Transmitted by the expert from EC (JRC)

Informal document **GRPE-86-30**
86th GRPE, 30 May - 2 June 2022
agenda item 13.

Periodic Technical Inspection: Particle Number (PN) Measurements

Joint Research Centre

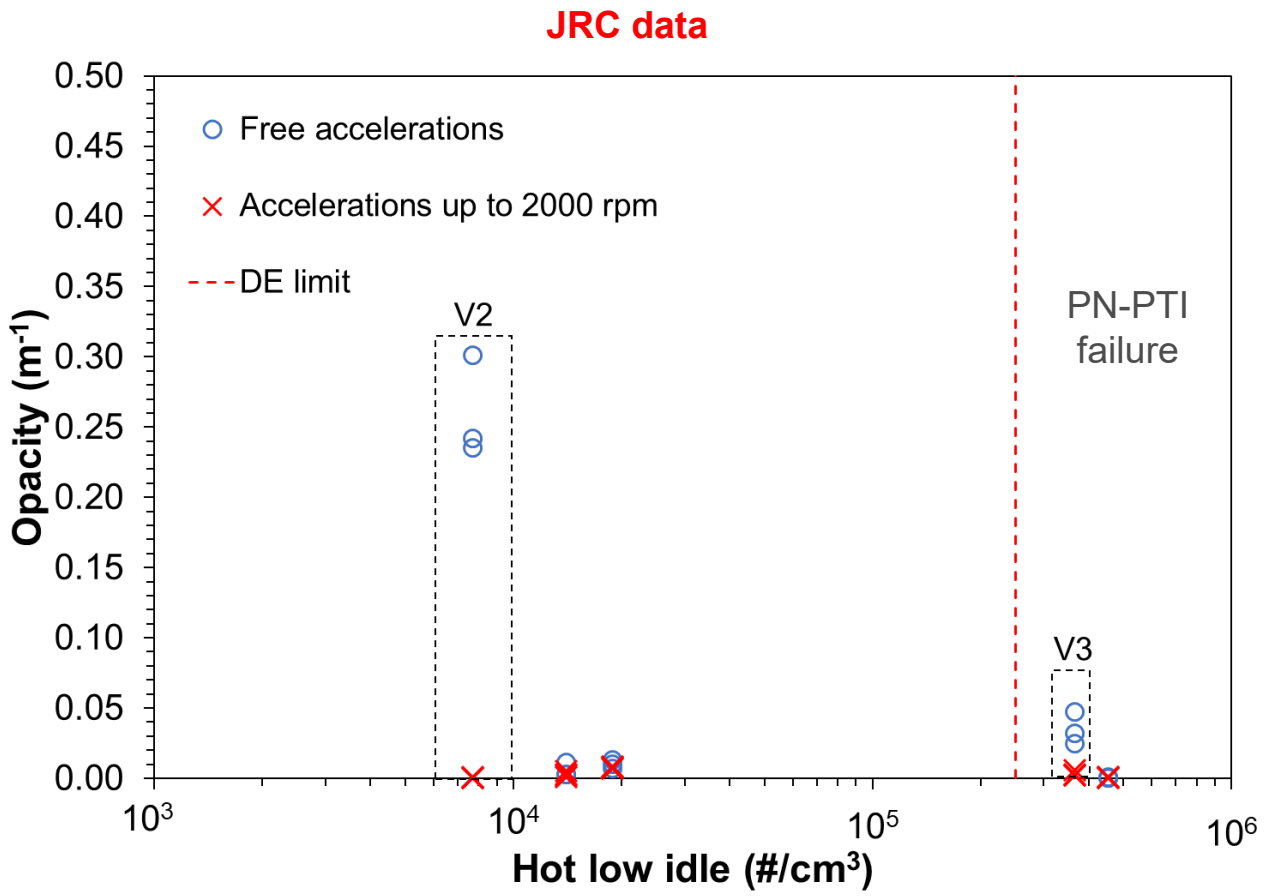
European Commission

National regulations

- In Switzerland, a PN measurement is conducted for non-road machineries during PTI
- Starting from July 2022, the Netherlands and Belgium will be the first countries to introduce a PN-PTI for vehicles. Germany and Switzerland will follow from January 2023
- The PN-PTI limit, the technical specifications of the PN-PTI sensors and the measurement procedures differ in national regulations

