Informal document **GRPE-85-34-Rev.1**
85th GRPE, 11-14 January 2022
Agenda item 13

New Periodic Technical Inspection – Particle Number Measurement

Joint Research Centre

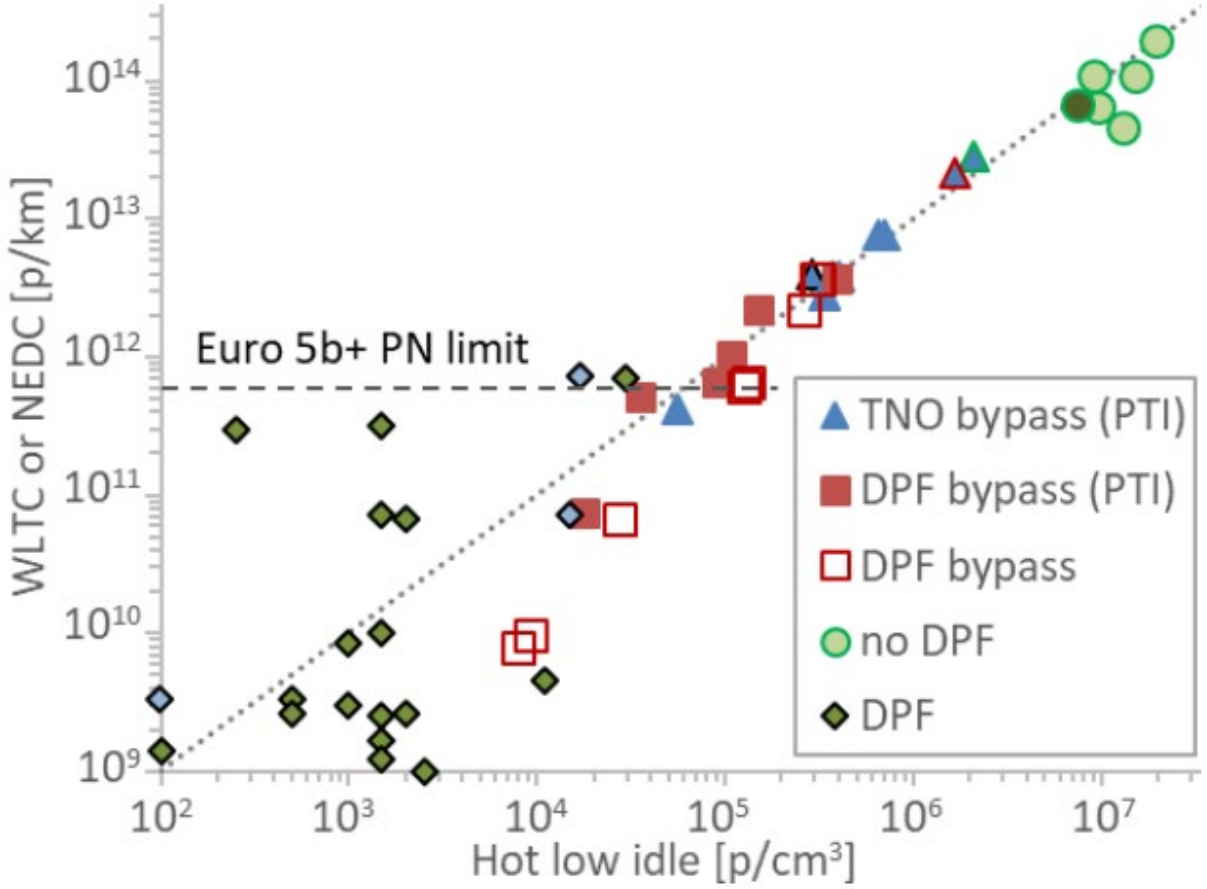
European Commission

New periodic technical inspection

- The regulation of solid particle number (**PN**) emitted by vehicles equipped with combustion engines, led to the implementation of very efficient particulate filters
- A small fraction of vehicles having broken or manipulated particulate filters can dominate the PN emissions of the fleet
- The technical possibilities of both remote sensing and on-board monitoring to particle number measurements is very limited
- A possible solution is the introduction of a PN measurement during the Periodic Technical Inspection (PTI)

