



FRAMEWORK OF THE IMPLEMENTATION OF A PTI PN TEST PROCEDURE

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TNO-Gerrit Kadijk,
Version 1.1

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HOLA GENTE QUERIDA!

TNO, The Netherlands.

(Independent research organisation, www.tno.nl)

Gerrit Kadijk (1963).

Researcher/consultant vehicle emissions

Start TNO career in 1988.

Since 2012 I have been involved in the development of the PTI PN test procedure.

Currently I am involved in research of gasoline vehicles with high mileages with focus on NOx emissions.



CONTENTS PRESENTATION

1. Introduction.
2. Goal.
3. Part 1: Implementation of new PTI test procedures in national regulations.
4. Part 2; Technical specification of the PTI-PN test procedure.

PTI = Periodic Technical Inspection

PN = Particulate Number

PART 1:

IMPLEMENTATION OF THE NEW PTI-PN TEST PROCEDURE IN NATIONAL REGULATIONS

1. INTRODUCTION

- › Chili, Mexico, Colombia and Peru have gradually implemented Diesel Particulate Filters (DPF) on vehicles and non road mobile machinery. This will improve air quality, PM₁₀ concentrations will decrease.
- › The long term performance of particulate filters is not obvious and must be monitored. Regular engine/DPF maintenance is a key factor for succes.
- › Removal of DPF's increase particulate emissions dramatically (100 to 1000 times) and must be avoided.
- › Governments need tools for periodic technical inspections (PTI) and road side inspections (RSI) to check the presence and filtration performance of DPF's.

1. DUTCH PTI DPF PROGRAM 2012 – 2021 IN A NUTSHELL

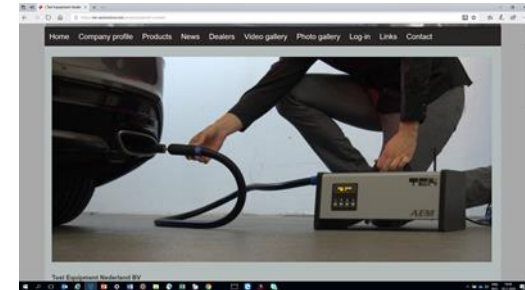
- › From 2012 to 2019 the Dutch Ministry of Infrastructure and Water Management has funded several projects for the development of a new PTI test procedure for diesel particulate filters. The new PTI test protocol was published in December 2019 in the Dutch Gazette (“Staatscourant”).
 1. Low idle speed test.
 2. Specification of a PTI-PN-tester developed by Dutch NMI.
 3. PN limit value of 250.000 – 1.000.000 #/cm³.
- › 2020-Q1: Dutch metrological institute has started certification of PTI PN testers.
- › The new PTI PN emission test procedure will be implemented in the Dutch PTI as soon as sufficient new affordable PN-tester are on the market (2021).

2. YOUR GOAL

Definition and implementation of a PTI PN test procedure from legislative and technical perspective in Chili, Mexico, Colombia and Peru.

PTI PN test procedure

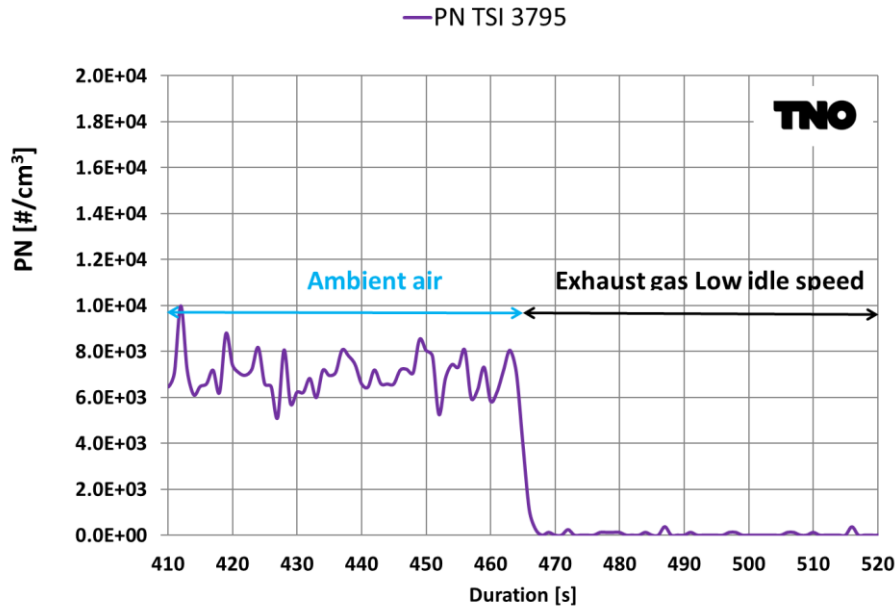
- › PTI emission test
- › PN emission tester + calibration procedure
- › PTI PN limit value



