



EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre



Update on the UN-ECE GRPE Particle Measurement Programme – Summer 2009

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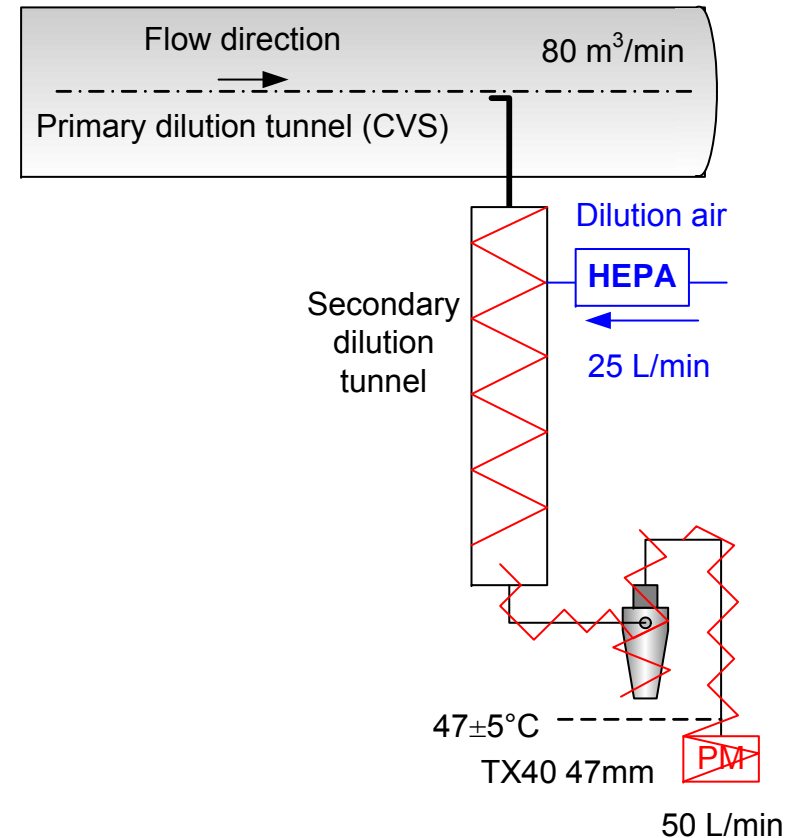
IES, JRC, Ispra, Italy

- Inter-governmental research programme under the auspices of UNECE GRPE to develop new vehicle exhaust particle measurement procedures for regulatory use
- Set up due to health concerns over nanoparticles...
- ...and concerns over the ability of the current particulate mass measurement method to enable the forced adoption of technologies which effectively control their emissions
- Mandate was to develop techniques to replace or complement the particulate mass measurement method
 - must be applicable to Light Duty Vehicle & Heavy Duty Engine type approval testing
- PMP also to provide data on the performance of different engine and vehicle technologies according to the new measurement procedures

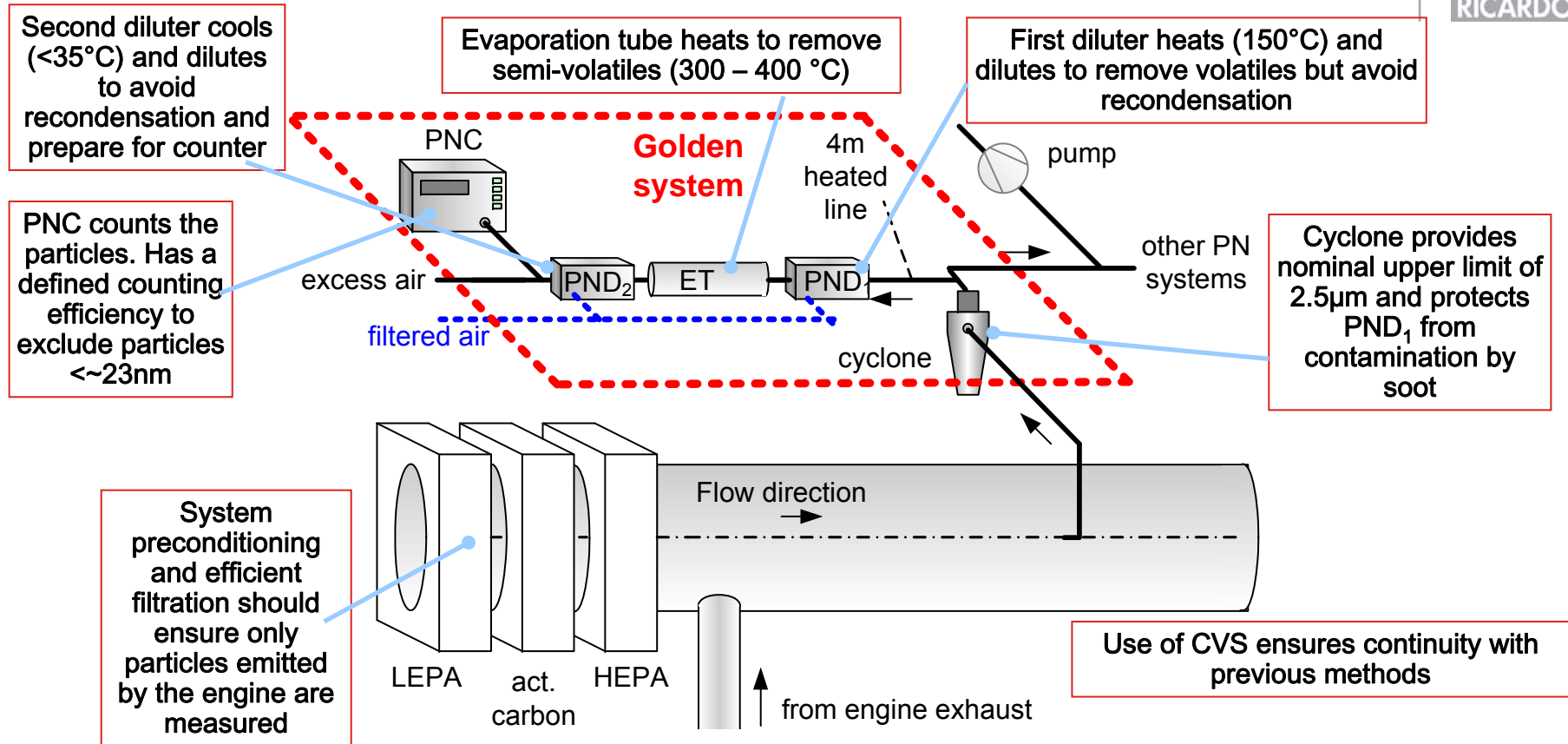
- Phase I (2001-2) developed protocols for examining different candidate measurement systems.
- Phase II (2002-3) evaluated a range of measurement techniques and sample conditioning systems.
- Phase III (2004-) is validating the recommended measurement techniques via inter laboratory test programmes.
- Validation exercise for light duty testing completed in 2006 and reported in 2007
- Validation and Round-Robin Exercises under way