Country	Test	Duration (s)	Limit (#/cm^3)	Application
NL, BE	Low idling	15	1 x 10^6	Euro 5 & 6 (in NL also older vehicles)
DE	Low idling	3 x 30	2.5 x 10^5	Euro 6
CH	Low or high idling	3 x 5	1 x 10^5 or 2.5 x 10^5	All vehicles with DPF

Opacity tests



- Five vehicles (V1-V5) were tested with the opacity test (3 Diesel). During idle tests opacity was almost zero for all vehicles.
- During acceleration tests only for one vehicle (PFI) the opacity meter measured ~0.3 m^{-1}. The PN emissions during this test (free acceleration) were ~10^8 #/cm^3
- Two vehicles that would have failed the PN-PTI test with a limit of 2.5 × 10^5 #/cm^3, passed the opacity test. This finding is in agreement with previous studies

European Commission PN-PTI guideance

- European Commission is currently working on a guidance document 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

Current status

The first draft guidance was shared with the Roadworthiness group and members provided comments. A revised version is currently under preparation

Outline of the PN-PTI guidance

- Scope
- Description of PN-PTI instruments
- Metrological controls
- Measurement procedure
- Regulation limit

Measurement procedure

Warmup of instrument and error free indication

Instrument self-checks and/or functional checks

Probe insertion at the tailpipe (recommended 30 cm, min 5 cm)

Idle operation of the vehicle (for hybrids: ICE on, no DPF regeneration)

Optionally 2-3 free accelerations, min 15 s low idle

At least one measurement of (at least) 15 s (earlier stop if concentration 2xLimit)

If fail: conditioning of 5 min (driving or accelerations) and repeat

Continue to all tailpipes

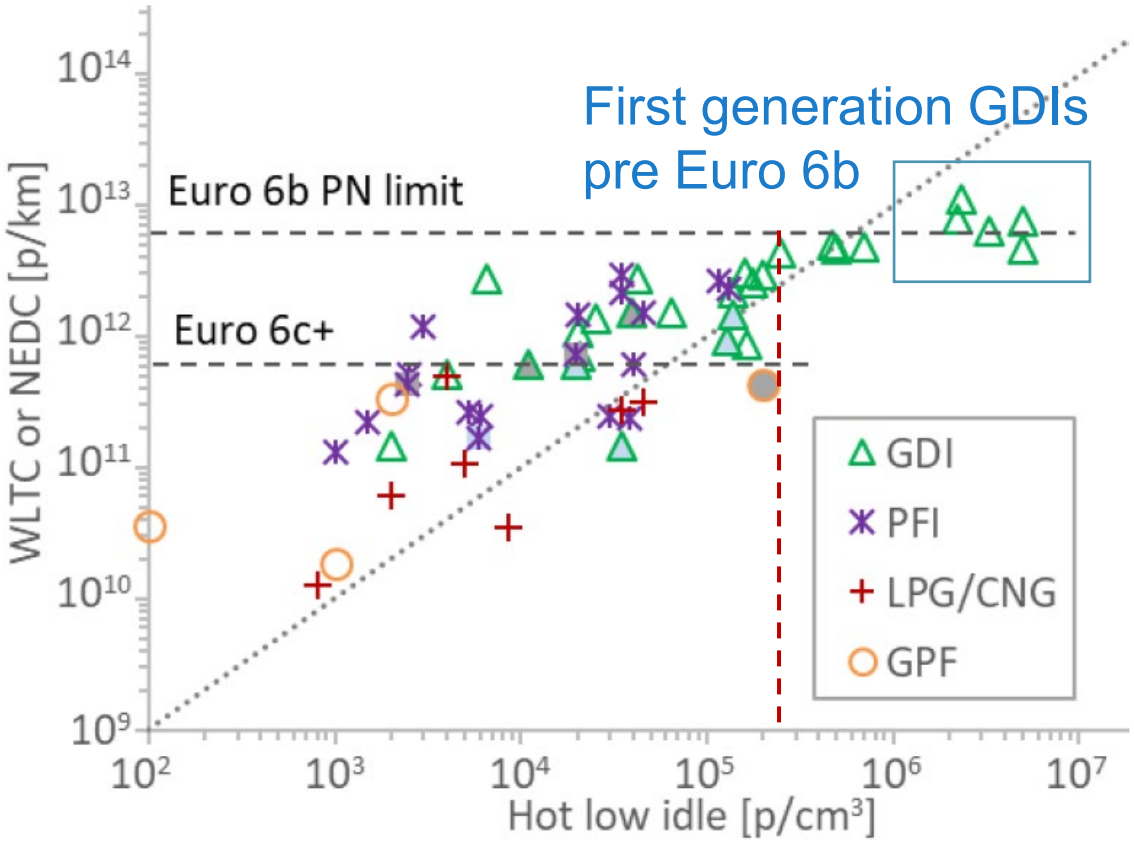
Thoughts on gasoline vehicles

Modern GDIs emit <1×10^{12} #/km even without GPF.