Low idling vs regulatory tests

- Several studies proposed that especially for diesel vehicles, the low idling PN concentrations correlate well with PN emissions during regulatory tests
- Diesel vehicles with >10^5 #/cm^3 low idling emissions emit more than the regulated 6x10^{11} #/km homologation limit.
- Malfunctioning or tampered particulate filters could be detected with low idling PN measurements during the periodic technical inspection



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Particle Number (PN) measurements in PTI

- In Switzerland, a PN measurement is conducted for non-road machineries during PTI
- The Netherlands was the first country to introduce in the periodical technical inspection of vehicles a PN measurement
- The Netherlands and Belgium regulation from July 2022 will apply to EURO 5 and 6 diesel vehicles and the limit will be $1x10^6$ #/cm^3. Germany will follow from January 2023
- German regulation will impose a limit of $2.5x10^5$ #/cm^3 to EURO 6 diesel vehicles. The technical specifications of the PN/PTI sensors and the procedures differ in DE and NL regulations
- European Commission plans to draft a recommendation for harmonising approaches for PN PTI measurements but leave the MS with the possibility to introduce PN measurements as an additional measure within their own national competence, pending the revision of the PTI Directive

Testing in JRC

- JRC will contribute to the drafting of PN/PTI measurement procedures and technical specifications in view of the Commission recommendation and the revision of the PTI Directive

- Two measurement campaigns (June and September 2021) will give the necessary scientific evidence

- Several instrument manufacturers provided their PN/PTI devices

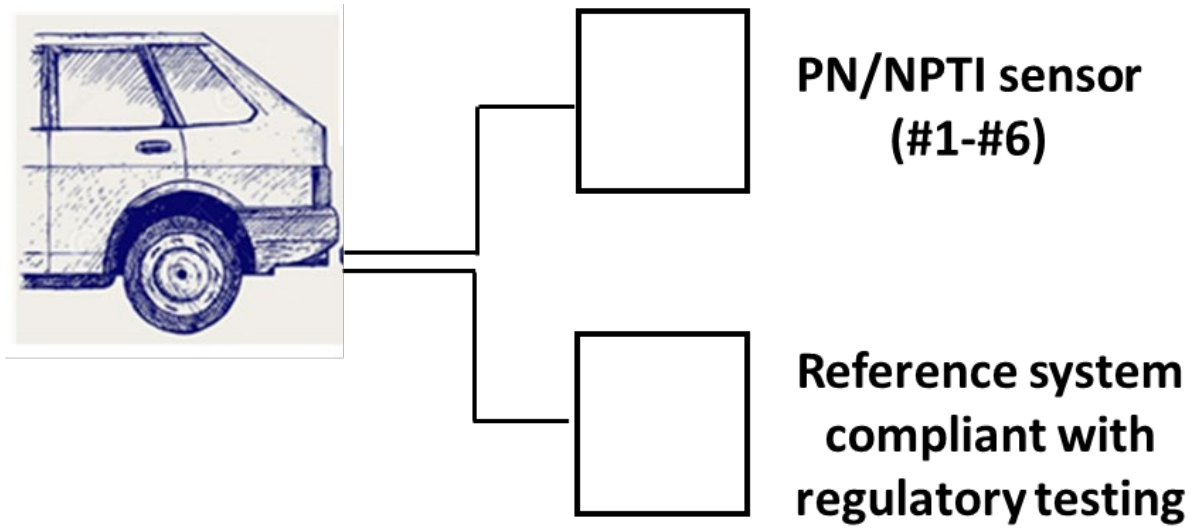
14-25/06/2021: Preliminary assessment with vehicle exhaust measurements using PN/PTI sensors (5 manufacturers participated).