PMP Phase II Recommendations – Improved Particulate Mass Measurement

- Improved dilution air filters
- Cyclone (2.5 μ m to 10 μ m cut-point)
- Sample to be held at 47°C +/- 5°C for >0.2s
- Filter face velocity (55cm/s to 90cm/s)
- Pallflex TX40 filters with no backup
 - One filter for the entire cycle
- Weighing
 - Static charge neutralisation
 - Buoyancy correction



Particle Number Measurement Approach - Validation Exercise



- Measurement employs a condensation nucleus counter, but uses sample pre-conditioning to eliminate the most volatile particles which may contribute significantly to variability
- Solid particles defined by the measurement equipment
 - ~23nm to 2.5µm and surviving evaporation at (or above) 300°C
 - Analogous to heated FID hydrocarbon method



PMP Inter-laboratory Correlation Exercises for Heavy Duty Engines (ILCE_HD)

- Evaluate measurement systems developed for light-duty programme in heavy-duty testing context
- Demonstrate repeatability between nominally identical systems within single laboratories
- Demonstrate reproducibility between nominally identical systems between laboratories
- Demonstrate inter-lab reproducibility of commercially available PMP compliant systems from a variety of manufacturers
- Evaluate the draft test protocols and measurement methods to assist in their development

Schedule of the PMP Phase 3 Heavy-duty Exercises



Date	Validation Exercise (VE) – 5 labs, Europe	Round Robin (RR) – 13 labs, Worldwide
Jan – Feb 2008	JRC	
Mar-Apr 2008	AVL-MTC	
May – Jun 2008	JRC	
Jul – Sept 2008		RWTUEV
Oct – Nov 2008		Ricardo
Dec 2008 – Jan 2009	Ricardo	NTSEL
Feb - April 2009	UTAC	JARI
April – August 2009	EMPA	NIER (Korea)
August– October 2009	JRC	
Oct – Nov 2009		JRC
Dec 2009 – Jan 2010		Volvo
Feb – Mar 2010		Scania
Apr – May 2010		UTAC
Jun – Aug 2010		TNO
Sep – Oct 2010		VTT
Nov – Dec 2010		Environment Canada
Jan – Feb 2011		RWTUEV rpt
Mar – Apr 2011		Daimler

