The Development and Characterization of a PEMs PMP-Compliant CPC-based Particle Counter for Real World on-Vehicle Measurements

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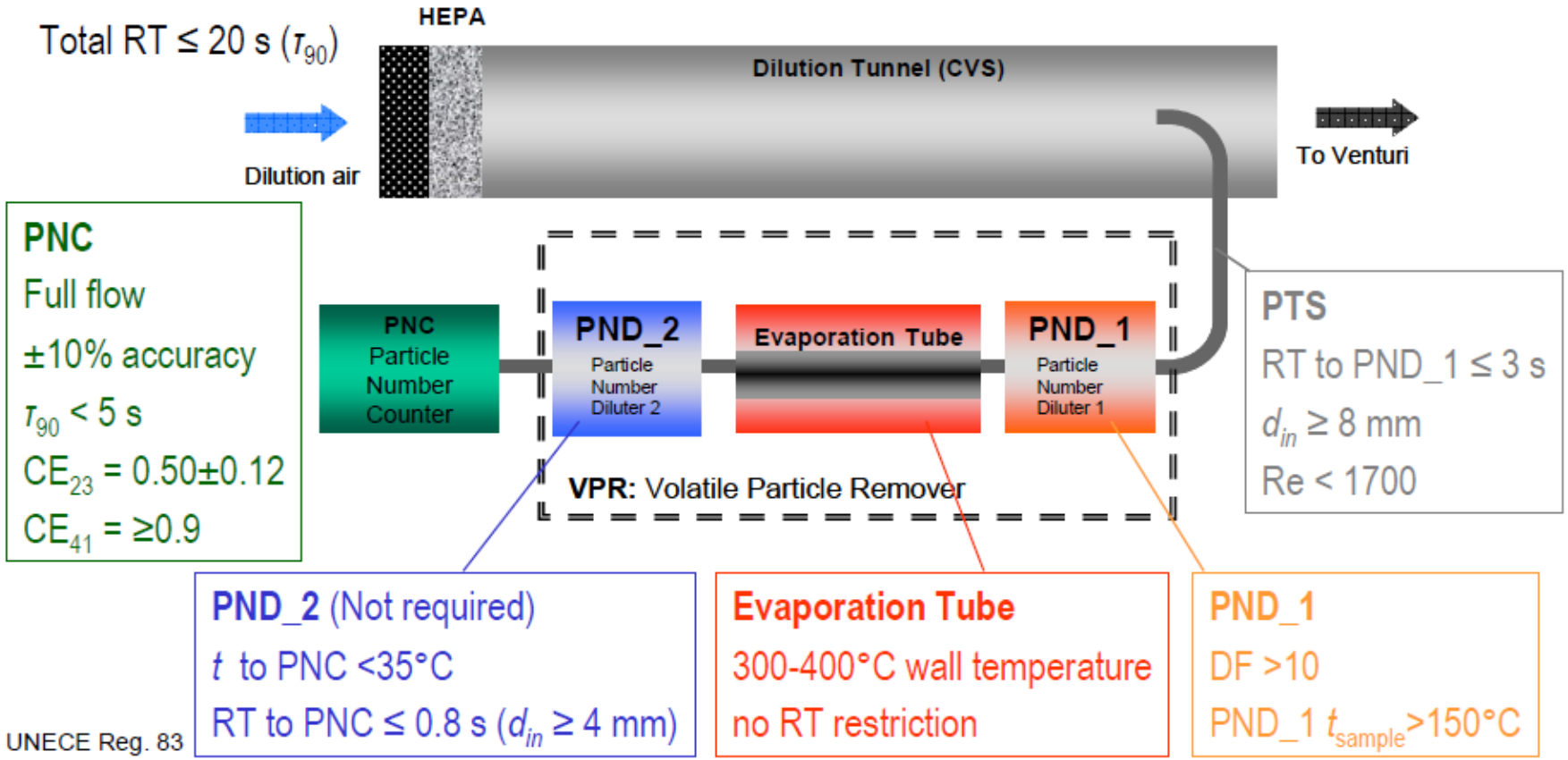
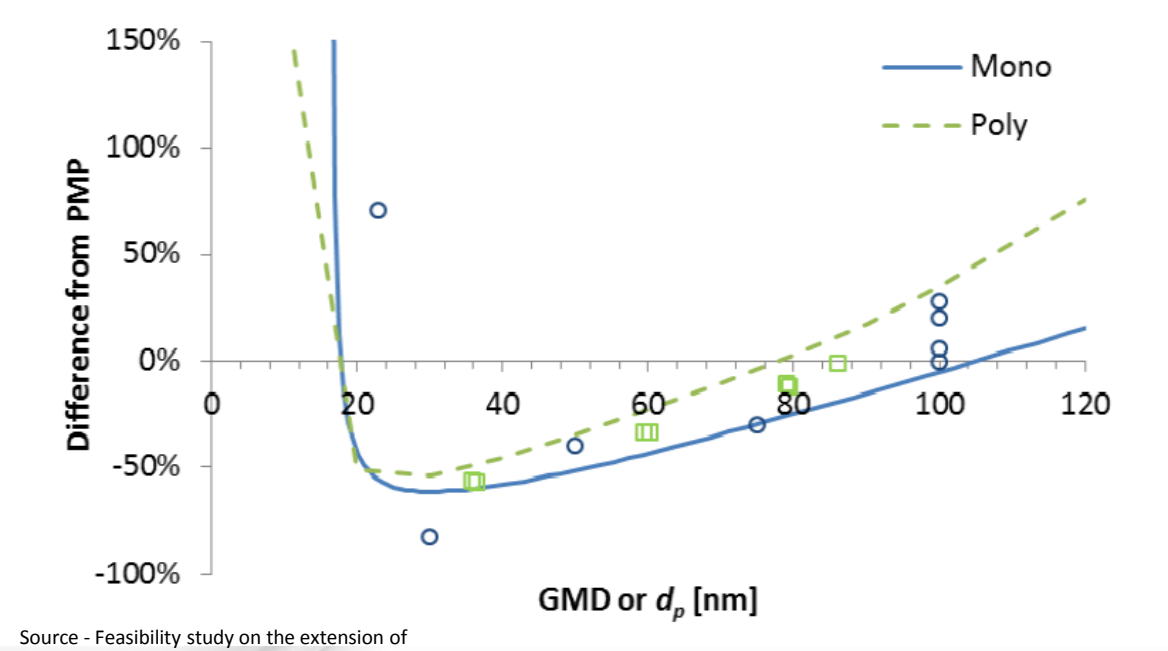
PN EU Regulation



Source - Feasibility study on the extension of the Real Driving Emissions (RDE) procedure to Particle Number (PN), JRC 2014

Technology: -Diffusion Chargers (DC) or Condensation Particle Counters (CPC)

- Particle Size - CPC dp^0 (CPC) or DC dp^1.4
- Morphology, Exisiting charge, Dilectric constant … etc



