Technical Guide – Version 2.0

Programa Clima y Aire limpio
en Ciudades de América Latina

TECHNICAL GUIDE FOR PERIODIC TECHNICAL INSPECTION (PTI) OF VEHICLES FITTED WITH DIESEL PARTICLE FILTERS BASED ON PARTICLE COUNTING

V- 21.07.2021

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CALAC+ is a Project of COSUDE implemented by Swisscontact

Technical guide for periodic technical inspection (PTI) of vehicles fitted with diesel particle filters based on particle counting

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This document has been prepared within the framework of the Climate and Clean Air Project in Latin American Cities Plus - CALAC+ (Phase 1) funded by the Swiss Agency for Development and Cooperation - SDC and implemented by the Swiss Foundation for Technical Development Cooperation - Swisscontact.
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Edition: version 2021-07-21

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Content

1. Introduction

The 1st Latin American Conference on nanoparticle emissions in internal combustion engines was held from October 15 to 17, 2019 in Mexico City. It was organized by the Secretariat of the Environment of the Government of Mexico City (SEDEMA), with the support of the Climate and Clean Air in Latin American Cities Program - Plus (CALAC+). The objective of the Conference was to increase knowledge about pollution and human health impacts caused by these emission sources, as well as to share experiences from Europe, North America and Latin America about technologies used to control and reduce nanoparticle emissions, standards and public policies for their control and finally to show the progress made in Santiago de Chile, Lima, Mexico City and Bogotá on these issues.

Within the framework of the Conference, the need for all countries in the Region to regulate the measurement of particle numbers in internal combustion engines as an effective way to replace opacity measurement in both vehicle technical inspection programs and road tests was seen.

This guide is intended to support those countries of the Region, and mainly those that are part of the CALAC+ program, as an instrument to harmonize the replacement of the smoke opacity test by the particle count test in vehicles equipped with diesel particle filters during periodic technical inspection. The guide has been prepared with the collaboration of a group of experts from the member countries of CALAC+, and has benefited from the technical advice of Gerrit Kadjik, an expert from the Dutch research institute TNO, who has led the research leading up to the new law on periodic technical inspection of diesel vehicles through particle counting in the Netherlands. For the elaboration of this document we have relied on the technical and legal information available in Europe and especially in the Netherlands, in addition to a series of articles and scientific literature available to date.

The use of diesel particulate filters (DPFs) has significantly reduced the emission of particles from these vehicles. Due to their high filtration efficiency, the concentration of the number of particles (PN) in the undiluted exhaust gas, with the engine at idle speed, is around or below the concentration of the number of particles in the ambient air. Detection of failure of a DPF in a vehicle's periodic technical inspection (PT) test is only possible when the requirements become more severe and a more sophisticated emissions test can be implemented. The current international regulation for periodic inspection of road vehicles in use, based on the opacity test at free acceleration without load, is not reliable for those vehicles that come with DPFs from the factory, because the sensitivity of the opacimeters is too low, the signal is interfered with by the emission of some gases emitted by diesel vehicles, particularly nitrogen dioxide (NO_2), which inhibits the light from the opacimeter sensor, and the measurement of this equipment is inaccurate for particulate matter sizes below 250 nm, which represent more than half of the emissions from current diesel vehicles [Jones, 2002; Kadjik, G. et al. 2016].

An appropriate test is currently available to verify the filtering efficiency in the Periodic Technical Inspection (PTI) of these road vehicles equipped with DPFs [Proposal for a particulate filter test with a particle counter, In the Netherlands PTI, version 2019-11-26, NMI (Netherlands): Proposal Particulate Number Counter. Instruments for measuring vehicle exhaust particulate number emissions. Part 1: Metrological and technical requirements. 2019-10-16, Part 2: Metrological controls and performance tests]. The Dutch Scientific Research Organisation TNO, the Netherlands Vehicle Authority (RDW), the Netherlands Metrology Institute (NMi) and the Ministry of Infrastructure and Water Management have developed a new test procedure for the ITP of road vehicles fitted with DPFs based on particle number (PN) counting. The test is performed at idle (idle speed) with a particle counter equipment per unit volume ($\#/cm^3$).

The method for measuring the number of particles in the exhaust of vehicles fitted with DPFs during ITP tests has been developed by an international working group (VERT-NPTI), in which the Netherlands participates with representatives from TNO, NMi, RDW and the Ministry of Infrastructure and Water Management. In addition, Switzerland, Germany, Belgium, the European Commission (JRC) and several manufacturers of particle counting equipment were represented in the working group. The working group established the technical specifications for particulate counting equipment for direct use in vehicle exhaust during ITP testing. The working group also discussed how particulate measurement should be performed, as well as how the limit value for the number of particles per cubic centimeter to pass the test should be set.