13/09/2021-01/10/2021: Dedicated laboratory testing as well as vehicle exhaust measurement with PN/PTI sensors and an opacity meter (6 manufacturers participated)

Topics to be addressed

- PN method vs opacity? *ongoing*
- Calibration procedures and technical requirements (instruments uncertainty) *ok*
- Idle concentration levels of vehicles with malfunctioning or without particulate filter? (procedure uncertainty) *ongoing*
- Implications for PN/PTI due to special cases? *ongoing*
  - Regeneration of the diesel particulate filter (DPF) *ongoing*
  - Particles with smaller size than the regulated cut-off size (23 nm) *ok*
- Specifications of the sensors and proposed limits (NL:$1x10^6$, DE: $2.5x10^5$ #/cm^3)? *ongoing*
- Extension of the methodology to gasoline vehicles? *ongoing*

Experimental setup & procedures



Reference system measurements

SPN_{23}= Solid particle number concentration down to 23 nm;

SPN_{10}= Solid particle number concentration down to 10 nm;

TPN_{10}= Total particle number concentration down to 10 nm

- The low idling PN emissions of the vehicles were continuously measured with a system that is currently used for regulatory measurements.
- 6 (7 in the 2nd campaign) PTI sensors were measuring for specific time frames (15 to 90 seconds) that depended on the regulation they follow
- The performance of an opacity meter was compared to the PN method

Testing in JRC (2/2)