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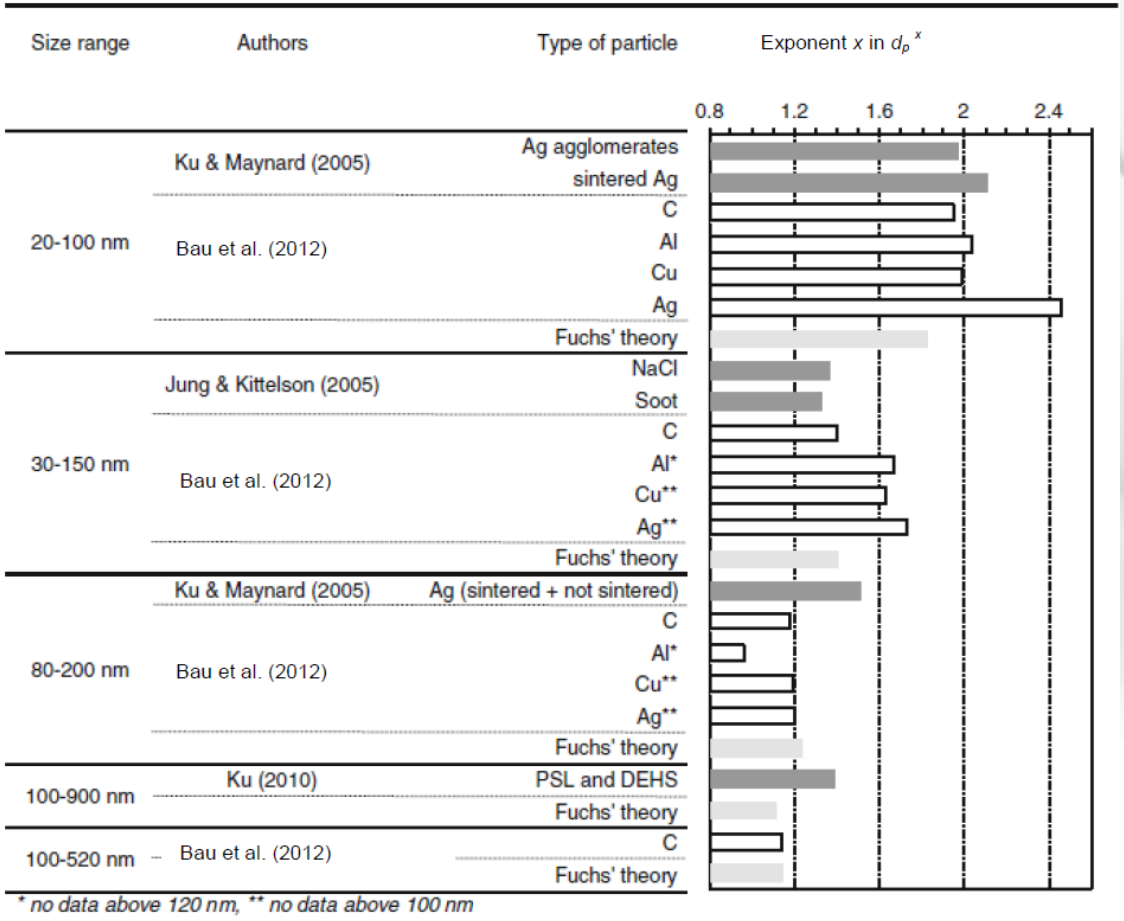
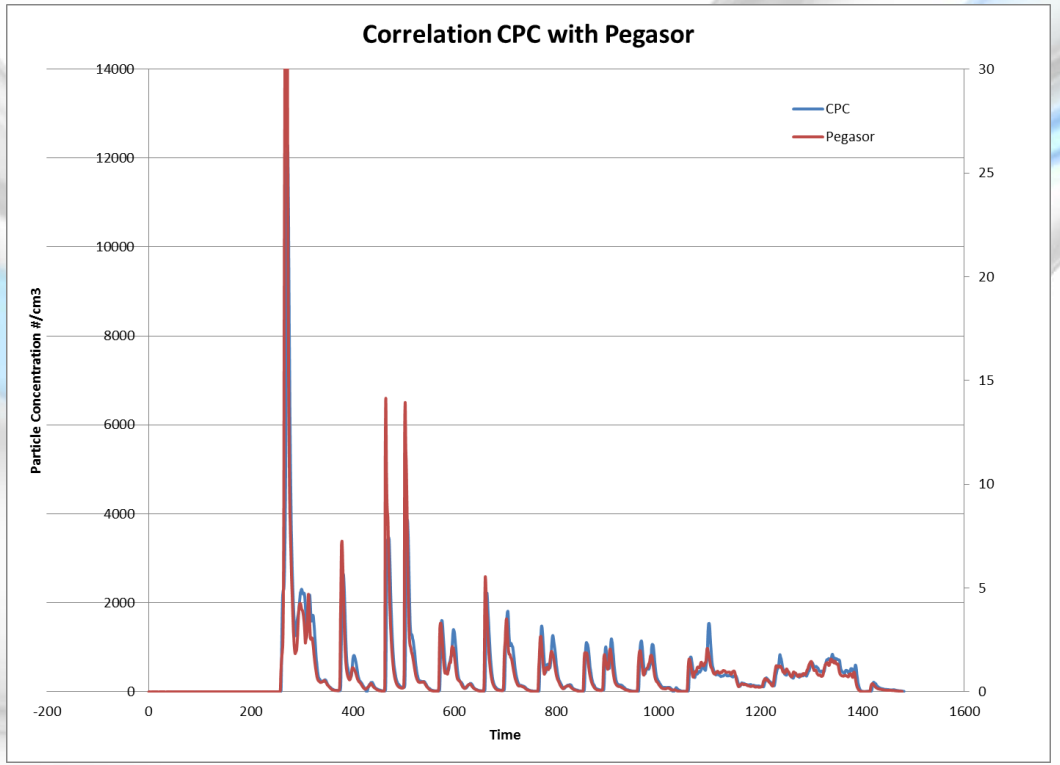
Relationship between active surface area and particle size. From Bau et al. (2012).

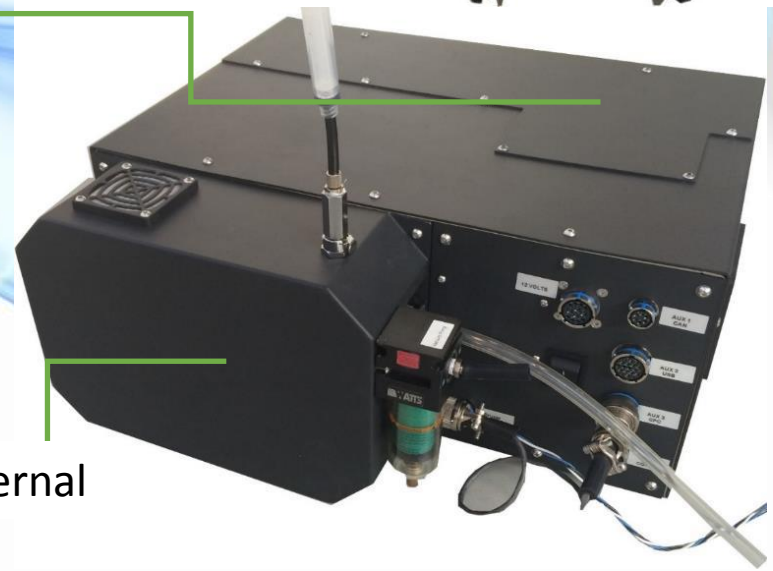


ECOSTAR CPC Prototype Evaluation Platform

- PN Module with Pegasor DC and Prototype CPC
  - 1 stage dilution for Pegasor with Catalyst
  - 2 stage dilution for CPC
  - Demonstrated good correlation on “some Test Cycles”
  - Less good correlation when vehicle generated small (nano) particles due to size dependency on DC sensor D^1.4



Pegasor



CPC Module external

SEMTECH PN PEMS (with CPC Module)

