

NEW PTI TEST PROCEDURES ARE NEEDED TO CHECK EMISSIONS OF SOOT PARTICULATES

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VERT-Forum 2018.
March 15th, 2018.
Dübendorf, Switzerland.



Ministerie van Infrastructuur en Milieu

Dutch **DPF-PTI RESEARCH PROGRAM**
RESULTS 2015-2017

TNO innovation
for life

OBJECTIVES OF DUTCH PTI DPF PROGRAM

- › Development of a PTI test protocol (Periodic Technical Inspection) to judge the performance of **Diesel Particulate Filters (DPF)**.

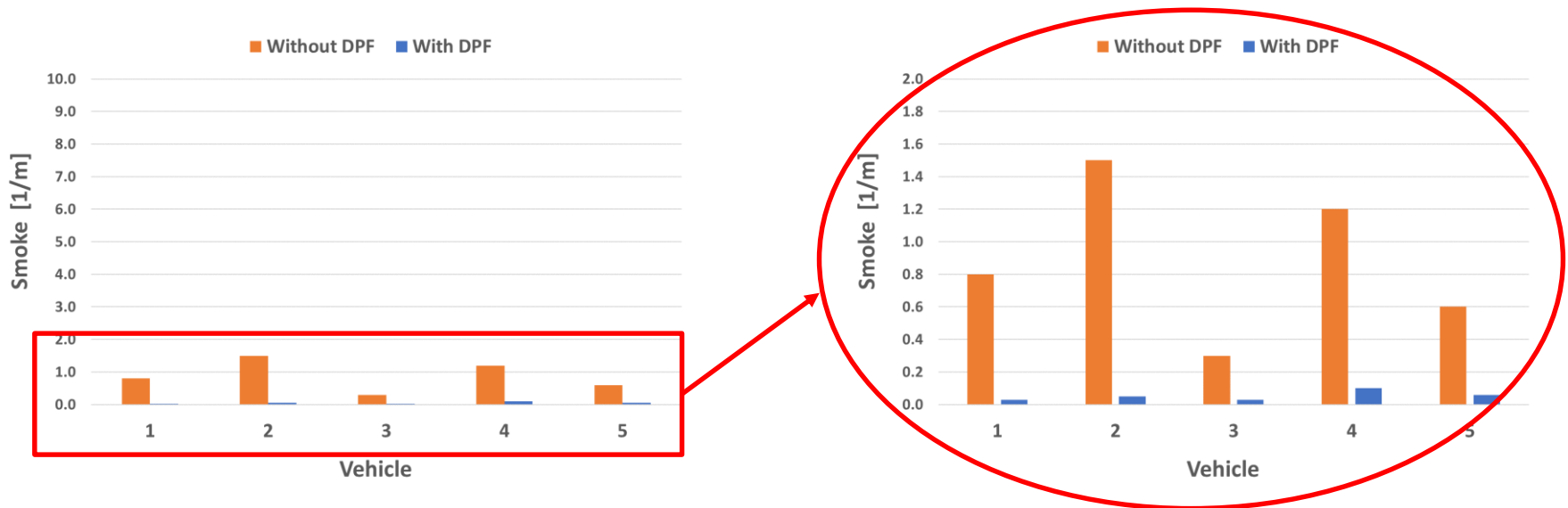
Main requirements of the PTI emission test:

- › PTI emissions must be related to the real world emissions of a vehicle.
- › PTI limit value is less stringent than the In Service Conformity limit value.

