AECC Heavy-duty Euro VI Test Programme

by AECC (www.aecc.eu)

11th ETH Conference on Combustion Generated Nanoparticles

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Association for Emissions Control by Catalyst AISBL

Association for Emissions Control by Catalyst (AECC)

AECC members: European Emissions Control companies

Technology for exhaust emissions control on all new cars (OEM and Aftermarket) and an increasing number of commercial vehicles and motorcycles

Objectives of AECC heavy-duty Euro VI test programme

- Demonstrate the performance of an integrated emissions control system on a modern, low NOx engine.
- Compare current gravimetric and heavy-duty PMP method for particulate mass (PM).
- Assess heavy-duty PMP particle number methodology.
- Provide data on European and World-harmonised and other major test procedures.

AECC heavy-duty Euro VI test programme

- Engine designed for US2007, provided by an engine manufacturer
  - 6 cylinder 7.5 litre engine
  - Common rail
  - Turbocharged (fixed vane)
  - Max. injection pressure 180Mpa
  - Cooled lambda-feedback EGR.
- Emissions control system provided by AECC:
  - Oxidation catalyst (DOC), catalyst-based particulate filter and urea-SCR with ammonia slip catalyst (ASC).
- Fluids:
  - Diesel reference fuel CEC RF-06 (max. 10ppm S)
  - Low ash 10w-40 engine lubricant
  - AdBlue® aqueous urea to DIN 70070 specification.

Preconditioning procedures

- For repeatability, the daily test regime started with a cold start test (WHTC, FTP or NRTC) and finished with a standard preconditioning regime.

- The end-of day preconditioning consisted of

- mode 4 warm-up:	15 min.	2130 rev/min.	560 Nm
- followed by:	60 min.	2575 rev/min.	700 Nm
- then:	60 min.	1300 rev/min.	150 Nm

- Following each test cycle the engine was run at a Mode 4 standardisation condition for 15 minutes.

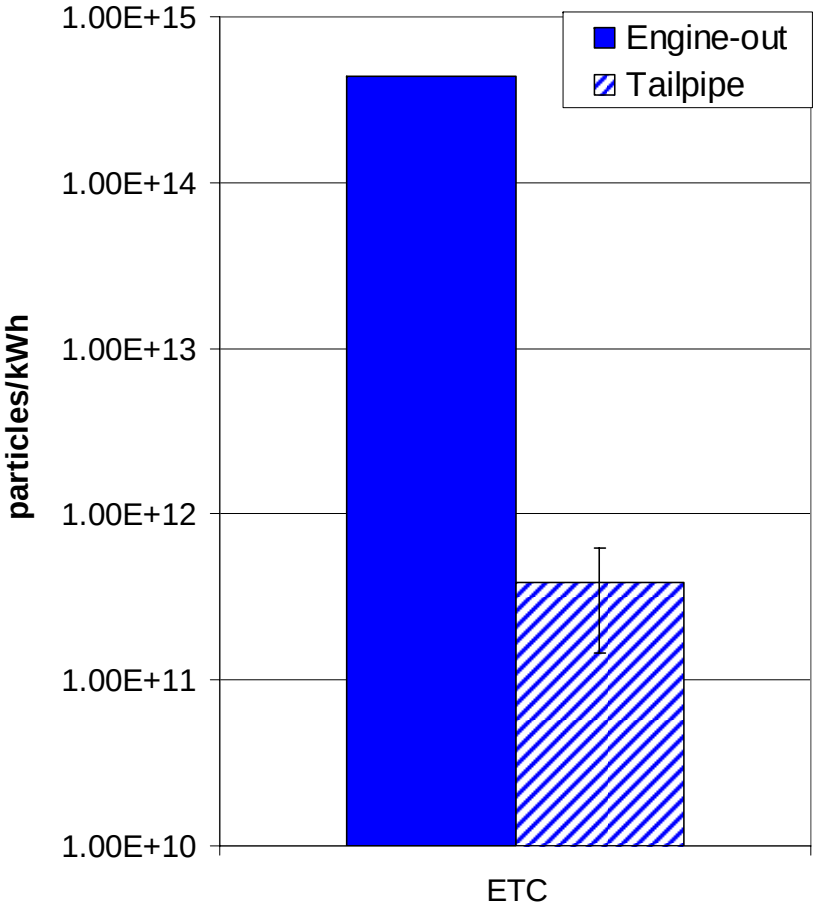
- Pre-test conditioning
  - ETC, JE05, ESC: 7.5 min. mode 4 (2130 rev/min, 560 Nm)
  - WHSC: 10 min. mode 9 (1816 rev/min, 373 Nm) followed by 5 min. soak.