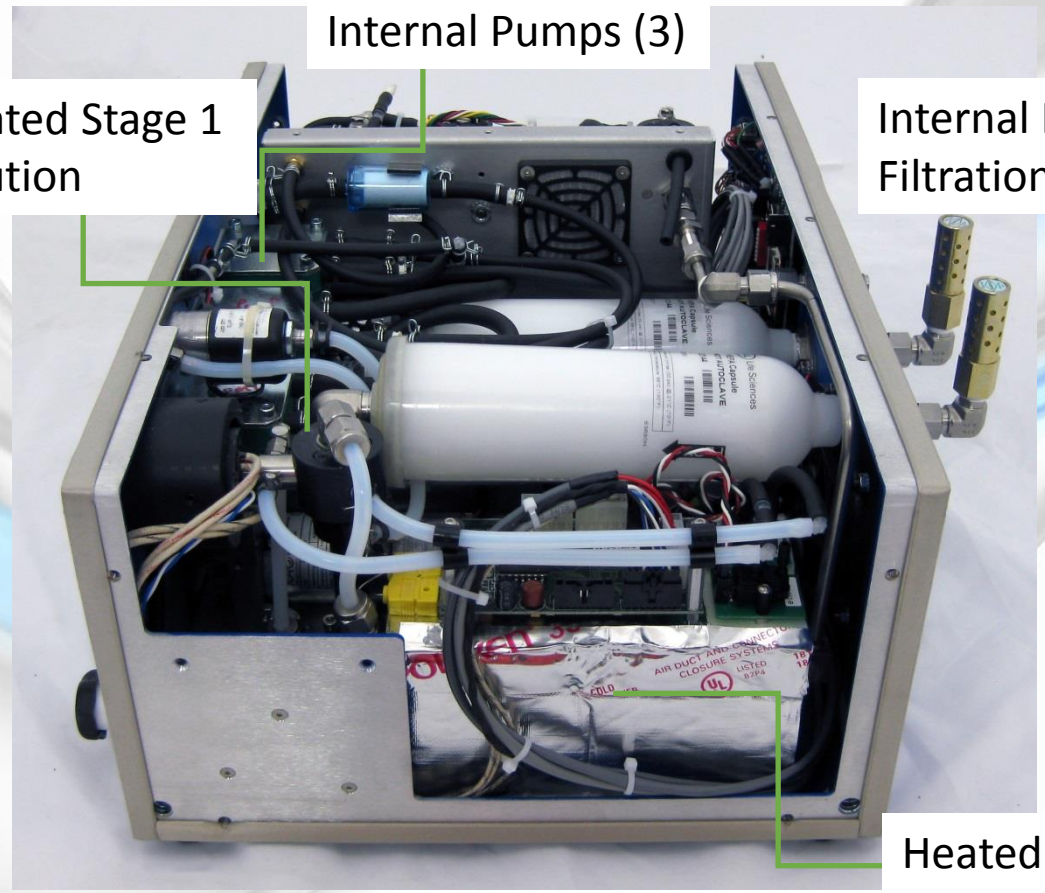
Specifications

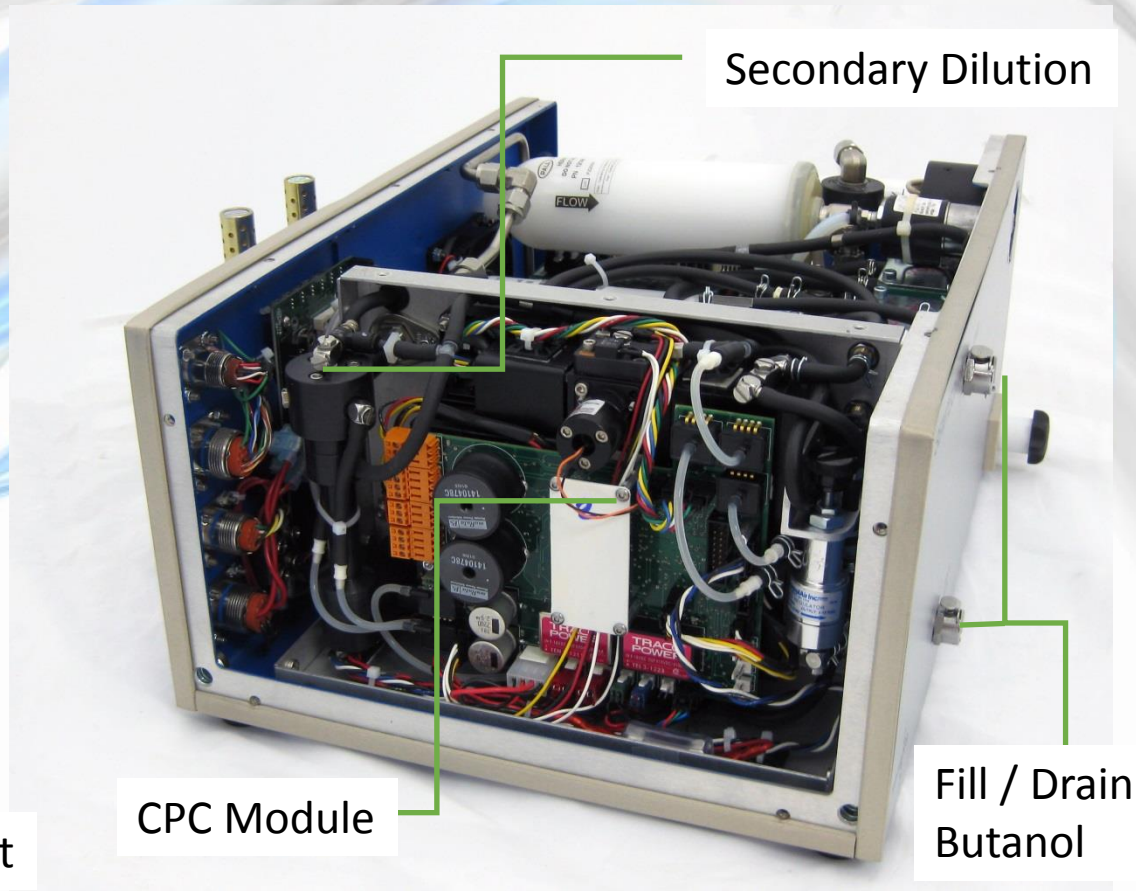
Power: 12 VDC, 200W
Size: 43W x 18T x 31D cm
Weight: 15 kg

Key Components:

- Modular Heated Line (SS core)
- Primary Diluter (10-20:1
- Heated Catalyst (250-300 C)
- Secondary Diluter (50-100:1)
- Mixing CPC (n-Butanol)
- ECOSTAR and SEMTECH RDE/LDV compatible