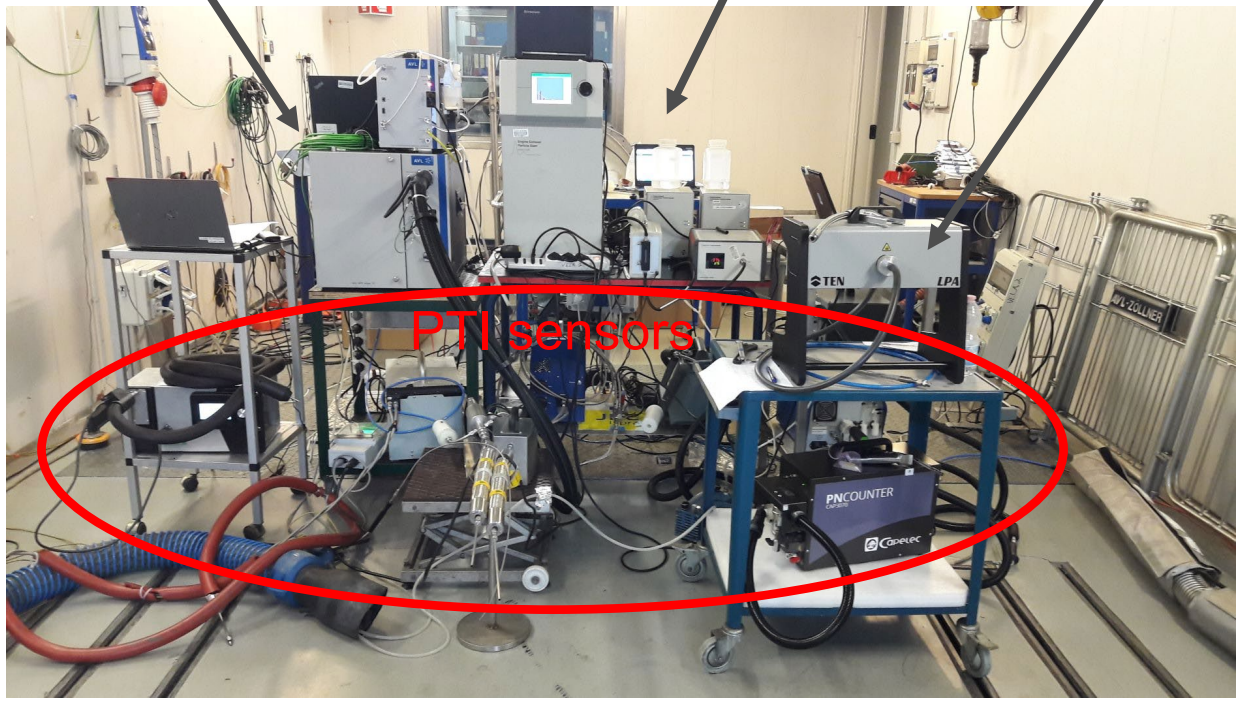
Companies that provided instruments

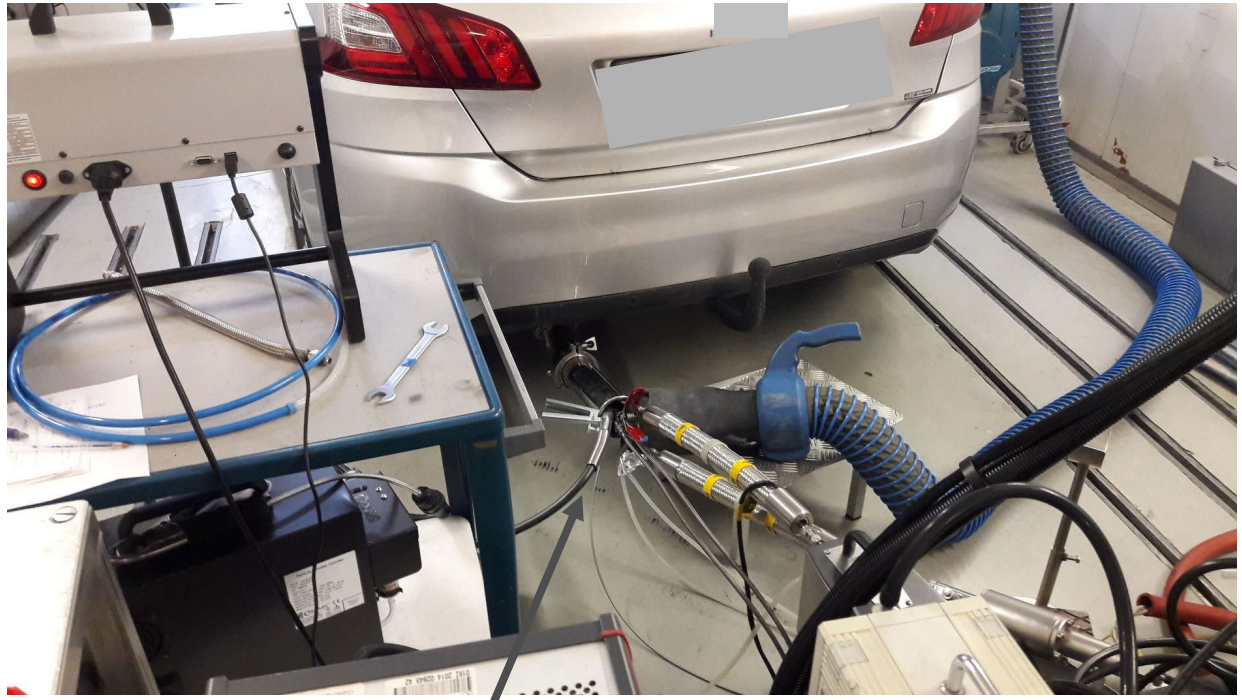
CAPELEC and PEGASOR
DEKATI
MAHLE
SENSORS
TEN
TSI