Particle number measurements

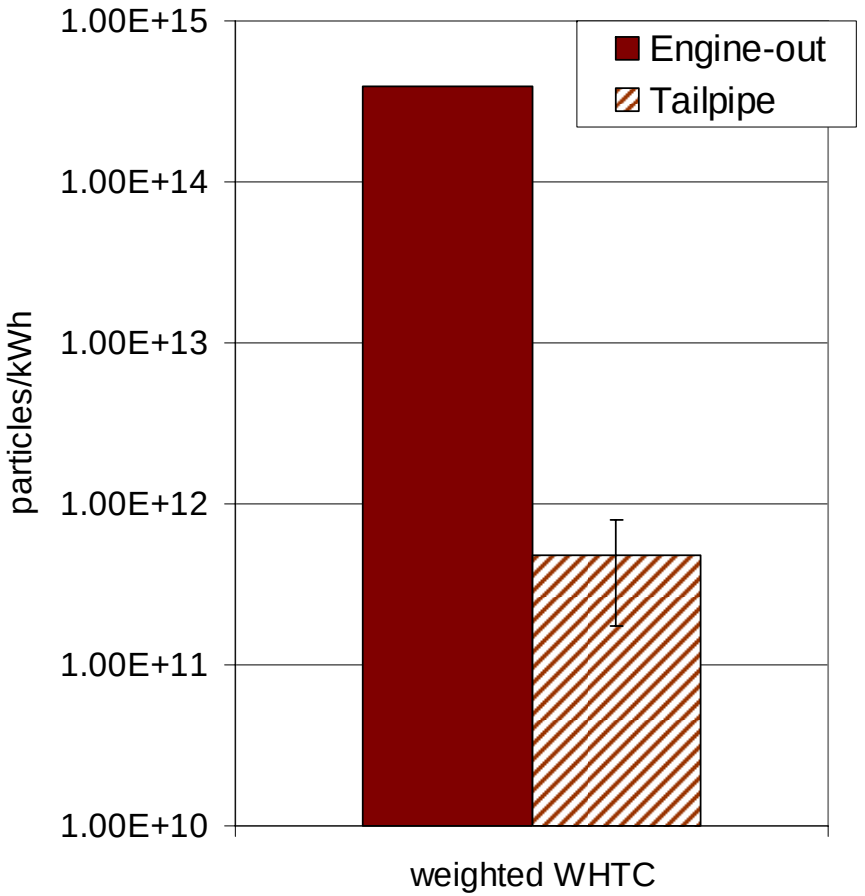
- Particle measurements from all tests according to the latest draft of the heavy-duty PMP inter-laboratory correlation exercise guide
- Particle number measured engine-out on additional tests from partial flow system
  - measurements from Horiba MDLT.
- Delivers
  - Particle number emissions.
  - Real-time particle emissions traces.
  - DPF filtration efficiency for solid particle numbers.
- PMP does not currently address partial flow for particle number, hence no partial flow tailpipe number measurements.

PMP particle number results for ETC & WHTC

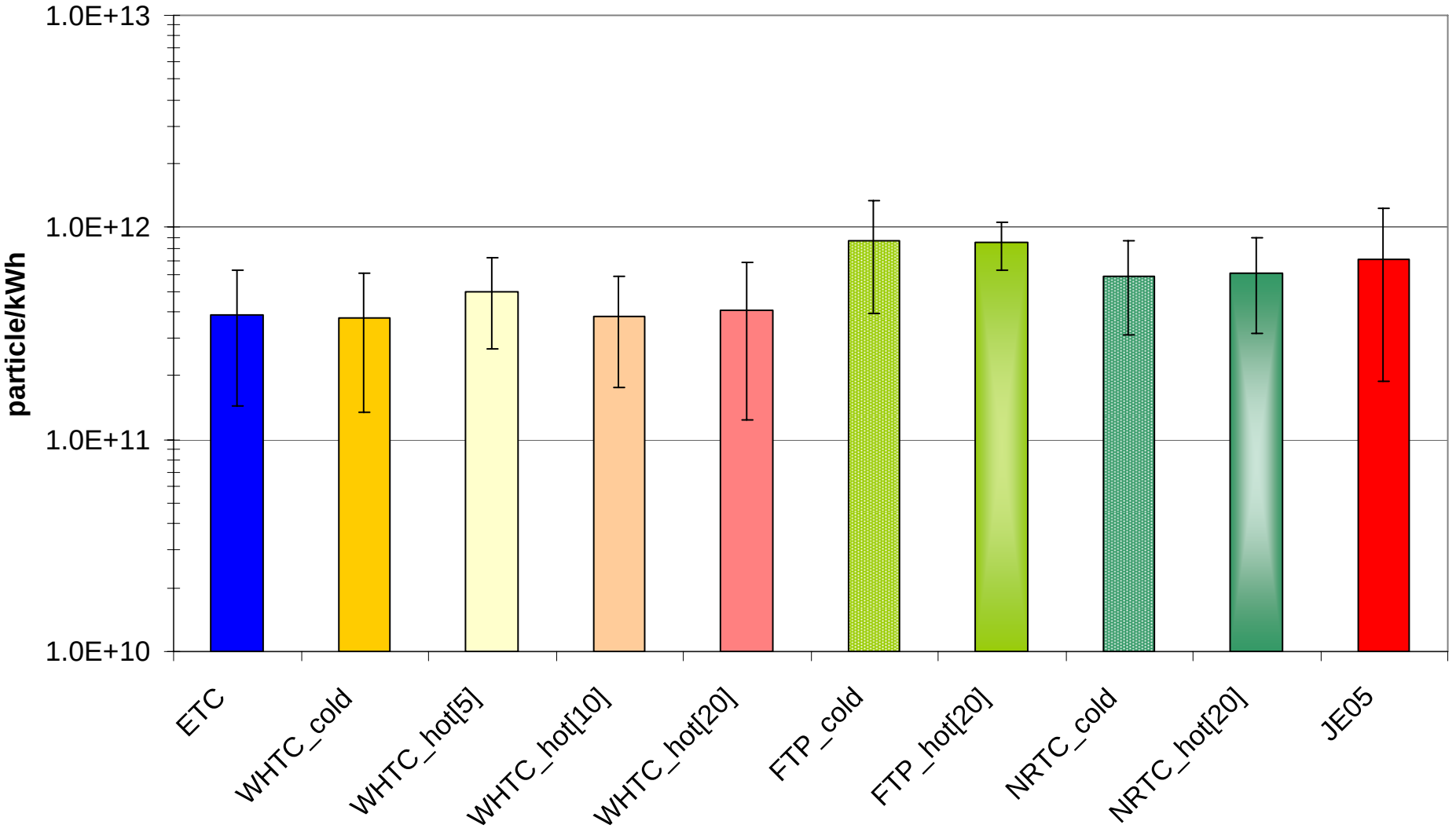
- ETC tailpipe emissions ~ 4 x 10^{11}/kWh
- DPF Efficiency > 99.9%



