Johnson Matthey
Catalysts

Particulate Number Measuring

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EMISSION CONTROL TECHNOLOGIES

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PMP Background

- Particle emissions remain a health concern.
- Small size and high numbers cause these concerns.
- Current legislation regulates particle emissions in mg/km – this is effective for larger particles but not for small particles.
- Particulate Mass (PM) emissions from new engine/vehicle technologies are reaching the limit of the existing legislative gravimetric measurement technique.
- A new system has been developed to complement or replace the existing gravimetric method for Euro 5+ (2011) and Euro 6 (2014) applications.
- Particulate Number (PN) measurements are found to be more repeatable than PM for low particulate emission vehicles.

PMP System

- Proposed UN/ECE Regulations 83 (LDD) and 49 (HDD) mandate that only the number concentrations of solid particles are measured.
- Therefore, nucleation mode particles (i.e., nanoparticles) formed by the condensation of volatile compounds found in engine exhaust must be suppressed or eliminated.
- This is done by the Volatile Particle Remover (VPR) – consisting of thermo diluters and an evaporation tube.
- PM on 1x47mm – replacing 2 pairs of 70mm filters for MVEG-B cycle. Respective 5 to 4.5 mg/km drop to the legislation limit.

Diesel Particulate Legislation

Euro 5+

- (09/2011 type approval, 01/2013 all registrations)

Euro 6

- (09/2014 type approval, 09/2015 all registrations)

(no change)

	PM (mg/km)	PN (#/km)
Diesel	**4.5**	**$6x10^{11}$**

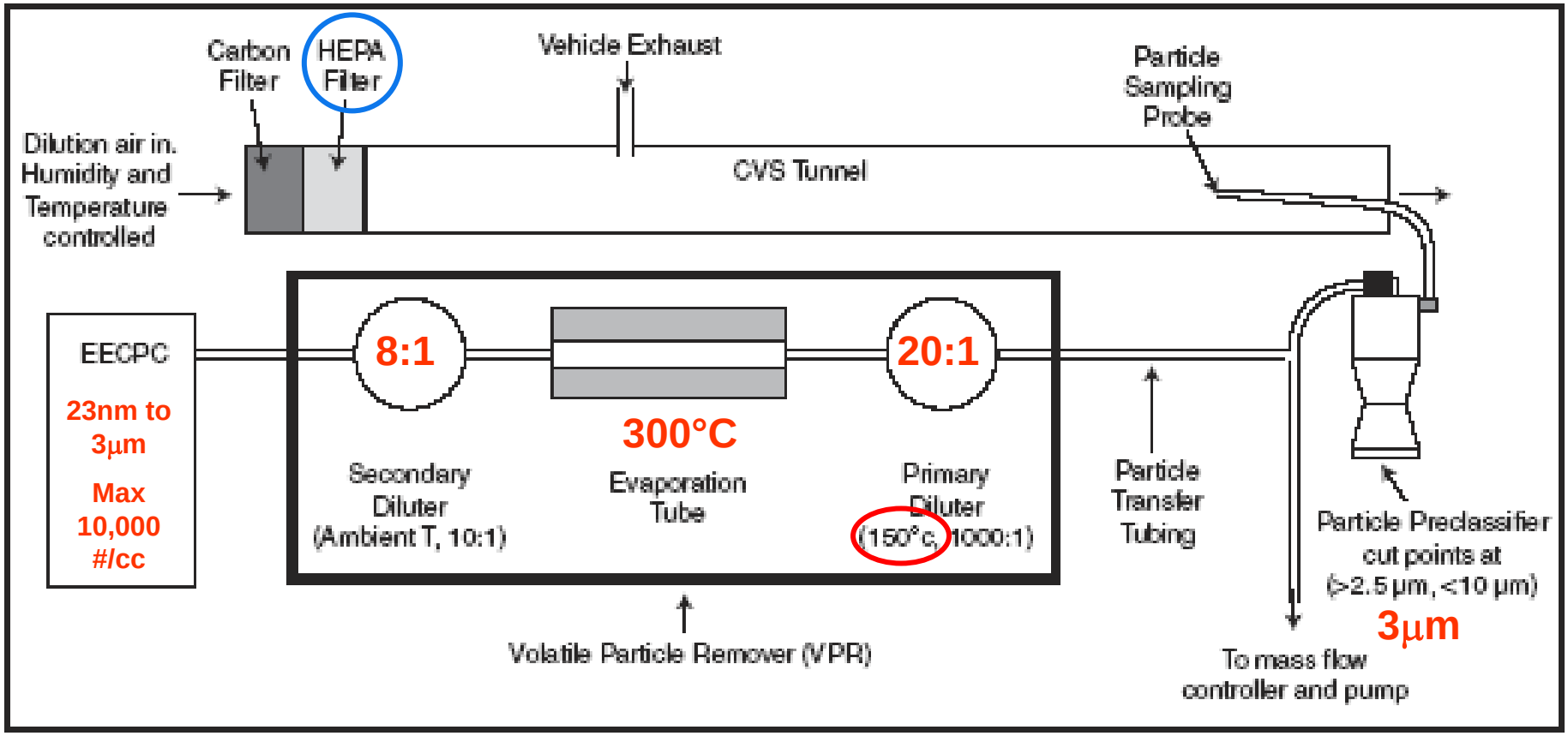
PMP Equipment - JM

- Fully compliant with PMP regulations.
- Same equipment used for the inter-lab correlation exercise run by the European Commission.
- Very good reliability and reproducibility.
- Matter Engineering Nanomet-C
  - Primary dilutor (includes cyclone)
  - Evaporation tube
  - Secondary dilutor

  } VPR

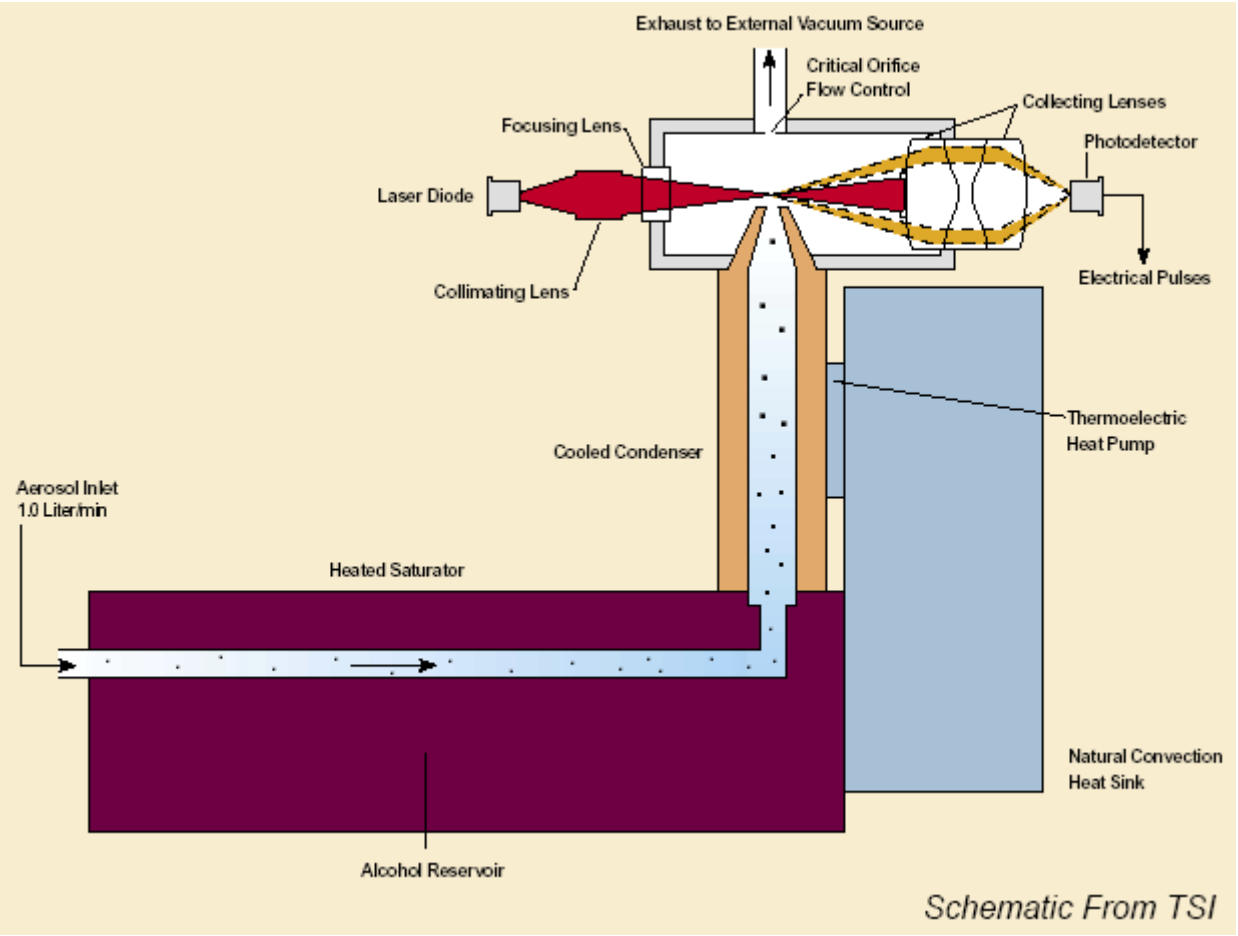
- TSI EECPC 3790
  - Linear response from 1 to 10,000 particles/cc
  - 23nm to 3μm