Reference system

Total particles and particle size distribution

Opacity meter





Sampling from the tailpipe

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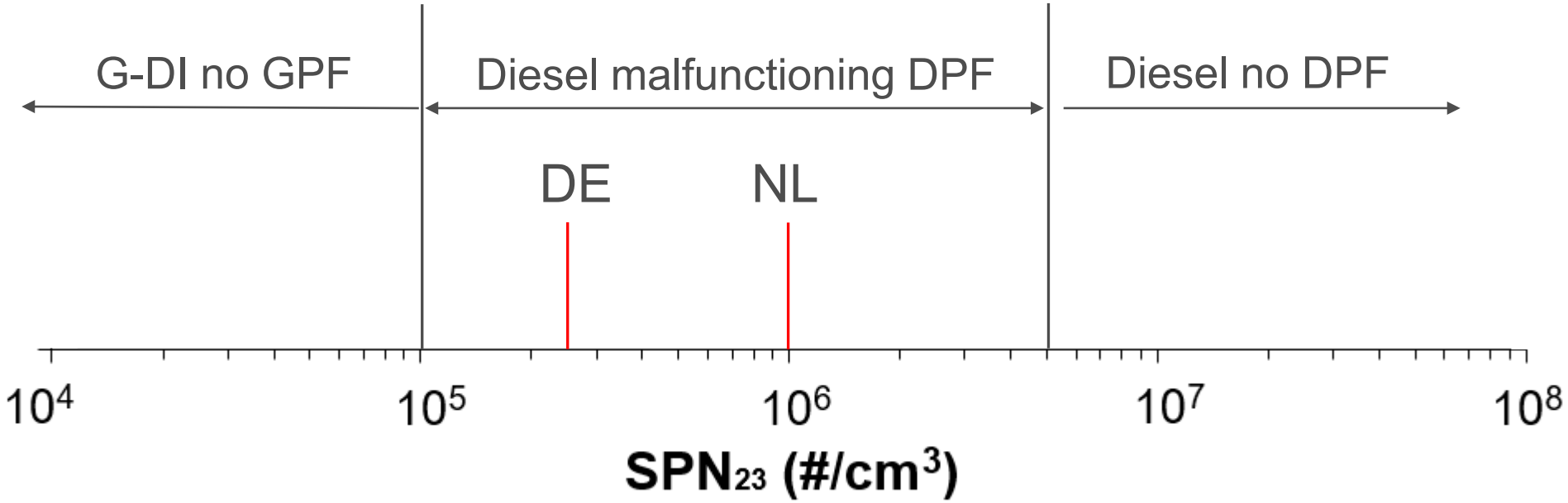
Summary of results (1/2)

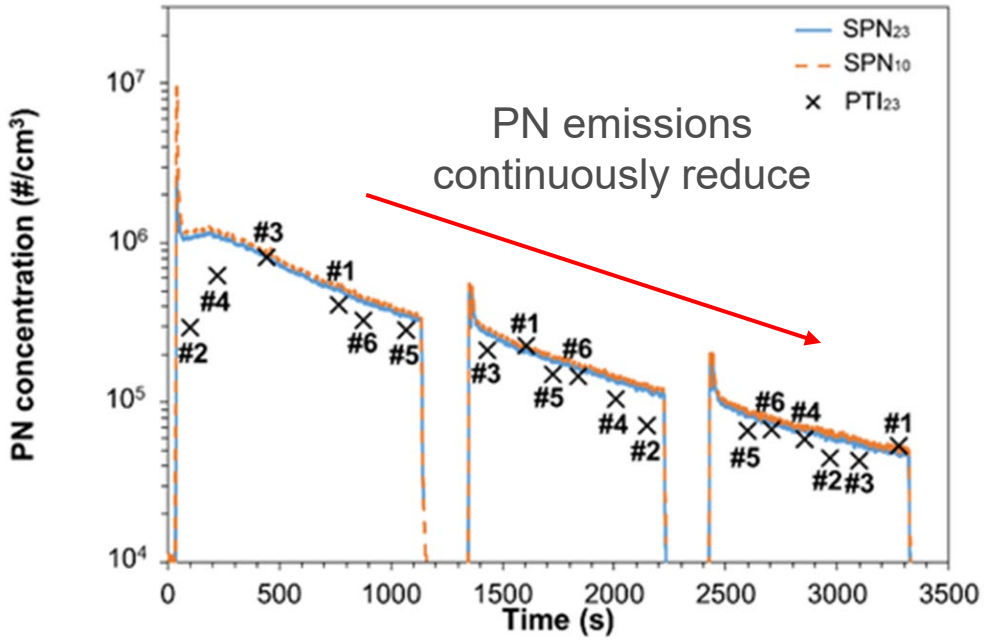
- PN emissions of vehicles with malfunctioning or without particulate filter?