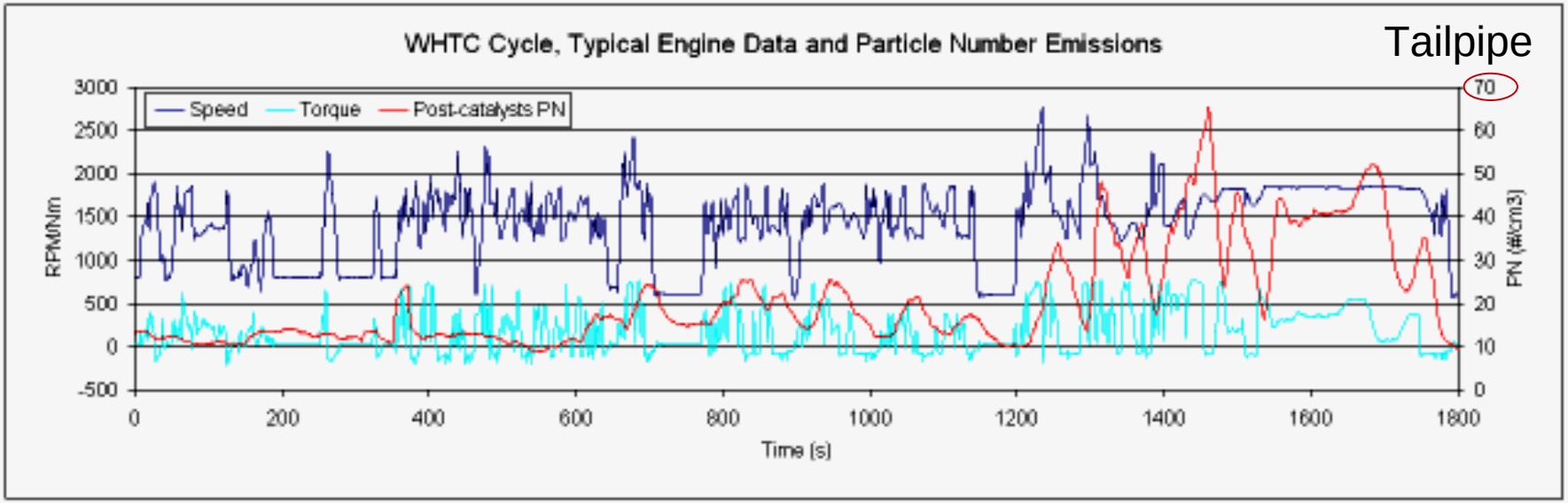
- WHTC tailpipe emissions < 5 x 10^{11}/kWh
- DPF Efficiency > 99.8%