PMP System Schematic



Matter Engineering Nanomet-C + TSI EECPC 3790

TSI EECPC Schematic

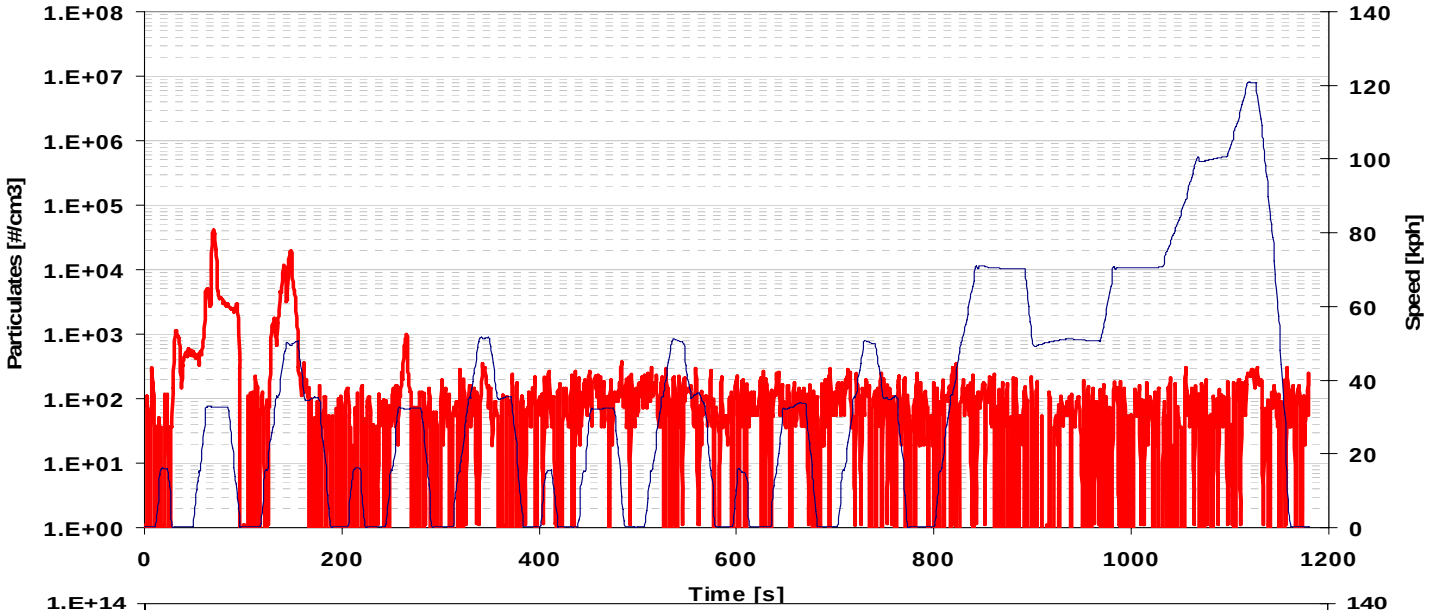


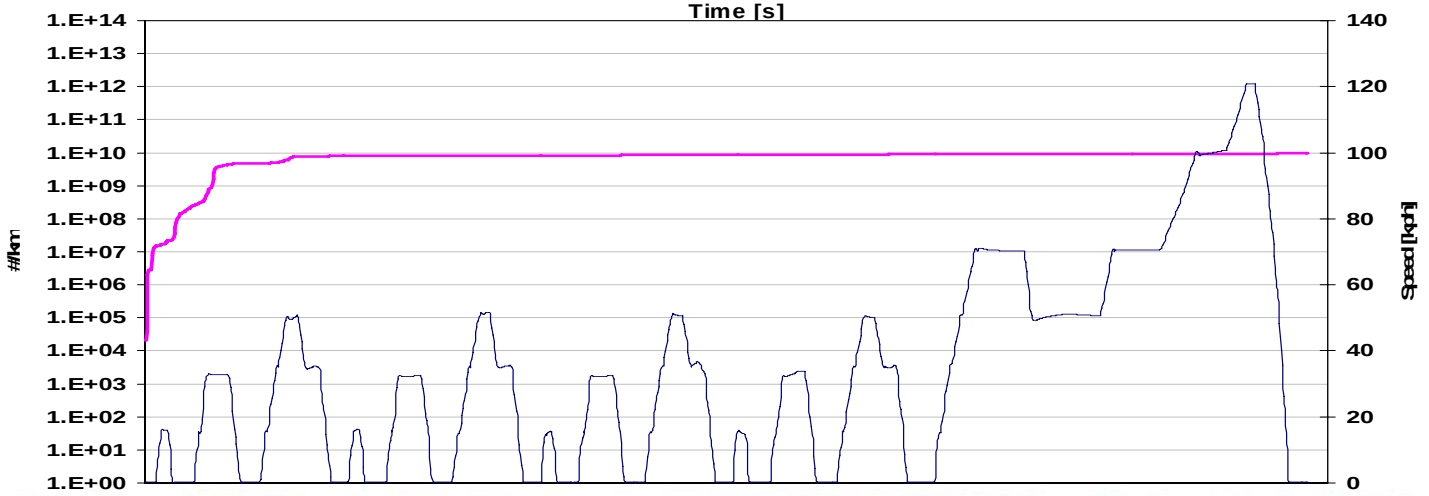
JM Testing

Confidential

- DPF, non-DPF tested.
- Diesel fresh/regenerated filter investigation.
- Diesel passive regeneration.
- PN during regeneration.
- All filters are SiC.