HISTORY

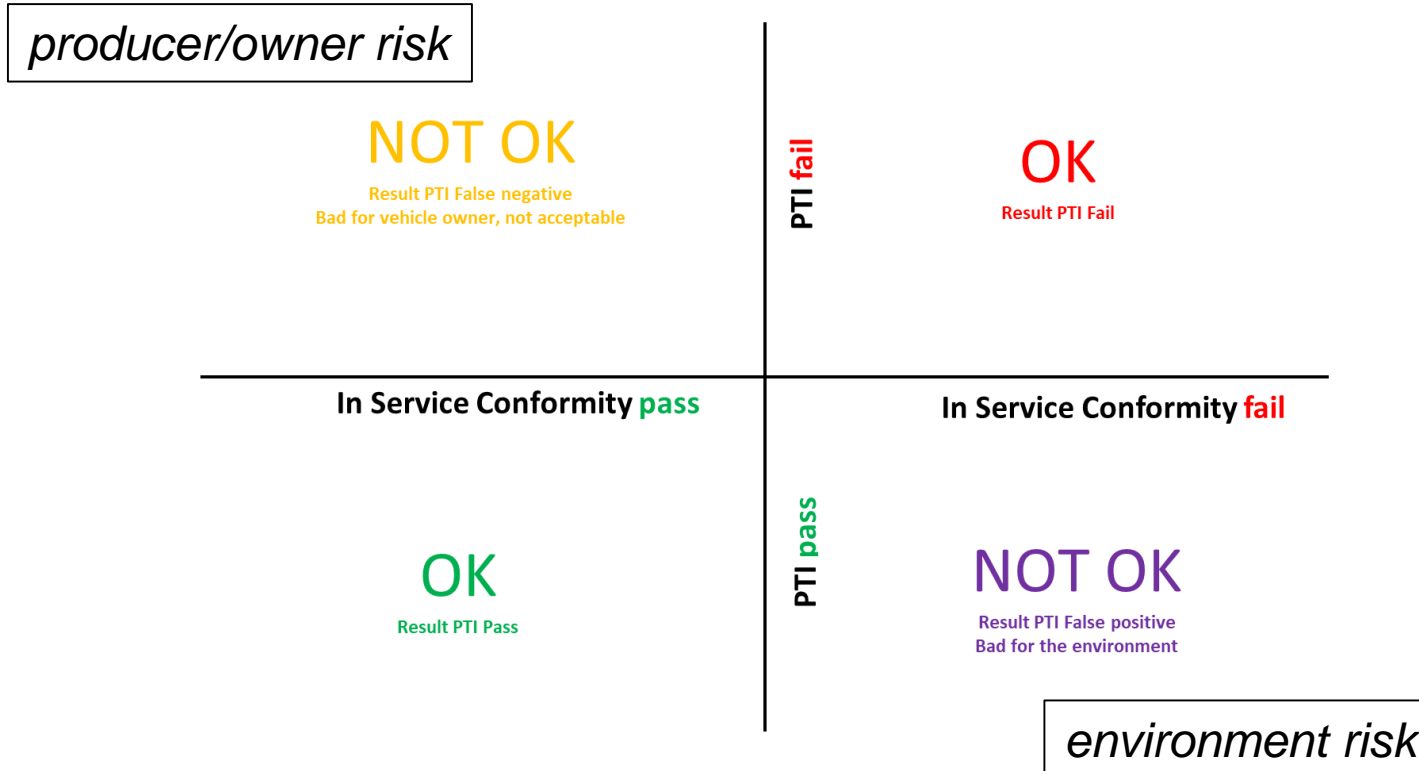
- › What changed in 2009 with the implementation of DPF's?
 - › 1970 - 2009, Euro 1,2,3,4: determination of the **quality of the combustion;** **smoke numbers (k) = 0,3 – 2,5 (+/- 0,3) on a scale of 0 – 10 m^{-1}).**
 - › 2009 – 2018, Euro 5,6: Determination of the **filtration efficiency of the DPF;** **smoke numbers are extremely low ($k = 0,0 – 0,1 m^{-1}$).**

IMPRESSION OF PTI SMOKE EMISSIONS



For diesel vehicles with a DPF the screening performance and accuracy of a free acceleration (FA) smoke emission test is too low.