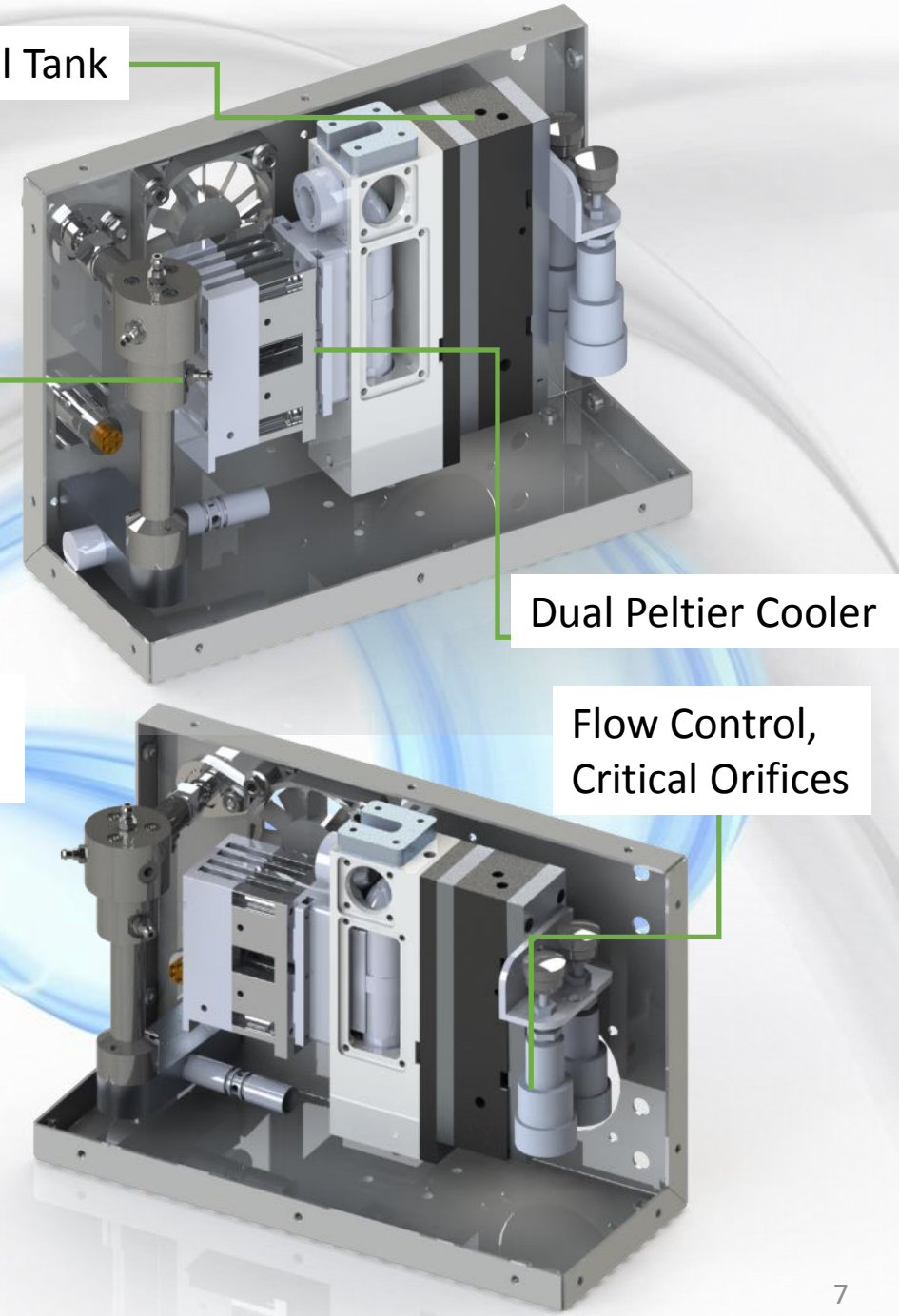
Integrated CPC Module





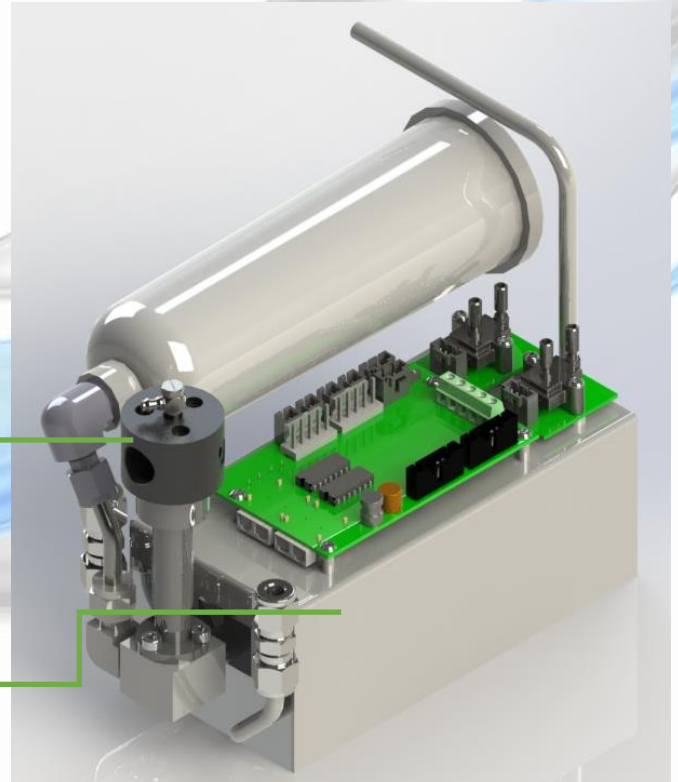
CPC Development

- Vibration and thermally stable
  - Dual Peltier Condenser cooler
- Small Butanol tank (<5 ml)
  - Exhaust controlled venting
  - No Butanol optics contamination
- Critical Flow for stable flow control
- Operates exclusively in single count mode



VPR-Catalyst

- Catalyst from Catalytic Instruments
  - PMP Specifications Met
  - 67% penetration at 10 nm



Stage 1 Heated Dilution
10-20:1

Heated Catalyst
250-300 C

Catalytic Instruments
hot technologies • clean solutions

CERTIFICATE OF CONFORMANCE

MODEL: 030CC00 catalytic core
SERIAL NUMBER: 030CC00-20130018

Catalytic Instruments herby certifies that the above referenced core conforms to the original manufacturer's specifications. The device performance has been tested and verified using the equipment, metrics, and methods described below.

Picture - Feasibility study on the extension of the Real Driving Emissions (RDE) procedure to Particle Number (PN), JRC 2014

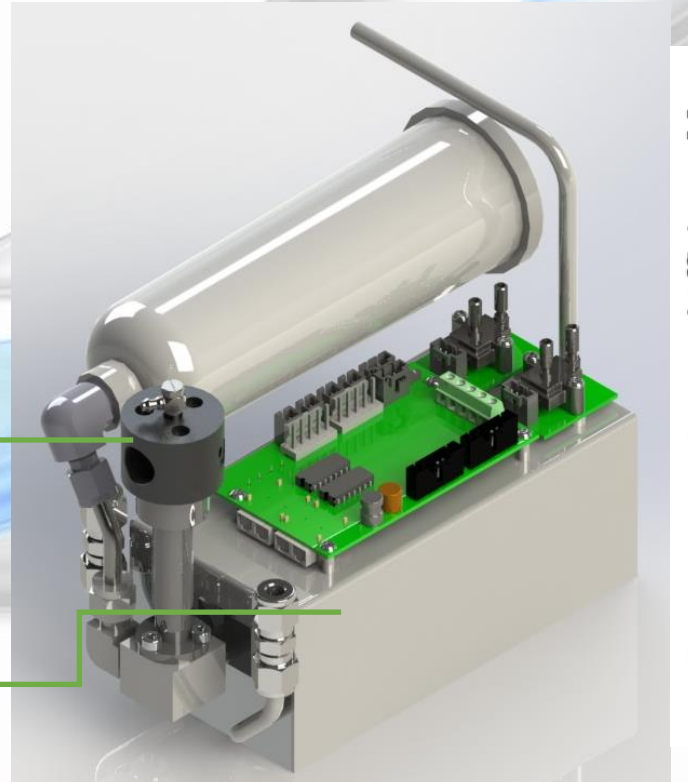
TEST EQUIPMENT USED: TSI 3080 L SMPS, HORIBA MEXA 584 L

Flowrate: 3 L/min
Heater setpoint: n/a
Propane oxidation: >99%
Solid particle penetration: 66 % **Size:** 10 nm

Penetration measured at room temperature

VPR-Catalyst – Experimental Verification

- Catalyst from Catalytic Instruments
  - PMP Specifications Met
  - 67% penetration at 10 nm