Diesel Results – Mid-Range Saloon 1 #/cc & Accumulated #/km



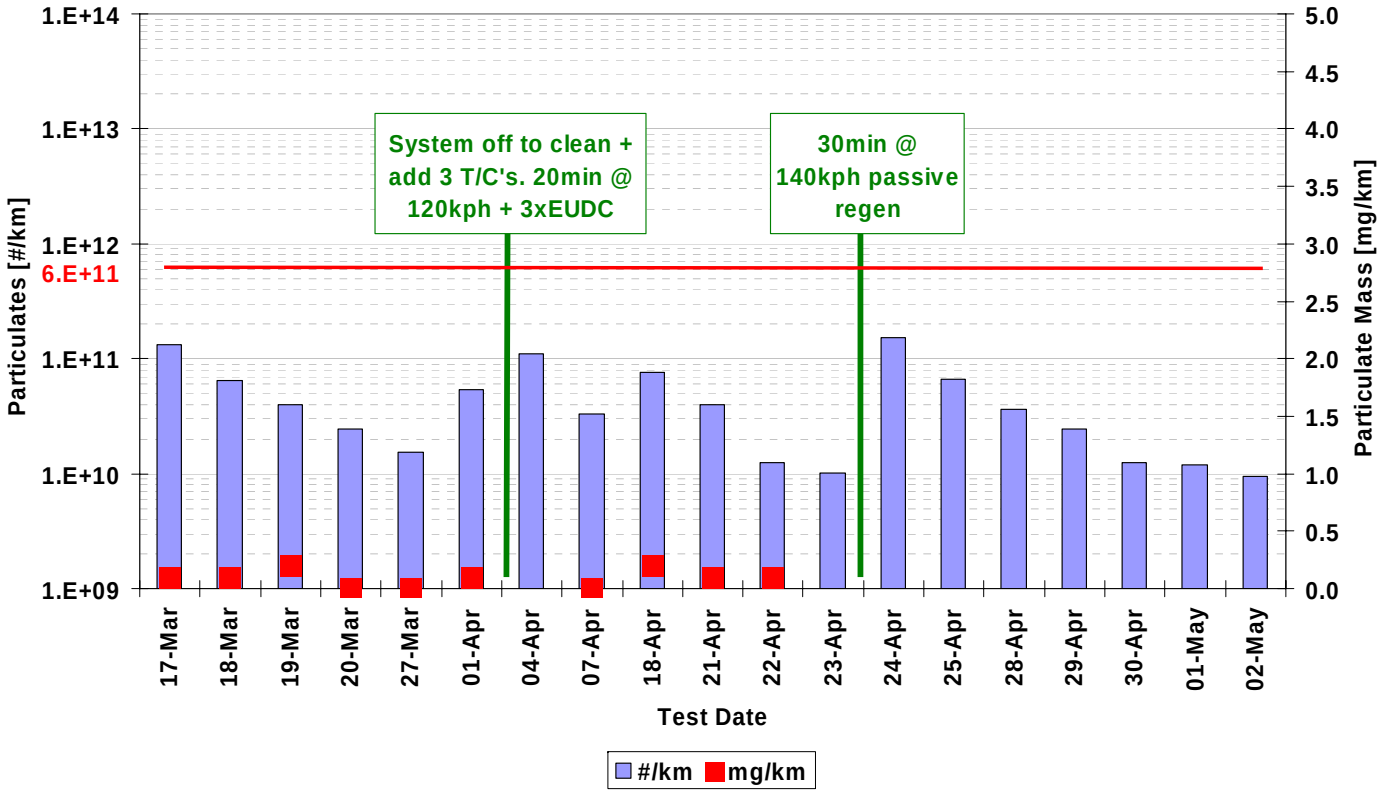


#/km = 9.5×10^9

Uncoated SiC after 7 MVEG-B tests post passive regeneration

After 250s PN is close to background levels

Diesel Results – Mid-Range Saloon 1



Clearly shows PN reducing as soot fill increases

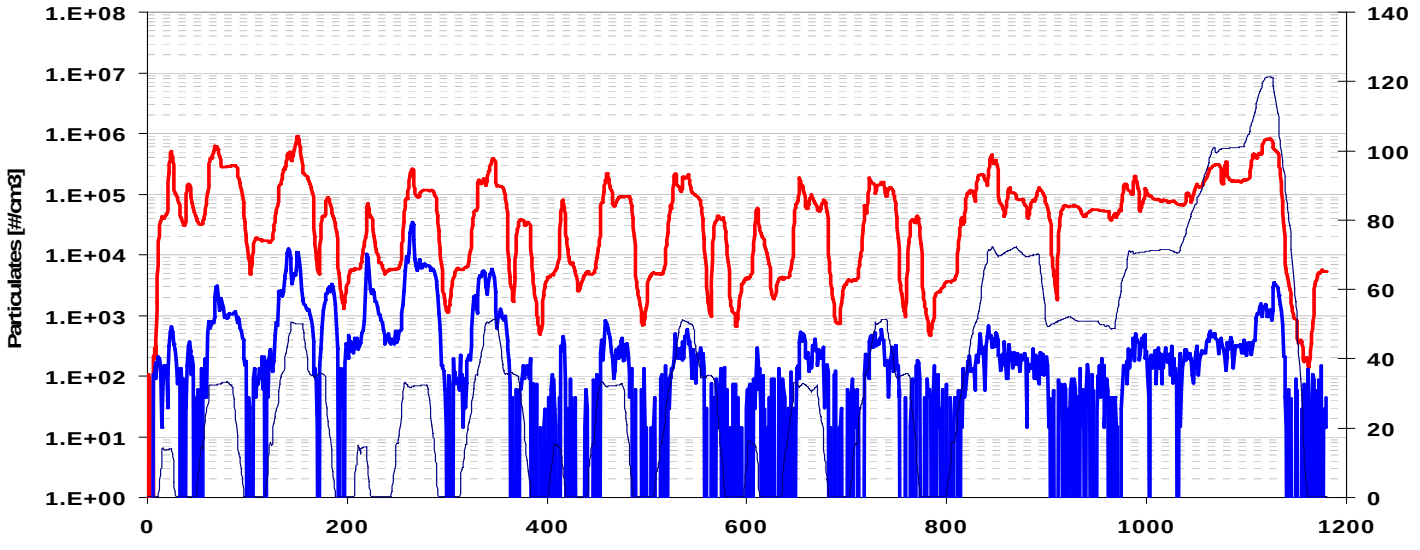
Even after passive regeneration #/km = 1.5×10^{11} (within limit)

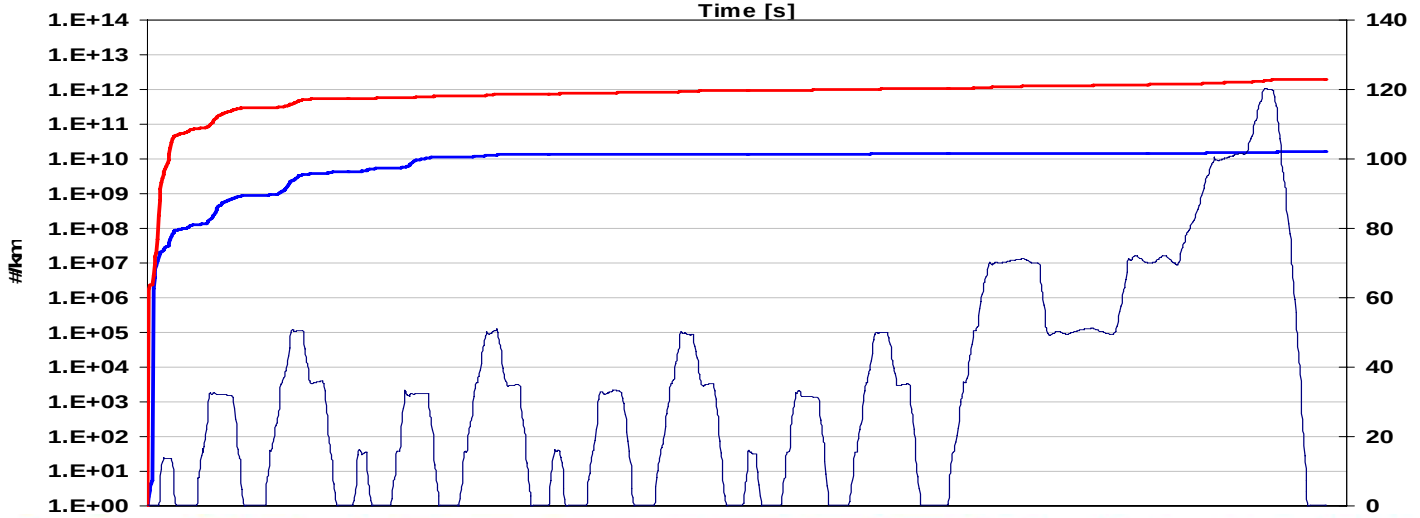
Mass very low <0.25mg/km

No active regeneration

Diesel Results – Mid-Range Saloon 2 (Cracked Cement and Fresh Filter) #/cc & Accumulated #/km