The low idle methodology (and limit) will not necessarily detect removal of GPF

To consider: will tampering of GPFs be an issue? What are the emissions of GDIs without GPF? Is the low idle the right method?

GDI = Gasoline Direct Injection
GPF = Gasoline Particulate Filter
PFI = Port Fuel Injection
LPG = Liquefied Petroleum Gas
CNG = Compressed Natural Gas



Sensors 2020, 20(20), 5790; https://doi.org/10.3390/s20205790

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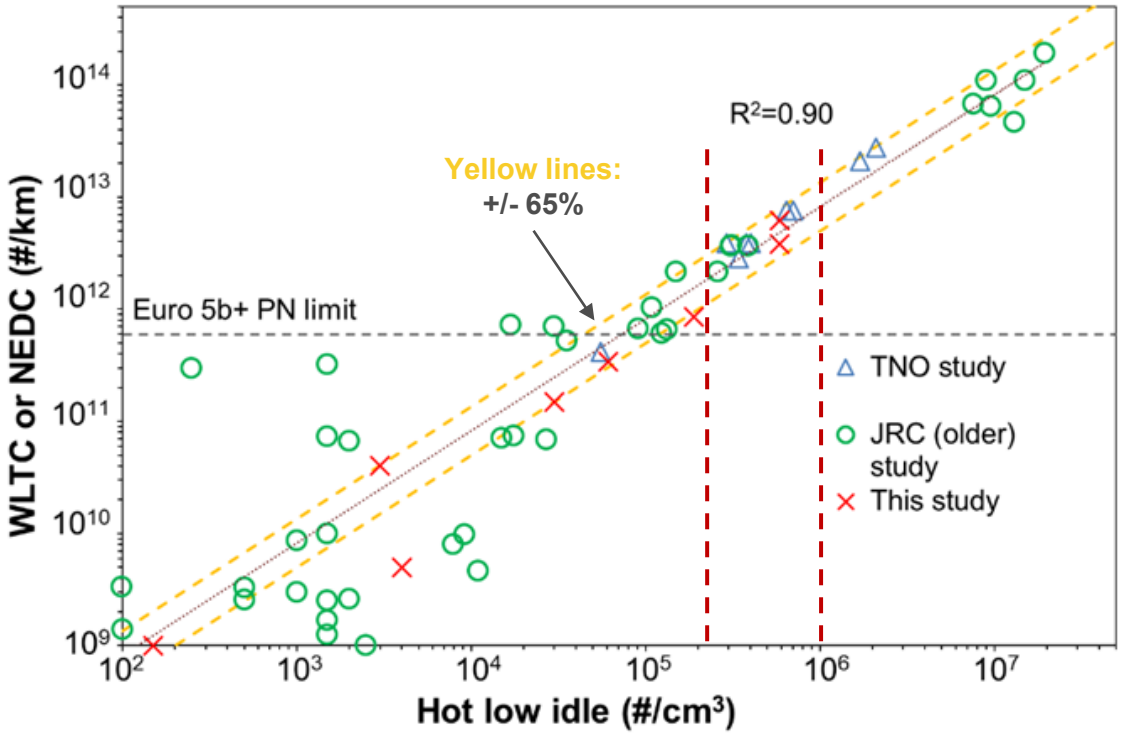
Regulation limit (diesel vehicles)

- JRC investigated the correlation between type-approval and PN-PTI emissions of diesel vehicles. Our results agree with older studies. Correlation factor can be defined: ~10^7 cm^3/km

- Considering that the type approval limit is 6 x 10^{11} #/km, vehicles with >10^5 #/cm^3 low idling emissions will fail the type-approval tests.

- Considering the *method* and *instrumentation* uncertainty a limit ≥ 250,000 #/cm^3 is reasonable and will depend on the stringency.