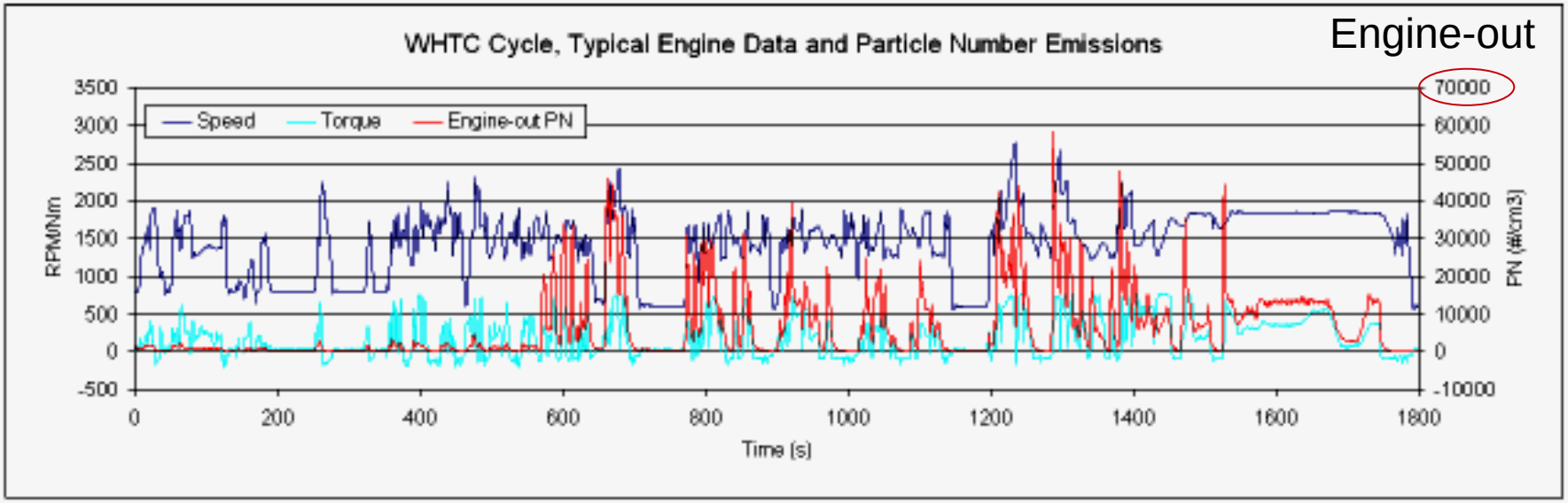


Particle numbers measurements over transient cycles



Continuous particle number traces



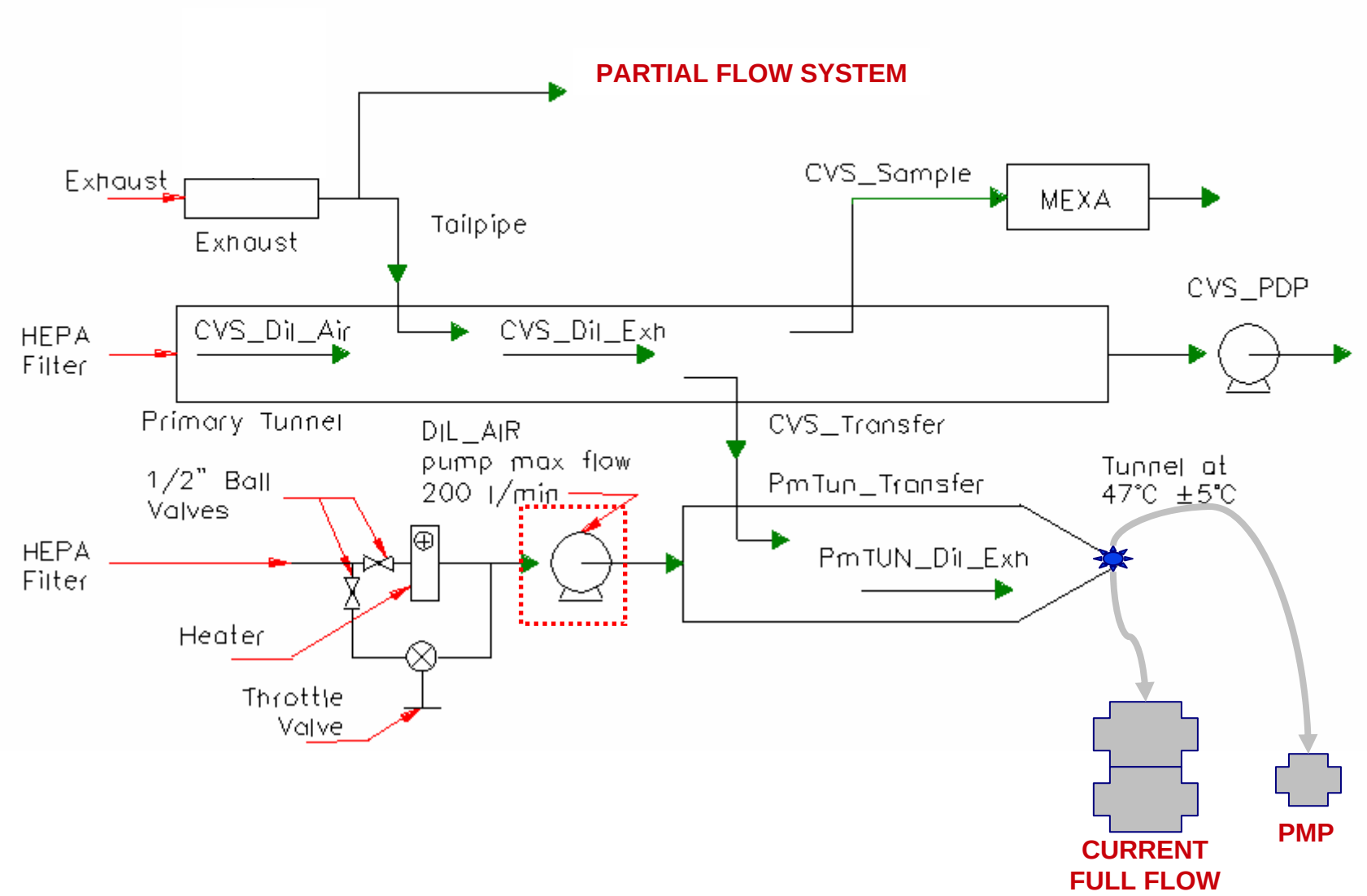


Particulate mass measurement methods

3 particle mass methods were tested.

- Partial flow system using mini dilution tunnel (MDLT)
  - Sample taken directly from exhaust, before CVS system and diluted (variable rate) in the MDLT before collection on sample filter.
  - current legislation allows this system to be used as alternative to full flow.
- Current full-flow legislative method
  - Diluted sample taken from the CVS system, further diluted in 2nd tunnel, sample collected onto 70mm TX40 filter paper from this secondary tunnel.
- PMP method
  - Sample is taken from the secondary dilution tunnel, as for current method.
  - Same principle as current method, but with improved control such as single TX40 sample filter, smaller (47mm) filter, tighter temperatures controls etc.