Confidential





Cracked Filter

#/km = 1.98×10^{12}

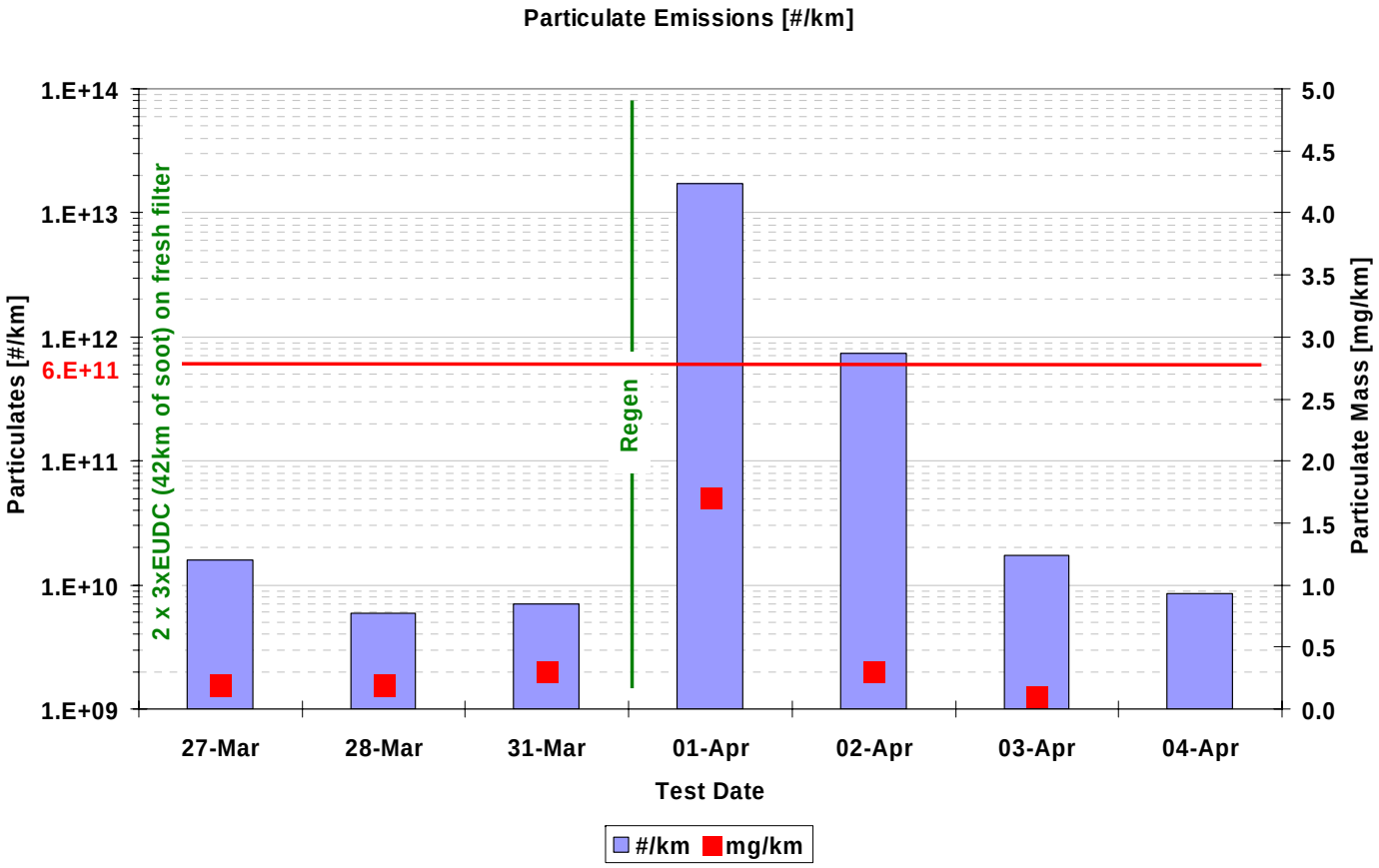
very high for DPF - FAIL limits:

PM not able to detect failure

Fresh Coated Filter

#/km = 1.59×10^{10}

Diesel Results – Mid-Range Saloon 2



PN stabilised on fresh filter after only 2 x 3xEUDC cycles (42km)

Post regeneration, PN has stabilised after only 4xMVEG-B cycles (44km)

Increase in PM after regeneration

Diesel Results – Medium Van

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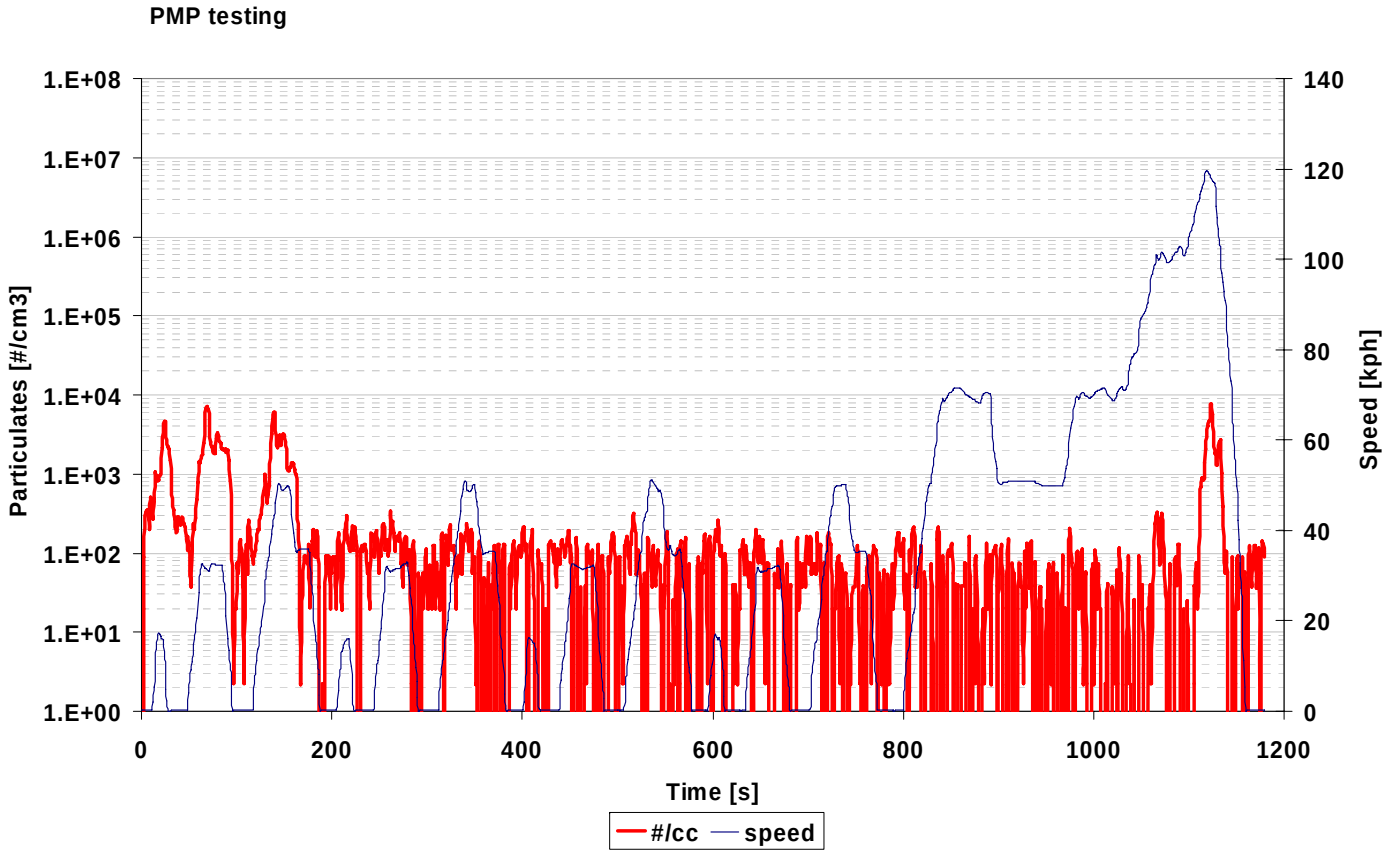