**Provisional
timings**

- Similarities and Differences Between VE and RR

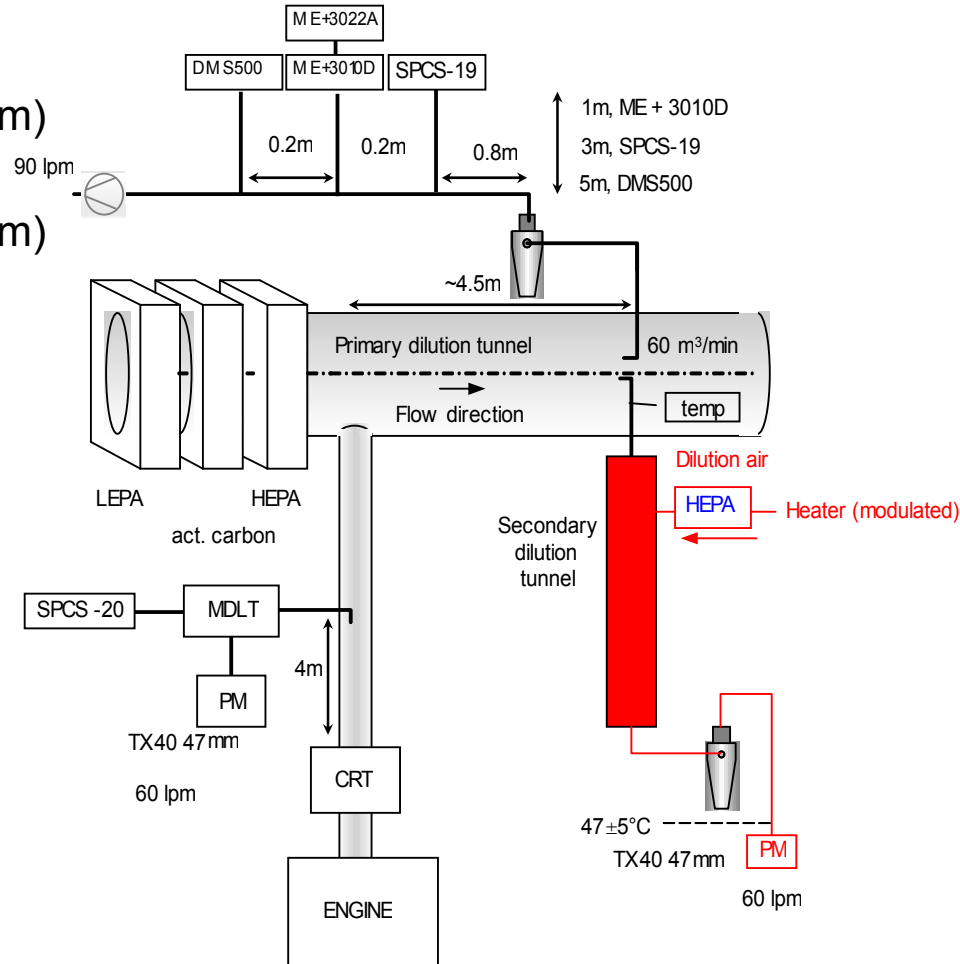
PMP HD Validation Exercise (PMP_VE_HD)	PMP HD Round Robin Exercise (PMP_RR_HD)
Golden Engine (VE-E1: Euro III + DPF, Iveco Cursor 8)	Round Robin Engine (RR-E2: Euro III + DPF, Mercedes OM501)
2 x Golden Particle Measurement Systems	Labs' own Particle Measurement Systems
Golden Engineer and Written Guide	Written Guide only
Fuel and lubricant from single batches	Fuel of defined spec, same lube fill in all labs
Full and partial flow used in parallel	Full and partial flow in initial 3 labs, then partial flow alone permitted
European labs only	European, Asian and N. American Labs
Aims to investigate issues with measurement approaches	Uses repeatability as metric for assessing system
Reproducibility addresses emissions of DPF equipped engines	Reproducibility includes uncertainty in different measurement systems

- Alternative systems welcomed in the VE

- Test Matrix addresses replicate European and World Cycles
 - Same tests for both VE and RR
- ≥ 8 repeats of each cycle
 - Cold WHTC [10 mins soak]
 - Hot WHTC
 - WHSC [Hot preconditioning]
 - ETC
 - ESC
- Protocol includes
 - Daily routines that provide fixed test timing
 - Forced passive regeneration
 - limited DPF fill
 - validation exercises for particle measurement systems

Typical laboratory set-up

- Validation Exercise
 - One particle number system (golden system) from full flow dilution system
 - One particle number system (golden system) from partial flow dilution system
 - PM measured to
 - PMP approach (full flow)
 - PMP recommendations (partial flow)
- Round-robin
 - One particle number system from either partial flow or full flow dilution system
 - Labs' own systems
 - Optional to test partial AND full flow
 - PM measured to
 - PMP approach (full flow)
 - Manufacturer's guidelines (partial flow)

