Integrated PN measurement system performance and VPR requirements

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Contents

- Volatile Particles
- Volatile Particle Remover (VPR)
- VPR requirements for PN measurements
- Integrated approach
- Results
- Discussion

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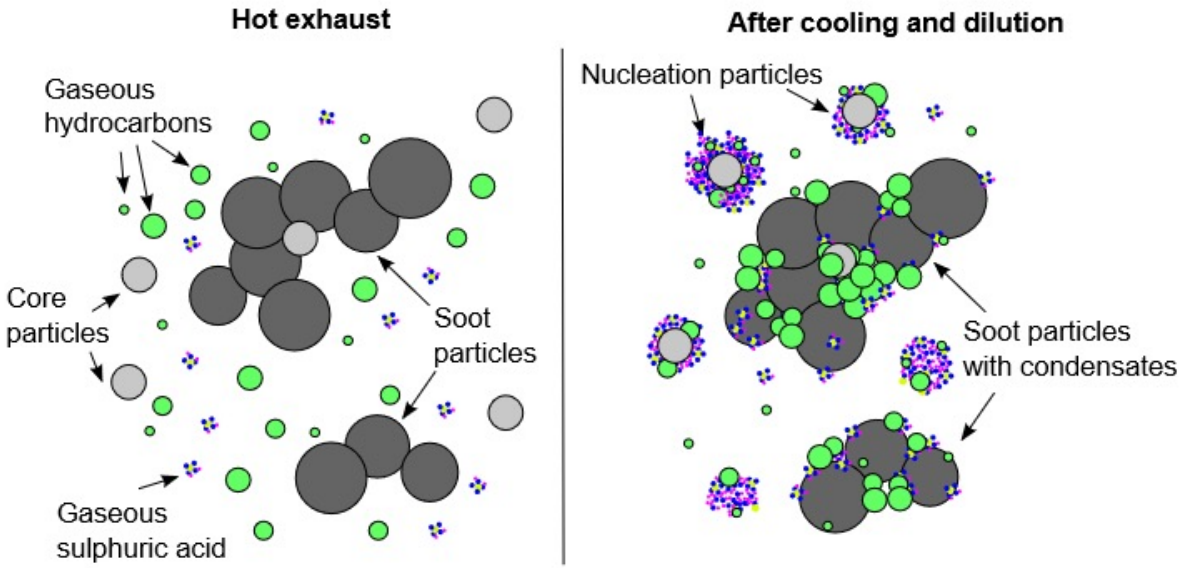
Volatile particles in PN context (in short)

- Volatile particles can evaporate and condense in or near engine
- This definition is very loose and leaves a lot for interpretation
  - Test substance or strict process conditions needed



Karjalainen, Vehicle nanoparticle emissions under transient driving conditions, Dissertation, 2014, ISBN 978-952-15-3411-9

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PMP: Volatile Particle Remover (VPR)

- Definition in PMP (ECE/TRANS/WP.29/GRPE/2007/8/Rev.1)
  - Test substance and test particle size and concentration.

- BUT, there are process recommendations, difficult to ignore

The VPR shall achieve > 99.0 per cent vaporisation of 30nm tetracontane ($CH_3(CH_2)_{38}CH_3$) particles, with an inlet concentration of ≥ 10,000 cm^{-3}, by means of heating and reduction of partial pressures of the tetracontane. It shall also achieve a particle concentration reduction factor (f_r) for particles of 30nm and 50 nm electrical mobility diameters, that is no more than 30 per cent and 20 per cent respectively higher, and no more than 5 per cent lower than that for particles of 100 nm electrical mobility diameter for the VPR as a whole.

Recommended System Description

The following section contains the recommended practice for measurement of particle number. However, any system meeting the performance specifications in paragraphs 1.2. and 1.3. is acceptable.

Evaporation Tube

The entire length of the ET shall be controlled to a wall temperature greater than or equal to that of the first particle number dilution device and the wall temperature held at a fixed value between 300 °C and **400 °C**.