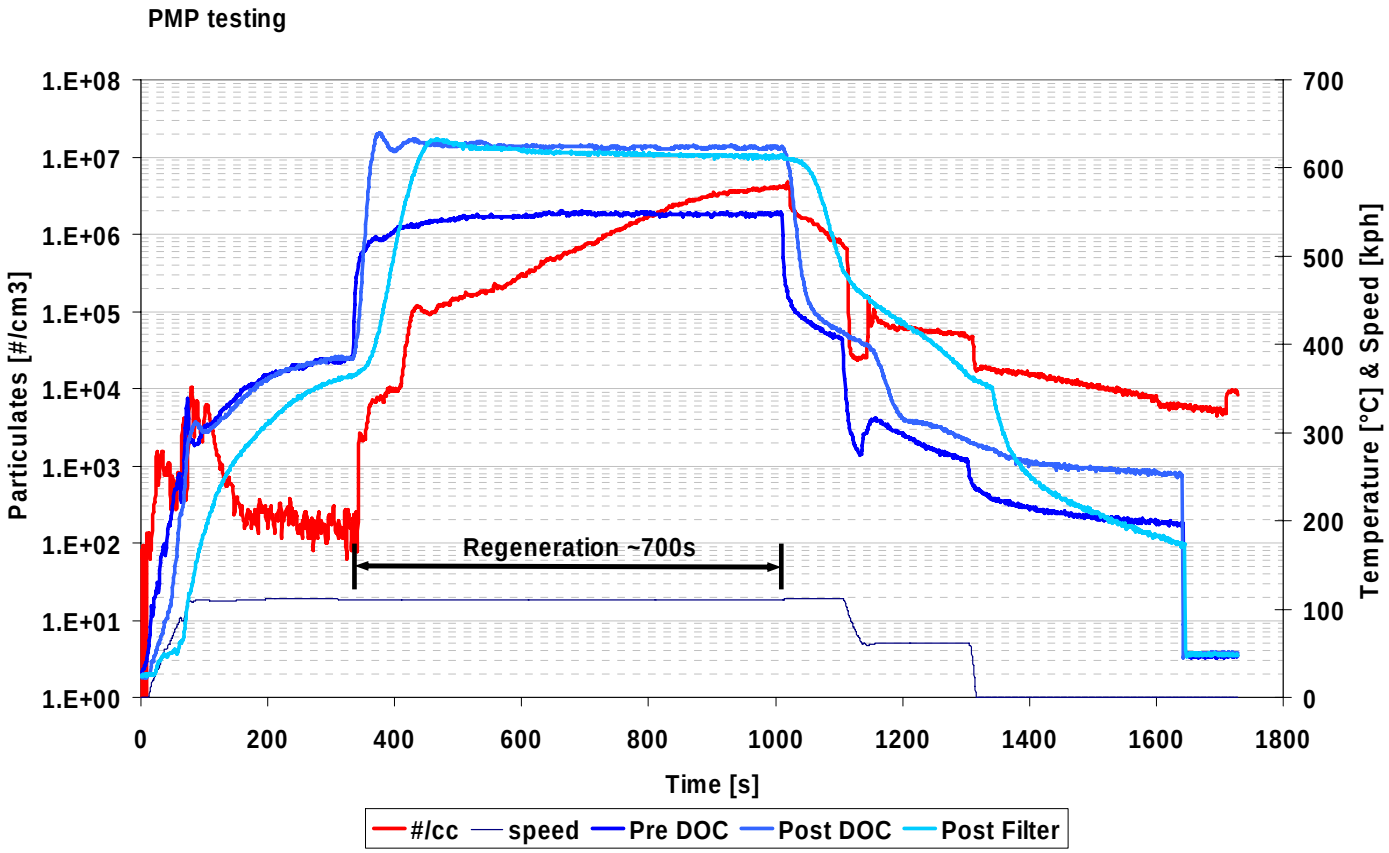
#/km = 6.53x10^9

Loaded with ~4g/l of soot, 47% porosity and 14μm pore diameter

Cold start break through and at the end of the EUDC

Gave very low mass (0.3mg/km)

Diesel Results – Medium Van (Regeneration)



Red = #/cc during regeneration

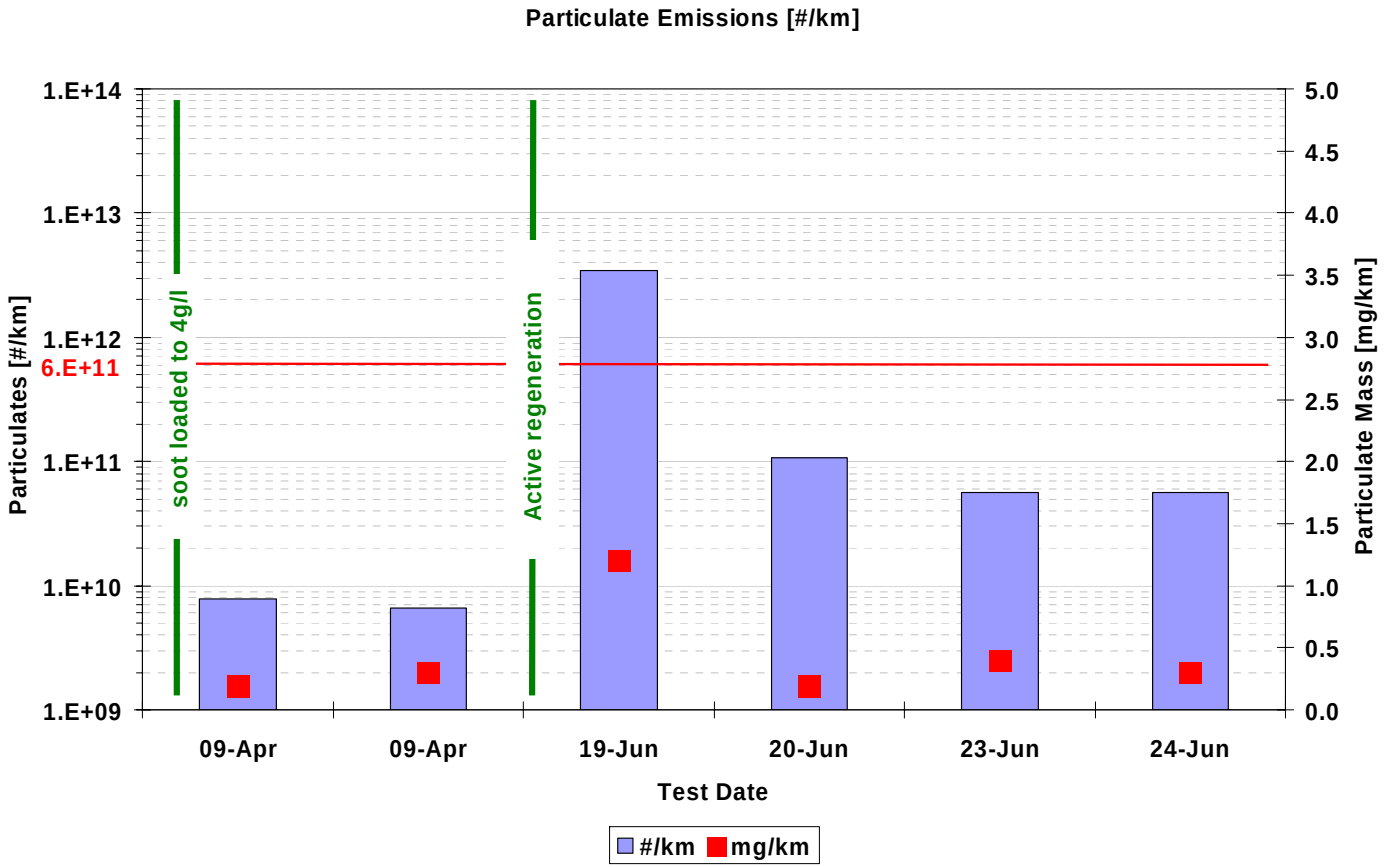
Blue = Temps

PN starts to increase as brick temperatures exceed 400°C

Constant increase during 700s regen

PN stays high after key off – residual tunnel particles

Diesel Results – Medium Van (Post Regeneration)