- A limit of 1,000,000 #/cm^3 can detect removed DPFs of older vehicles



https://doi.org/10.3390/s20205790 and new JRC results

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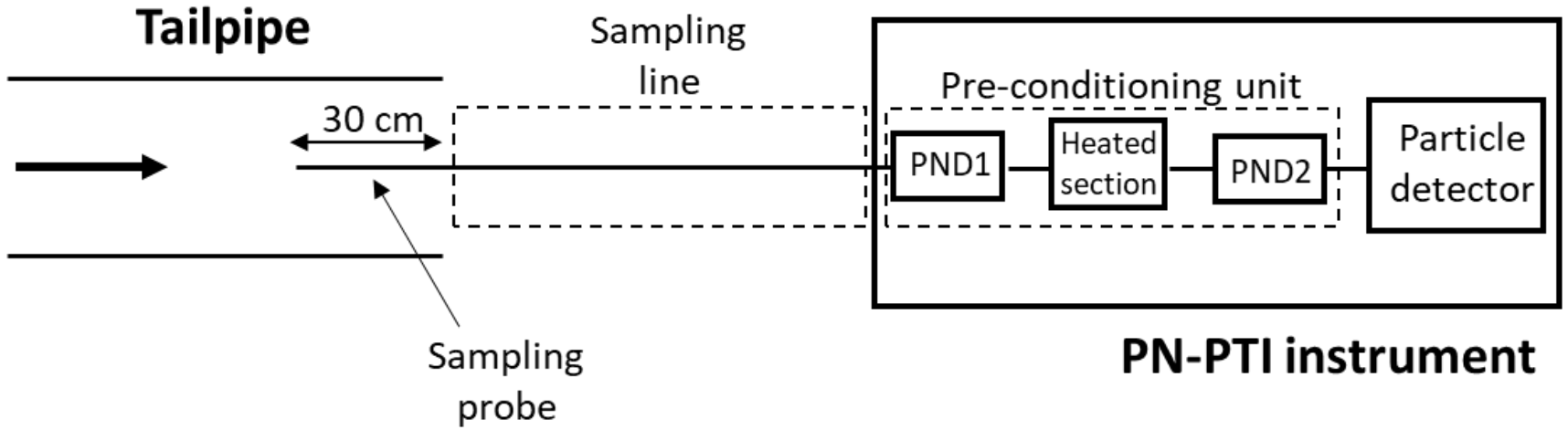
Scope (on-going work)

- Gasoline vehicles are out of the scope at this stage due to lack of experimental data to support a robust measurement procedure
- According to the draft guidance, the PN-PTI test can be applied to all M and N category vehicles equipped with compression ignition engine.
- It is suggested to include in the scope vehicles registered after 01/01/2013 (date of introduction of a PN limit for these vehicles)
- For Heavy Duty Vehicles (HDVs), DPF malfunctioning can be detected with low idling tests according to the literature. JRC does not have currently experimental data.

Description of the PN-PTI instrument

- The PN-PTI instrument shall be comprised of a sampling probe, a sampling line (optional), a device/technique to avoid water condensation, a pre-conditioning unit for removing volatiles (optional), and a particle detector



With dash lines the optional parts

Controls over life-time of instrument

Type approval

At least 1 PN-PTI instrument of definitive type (family)

NMi facilities

Metrological requirements:
Complete Linearity 9 points (25%)
Counting efficiency
Volatile removal efficiency (>95%)
Rated operating conditions (50%)
Disturbances (50%)
Technical Requirements

Initial verification

Every new PN-PTI instrument

Manufacturer facilities

Simple Linearity 5 points (25%)
Functional tests
-Leak check
-High PN response (optional)
-Flow check
-Response time

Subsequent verification

Every PN-PTI instrument at least every year

Manufacturer facilities or on-site

Simpler Linearity 3 points (50%)
Functional tests

NMI: National metrology institute

Metrological requirements (efficiency – linearity)

Soot	23 nm	30 nm	41 nm	50 nm	70 nm	80 nm	100 nm	200 nm	Linearity *	30 nm C40
NL, BE	0.2 – 0.6	-	-	0.6 – 1.3		0.7 – 1.3	-	-	80 nm	<5%
DE	0.2 – 0.6	0.3 – 1.2	-	0.6 – 1.3	0.7 – 1.3	-	0.7 – 1.3	0.5 – 2.0	70 nm	<10%
CH *	<0.5	-	>0.4	-	-	0.7 – 1.3	-	<3.0	80 nm	<5%
JRC **	0.2 – 0.6	recom.	-	0.6 – 1.3	0.7 – 1.3		recom.	recom.	70 – 80 nm	<5%