RELATIONSHIP OF ISC AND PTI TEST PROCEDURES



Pass/fail criteria of the PTI test must be related to the pass/fail criteria of the in-service conformity type-approval test but less stringent.

DPF FAILURE OF A EURO 5A VEHICLE



Backside of the DPF with some cracks

- › Euro 5A diesel @ 160.000 km > in service conformity (ISC) of 100,000 km
- › ISC NEDC emissions: PM **5.1** mg/km, PN 1.5 E13 #/km.
- › PTI emissions: Smoke 0.30 m⁻¹, PN >540,000 #/cm³ (out of scale reading)



ISC & PTI, VERY DIFFERENT TEST METHODS

	In Service Conformity, chassis dynamometer			Type Approval & PTI
	NEDC test 11 km			Free acceleration test
Emission class	PM limit value	PN limit value		Smoke (Opacity)
	[mg/km]	[#/km]		k [m ⁻¹]
Euro 1 – 1993	140	-		3.0
Euro 2 – 1996	80	-		
Euro 3 – 2000	50	-		2.5
Euro 4 – 2005	25	-		
Euro 5a – 2009	5	-		
Euro 5b – 2011	4.5	6 * 10 ¹¹		1.5
Euro 6 – 2015	4.5	6 * 10 ¹¹		
				0.7



*The ISC chassis dynamometer test can determine (very) low **PM&PN** emissions.*
*The PTI emission test can determine high peak **smoke** emissions. The current PTI smoke limit value of 0.7 m⁻¹ can be met without a DPF*

REQUIREMENTS PTI EMISSION TEST

- › Fast and easy operation (i.e. 15 seconds and a simple test).
- › Low cost emission tester (< 5000 Euro), easy calibration.
- › Repeatable and reproducible procedure.
- › < 3% false positive and no false negative test results.
- › Robust. Different real world situations must be covered (DPF load & temperature, ??)

OPACIMETERS [M⁻¹] & PN TESTERS [# / CM³]



$K = 0 - 10 \text{ m}^{-1}$.



