Emissions Measurements from the Golden Vehicle –
A Light Duty Diesel Vehicle Used During Validation of the European PMP Protocol

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Acknowledgements

- European Union – Directorate General – Joint Research Center (JRC), Ispra, Italy. Dr. Penny Dilara and many others

- Dr. Tao Huai, Ronald Haste, Sharon Lemieux, Wayne McMahan, Paul Rieger, and many other members of CARB’s technical staff

- Dr. Tom Durbin and others at UCR/CE-CERT

- Dr. Markus Kasper/Matter Engineering AG

- Jon Andersson/Ricardo UK Ltd
CARB’s Research Portfolio on Ultrafine Particle Emissions from Mobile Sources

- CARB PMP-based Program on LDDV (Golden Vehicle)
- HDDV PMP Study
- CARB/CE-CERT/ESP/DRI
- LDGV PM Study
- Investigation of multiple engine/aftertreatment technology

In-house Investigation
- Extensive Domestic and International Collaboration
- Portable and fixed systems
- Measurement Instrument Evaluation
- Sampling Methodology
- Investigation of Nature and Relative Toxicity of Emissions
  - CARB/SCAQMD/USC/UCLA
  - Inform ACES
- Investigations:
  - Laboratory
  - on-road
  - chase vehicle
  - In-vehicle

Extramural Research
- Comparison of PM mass, number, other metrics
CARB PMP-based Program

Study Drivers

• Potential health impacts of ultrafine particles

• CARB and JRC Memorandum of Understanding (MOU) for Research

• Need to understand the potential of the new European proposal for particle emission standard
  
  ➢ Assess robustness of PMP Protocol vis a vis gravimetric measurement
  ➢ Evaluate non-specified particle counters, alternative systems, and dilution methods

• CARB is exploring PMP’s utility and “enriching the main programme” for LDVs and HDVs

• Investigate nature of particles emitted at the tailpipe and their relative toxicity
UNECE-GRPE Particulate Measurement Programme (PMP)

- Initiating governments: France, Germany, Netherlands, Sweden, & UK. Joined by Switzerland, Japan, and Korea

- Key objective: “Development of type approval test protocols for assessing vehicles fitted with advanced particulate reduction technology that would complement or replace current legislative measurement procedures”

- Main driver behind PMP is the impact of particles on health

- Key objective is development of new particle measurement technique for very low emission levels

- Inform EU Directives: LDV EURO5 and HDV EURO6

Sources: 1) M. Dunn, UK Depart. Of Transport, ETH Nanoparticles Conference, 2003, Zurich
2) Andersson et al., PMP Light-duty Inter-Laboratory Correlation Exercise Final Report, GRPE-PMP-18-2, Mar.2007
UNECE-GRPE PMP – cont’d

- Phase 1 – instrument comparison (mass, number, surface, chemistry, dilution, sample conditions, cost, ease of use, etc)

- Phase 2 – More rigorous evaluation of best performing systems. Conclusions were,
  - An improved filter-based method based on US07
  - A particle number method based on counting, dilution, and thermal treatment to eliminate volatile particles

- Phase 3 – Inter-Laboratory Correlation Exercises (ILCE)

- 9 international laboratories (Europe, Japan, Korea) + California

- 17 vehicles (Euro 4), including GV (“transfer standard”)

- **CARB testing of GV is on-going (Jan 07 – present)**

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*Source: Andersson et al., PMP Light-duty Inter-Laboratory Correlation Exercise Final Report, GRPE-PMP-18-2, Mar.2007*
Heavy-duty Vehicle Testing

- Extensive testing to data (CRC '06)
- Applying PMP protocol for pre- and at CVS sampling
- California DPF-equipped truck
  - 2000 Isuzu MHD truck (8.3L, 22K lbs)
  - JMI's CRT
- CARB's Heavy-duty Vehicle Emissions Laboratory
- Various US transient duty cycles and steady-state operation
- PMP testing in 2006 and 2007
Particle number measurements are considerably more precise than the mass measurement in the current study. Upcoming improvements in gravimetric measurements at CARB labs are expected to get closer to new US07 1065 Rule.

“Solid” particles can be smaller than 23nm (PMP D50 cut).

Source: Herner, Robertson, and Ayala, SAE Technical Paper 2007-01-1114
Testing has not been problem-free

One example

- Lubricating coating on rotating disk and diluter head can quickly degrade and wear off
- Once the coating starts to break apart, the instrument appears to generate particles
- It may be preferable to operate the instrument at 80°C or 120°C to avoid wearing off the coating when operating at 150°C
European Gold descending on California
Preliminary Results for Golden Vehicle

PMP’s Golden Vehicle – Euro 4 Peugeot 407 Saloon 2.0 HDi 136 SE equipped with an uncoated diesel particulate filter and cerium based fuel borne catalyst

- Testing at one of CARB’s clean light-duty vehicle emissions laboratories with CA ULSD
- Pre-conditioning effects
- FTP, NEDC, and steady-state operation
- SHED testing for evaporative emissions
- Testing Jan – Mar 2007 (on-going)
Golden Vehicle Testing - Instrumentation

Particle Counters

TSI 3790
TSI 3010D
Grimm CPC

Matter Engineering MD-19

TSI EEPS
EcoChem PAS2000
Matter Engineering LQ1-DC

Horiba SPCS
Average Mass Emissions during NEDC for Au Vehicle Preliminary CARB Results

Pollutants

- THC (*10)
- CO
- CO2 (/1000)
- NOx
- PM (*1000)

Average Emissions (g/km)

CARB

Au-DV1

Particle Emissions during NEDC Au Vehicle (excluding regeneration) Horiba SPCS

Tests

- 1-NEDC-8
- 1-NEDC-10
- Mean Au-Veh

Preliminary Results
Particle Size Distribution (1-NEDC-10, 02MAR07)*
Au Vehicle

*EEPS average over entire NEDC
Regeneration achieved as expected
Summary

• Study of Au-Veh is on-going, no final interpretations or conclusions yet

• But our findings to date are very encouraging. Preliminary results are consistent with those of 9 other international laboratories

• Gaining important experience with PMP protocol, its potential, and new opportunities for use in California

• Enhancing understanding of nature of ultrafine particle emissions

• PMP project is giving important exposure to light-duty diesel vehicle technology

• From HDV testing:
  – The PMP particle number measurements are more precise than gravimetric measurements
  – There are sub-23nm solid particles post PMP sampling that can be counted with equal accuracy as those >23 nm

• On track to complete study successfully by mid-2007