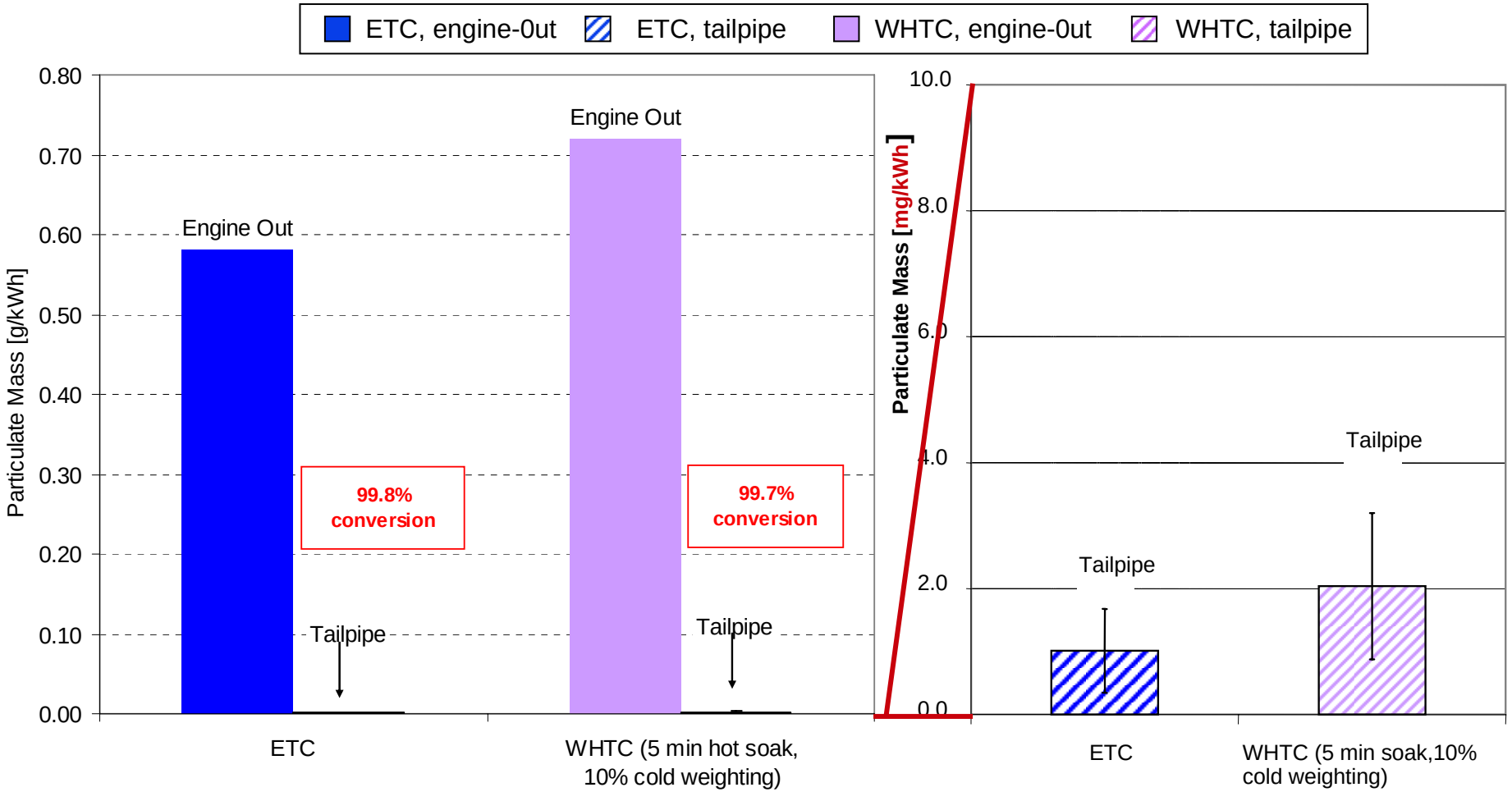
Schematic of PM sampling systems



Partial flow particulate measurements

- Partial flow PM measurements from mini dilution tunnel (MDLT) show very low levels of mass
  - Maximum total mass collected on filter was only 41µg (ESC).
  - Typical uncorrected specific emissions from ETC/WHTC/JE05 cycles ~ 1 to 2mg/kWh.
  - ESC results were higher, believed to be due to mode 10 desorbing low volatility materials.
  - Particle number counting was used to verify MDLT operation.
  - Subtraction of background reduces all masses to zero.