3. WHAT DO YOU NEED AS A POLICY MAKER TO IMPLEMENT THE PTI PN TEST PROCEDURE?

- › **Acceptance of a PTI PN test procedure:**
 - › **The definition of the new PTI low idle speed test and PTI PN limit value.**
 - › **The definition of the PTI PN tester and calibration procedures.**
- › *In 2020 the Dutch PTI PN test procedure and limit values were published by TNO.*
- › *From 2016 to 2019 the specification of PTI PN tester was developed in the VERT-NPTI group and published in 2020 by the Dutch metrological institute (NMI).*
- › *Currently there is only one national norm of a low cost PTI PN tester.*
- › *Different other initiatives are on-going (OIML, Germany) but not ready.*
- › *UNECE in Geneva and EU in Brussels just started first investigations for implementation of the PN test procedure in the PTI and homologation of new vehicles.*

3. PTI PN EMISSION TEST IN A NUTSHELL



Every vehicle or engine with DPF will be tested in the PTI or in a road side inspection with a tail pipe PN measurement of 30 seconds.

The test is simple, fast, robust, reliable, cheap and effective.

3. DUTCH PTI PN LIMIT VALUES AT LOW IDLE SPEED

Vehicle class	Emission class	PN limit value [#/cm ³]
M1 + N1	Euro 4 + DPF	1,000,000
M1 + N1	Euro 5a + DPF	1,000,000
M1 + N1	Euro 5b + DPF	250,000
M1 + N1	Euro 6 + DPF	250,000
N2 + N3	Euro VI + DPF	250,000

Vehicle classes:

M1 = Passenger vehicles.

N1 = Light commercial vehicles
(GVW < 35 00 kg).

N2 + N3 = Trucks + buses.

3. 2017 - 2019 VERT-NPTI GROUP



Potential suppliers of
PTI-PN testers:

- TSI
- Testo
- Naneos
- Sensors
- AVL
- Dekati
- TEN
- MAHA
- Premier Diagnostics
- Pegasor
- Continental
- Mahle
- TEXA

Expected price range of PTI PN testers € 4,500 to € 8,500.
Earliest expected date of availability is Q4 – 2020.

3. WORLD WIDE HARMONISATION OF THE PN TESTER

- › Minutes 53rd CIML Meeting (OIML workgroup), Hamburg, Germany 9–12 October 2018
- › *Resolution no. 2018/27 (agenda item 12.1.2.5) The Committee, Noting the comments made by its members on the details of the terms of reference included in Addendum 12.1.2.5, Approves as a new project, under the responsibility of TC 16/SC 1, the development of a new Recommendation on Instruments for measuring the vehicle exhaust soot particle number (PN), to be conducted as specified in the project proposal provided in the addendum 12.1.2.5 to the working document of this meeting.*
- › Germany (PTB, Prof. Volker Ebert) and Netherlands (NMI, Mr. Paul Kok) are leaders of this new OIML project which will be executed in the coming years.

3. ROAD MAP LEGISLATIVE PROCES

- Document 1: Description of the PTI PN test procedure and PN limit values (TNO).
- Document 2: Specification of the PN tester (NMI)
- Document 3: Dutch national PTI legislation (Ministry of Infrastructure)

All national documents are published in The Netherlands and available on internet.

You are allowed to copy these documents or to use them as a basis for your procedure.

Until now no other applicable documents are available.

- Next step: Implementation of the test procedure in your national PTI legislation.

3. RECOMMENDED STEP APPROACH

- › 1. Define PTI PN emission test.
- › 2. Define PTI PN limit values per emission class.
- › 3. Define specification of the PTI PN tester.
- › 4. Define calibration procedures of the PTI PN tester.
- › 5. Define structure for calibration of PTI PN testers and traceability.
- › 6. Register vehicles with DPF in your national vehicle database.