* Polydisperse aerosol
** Monodisperse or polydisperse

Soot ***	MPE	zero	L / 10	L / 5	L / 2.5	L / 1.67	L / 1.25	L limit	L × 1.2	L × 1.6	L × 2.0
Type approval	25%	Yes	Yes	(Yes)	(Yes)	(Yes)	(Yes)	Yes	(Yes)	(Yes)	Yes
Initial	25%	Yes		Yes		(Yes)		Yes		(Yes)	Yes
Subsequent	50%	Yes		Yes				Yes			Yes

*** Other material can be used at initial and subsequent verification if correlation factor during type approval is established
() In brackets recommended (indicative)

Next steps

- A second draft version of the PN-PTI guidance is under preparation
- The revised guidance will be presented at the next experts roadworthiness group meeting
- The guidance will undergo a second round of comments by the members of the roadworthiness group
- JRC is working on technical details (are minimum requirements sufficient? What calibration factors can be applied by manufactures, what calibration materials are allowed etc).
- The guidance could be the basis of PN-PTI regulations of future MS

Thank you

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Metrological controls: Open points

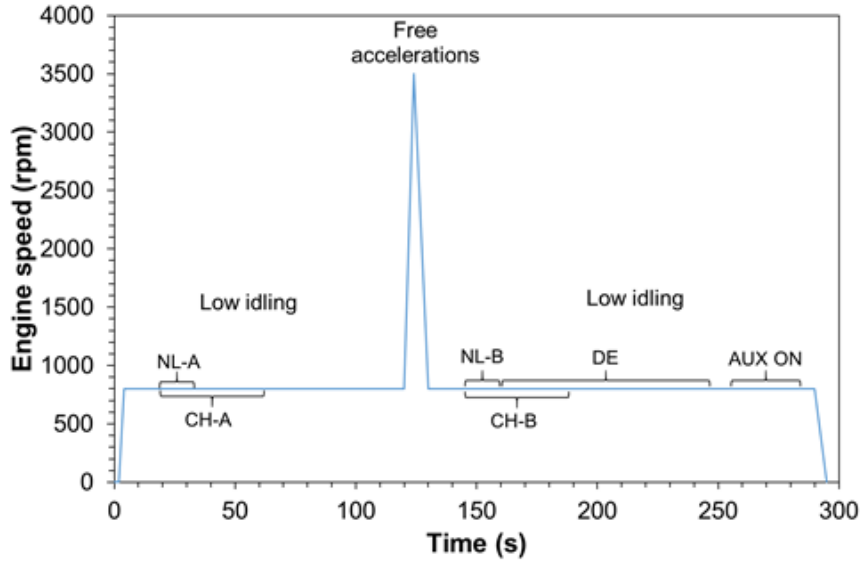
Critical

- The counting efficiency during type-approval of instruments differs in national regulations.
- Uncertainty of reference instrumentation during type approval and initial verification
- Maximum permissible errors

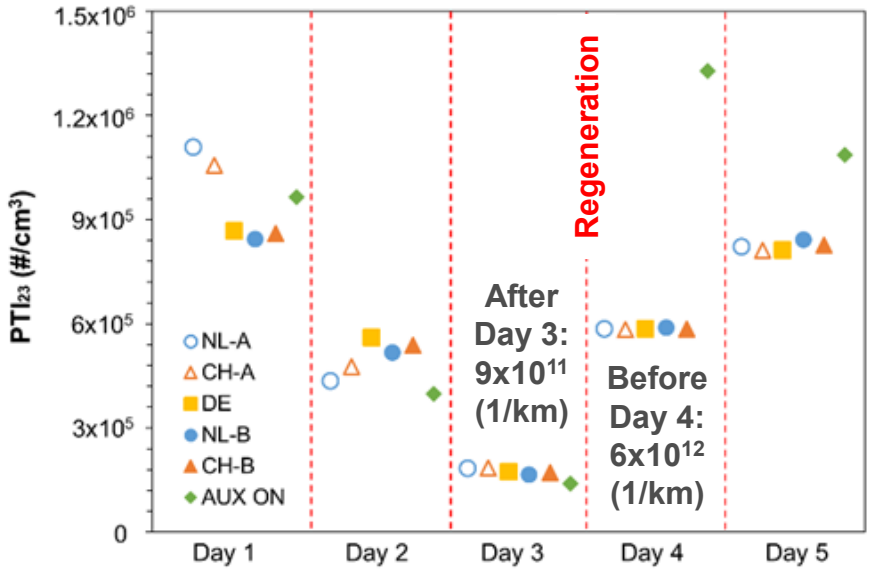
Less critical

- Differences at volatile removal efficiency tests

Measurement procedure (1/2) (on-going work)