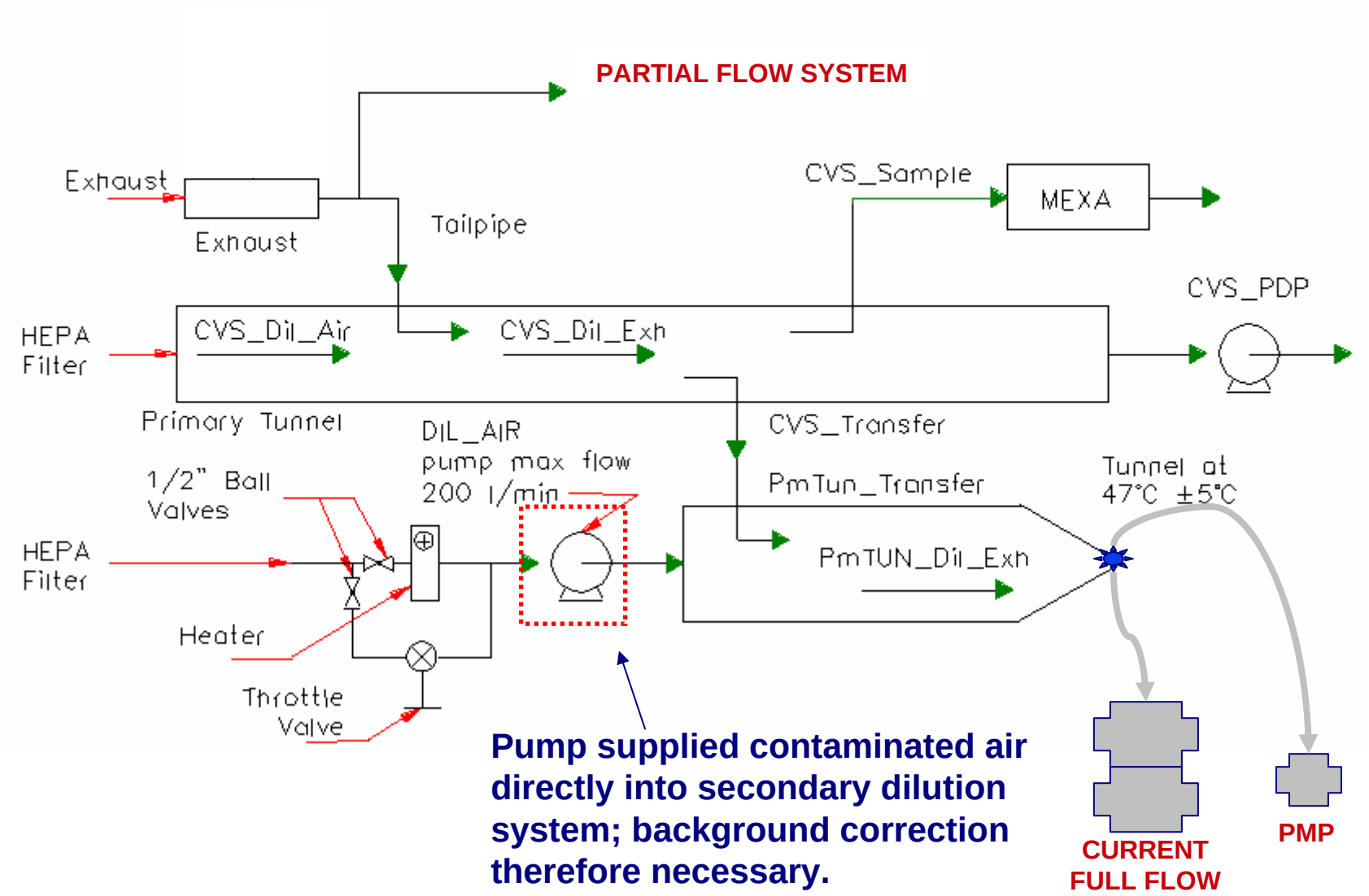
ETC and WHTC tests
PM emissions for engine-out and tailpipe



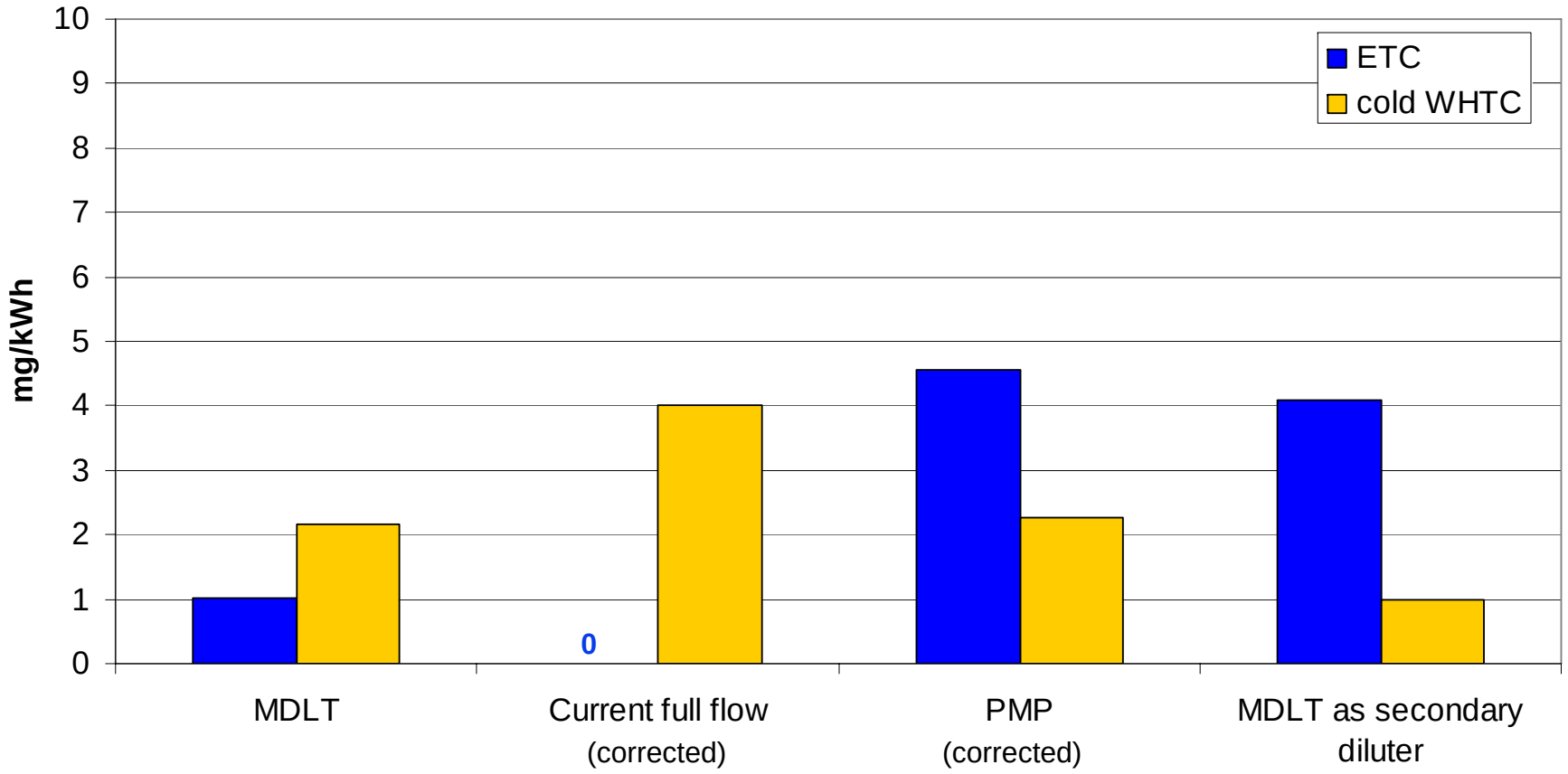
Full flow particulate measurements (current & PMP)