- › 7. Define pathway for implementation of the PTI PN test procedure:
 - › Announcement in national Gazette of the new PTI PN test procedure.
 - › Pilot phase (one region?).
 - › Final implementation.

END OF PART 1

PART 2:

TECHNICAL IMPLEMENTATION OF THE PTI-PN TEST PROCEDURE

4. TECHNICAL SPECIFICATION OF THE PTI-PN TEST PROCEDURE

- › Type approval and In-Service-Conformity requirements.
- › Diesel Particulate Filters and filtration behaviour.
- › Details of the PTI test procedure.
- › Calibration of the PN counter.

4. REQUIREMENTS PTI EMISSION TEST

- › Fast and easy operation (i.e. 30 seconds and a simple test).
- › Low cost emission tester, easy calibration.
- › Repeatable and reproducible test procedure.
- › < 3% false positive and no false negative test results.
- › Less stringent than type approval and In Service Conformity levels.

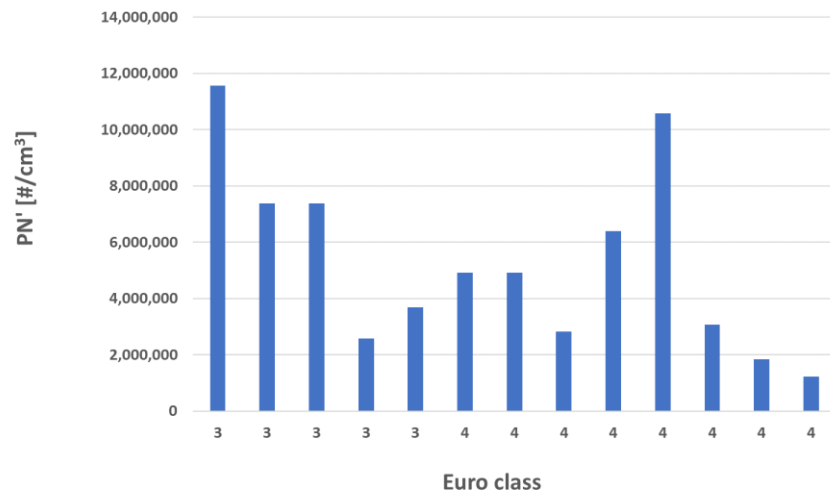
4. DPF: 95 - 99% REDUCTION OF PM

- › What was changed in 2009 with the implementation of DPF's?
- ›
- › 1970 - 2009, Euro 1 to 4 and I to V: 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 4,5,6 and VI: Determination of the filtration efficiency of the DPF; smoke numbers are extremely low (**k = 0,0 – 0,1 m⁻¹**).

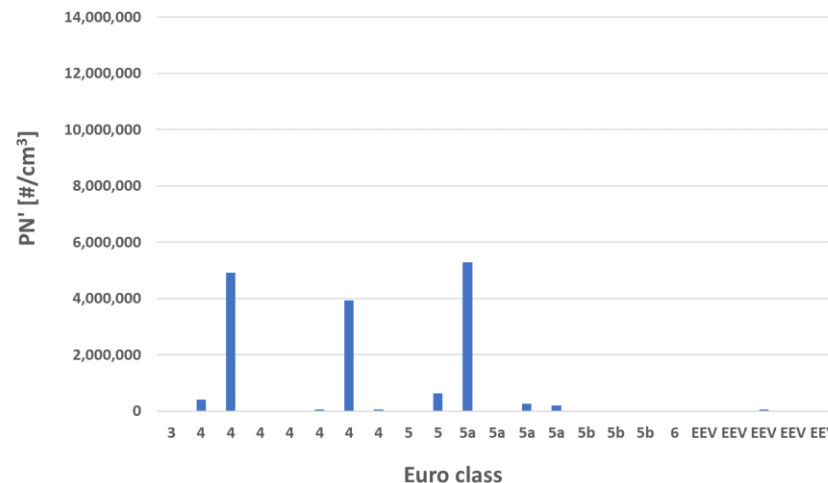
Due to low particulate emission levels of vehicles with DPF a new PTI emission test is needed.