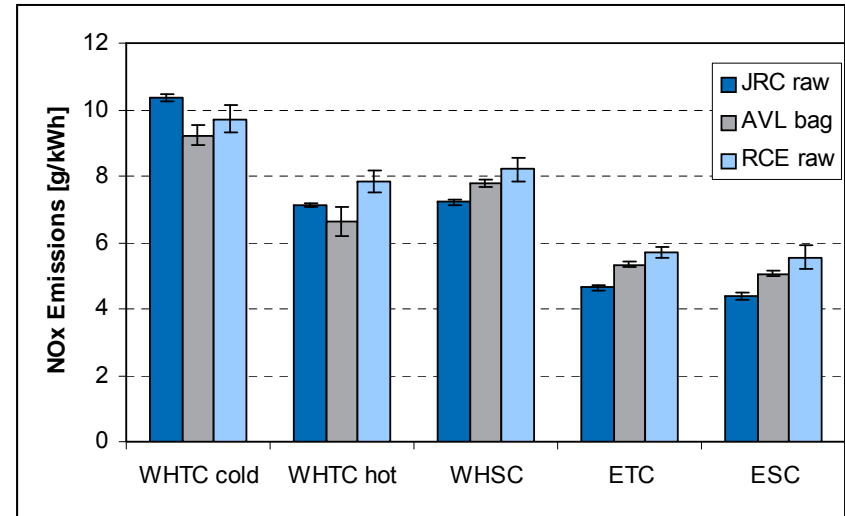
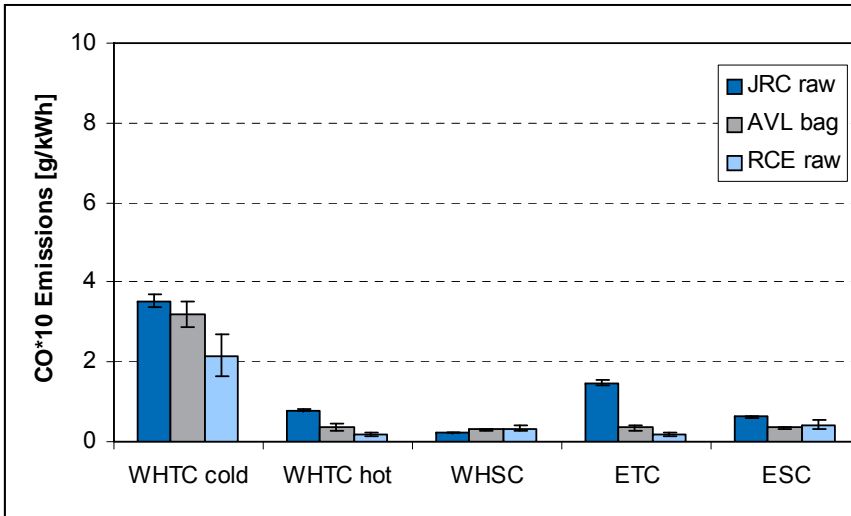
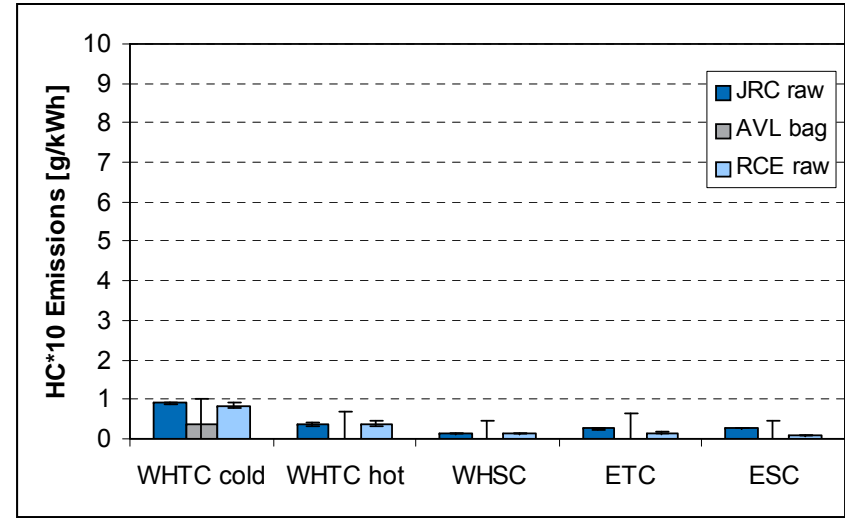
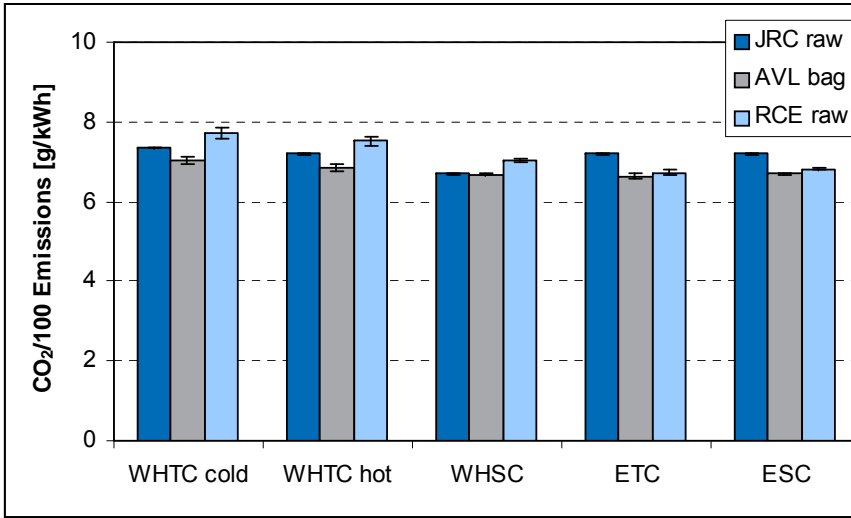


