodiesel soot
  - Higher oxygen content for biodiesel soot
  - Higher ratio of disordered carbon for biodiesel soot
- Phase II Test Plan
  - 2007 compliant engine
  - Transient testing with controlled avg exhaust temps
  - Quantify fuel penalty associated with active systems
  - Evaluate maintenance and durability issues through fleet testing