PN EMISSION AT LOW IDLE SPEED

13 vehicles without DPF



23 vehicles with DPF



TYPE APPROVAL VEHICLES OR ENGINES WITH DPF

Limit values:

Particulate Mass (PM)

Euro 4 and 5a 5.0 mg/km

Euro 5b and 6 4.5 mg/km

Euro VI 10 mg/kWh

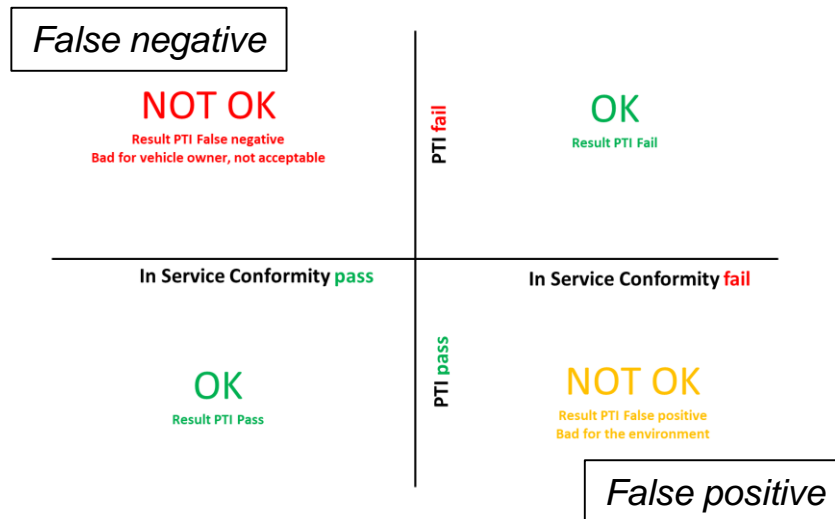
Particulate Number (PN)

Euro 5b and 6 $6 \cdot 10^{11}$ #/km

Euro VI $6 \cdot 10^{11}$ #/kWh



4. QUALITY OF PTI PN TEST PROCEDURE MUST BE GOOD



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

4. SPECIFICATION OF NEW PTI PN TESTER

- › Solid Particles.
- › Particle sizes: 23, 50 and 80 nm.
- › Measuring range: 0 – 5.000.000 #/cm³.

- › Part 1: Specification of the tester
- › Part 2: Calibration procedures
 - › Initial, Subsequent & In-field calibration.

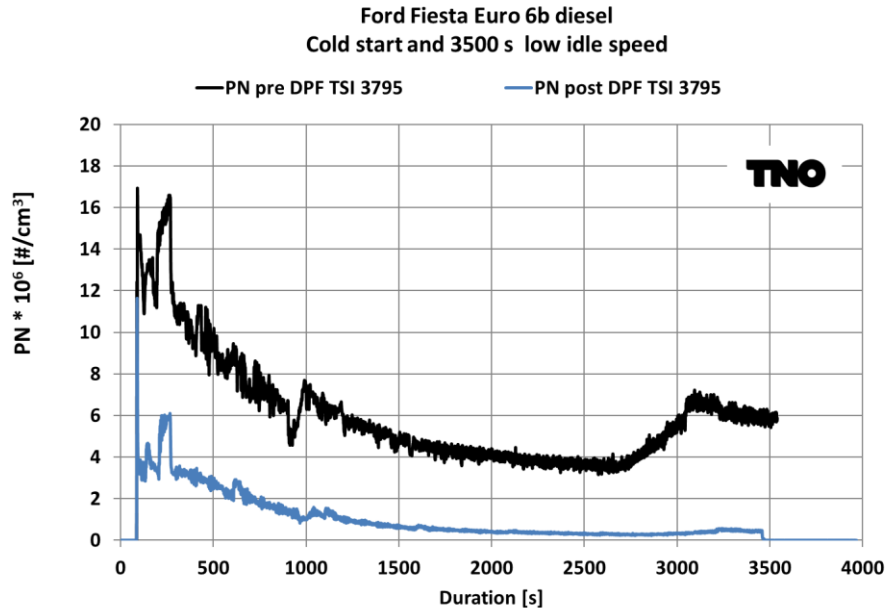
- › Documents are published and certification is now possible.
- › <https://www.nmi.nl/special-particle-number-counters/>
- › Contact details NMI: pkok@nmi.nl