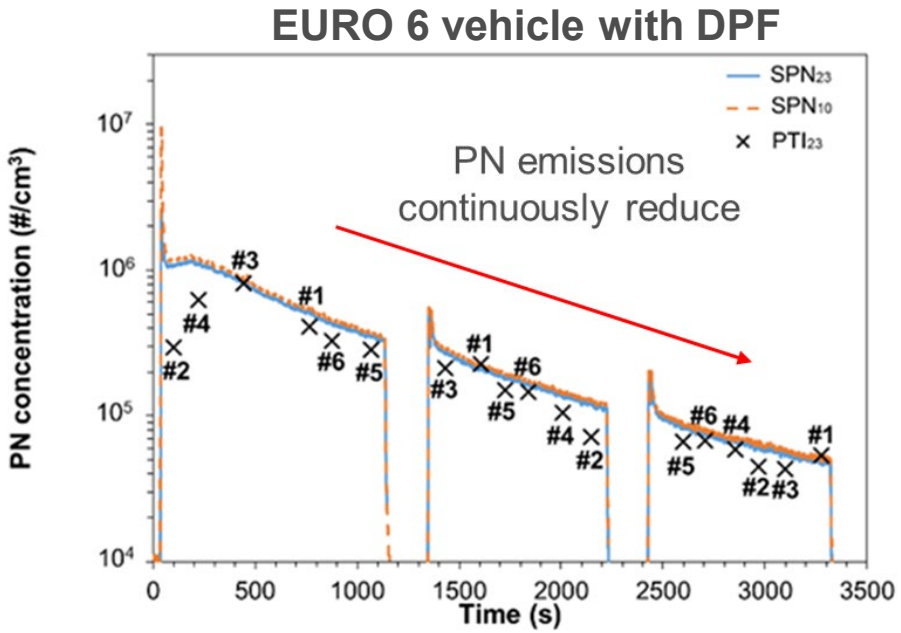


JRC results: EURO 4 vehicle with DPF

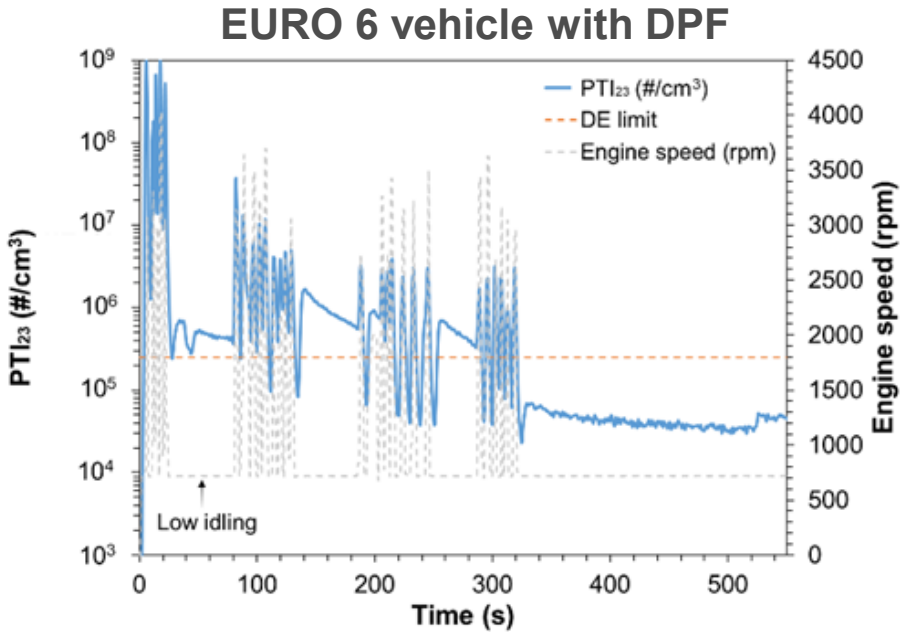


- A repeatability study performed by JRC showed that the main factors that have impact on PN-PTI are the DPF fill state and EGR status change.
- PN-PTI measurements shall be short but at least 15 s (total measurement time)
- Cold engine PN-PTI tests are permitted but in case of failure the test shall be performed with hot engine

Measurement procedure (2/2) (on-going work)



https://doi.org/10.3390/s21248325



JRC data

- Low idling PN concentrations are very high just after a DPF regeneration raising the danger of false fails for well-functioning DPFs

- Proposal: When the vehicle fails at the 1st test then a conditioning of 5 minutes is done and the PN-PTI test is repeated

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