Sampling Schematic – Ricardo; Validation Exercise

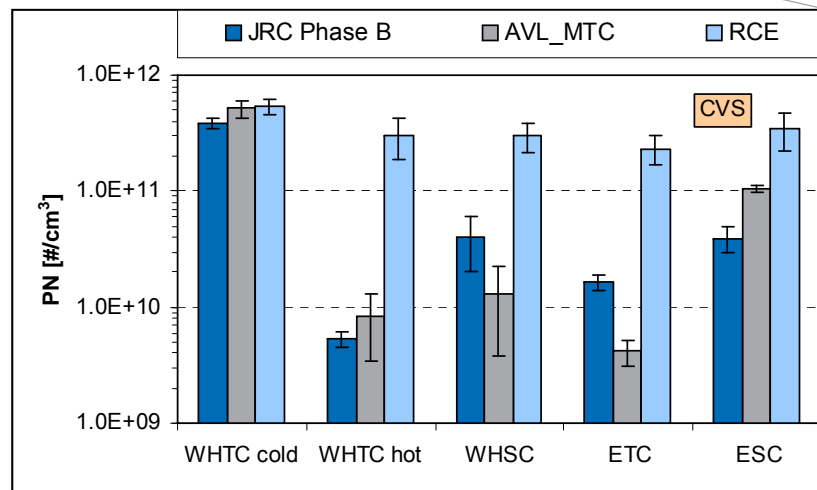
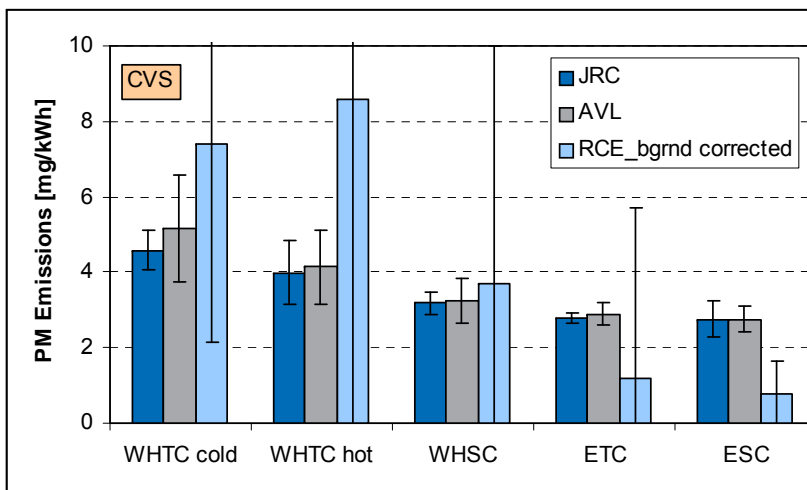
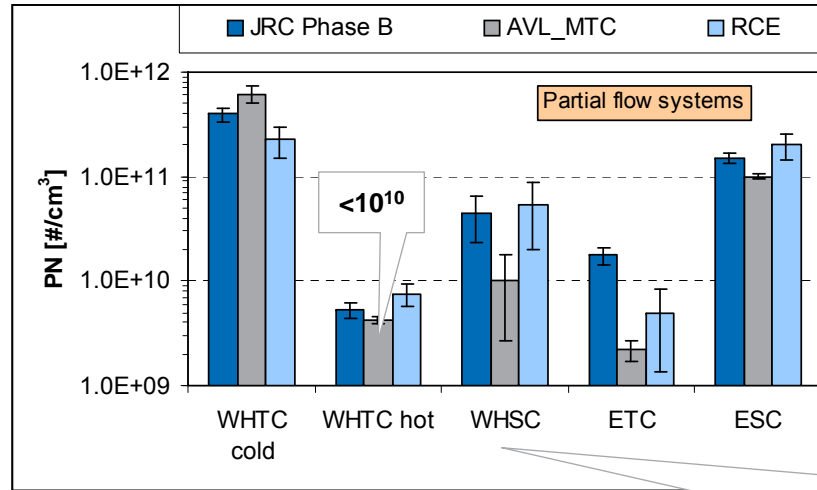
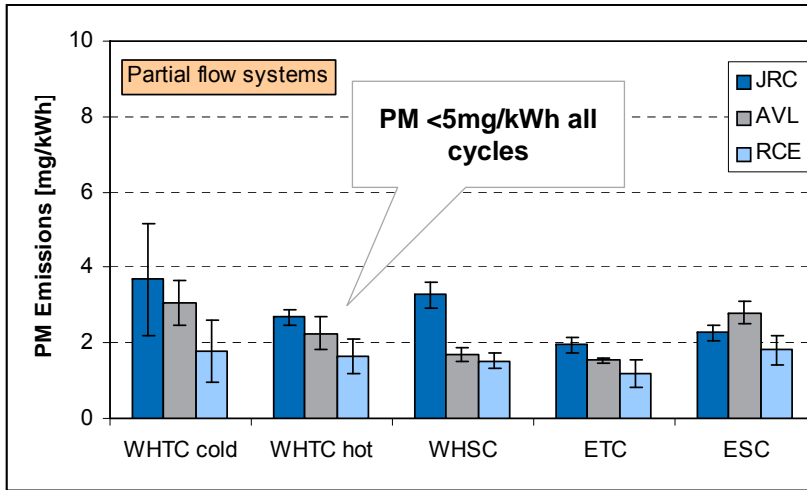
Validation Exercise Results

Preliminary data

VE Comparisons – gaseous emissions show expected repeatability levels



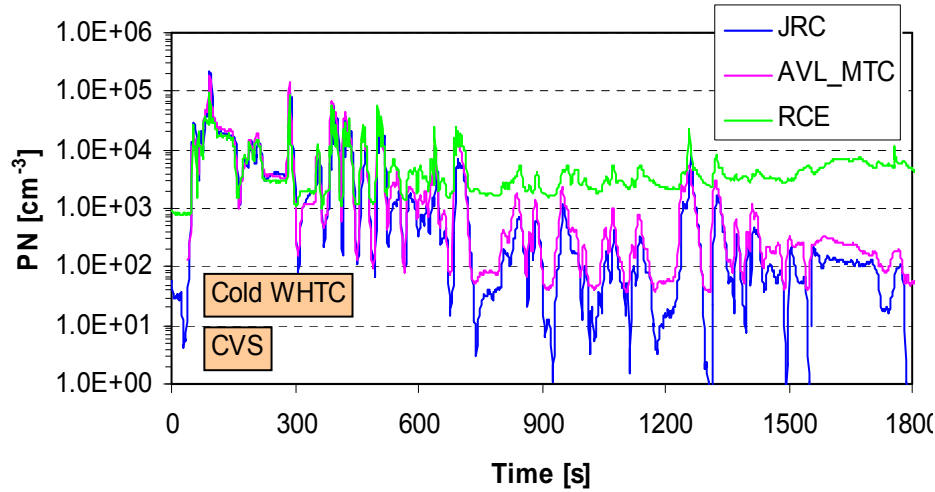
VE Comparisons – PM typically <5mg/kWh, PN <10¹²/kWh with highest emissions from Cold WHTC