Filter initially loaded with 4g/l

Active regeneration increased PN by ~10^3

Only PM fluctuation 1st test after regeneration – still <1.5mg/km

Diesel Results – Medium Van DMS500 Measurements

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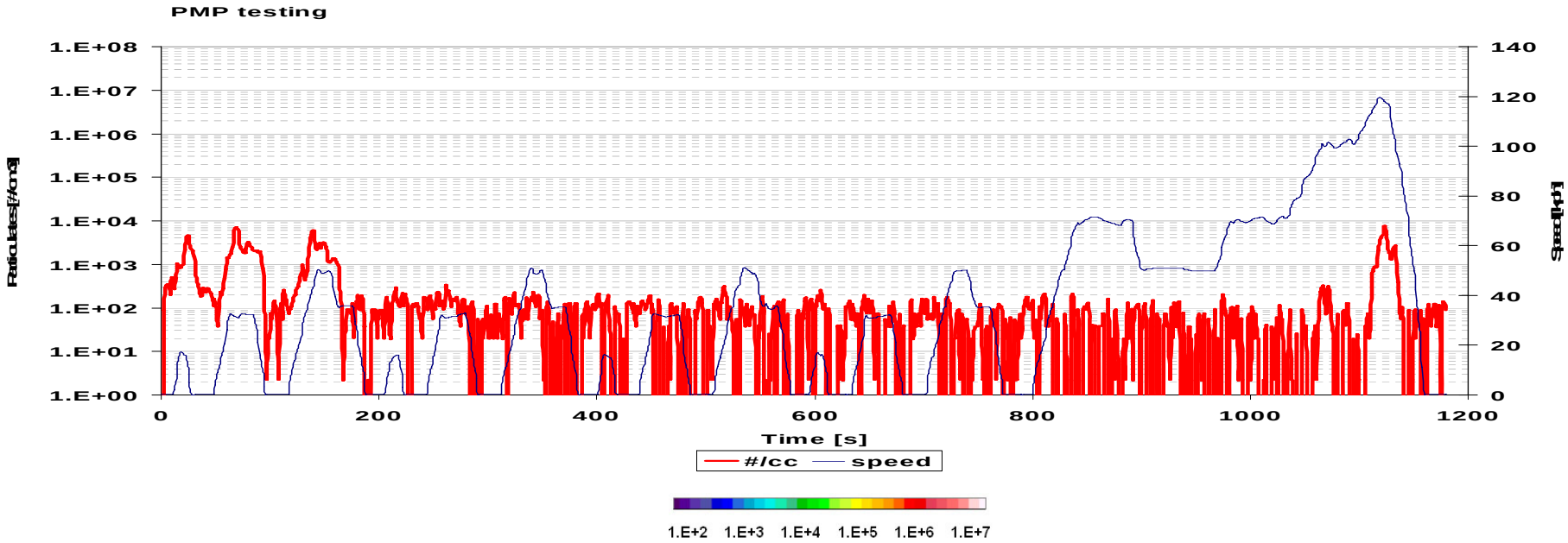
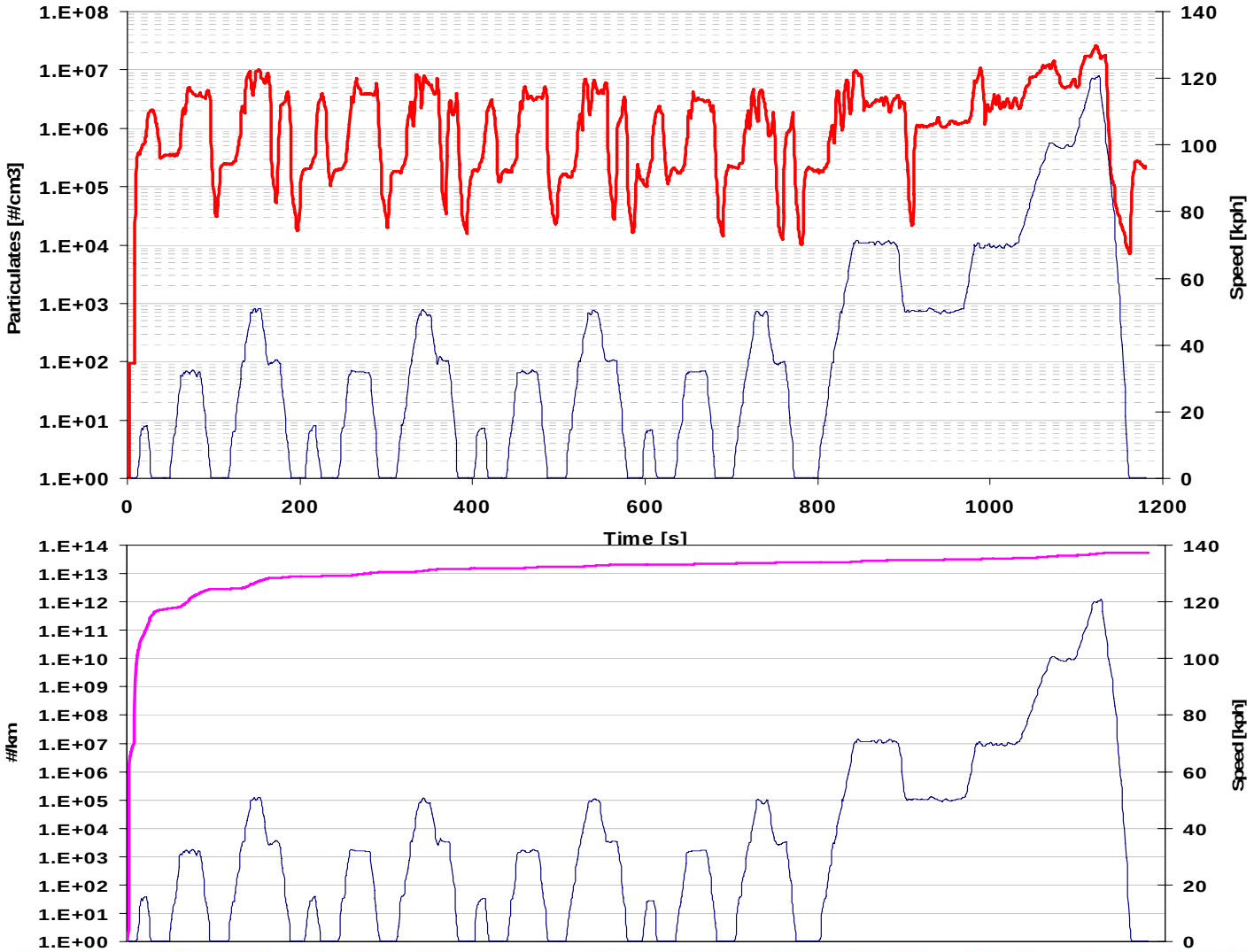