> 23 nm
solid

DF 100
Max. 5^E07

> 23 nm
solid

10
5^E06

> 20 nm
solid+volatile

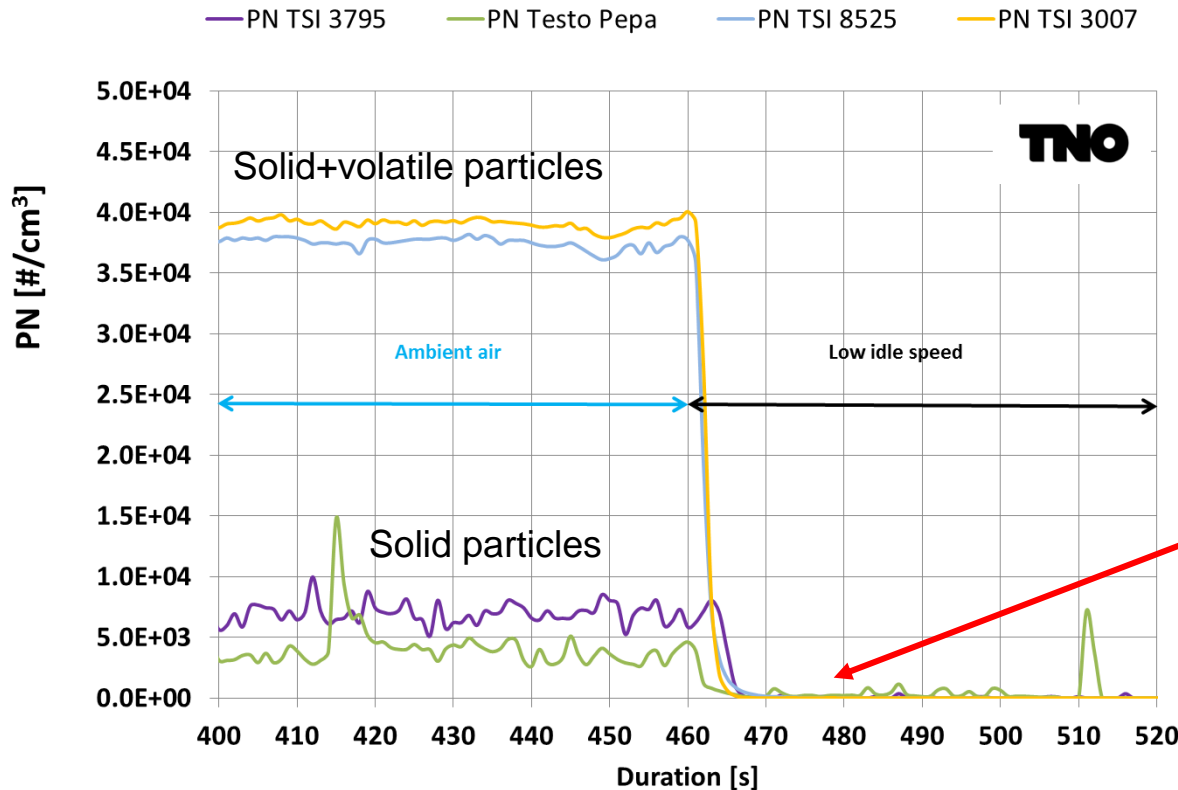
1
5^E05

> 10 nm
solid+volatile

1
1^E05

IDLE SPEED TEST WITH 4 PN-COUNTERS

PEUGEOT 308 EURO 6 @ 104,755 KM



All PN-testers
measure near zero
#/cm³ with a 'normal'
(= well functioning)
DPF.

Ambient air is cleaned!

No solid & volatile
particle emission at
low idle speed.

***Candidate 10 second
PTI test @ low idle
speed***

OPTIONS FOR A NEW PTI EMISSION TEST

FA: FREE ACCELERATION TEST

Test	Unit	Pre DPF	Post DPF	Reduction Factor
Smoke @ FA	[1/m]	0.5 – 1.5	0.01-0.10	50 - 1500
PN @ FA	[#/cm ³]	>50,000,000	5,000-10,000	5,000 - 10,000
PN @ low idle speed	[#/cm ³]	2,000,000 – 20,000,000	1 – 5,000	400 - 20,000,000

At low idle speed the PN test has the highest sensitivity in the most appropriate measuring range for a PN-tester.

TNO 2015-2016: PTI VEHICLE SELECTION

- › Lease companies, service shops
- › **220 vehicles** were selected at random at the 7 test locations.
- › Age 2 - 5 years old @ 50,000 – 250,000 km
- › Selection is not representative for the Dutch fleet (no private cars).
- › Test period: December 2015 – February 2016.