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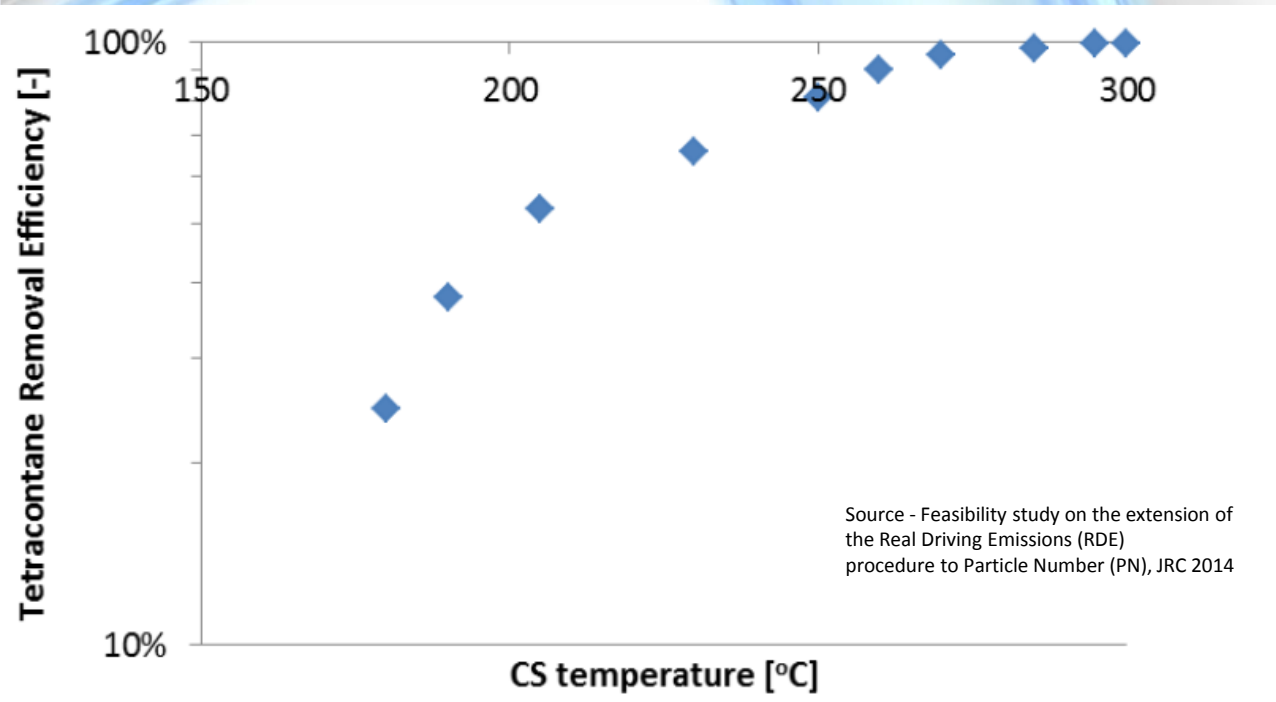

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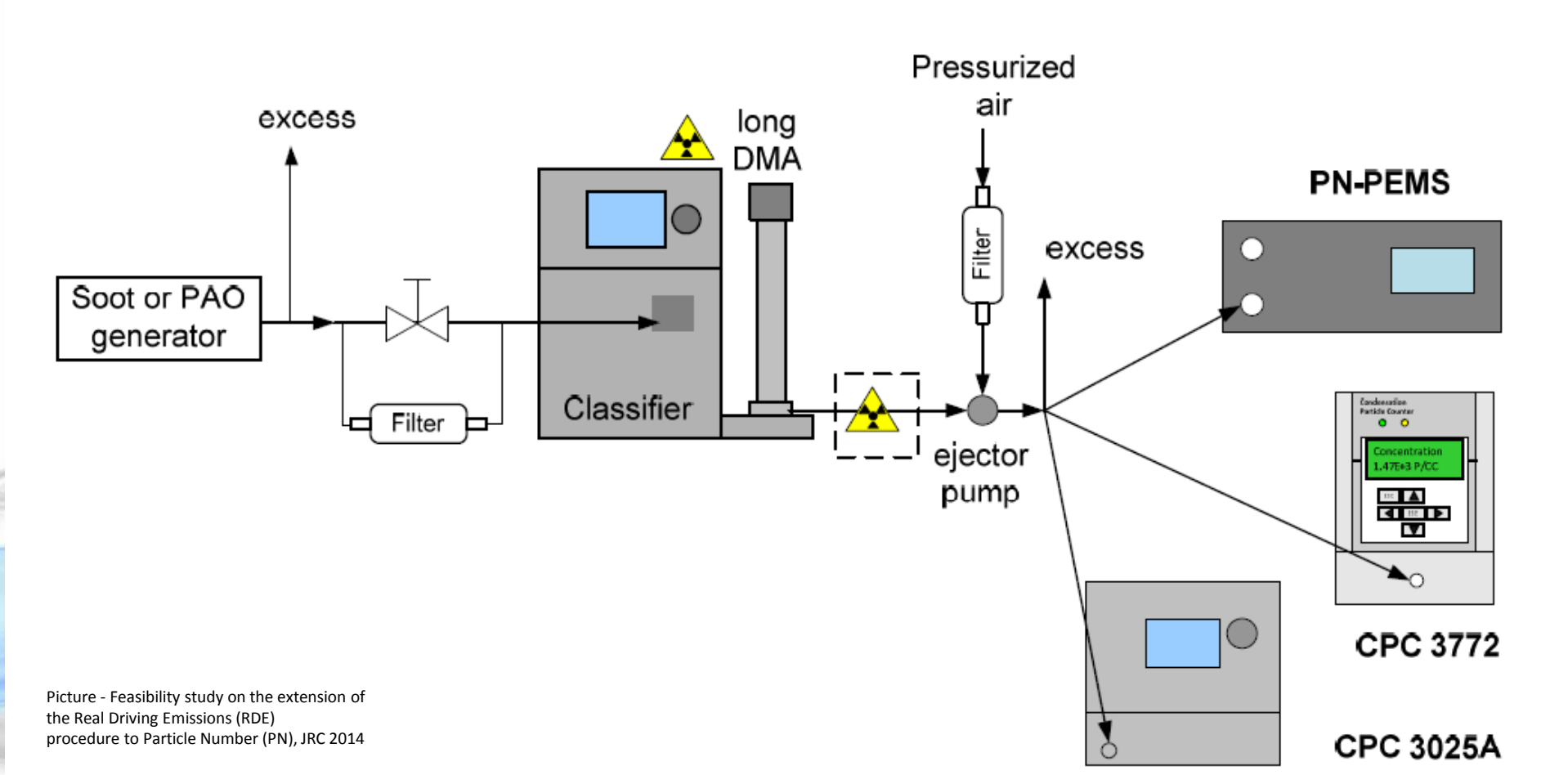
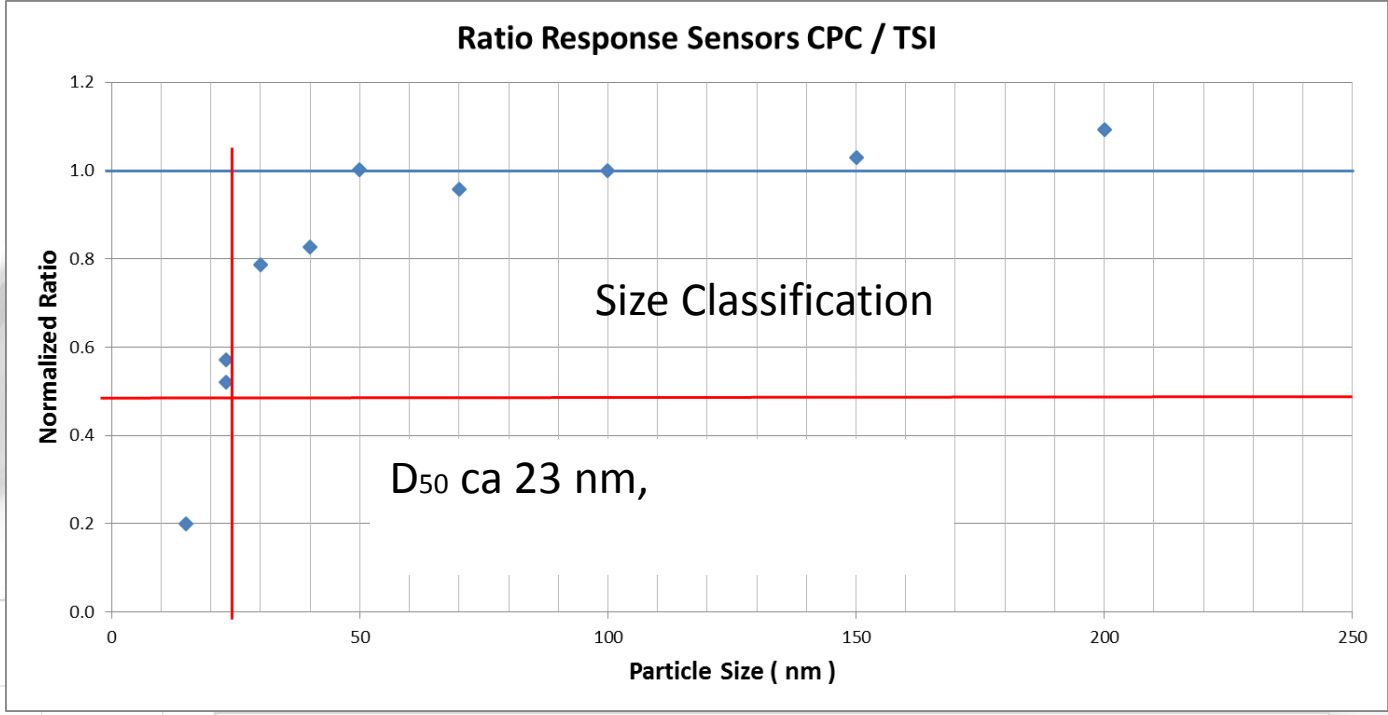
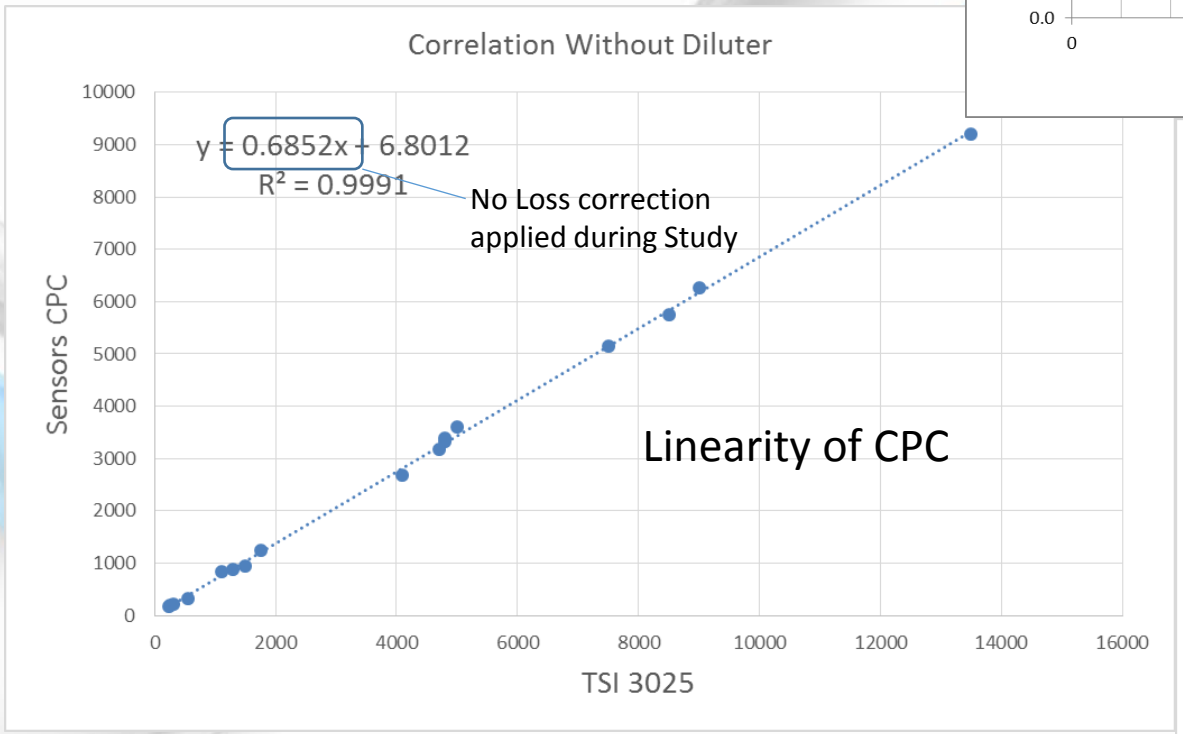
Laboratory Characterization Test Set-Up