Diesel Results – Small Vehicle Non-DPF
#/cc & Accumulated #/km



#/km = 5.48×10^{13}

No filter

High constant #/cc

Follow drive trace very well, with slight PN improvement by end of ECE @ 800s

PM ~15mg/km

Diesel results – Hatchback Non-DPF
#/cc & Accumulated #/km

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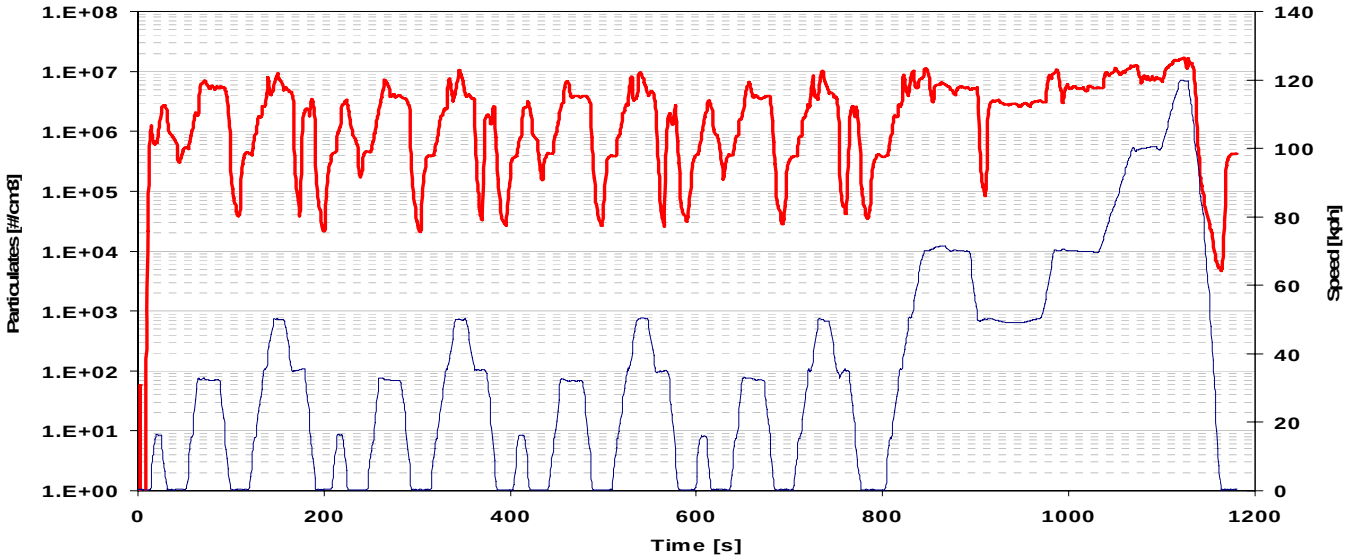
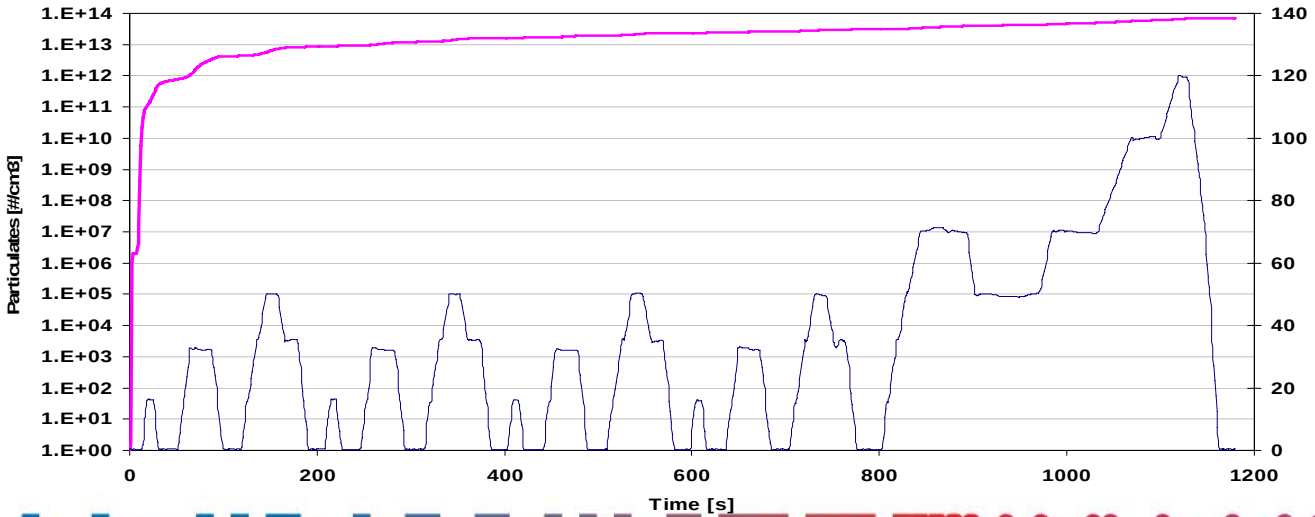