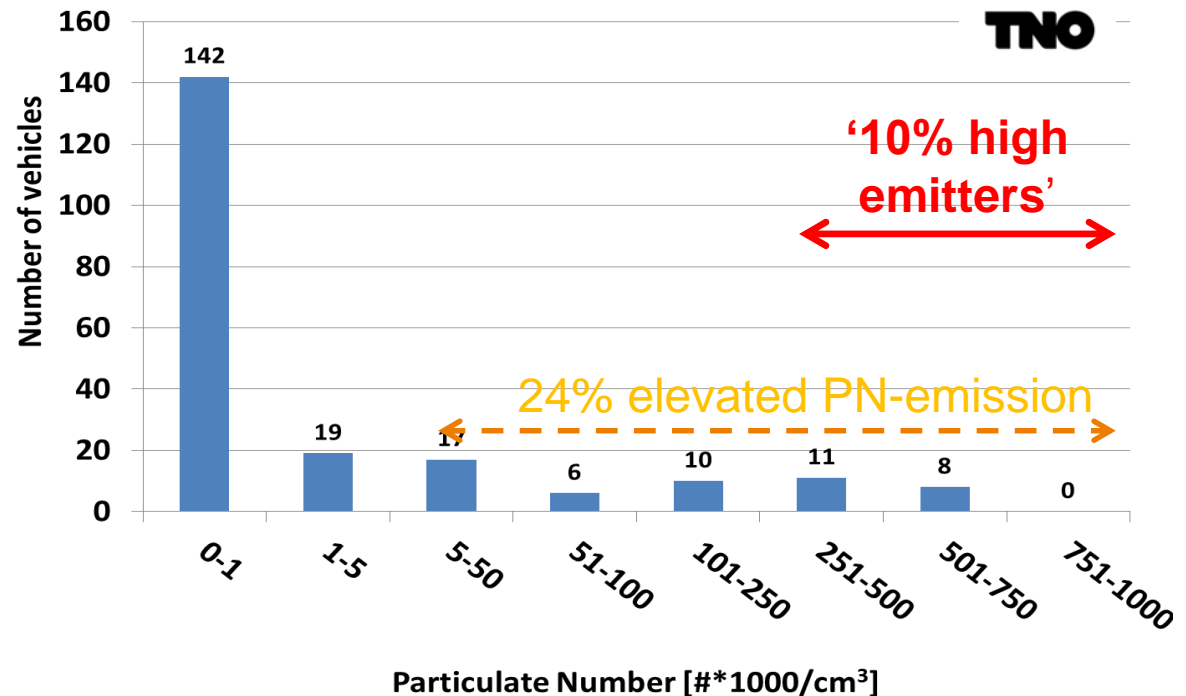


Research of a new PTI DPF PN emission test procedure



Dübendorf VERT-Forum, March159th, 2018.

PN EMISSIONS @ LOW IDLE SPEED



- 161 vehicles (76%) have a PN emission of $< 5000 \text{ \#/cm}^3$.
- 52 vehicles (24%) have an elevated PN emission of $> 5000 \text{ \#/cm}^3$.
- 10% of the vehicles have a PN emission of $> 250.000 \text{ \#/cm}^3$.