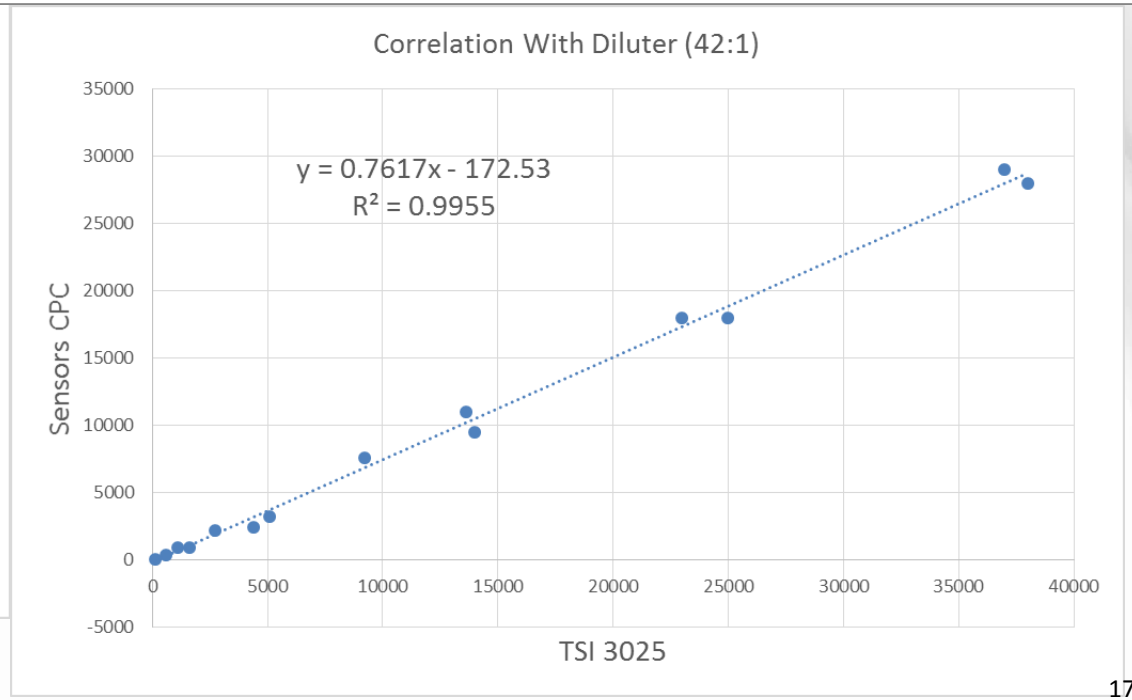


Picture - Feasibility study on the extension of the Real Driving Emissions (RDE) procedure to Particle Number (PN), JRC 2014