- Full flow PM measurements from CVS
  - Samples from current European legislative method and PMP method taken simultaneously from the tunnel – normally only a single sample would be taken.
- Measurements from both samples (PMP and current method) showed higher than expected results, but also measured background levels were as high.
- Background subtraction of secondary dilution air blank, as permitted in current legislation, reduces all masses to zero at the 95% confidence interval for both methods.
- Background air contamination traced to the pump used for the extra secondary dilution (not normally used when taking single samples from the secondary diluter.

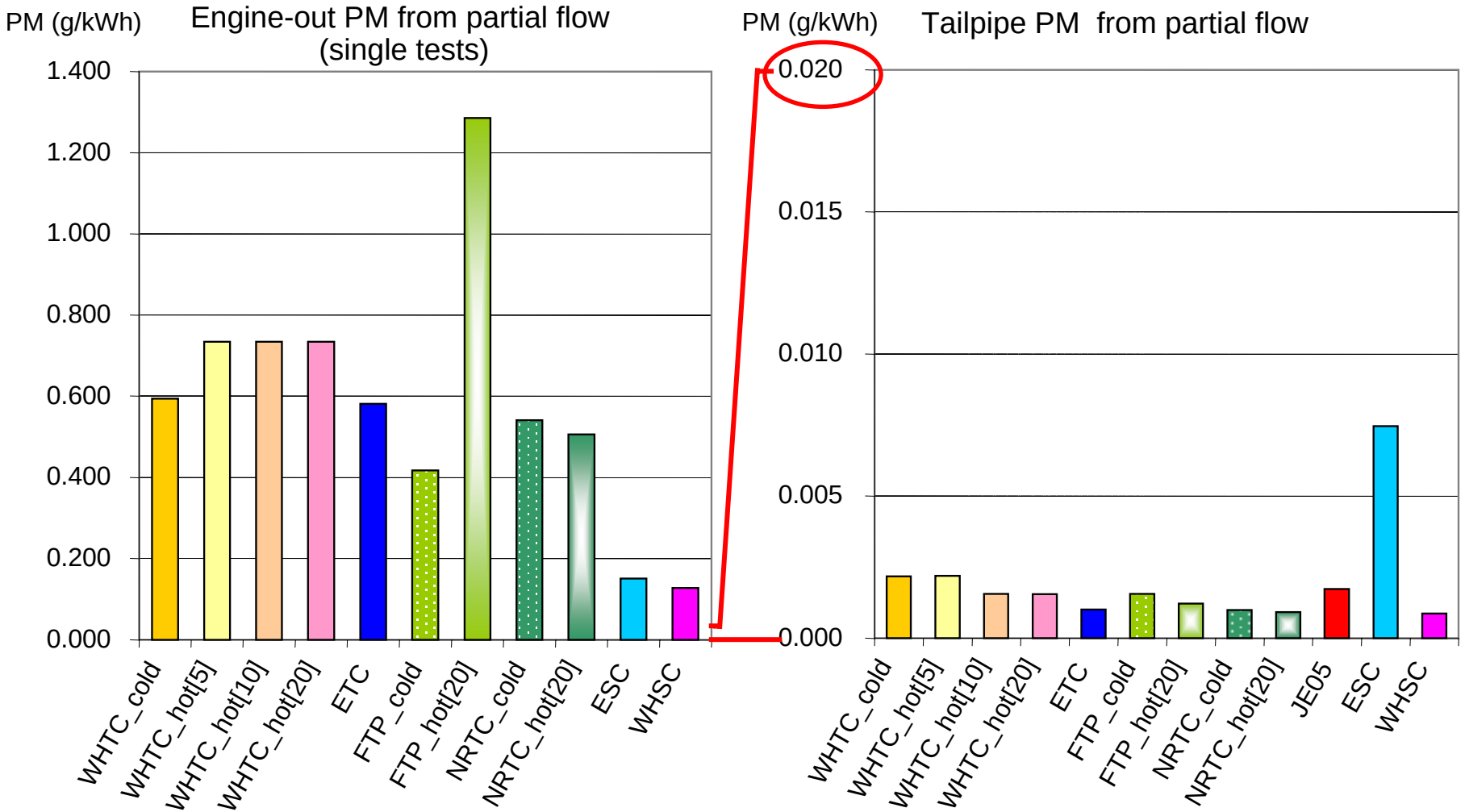
Source of background contamination



Comparison of average PM results using different methodologies



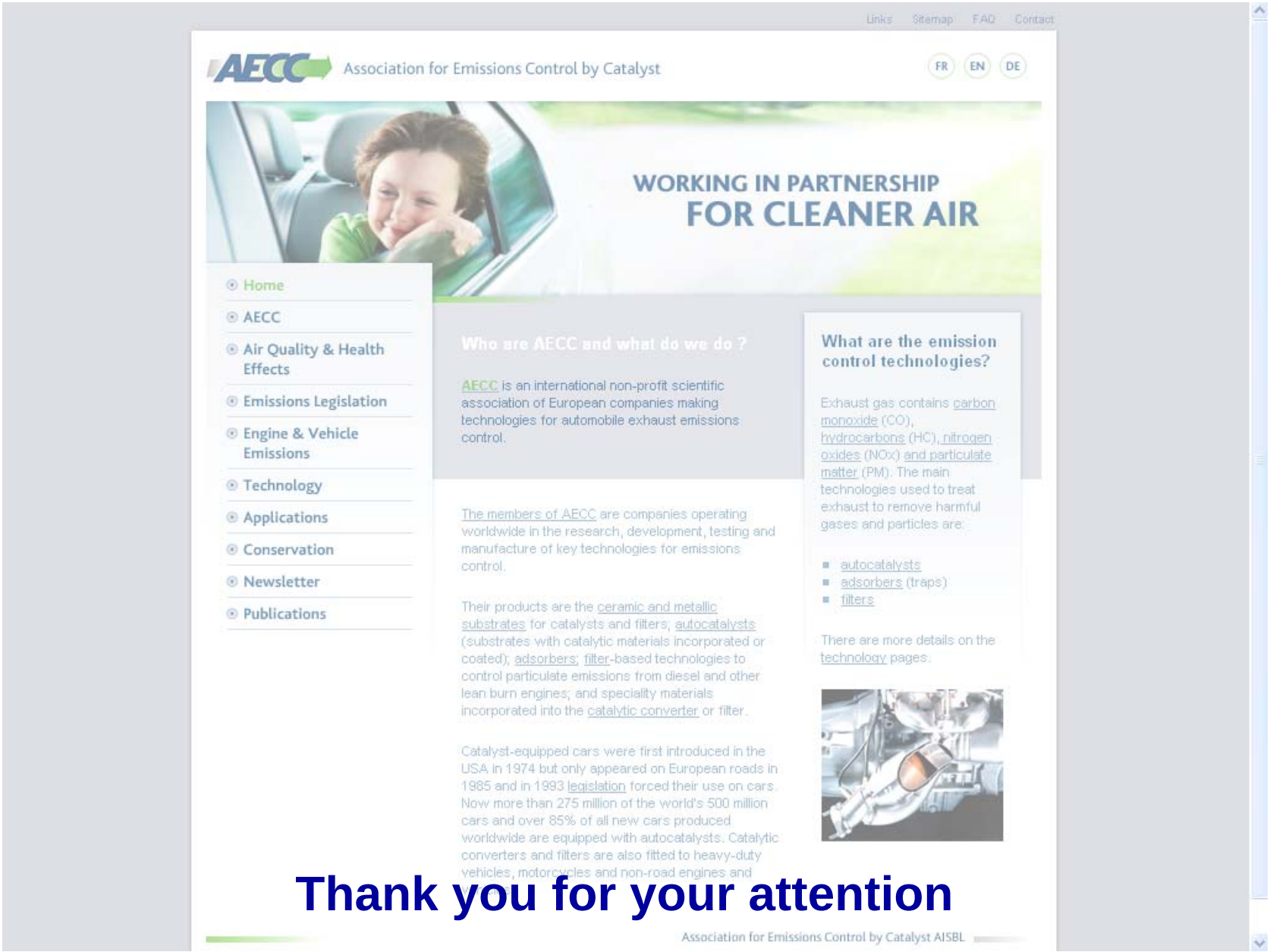
Average PM results for engine-out and tailpipe



Higher ESC results were believed to be due to mode 10 desorbing low volatility materials.

Summary

- The PMP particle number method proved very repeatable even at near-ambient particle emissions levels.
- Engine-out particle number data was in the range of 2.5 to 5 x 10^{14}/kWh.
- All transient cycles data showed tailpipe particle number emissions below 10^{12}/kWh.
- Particle numbers were essentially cycle-independent.
- Background-corrected PM from PMP method gave results below 5mg/kWh.
- PM measurements from MDLT show very low mass levels
  - Maximum 41µg total mass on filter (ESC).
  - Typical uncorrected emissions from ETC and WHTC: ~ 1 to 2 mg/kWh
- Background contamination problem encountered on both full flow methods but
  - Masses indistinguishable from background levels from all tests.
  - Subtraction of background reduces all masses to zero.
  - Contamination problem found to be due to taking of duplicate samples.



Thank you for your attention