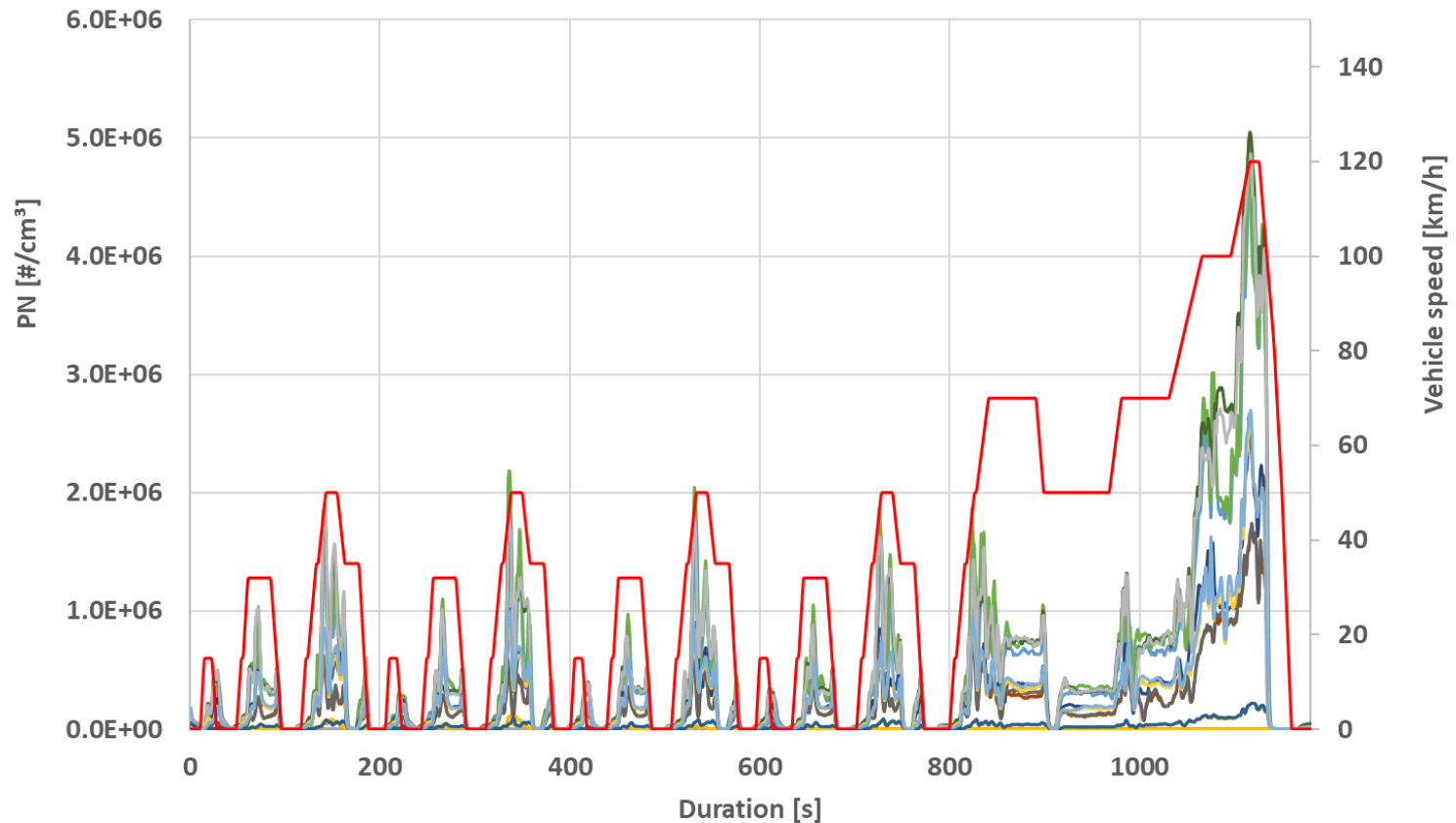
RELATIONSHIP OF ISC & PTI EMISSIONS OF A EURO 6B VEHICLE WITH DPF BYPASS



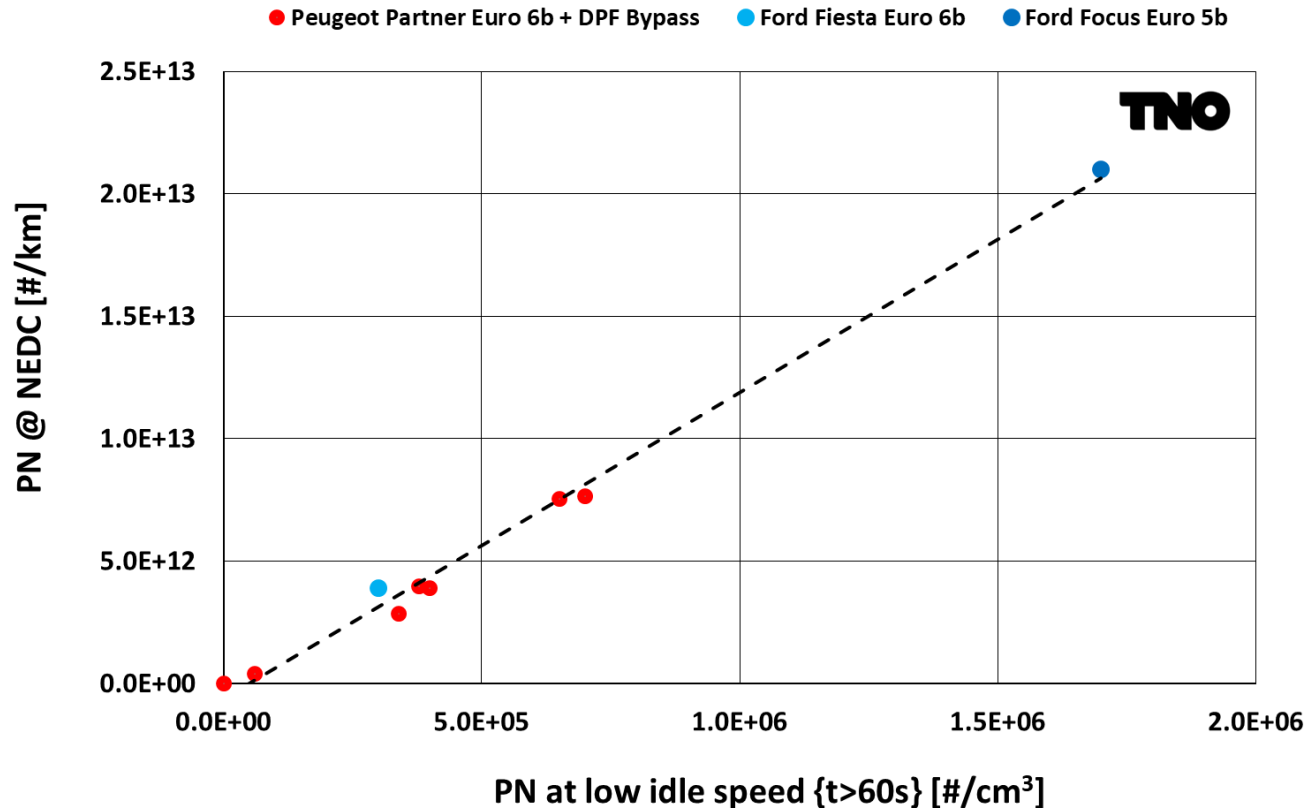
Research of a new PTI DPF PN emission test procedure

PN EMISSIONS @ IDLE SPEED ARE LOW

NEDC's with different DPF leakages
Peugeot Partner Euro 6



ISC-PN NEDC VERSUS PTI-PN @ LOW IDLE SPEED



PN (solid > 23 nm) @ low idle speed seems to have a good correlation with PN in the ISC-NEDC test for these vehicles. Additional validation is needed.

NPTI INFORMAL GROUP 2016 - 2018

- › **Further development of a new PTI DPF emission test procedure**
 1. Definition of a relevant emission test
 2. Definition and specification of a low cost PN-tester
 3. Definition of a feasible PN limit value
 4. Validation of ISC and PTI emissions on different vehicles.

- › *Since 2016 the informal NPTI workgroup (chairman Dr. Andreas Mayer) works on the development of a new PTI DPF test procedure. Scientists, (local) governments, a metrological institute, equipment manufacturers and policy makers from Switzerland, Germany, Belgium, Netherlands and United Kingdom are involved and exchange data and experiences.*