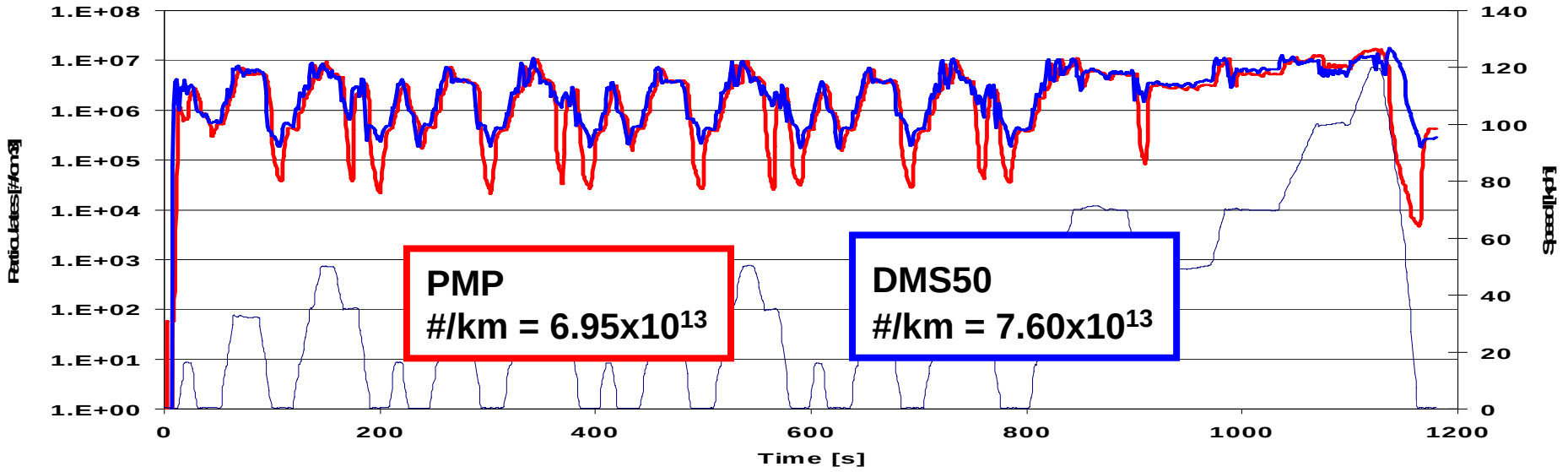
#/km = 6.95x10^{13}

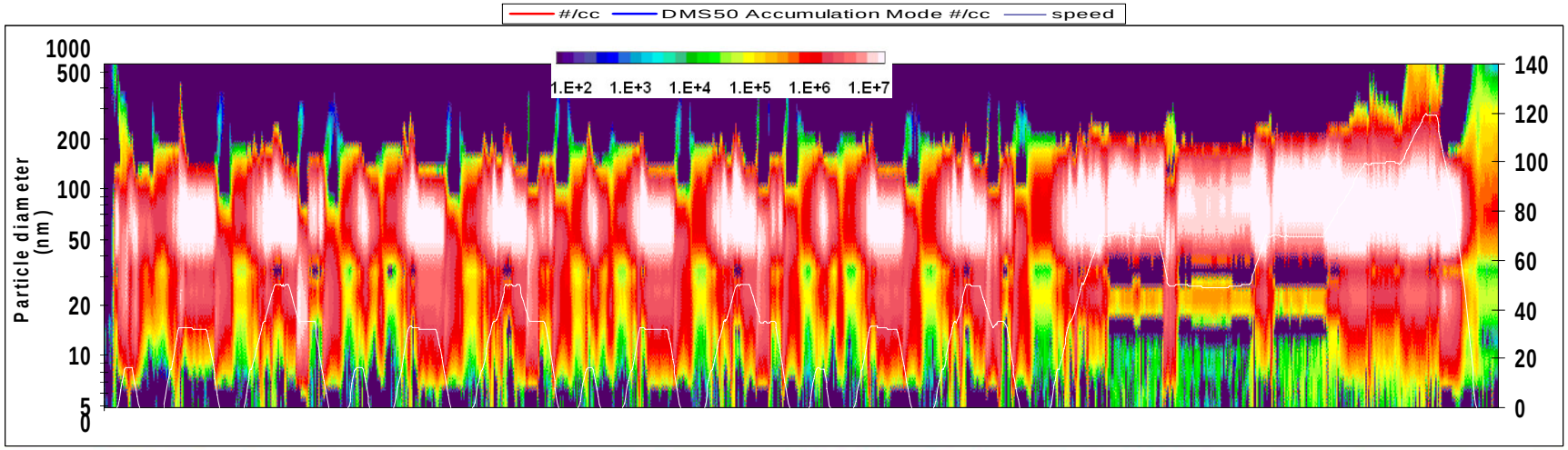
No filter

High constant #/cc

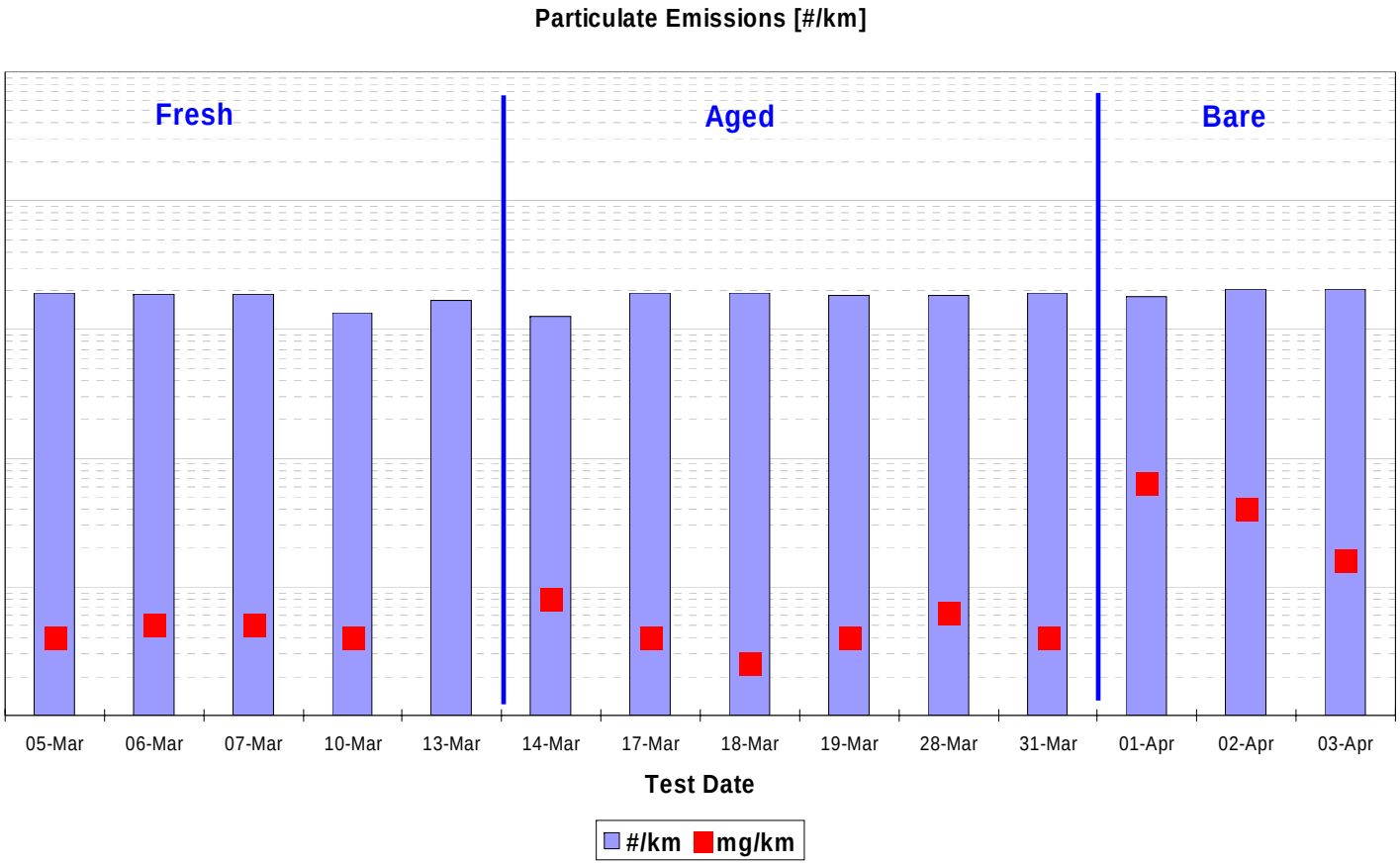
Diesel results – Hatchback Non-DPF
PMP #/cc & DMS50 Accumulation mode #/cc

Confidential





Flow Through Catalysts PM Artefacts and PN



3 systems tested – fresh, aged and bare respectively

PN remains consistent –

Volatiles = mass difference?

Different Technologies - Typical #/km

Conventional Diesel	**x10^{13}**
DPF Diesel	**x10^{9} / x10^{10}**

Measured Background Levels ~ 2x10^{9} to 9x10^{9} #/km

#/km For All Vehicles Tested

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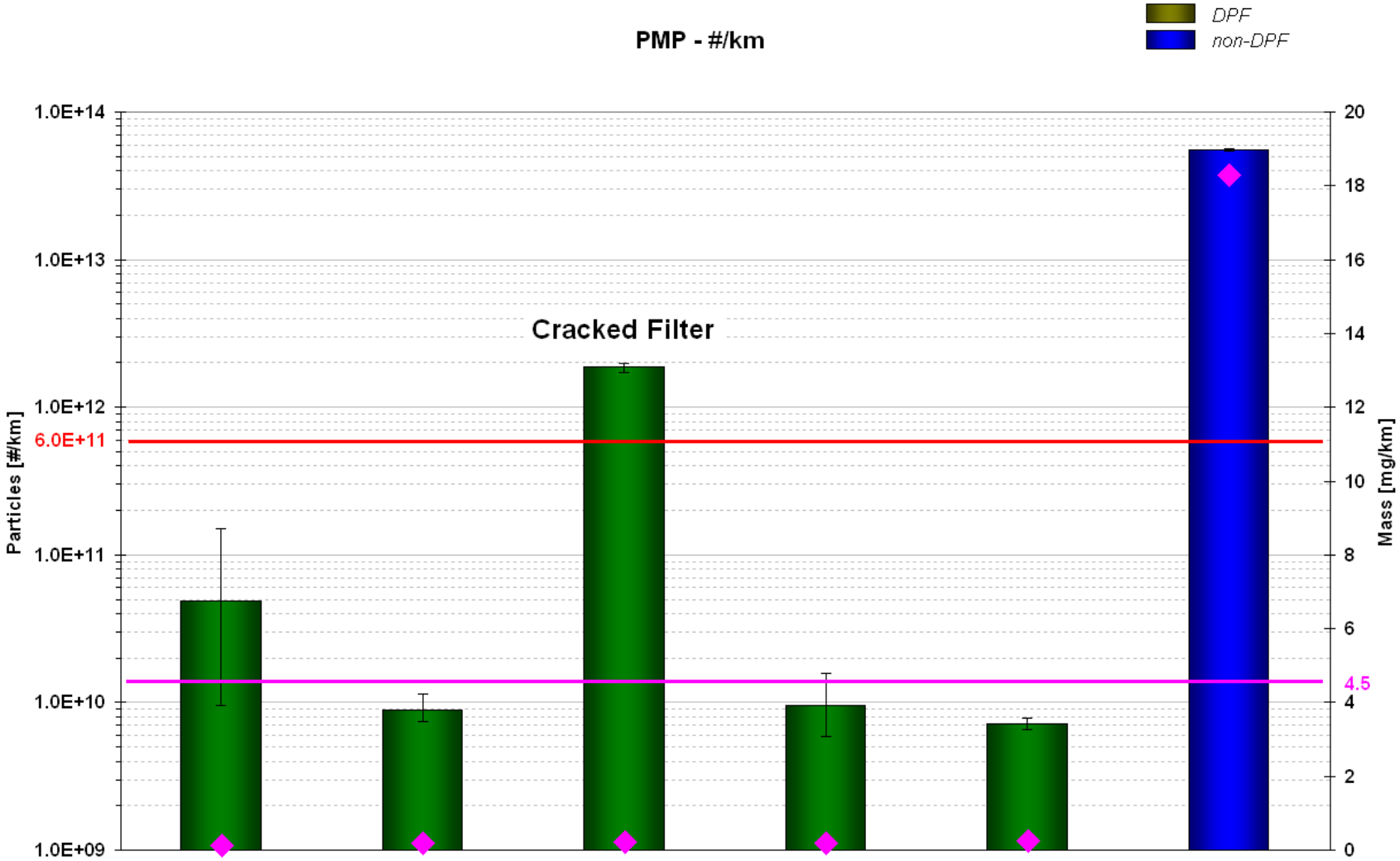

JM Summary - Diesel

- PM limit is easily met.
- All SiC filters are meeting PN limit comfortably.
- Particle breakthrough during cold start on some filters – filter expanding and exposing initial voids?
- Also some particle breakthrough during 120kph section – filter dependant?
- ~40km (4xMVEG) is only required to approach a stable PN level.
- SiC cement failure exceeded PN limit – PM was not affected and therefore was unable to detect the filter failure alone.