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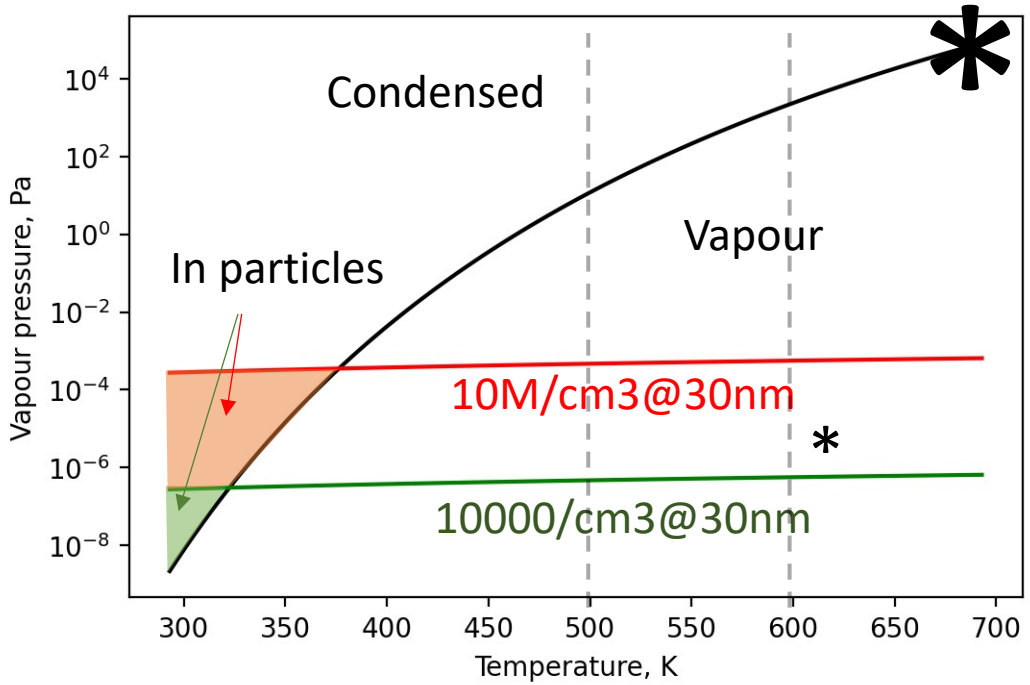
Thermodynamic reasoning

- Tetracontane boiling point is not well defined, expected boiling point is >400°C (J. Chem. Eng. Data 1966, 11, 2, 253–255, 1966, https://doi.org/10.1021/je60029a039)
- However, the vapour pressure is not zero below boiling point.



* C40H82 data extrapolated with Clausius-Clapeyron relation from NIST latent heat data for tetracontane and boiling point data at 5mmHg pressure from alkanes between C20 and C36.

* Particle evaporation data from molar mass and density of 800kg/m^3 from chemspider.com/Alfa Aesar.