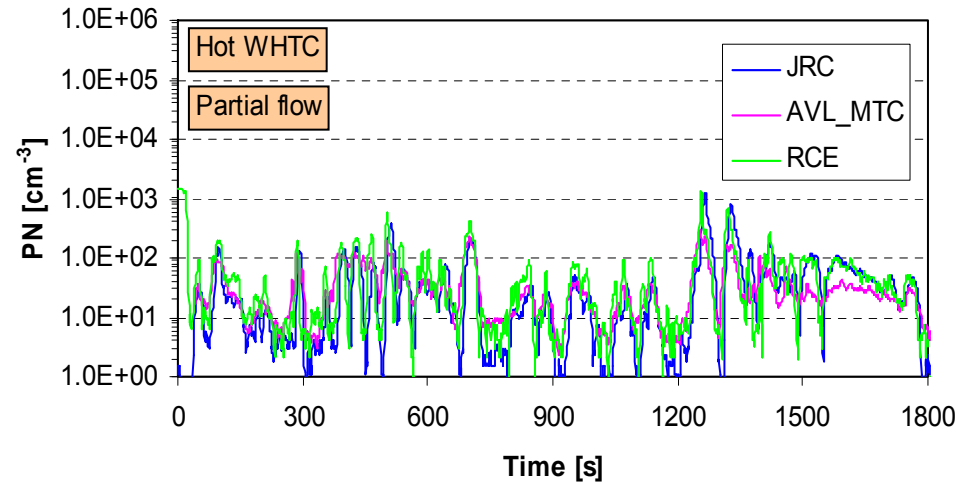
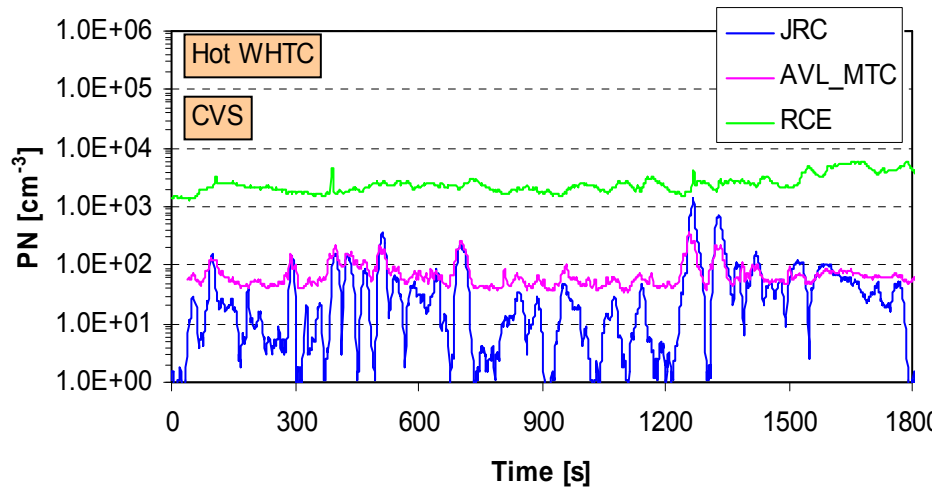
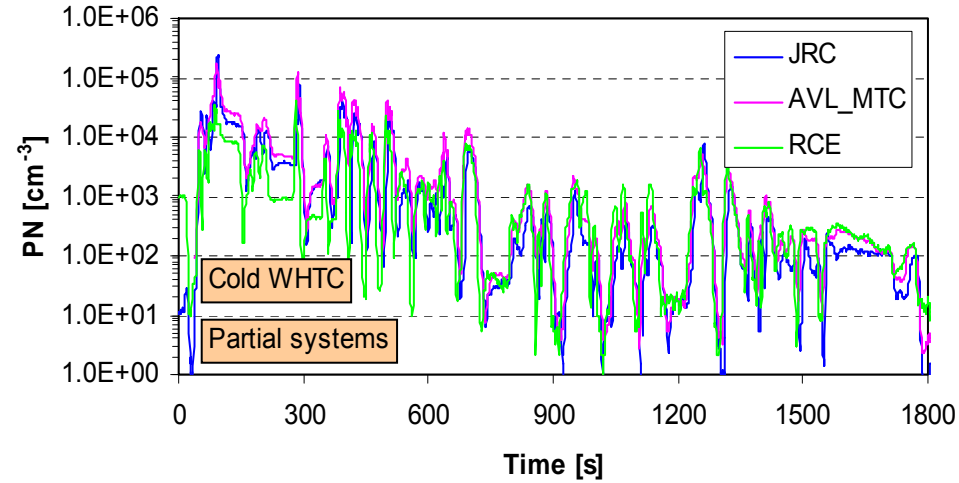
Higher variability from WHSC – passive regeneration

VE Comparisons – Real time PN influenced by background, but impact only substantial with hot cycle results