4. PARTICLE SIZES & COUNTING EFFICIENCIES OF PN TEST EQUIPMENT

Mobility Diameter [nm]	23	30	41	50	55	70	80	100	200	Accuracy
Chassis dyno min UNECE R83 max	0,38 0,62	-	> 0,90	-	-	-	-	-	-	+/- 0,10
PEMS min EC 2017/1145 max	0,2 0,6	0,3 1,2	-	0,6 1,3	-	0,7 1,3	-	0,7 1,3	0,5 2,0	+/- 0,10
PTI The Netherlands	0,2 0,6			0,6 1,3			0,7 1,3			+/- 0,25

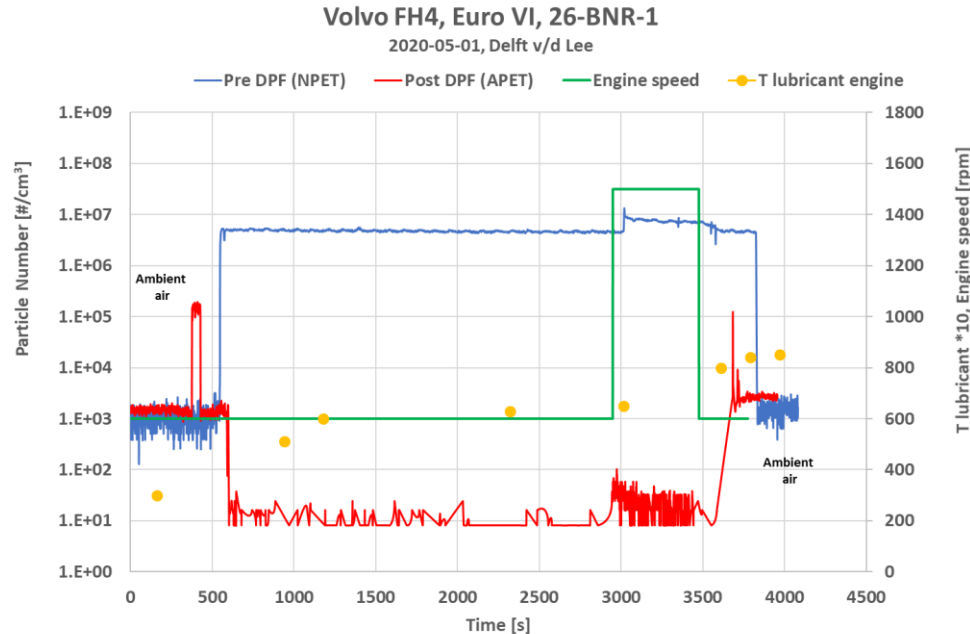
4. PN PRE & POST DPF DURING WARMING UP OF A LIGHT DUTY VEHICLE @ LOW IDLE SPEED



Two separate idle tests.
DPF with small leakage.

PN:
Pre DPF: 4 – 15 million #/cm³
Post DPF: 0.25 – 6 million #/cm³

4. PN PRE & POST DPF DURING WARMING UP OF A EURO VI HEAVY DUTY VEHICLE @ LOW IDLE SPEED



PN:

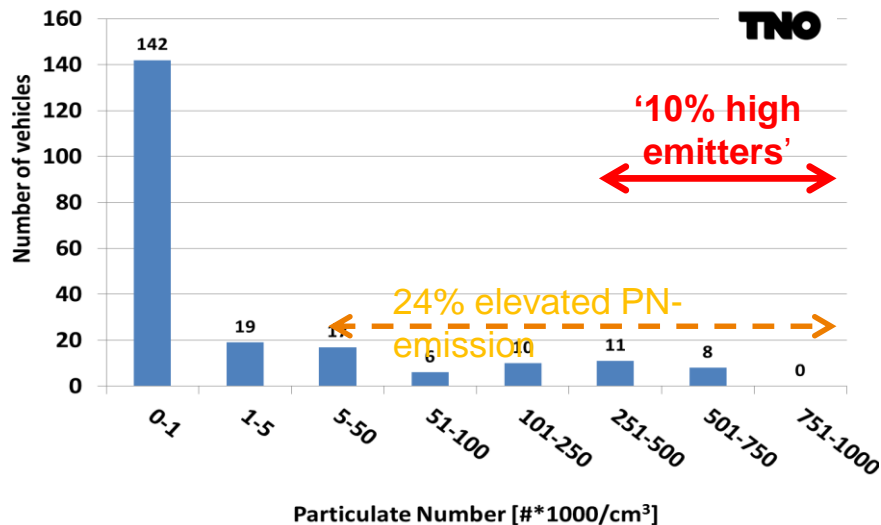
Ambient air: $3,000 \#/cm^3$

Pre DPF: 5 – 8 million $\#/cm^3$

Post DPF: $< 100 \#/cm^3$

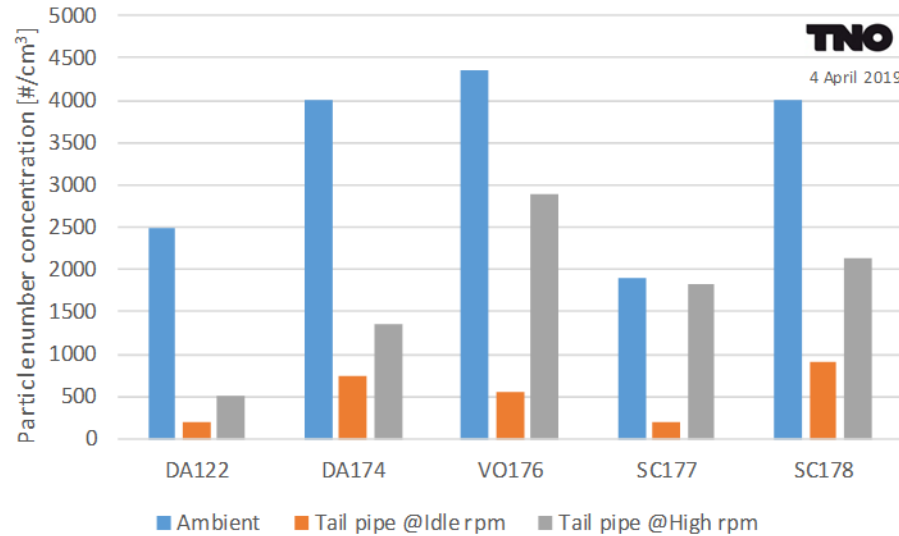
DPF filtration efficiency is 99.99 %.

4. PN EMISSIONS OF 220 DUTCH IN USE VEHICLES



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 $> 250.000 \text{ \#/cm}^3$.

4. PTI PN EMISSIONS POST DPF OF EURO VI VEHICLES



PN emissions @ idle speeds of Euro VI trucks are all below the PN concentration of ambient air.

4. REFERENCE CONDITIONS OF THE PTI PN TEST

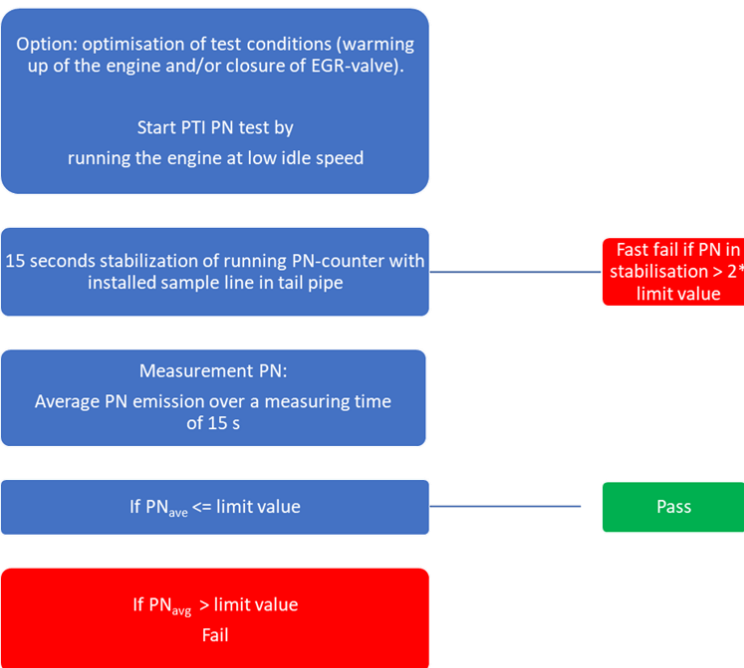
- › Warm engine at low idle speed.
- › EGR valve closed.
- › Start emission sampling with the PN counter.
 - › 15 seconds stabilisation time.
 - › 15 seconds measuring time for averaging of the PN concentration.
- › Determination of pass/fail.
- › *Note: Most DPF's have a very high filtration efficiency and vehicles will pass the PTI test with a cold engine with EGR. In case of a fail the engine must be set in the reference condition and the test must be repeated.*