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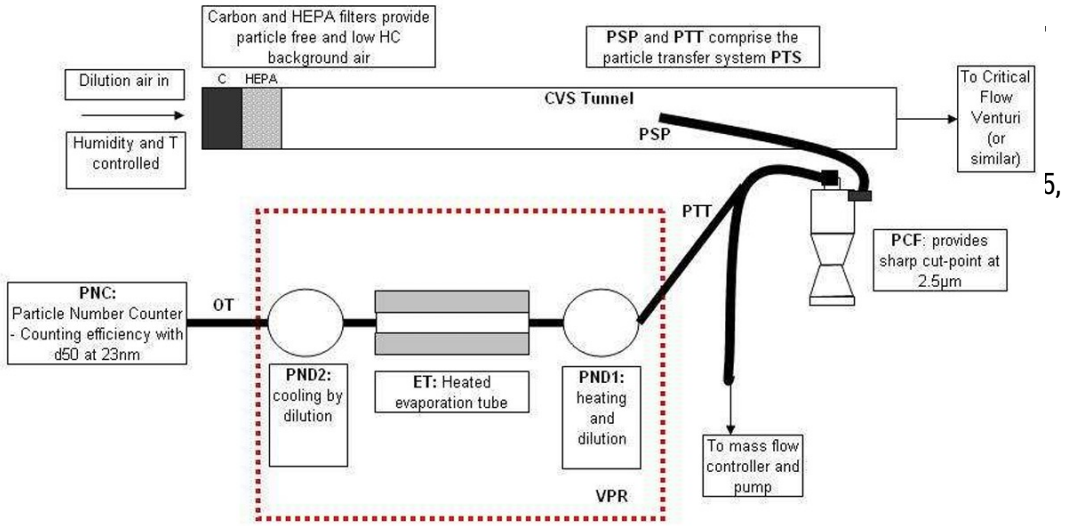
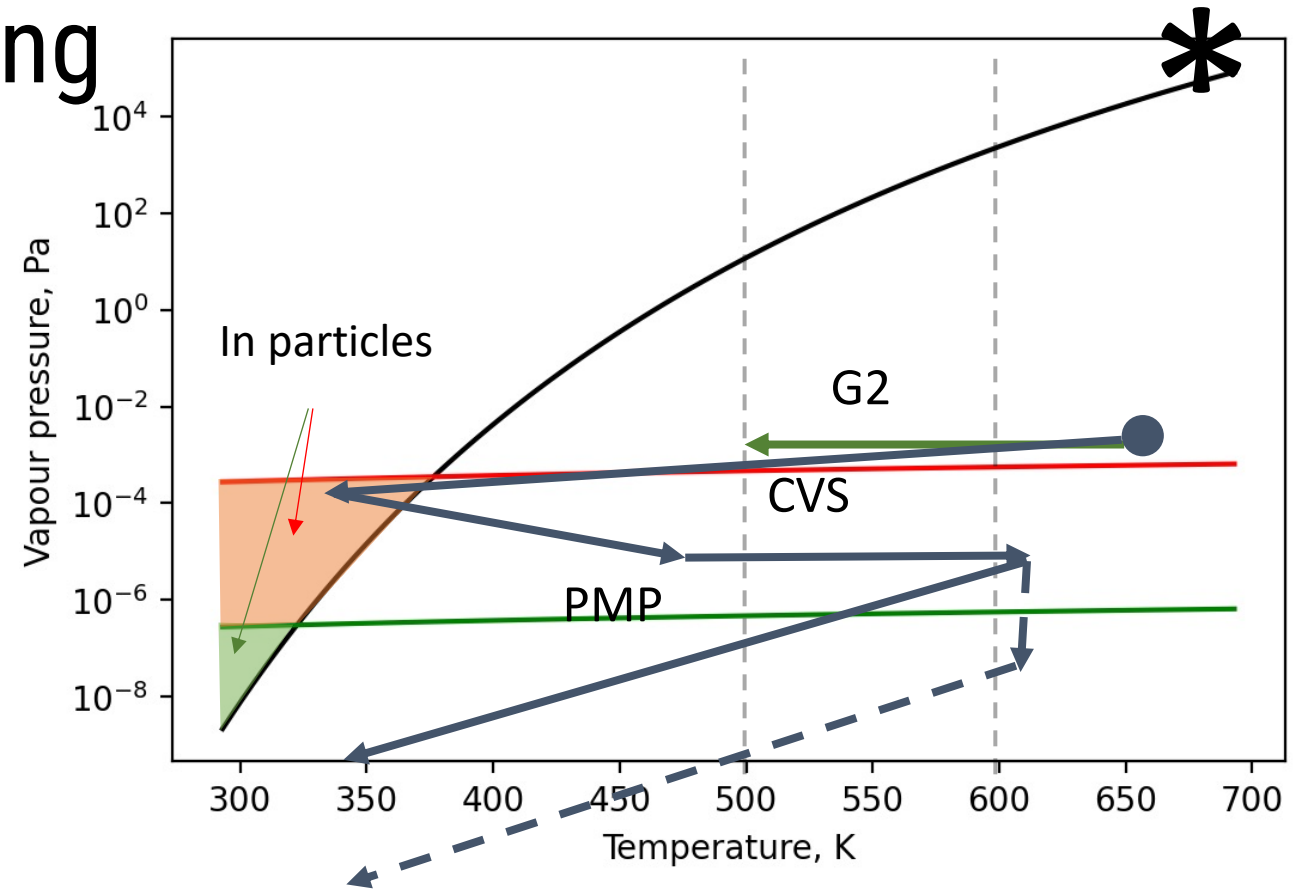
Thermodynamic reasoning