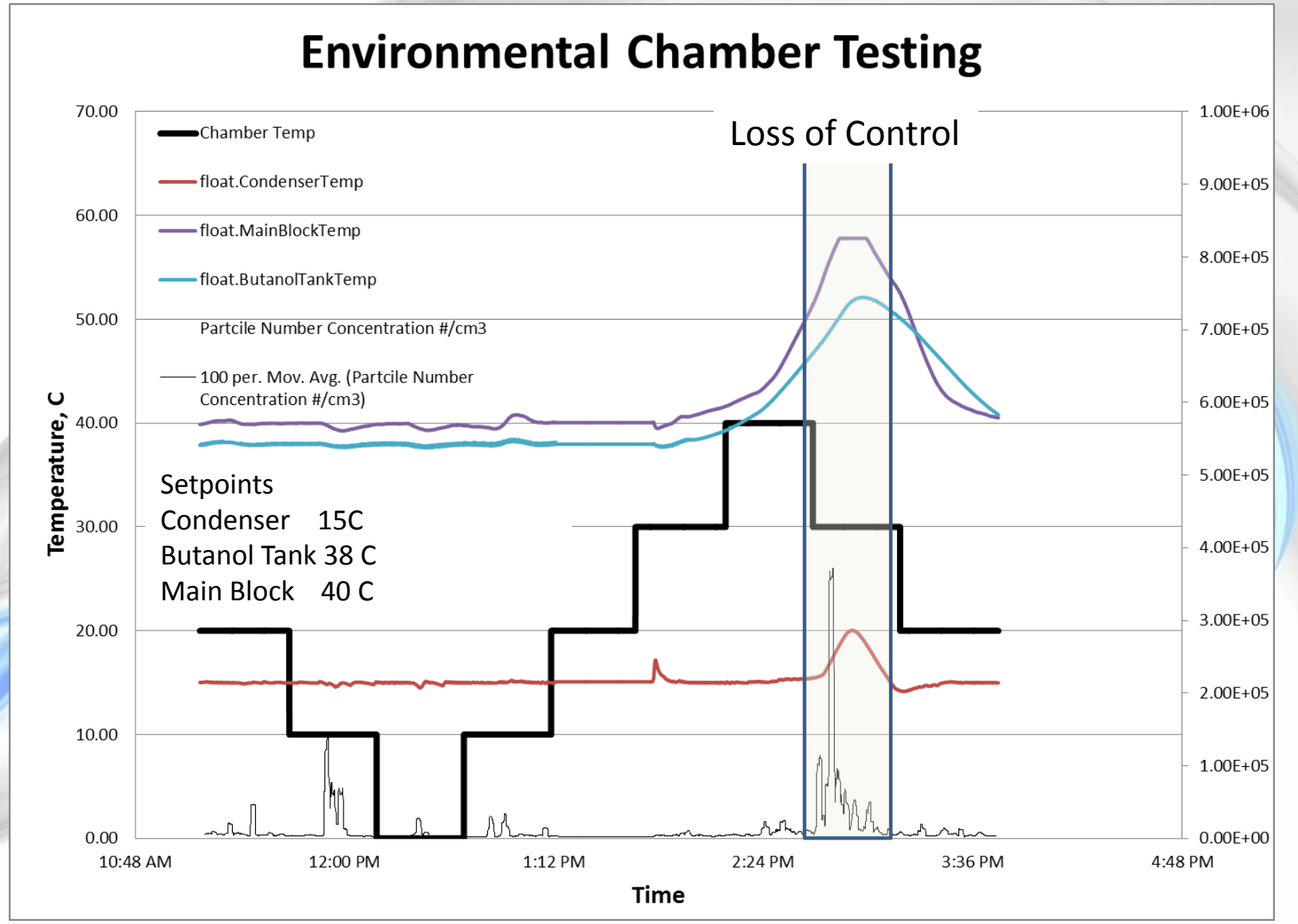
Aerosol Laboratory Evaluation







Environmental Chamber Testing (0-10-20-30-40-30-20 C)



Summary

Condenser, Butanol Tank and Main Chamber remain controlled over the temperature range 0 to 30 C

Action Item

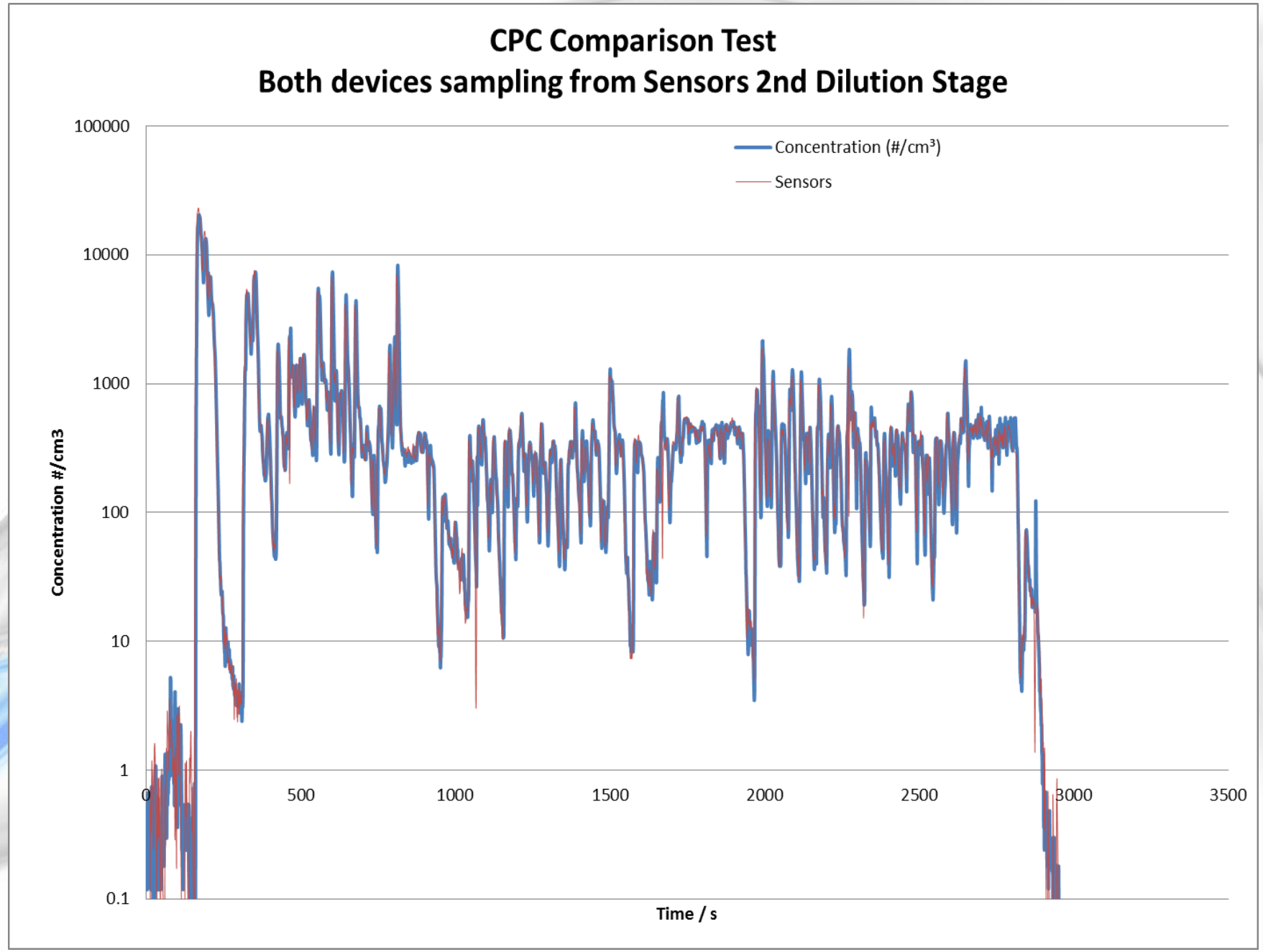
Additional cooling required to meet 40 C ambient specification