SPECIFICATION OF NEW PTI PN TESTER

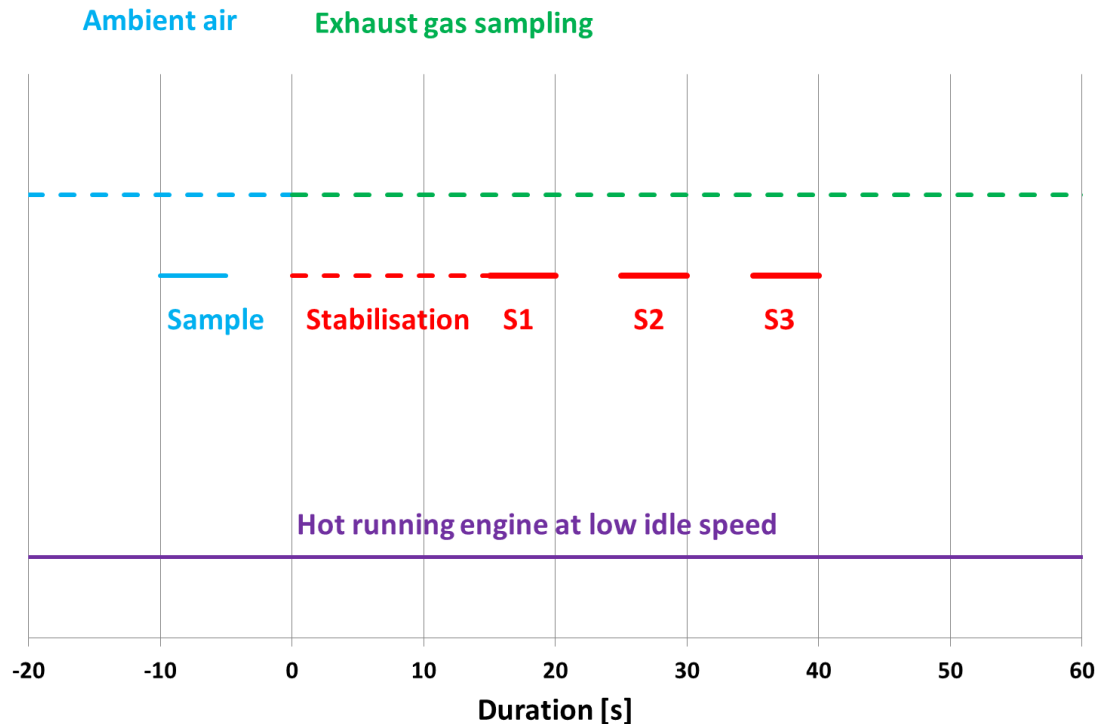
- › Particle size: 70 nm.
- › Counting efficiency 100%
- › Measuring range: 0 – 5.000.000 #/cm³.
- › No catalytic stripper (solid + volatile particles)
- › Recommendation: Heated PN device @ 120 – 140 °C.

In order to have a PTI PN counter with an acceptable price (< 5000 Euro) a simplified specification of the PN tester is needed.

Currently, the Dutch Metrological institute (NMI) prepares a draft specification of a new PTI-PN-tester.



PROPOSAL NEW PTI TEST PROCEDURE



Low idle speed test.

New
specification of
PTI PN-tester

Proposed
PN limit values
250,000 –
1,500,000 #/cm³

The PTI PN emission test, PN limit value and the new PN-tester are related and must be defined in one test procedure and validated with type approval emissions

ROBUSTNESS OF THE NEW PTI PN TEST

- › Temperature of the DPF.
- › Soot load of the DPF.
- › Engine condition
 - › EGR active or not active
 - › Fuel injector condition (fouling)
 - › Level of oil consumption

- › Validation: Field tests with sufficient vehicles (>100) are needed to prove the robustness of the new PTI-PN-test.

NEXT STEPS

- › Step 1: New specification of a PTI-PN-tester.
- › Step 2: Definition of a draft final PTI-PN test procedure.
- › Step 3: Validation of the draft PTI-PN test procedure with type approval emissions on the chassis dynamometer with 10-20 vehicles with different PN emission levels with at least 3 new PTI-PN-testers of different manufacturers.

IMPRESSION OF NPTI TEST PROCEDURE





**THANK YOU VERY MUCH FOR
YOUR ATTENTION**

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- › www.tno.nl/vehicle-emissions or www.tno.nl/voertuigemissies

- › <https://www.tno.nl/en/focus-area/urbanisation/mobility-logistics/clean-mobility/emissions-of-particulate-matter-from-diesel-cars/>

ABBREVIATIONS

- › DPF = Diesel Particulate Filter
- › DF = Dilution Factor
- › FA = Free Acceleration
- › ISC = In Service Conformity
- › NEDC = New European Driving Cycle
- › PM = Particulate Matter
- › PN = Particulate Number
- › PTI = Periodic Technical Inspection