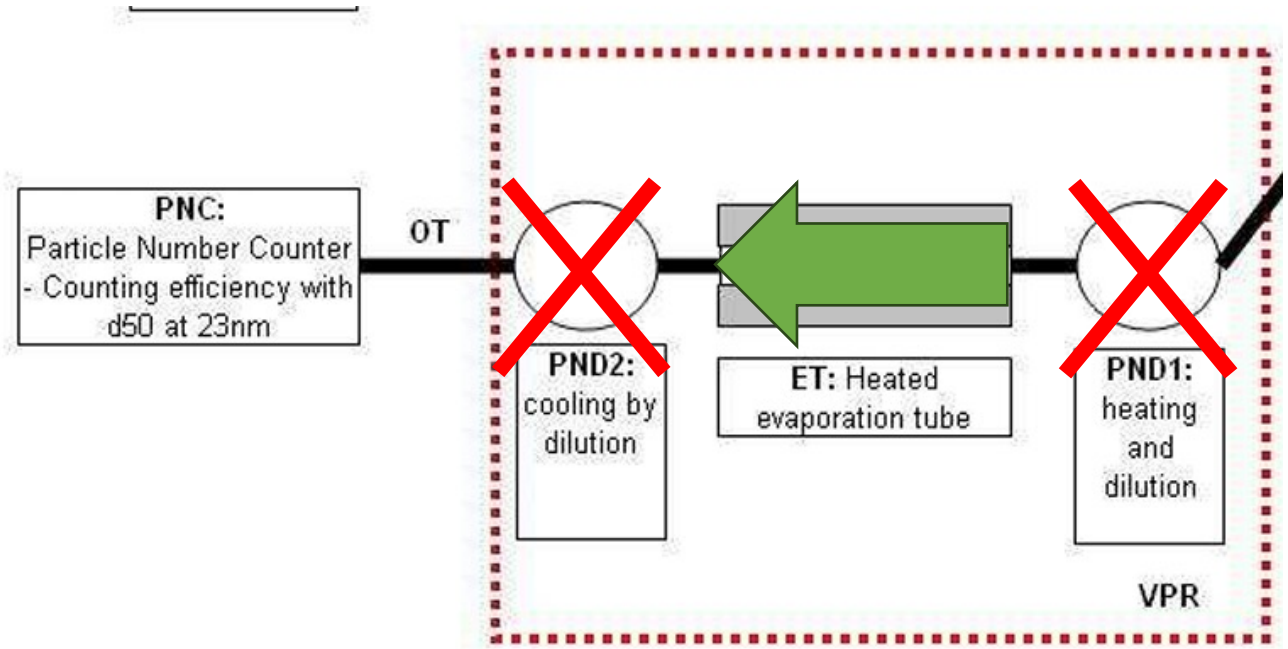
Figure **14**: Schematic of **Recommended** Particle Sampling System





Lower temperature for simplified instrument – or vice versa

- When the materials and structure allows, the VPR can be integrated into the device
- As the sample is not cooled for measurement, much lower temperature is needed!
- Simplicity also reduces errors!