Dyno Testing

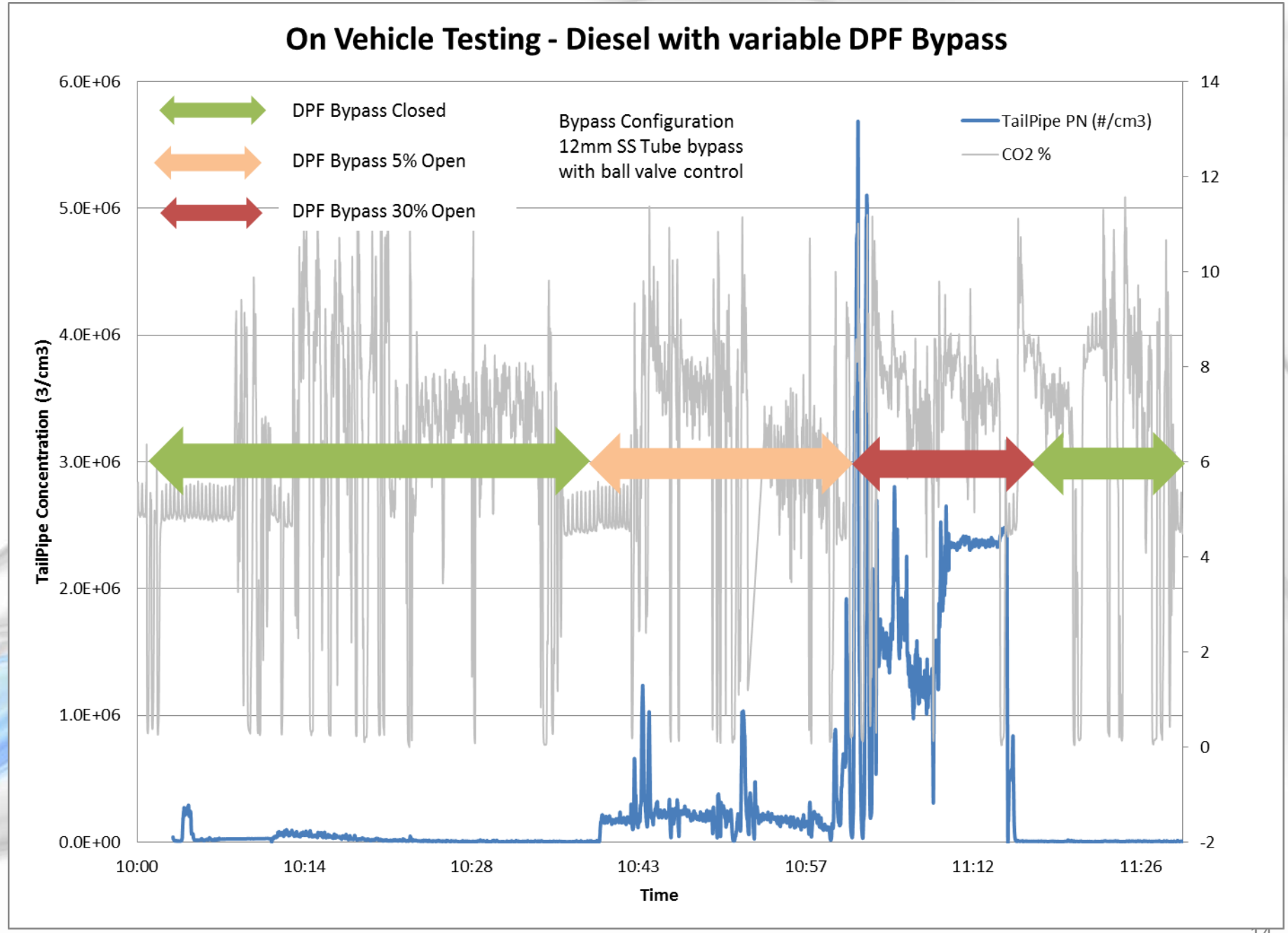
Data obtained at JRC ISPRA

CPC Evaluation:

Exhaust of CPN module measured simultaneously by TSI CPC and Sensors CPC during chassis dyno testing



On Vehicle Testing



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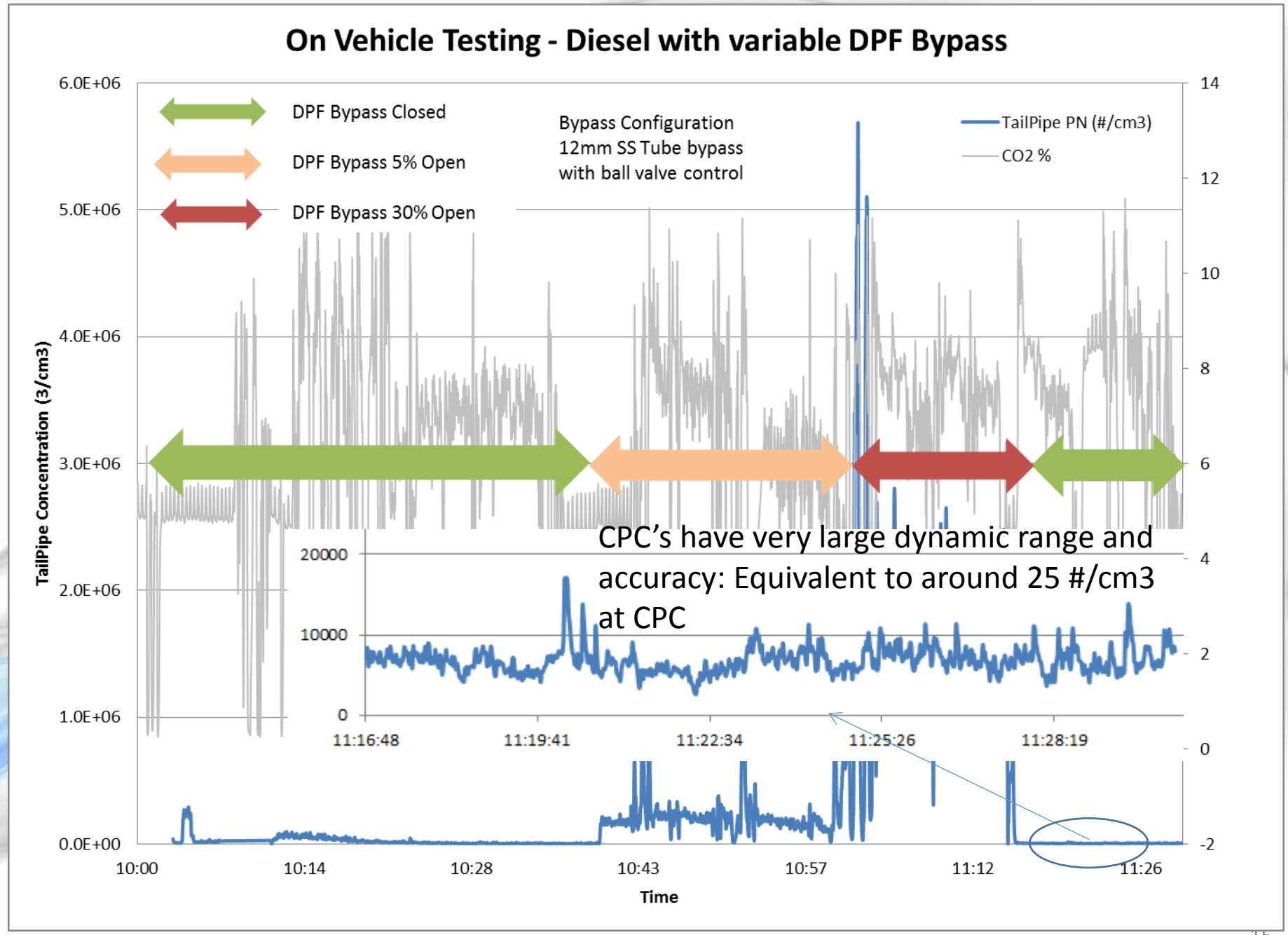

Observations – Against PMP Calibration Protocol

• The absolute losses are on the order of 25%.	Correction factor applied re PMP
• The d50 should increase slightly (ca 30nm), because when the penetration is normalized to 1, the d23nm goes >50% and to match PNP systems	Will add diffusion screen
• The heated line introduces some losses (10% at 100 nm 40% at 15 nm).	Will investigate further
• The polydisperse checks showed a good agreement with a simulated PMP system for GMDs between 35 and 80nm.	No action required
• No observable deterioration in performance during on-vehicle testing	Testing continues
• PMP Correlation testing (fuel, vehicle, cycle etc)	On-going
• Increase cooling in high Ambient temperature conditions to enable 0-40 C operation specification	Will investigate further