Experimental Plan to Develop DPF Maps

CLEERS Presentation

May 17, 2005

Purpose

Develop standard test procedures for determining the oxidation rates for soot in a DPF.

- This information is crucial to develop engine control strategies for DPF regeneration.
- There is a need to create an industry standard procedure between manufacturers, suppliers and research groups.

Approach

- Capture the soot from a range of engine conditions and measure the oxidation rates within the filter.
  - Synthetic soot does not capture the inherent complexity of actual engine particulates, especially with regards to oxidation. Engine tests are required.
  - A slipstream/mini-core approach retains experimental flexibility.

Method Development

“White” paper proposal to develop and test the proposed protocols from the CLEERS DPF focus group.

- Initial paper created by a small working group:
  - Dick Blint (GM)
  - Alex Yezerets (Cummins)
  - Houshun Zhang (DDC)
  - George Muntean (PNNL)
  - Mansour Masoudi (Delphi)
  - Chris Rutland (U of Wisc)
- Reviewed/endorsed by the full subteam
- Specific details and protocols are still being discussed and refined

Instrumentation Requirements

- Engine Dynometer Capability
- Exhaust fixtures for mini-filter or core
- Gas analyzers
- Pressure Drop measurement
- Smoke meter, ELPI, TEOM, SMPS
- Full dilution tunnel
- Micro dilution tunnel
- Thermography
- *in-situ* soot mass measurement / estimation

Soot Measurement

- Estimation procedure will likely be required as no accurate technique is publicly available to measure in-situ soot mass
- Develop a correlation between the smoke number and DPF weights, with all weighing done at temperatures above 150 C to avoid issues with water adsorption.
- Improve correlation between pressure drop and soot loading

General Specifications

- Passive regeneration schemes only (no burner systems, resistance heaters, microwave regenerator are to be tested at this stage) Note: the temperature ranges in this proposal DO cover the ranges experienced in many active schemes and implicitly cover active regeneration strategies involving exhaust temperature management.
- Measurements made on degreened & preconditioned monolith core sample having 1:3 aspect ratio.
- Preconditioning procedure will be such that soot capacity has been stabilized to be representative of “normal operation” loading (e.g. continuous HD or LD certification cycling)
- .01-inch-diameter thermocouples installed in gas stream at core inlet and outlet and one in contact with the wall of a central channel at the catalyst midpoint
- The primary focus of the test matrix runs is on the cake regime. Thus, run times need only be long enough to assure this regime dominates.

Procedure

- Degreening – {under review, looking at DECSE procedure as a staring point}
- Establish baseline, clean trap delta P measurements
- Calibrate smoke measurements with soot loading . Use smoke measurements during test matrix runs.
  - Run at all baseline engine operating modes defined in test matrix
  - Measure smoke and change in DPF weight over specified run time (method to be determined)
  - Calibrate smoke correlation for soot prediction with weight measurement
  - Measurements of NO, NO_2, H_2, CO, CO_2, O_2, and total hydrocarbons at the reactor exit collected at 1sample/s for an empty reactor (no core sample present)