IMPRESSION OF EFFECTS OF EGR AND ENGINE TEMPERATURE ON PN EMISSIONS @ LOW IDLE SPEED

EGR %	High	Medium	No
Engine temperature	PN [10^6 #/cm ³]	PN [10^6 #/cm ³]	PN [10^6 #/cm ³]
Cold	12 - 15	5 - 10	3 - 5
Warm	10 - 15	4 - 8	1 - 3

All modern warm engines without EGR have similar PN emissions

4. DUTCH PTI PN TEST PROCEDURE



CALIBRATION OF THE PN TESTER

- › 1. Initial verification of a prototype PN tester by the metrological institute.
 - › (Type approval)
- › 2. Subsequent verification for every new PN tester by the manufacturer.
- › 3. Yearly (in field) verification for in use PN tester by the calibration service.
- › All these verifications are published by NMI.
- › <https://www.nmi.nl/special-particle-number-counters/> .

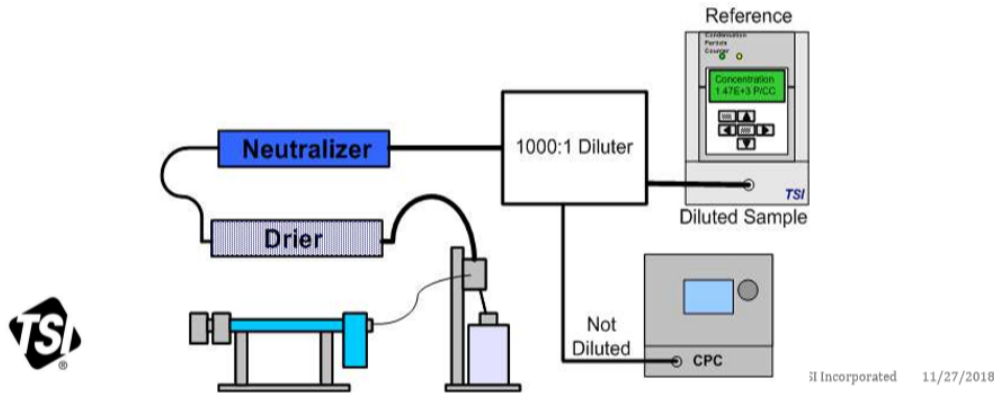
CALIBRATION TEST SET UP (ISO 27891: 2015)

+ Dilution Bench

- Reference: Single flow, single particle counting CPC
- Adjusted diluter - Exact diluter ratio determined
- Can measure up to 10 million particles/cc

Every new PTI PN counter must be tested in this test set up by the manufacturer.

In field calibration requires a PN source and a validated PN counter similar to the test sample.



A nighttime photograph of a city street featuring a prominent curved pedestrian bridge with a glass railing. The bridge is illuminated with warm lights, and its reflection is visible in the wet pavement below. In the background, there are several multi-story buildings with lit windows. A long-exposure light trail of a green vehicle is visible, curving along the bridge. The overall scene is a blend of urban architecture and modern transportation.

GRACIAS POR SU INTERÉS EN EL

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YOUR QUESTIONS & DISCUSSION

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- › www.tno.nl/vehicle-emissions

- › <https://www.tno.nl/en/focus-areas/traffic-transport/roadmaps/sustainable-traffic-and-transport/sustainable-mobility-and-logistics/improving-air-quality-by-monitoring-real-world-emissions/emissions-of-particulate-matter-from-diesel-cars/>

ABBREVIATIONS

- › DPF = Diesel Particulate Filter
- › ISC = In Service Conformity
- › NEDC = New European Driving Cycle
- › NMi = Netherlands Measurement Institute
- › PM = Particulate Matter
- › PN = Particulate Number
- › PTI = Periodic Technical Inspection
- › RSI = Road Side Inspection
- › TA = Type Approval
- › TNO = Netherlands Organisation for Applied Scientific Research