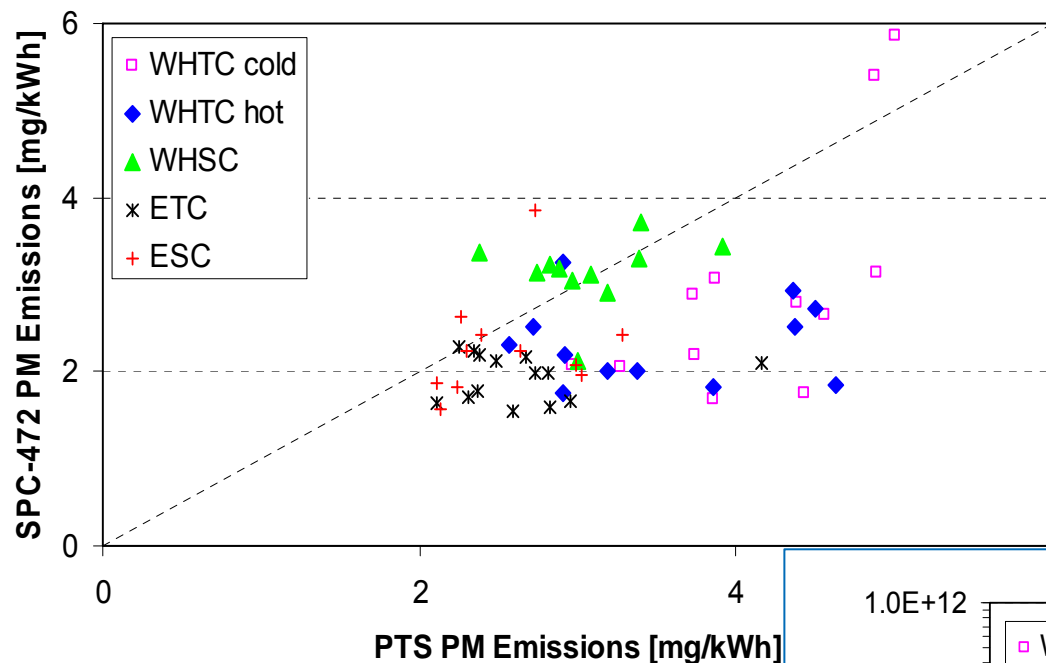
Background Impacts hot WHTC, but minor influence on cold WHTC