Diesels (no DPF) emit ~1x10^7 #/cm^3 (higher than the NL and DE limits) while gasolines (no GPF) may emit less than 10^5 #/cm^3. The SPN_{23} emissions of two diesels with malfunctioning DPF was >2.5x10^5 #/cm^3 (DE limit) (but close).

Summary of results (2/2)

- Implications for PN/PTI due to special cases?
  - DPF regeneration → After a DPF regeneration, diesel vehicles may necessitate a short conditioning (e.g. some minutes of driving) before testing. The analysis of the results is ongoing
  - Particles with smaller size than the regulated cut-off size (23 nm) → The highest deviations of the PTI_{23} sensors were observed at very high sub-23 nm fractions possibly due to the different efficiency below the 23 nm size cut-off.



In one case high sub-23 nm particles were emitted during low idling at cold start, not seen at the WLTC

WLTC 10 nm	Low idling 10 nm
+27%	+700%

Sensors 2021, 21, 8325; https://doi.org/10.3390/s21248325

On-going work (1/2)

- Proposed limits (NL:1x10^6, DE: 2.5x10^5)

The on-going work on the definition of the sensors' specifications and dedicated tests for the correlation of the low idling emissions of vehicles with homologation cycles (WLTC, NEDC) will give important input

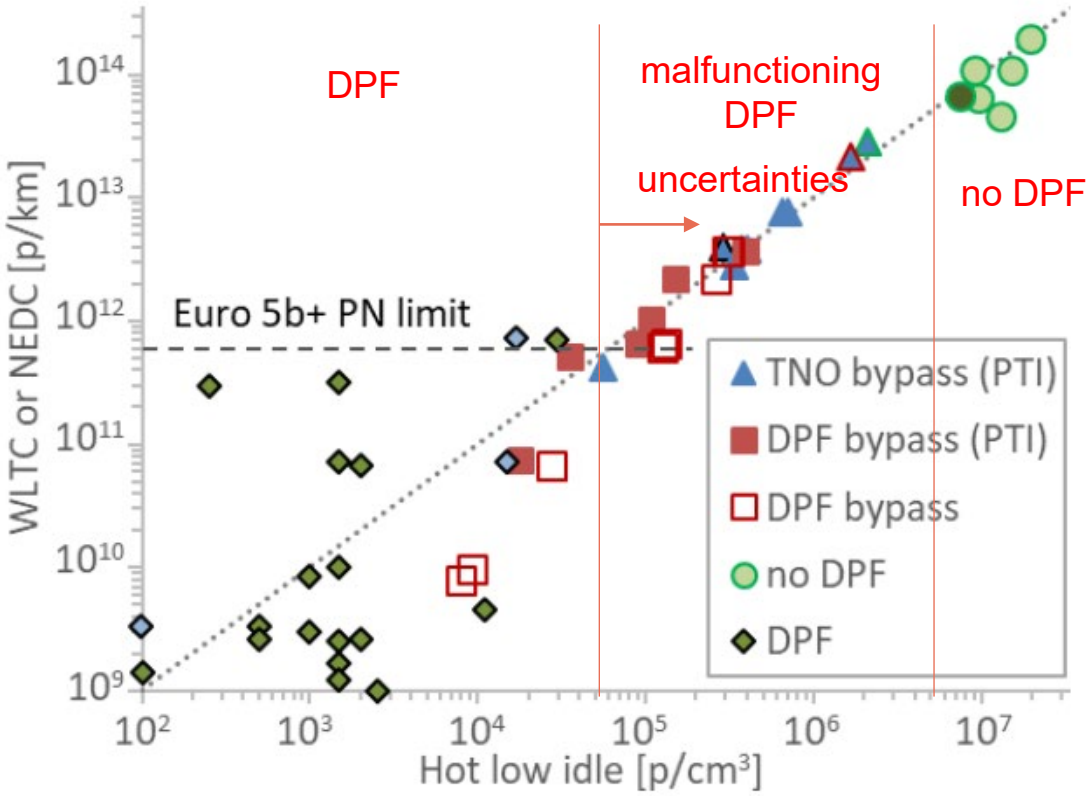
- Specifications of the sensors?

