### NRC.CNRC

### Motivation

- Support increased technical productivity by developing process technology to more effectively and efficiently estimate concentrations of particulate matter (PM) in Diesel engine exhaust
- This will enable the further development of emissions compliant engine products
  - -Develop efficient and effective soot management and dosing strategy for DPF's
- -Develop effective engine calibrations for reducing PM levels at different engine conditions
- -Facilitate further development of emissions compliant engine products

### Background

- Currently "Gravimetric PM Sampling System" is used to measure PM, which is not real-time
- Laser Induced Incandescence (LII) is a real time, non-intrusive soot measurement techniques for rapid characterization of diesel particulate emissions
- The LII method has the advantage of being able to sample and report particulate emissions from either the direct exhaust or from a dilution tunnel facility

### Approach

- In the present investigation, the LII instrument was evaluated extensively at the Constant Volume Sampling (CVS) emission laboratory at the Cummins Technical Center, where a Cummins' standard gravimetric PM measurement system is available as a comparative standard
- Collaborative efforts between Cummins Inc. and Artium Technologies are ongoing with the goal of advancing the LII capability for measuring real time soot at pre- and post DPF locations at transient and steady state engine operating conditions

### Artium LII-200 Instrument

- LII technique evaluated was developed and patented by NRC Canada
- Artium Technologies Inc. commercialized LII-200
- LII-200 has 4 sub-systems:
- –LII power supply
  –Gas Flow Controller
- -LII Sensor Head
- -On-board computer with
- AIMS software (Advanced Instrument Management Software)

### LII Advantages and Features

Measures real-time soot concentration (ppb & mg/m<sup>3</sup>)
 Sample dilution not required, can be used to estimate SVF in raw exhaust

# Assessment of a Laser-Induced Incandescence Sensor for Real-Time Particulate Emissions Measurement

### Ritesh C. Gujarathi<sup>a</sup>, Virendra Kumar<sup>a</sup>, Shirish A. Shimpi<sup>a</sup>, William D. Bachalo<sup>b</sup>, and Gregory J. Smallwood<sup>c</sup>

· Short-term transient repeatability (COV)

-Gravimetric TPM: 2.1%

-SOF extracted PM: 5.3%

atest Results with Correct Calibration

· An issue was discovered with the neutral density

filters in the LII instrument; it was recalibrated on-site

-LII now is reporting lower SVF values than TPM

I E Sameline Dilute Exhaust

LII Sempling Day Exhau

· At high load, in both diluted and raw exhausts, LII

measured by the Cummins Gravimetric method

At low load, in raw exhausts, LII measures higher

measures about 95% of Dry PM from diluted exhaust

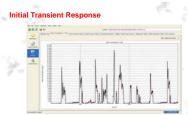
(ranging from 1.1 to 2 times), and in diluted exhaust

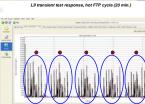
substantially lower, as compared to Dry PM from

diluted exhaust measured by the Cummins

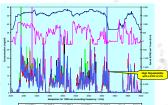
-LII: 3.5%

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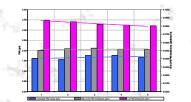




Five repeats of LII transient test response, hot FTP cycle (20 min.

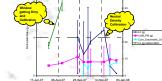


s of LII response vs. speed and torque for transient tests, hot FTP cycle (20 min.)



PM emissions (gm) from five repeats of transient testing • LII transient response higher by 1.6 \* TPM and 2.0 \* SOF extracted PM

## Gravimetric method



Above graph shows the historical development of LII system at Cummins. This involved combined partnership to work with Artium and NRC to resolve sampling and instrument issues including: Leak in the system, software issues, improving sampling system, correcting Neutral Density filter issues
 There is still work in progress to further refine the system to expected traceability and accuracy

### Critical Parameter Measurement



 Cummins, Artium, & NRC worked during the on-site visit at Cummins (13-15 Nov'07) to identify sources of uncertainty

### Summary

### LII current status:

- -The LII technique is capable of monitoring PM emissions by estimating soot concentration and primary particle size
- The currently implemented improvements to the LII resulted in repeatable measurements of soot volume fraction from the LII with a short term Coefficient of Variation (COV) of 3-7% for steady state cycles and a COV of 3-5% for FTP transient cycles for the equivalent gravimetric PM level ranging from 0.01 to 1.00 g/bhp-hr
- The correlation between time-integrated LII signals and the standard gravimetric PM measurement system was found to be robust with a correlation regression coefficient ranging from 96%-99.8%

### -LII has been tested for Steady States, Transients, Raw Exhaust, PM Trap-out

- -LII reported similar readings compared to Dry PM measured using Cummins gravimetric method at higher load conditions, and much lower to about 0.9 to 2 times at low load conditions
- -LII-200 is nearing readiness for Prime Testing -Expected in the near future

### • Work Ahead:

- –Reliable calibration of Neutral Density filters from 3<sup>rd</sup> party laboratory
- Determine most appropriate values of Soot Absorption Function  $E(m\lambda)$  and relative absorption function
- Ongoing work to increase sensitivity through improved signal averaging and processing
- Packaging Feasibility of installing exhaust gas Sampling System to control volumetric flow and pressure in the sample cell

National Research Conseil national Council Canada de recherches Canada



#### 18th CRC On-Road Vehicle Emissions Workshop San Diego, California, March 31 – April 2, 2008

LII steady-state response higher by ~ 1.7.2.5 \* TPM.
 Short-term steady-state

Initial LII Steady State Response

Technologies In

· Insensitive to presence of other emission gas species

High resolution (0.01mg/m<sup>3</sup>) and high repeatability (2-

(counts vs. size): Below - validated mass

Data recording frequency: 1-20 Hz and connectivity

· Ease of operation, portable to transport and

**Comparison Between Two LII-200 Instruments** 

LI Comparisor

LEA1 main?

with host data acquisition system

maintenance free working

5%)

Absolute intensity calibration

Example AIMS results from LII-200

-LII: 3-7% -Gravimetric TPM: 2-5% -SOF extracted PM: 3-25%

PM mass (gm) representation for 5 mode s/s tests (with 3 repeats)