Backgrounds low in all partial flow systems

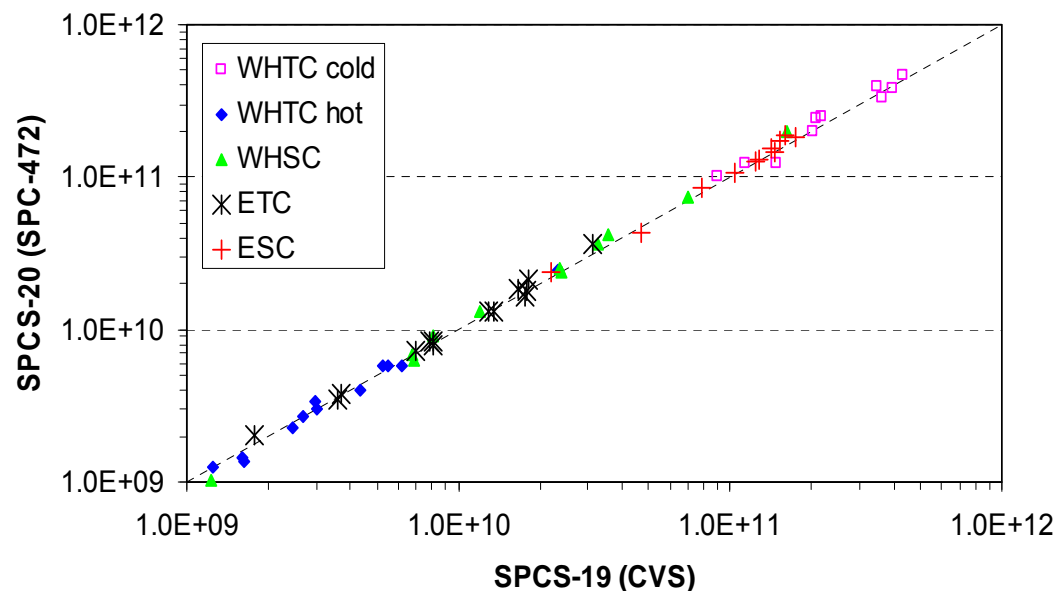


VE partial-full flow systems correlations: good for number, poor for mass

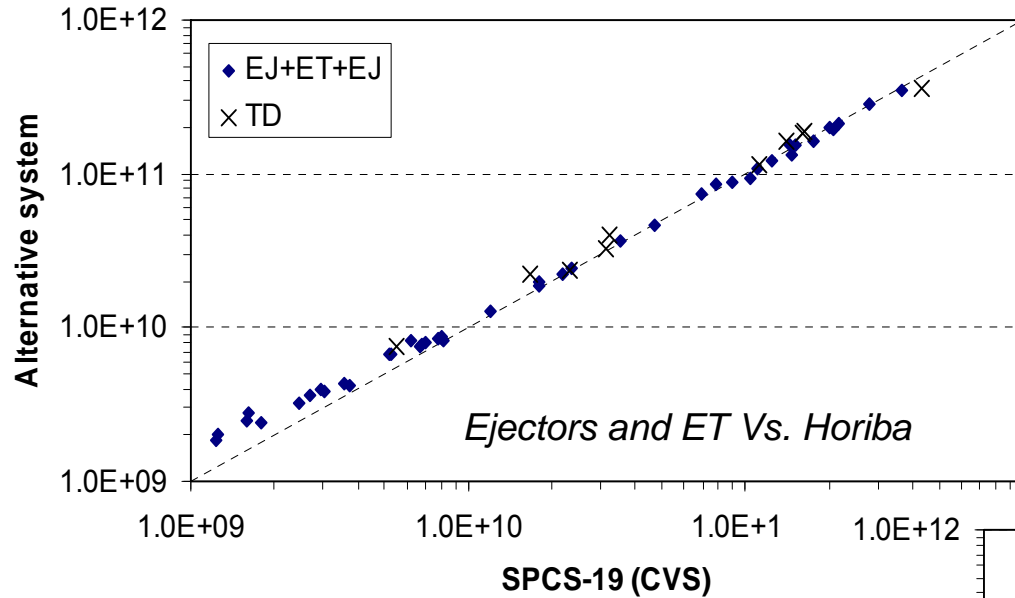


- **Poor PM correlation**
 - between partial and full flow systems
 - But similar emissions levels

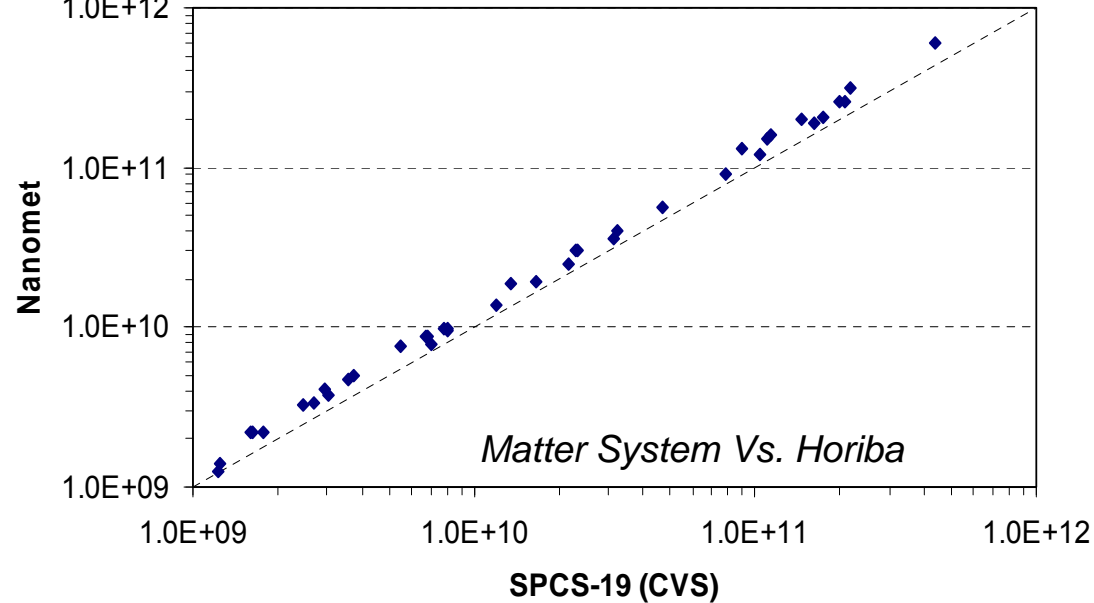
- **Excellent PN correlation**
 - between partial and full flow systems



VE testing shows good golden system and alternative system comparisons



- Very good agreement between alternative and golden systems measuring from CVS in parallel
 - Without PCRf correction



- Validation Exercise
 - Good correlation between partial and full flow systems
 - Good correlation between particle number systems
 - PM typically <5mg/kWh; Cold WHTC highest
 - PN typically $\sim 5 \times 10^{11}$ /kWh Cold WHTC can be $< 10^{10}$ /kWh from hot cycles
 - Background can be an important influence in hot cycles results
- Validation Exercise comparisons
 - Quite good lab-to-lab repeatability of PN emissions especially from partial flow systems
 - Background important
 - WHSC repeatability impacted by passive regeneration

- Robustness of VPR operating parameters when challenged with particles generated during prolonged high temperature and regeneration operation
 - Horiba VPR appears very efficient
 - Further study at JRC following completion of the VE
- Presence of mode comprising solid nanoparticles at or below PNC cut-point
 - Some of these particles exist, but are of similar magnitude to the >23nm particles
 - Further work is planned
- Effects on particle emissions of active and passive DPF regenerations
- Correlations between PMP systems with different manufacturers' PCRF calibrations
- Others to be identified...

- Complete VE exercise in October 2009, carry out additional experiments
- Analyse data and prepare reports for PMP WG
 - Consideration of on-going RR testing (to complete 2011)
- Final data analysis and reporting by the end of 2009
- On-going revision of draft regulatory document (R49)
 - Consideration of implications of differences between light and heavy-duty measurement system results
- Submission to GRPE and WP29 of proposals to incorporate new measurement procedures in R49
- EC consideration in Brussels of revised R49 procedures as part of Euro VI requirements
- Parallel consideration of PN limit(s)