❖ Counting efficiency (mono / polydisperse)

❖ Linearity

❖ Volatile removal efficiency

<u>Lines are indicative only</u>
Limit depends on stringency of malfunctioning DPF plus uncertainty



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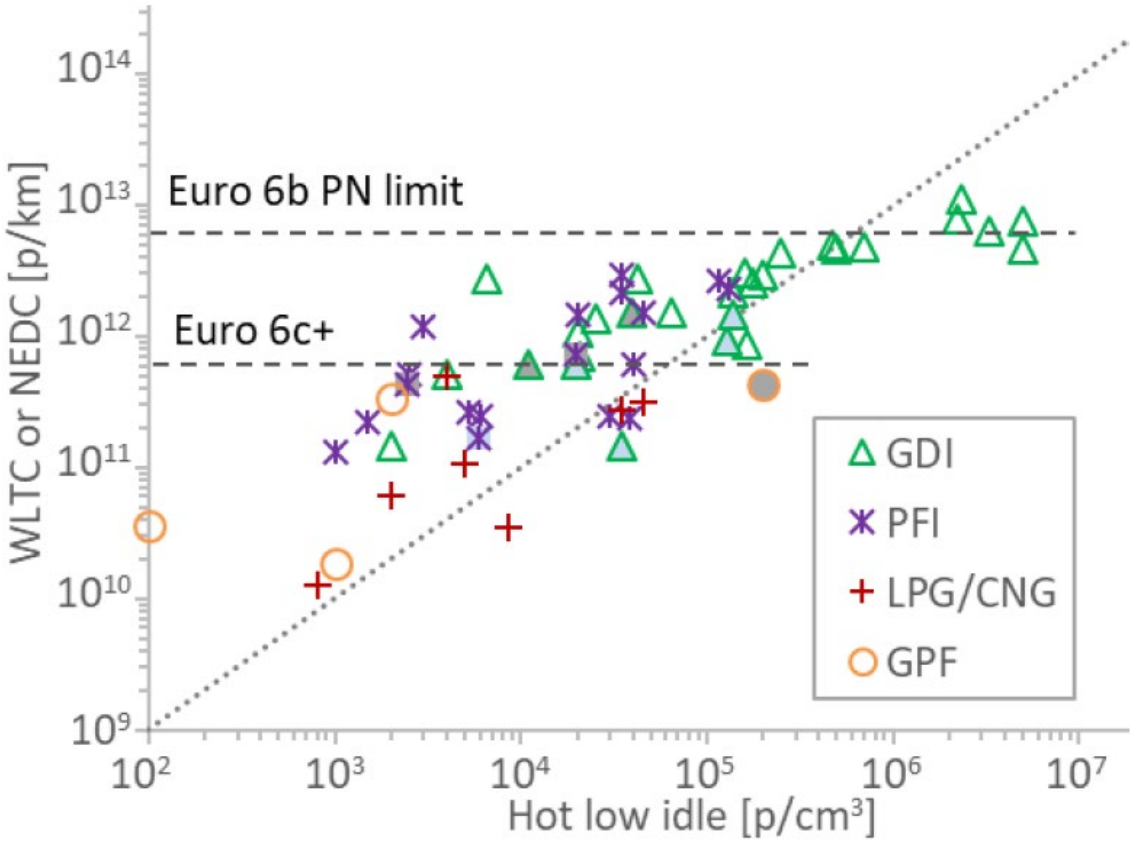
On-going work (2/2)

- PN method vs opacity?

Both methods were tested in the 2nd testing campaign of JRC

- Extension of the methodology to gasoline vehicles?

More studies are necessary for defining the procedures and the limits for gasoline vehicles. Low idling and free acceleration tests are evaluated and the correlation with WLTC PN emissions will be examined



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Thank you

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