Procedure

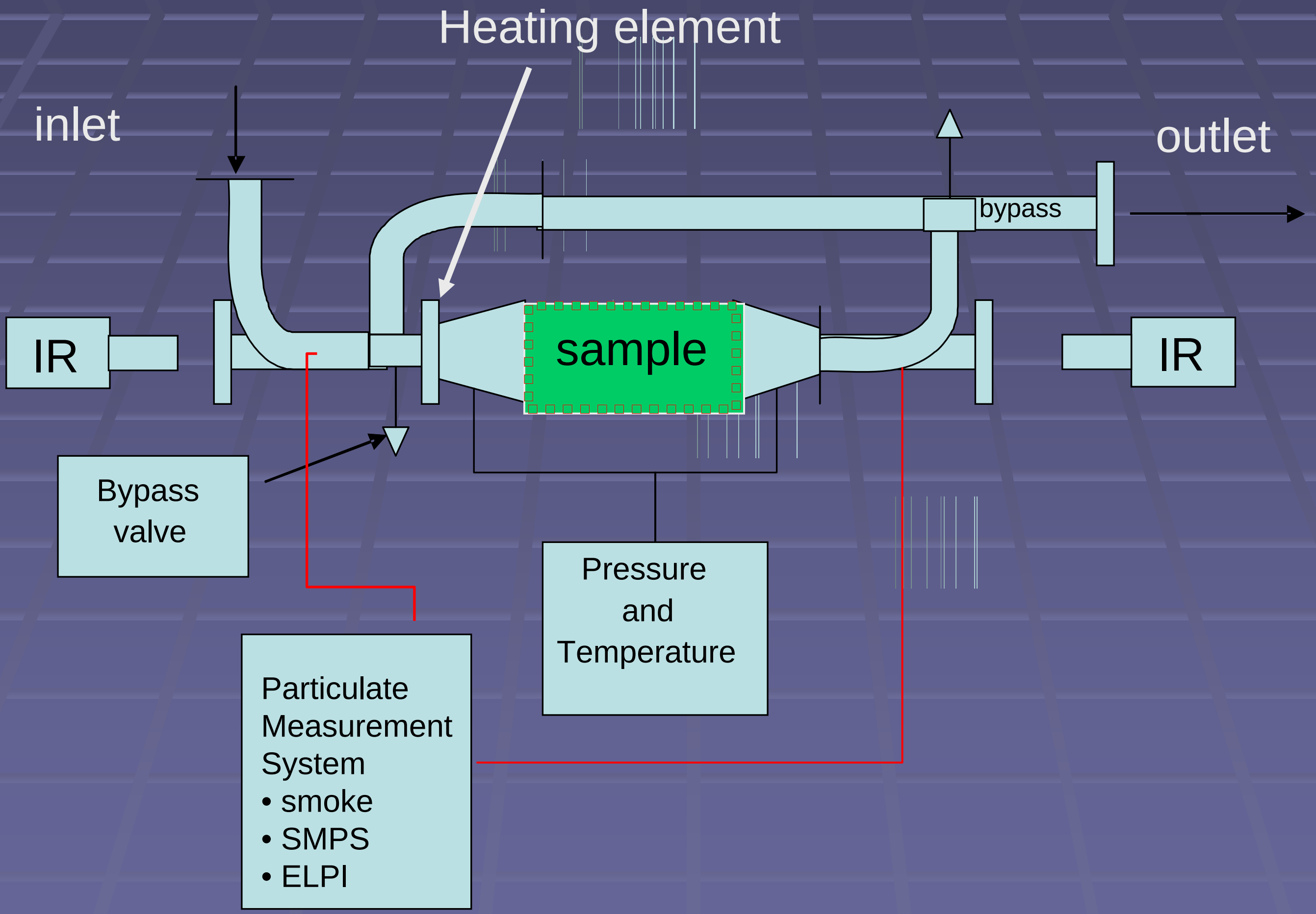
Run test matrix

- Run time: two hours
- Measurements: For slow cycles, measurements of NO, NO_2, H_2, CO, CO_2, O_2, N_2O, and total hydrocarbons at the reactor exit collected at 1 sample/s

Engine-off oxidation runs

- After a soot loading run, divert all engine exhaust away from filter. Then run temperature and flowrate controlled flow through filter for specified run time (tbd). Measure pressure drop as a function of time during oxidation process.
- Goal is to have oxidation only under controlled conditions

Approach - slipstream



Bypass valve

Pressure and Temperature

Particulate Measurement System
- smoke
- SMPS
- ELPI

Slipstream

- Slipstream/mini-core approach has been used to good effect on several PNNL catalyst projects
  - Versatile
  - Quick
  - Cost Effective
  - Proven and accepted concept
- Sample
  - Mini filter or cored sample, available in 1 and 3 inch diameter
- Bypass valve/heating element
  - allows control of space velocity and gas temperature
- IR windows gives data on temperature distributions