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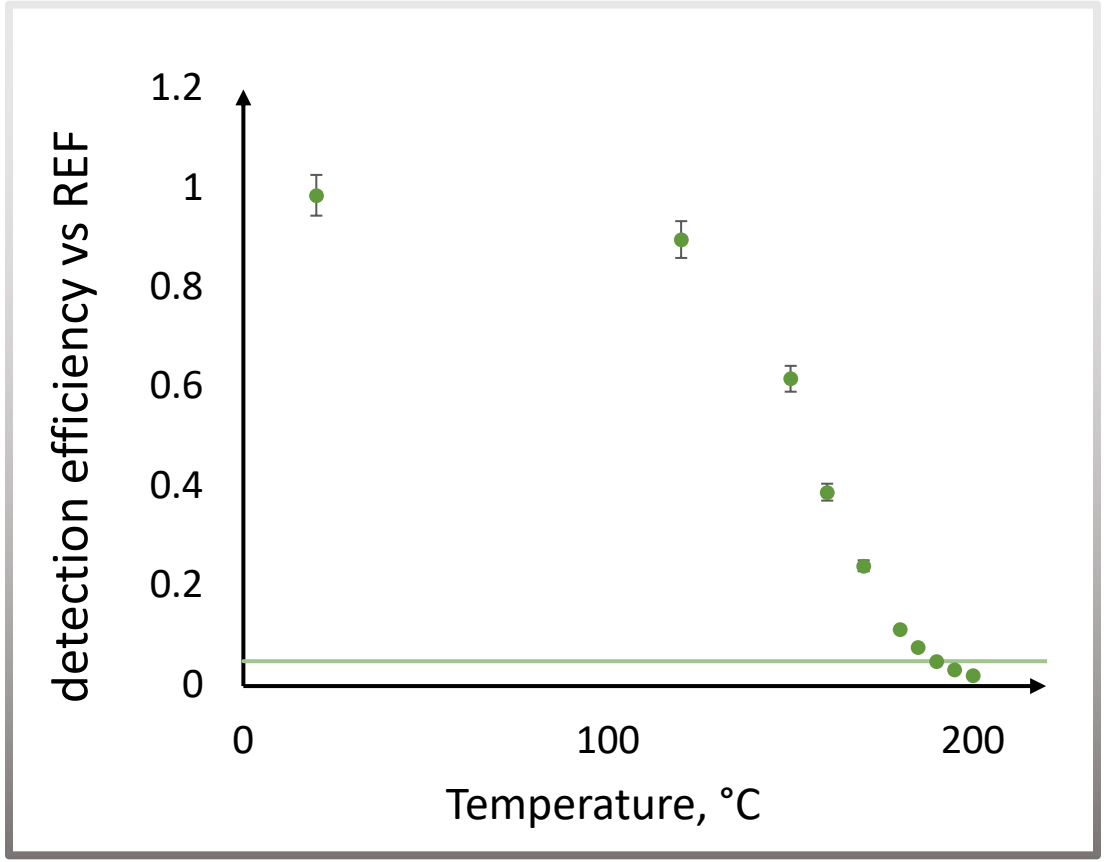
Tetracontane test for PTI certification

- Tetracontane evaporation begins already around 100°C (90%@120°C)
- PTI requirement level reached already at 190°C, at worse-than-field -conditions



Data by Kevin Auderset@METAS

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Discussion

- Performance requirement instead of process requirement →innovation and simplifi
  - Success of NPTI –program!
- Process requirement drives overspecification:
  - Eg: Too hot VPR-> separate components, high performance materials-> dilution, dilution error
  - Discussion of 400°C VPR for PTI, higher than aerospace VPR of 350°C!

Evaporation Tube

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Best Available Technology ≠ Strictest requirements

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Thank you!

See you at Pegasor booth!

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