Test Matrix

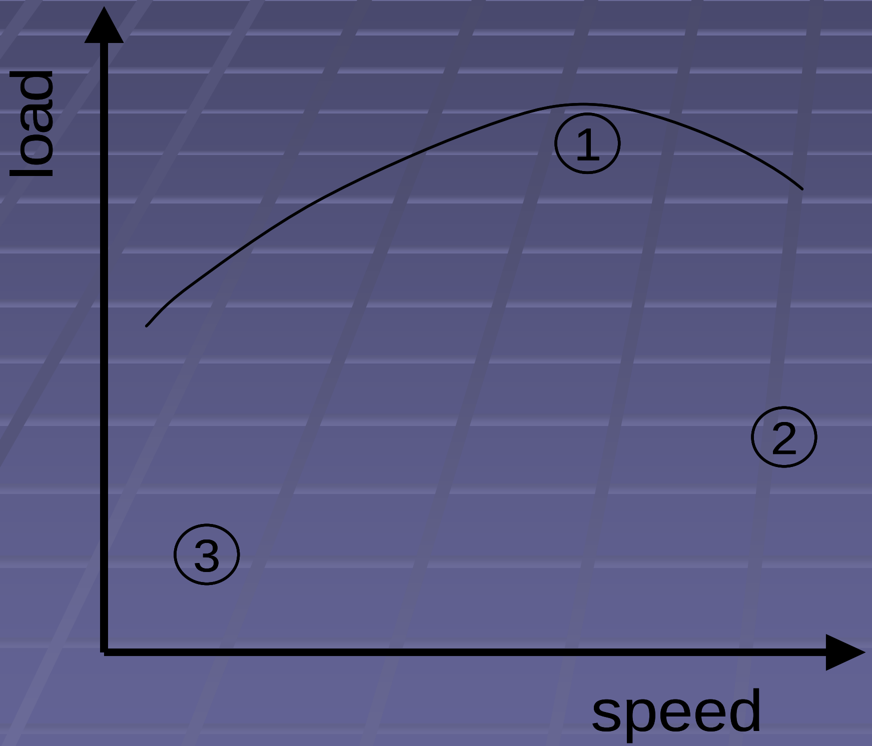


Figure 1: Baseline engine test modes

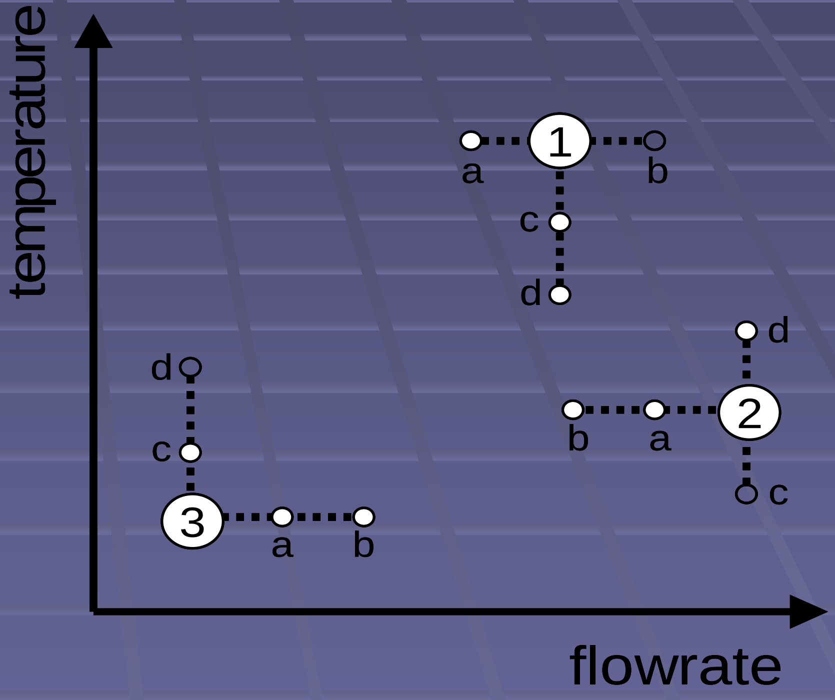


Figure 2: Temperature and flow rate perturbations

Test Matrix

Engine Mode+	Temperature+++	Flow rate +++	Feed Gas Mix++
1	B	B	B
1a	B	- ∆	B
1b	B	+ ∆	B
1c	- ∆	B	B
1d	- 2∆	B	B
1e	B	B	1
1f	B	B	2
1g	B	B	3
2	B	B	B
2a	B	- ∆	B
2b	B	- 2∆	B
2c	- ∆	B	B
2d	+ ∆	B	B
2e	B	B	1
2f	B	B	2
2g	B	B	3
3	B	B	B
3a	B	+ ∆	B
3b	B	+ 2∆	B
3c	+ ∆	B	B
3d	+ 2∆	B	B
3e	B	B	1
3f	B	B	2
3g	B	B	3

Test Matrix (notes)

B = baseline

\+ Engine mode 1: Max load, rated speed
Engine mode 2: 25% max load, max speed
Engine mode 3: Idle
See Figures 1 and 2

++ gas mix 1 = double NO2 concentration from baseline
gas mix 2 = increase O2 by 2% from baseline
gas mix 3 = double NO2 from baseline and increase O2 by 2%

+++ Temperature and flow rate D definitions:
Temperature: 50 ^{o}C
Flow rate: 15% of baseline