In November 2016, because of too many manipulations of DPF, either OEM or retrofitted, VERT-NPTI international working group teamed up with TNO and the government of the Netherlands to develop a new PTI procedure and normative document for type approval of new low cost instruments counting solid (non-volatile) particles at low idle engine speed, to control que filtration quality of the DPF. These two documents were elaborated based on the earlier METAS documents (with METAS cooperation) and published by NMI, the Dutch metrology authority in 2019.

In January 2021 the Dutch government approved the new PTI test based on counting the number of particles (Regulation No IENW / BSK-2020/125046) in replacement of opacity, to detect removal / tampering or failures in the DPF of Diesel vehicles of model year 2016 and later. This new directive will take effect from July 2022. Germany announced in 2017 the introduction of the PN-PTI test from January 2023. Belgium adopted in 2020 the Netherlands proposal for PTI of vehicles provided with DPF. In Appendix 3, a comparison between the test and measurement equipment requirements for Switzerland, Holland, Germany and the suggestion of the VERT association is presented.

The introduction of a test to verify the correct functioning and condition of particulate filters is part of CALAC+'s action plan to harmonize the TPI procedure for road vehicles in use in Latin America..

2. Objective

The purpose of this document is to make available to CALAC+ member countries and the Latin American region in general, a technical guide for the development of their respective standards/regulations regarding the description of the emission test procedure for the ITP and the Roadside Inspection (CI) in order to evaluate the condition of the diesel particulate filters (DPF) by means of a concentration test of the number of particles per cubic centimeter of exhaust gas (#/cm3), while reviewing international experiences of the procedures for establishing limit values.

3. Scope

Establishment of requirements to be met by equipment and instruments for measuring the number of particles used to determine the amount of particles per volume of the exhaust gases produced by internal combustion engines (#/cm3). It also establishes the test procedure, and the maximum permissible limits for knowing whether or not a vehicle passes the particle count test.

3.1 Type of vehicle:

The guide applies to all vehicles, light or heavy, equipped with full-flow diesel particulate filters through the wall. The Dutch standard considers this to be the case, while the vehicle ITP particle counting technique applies to detect the state of the DPF, regardless of the size/weight of the vehicle. This scope is valid for any vehicle with a compression-ignition engine equipped or retrofitted with a DPF, regardless of where it comes from (country of origin), and regardless of the emission standard under which it has been approved.

3.2 Type of DPF:

This guide does not apply to vehicles retrofitted with partial flow filters or catalytic oxidation particulate filters. The European experience in implementing particle number counting for diesel vehicle ITP, taken as a technical reference, was based on tests on vehicles equipped with full-flow through wall DPFs. It is recommended that the competent authority of each country establish the mechanisms to include the information of the diesel particulate filter technology of each vehicle.

3.3 Particulate Filters for Gasoline Vehicles (GPF)

The guide does not apply to direct injection induced ignition engines fitted with particulate filters, called OPF (Otto particulate filter), or GPF (gasoline particle filter). There is not enough support in the international technical literature at the time of preparation of this guide to allow inclusion of this type of filter. On the other hand, it has been reported that the lower particle emission of this type of engine compared to compression-ignition engines means that the number of particles emitted with GPF is within the uncertainty range of current particle counting equipment, which compromises, to date, the repeatability and traceability of the result (TNO Report. TNO 2020 R10006. Follow-up research into the PN limit value and the measurement method for checking particulate filters with a particle number counter).

3.4 Non-road machinery

The guide does not apply to non-road machines. It is designed for periodic roadworthiness testing of vehicles in use equipped with DPF.

3.5 Other limitations:

The guide does not apply to events where DPF regeneration occurs.

It does not apply to vehicles equipped with positive-ignition engines operating on compressed natural gas as fuel. The technical literature agrees that most of the nanoparticles emitted by this type of engines are considered volatile particles (below 23nm) (Holmen, B., Ayala, A. Ultrafine PM emissions from Natural Gas, oxidation-catalyst diesel, and particle-trap heavy-duty transit buses. Environmental Science and Technology, 36 (2002). 5041-5050).

4. Terms and Definitions

Mobility diameter: Diameter of a particle that shows the same electrical mobility as a spherical particle when measured in a mobility analyzer according to ISO 15900:2009.

Nanoparticles: Solid and carbonaceous components present in the hot exhaust gas in the exhaust pipe of internal combustion engines. Particles have a mobility diameter in the range of 20 nm to 300 nm. Condensation fractions are not characterized as nanoparticles.

Particle number concentration: Number of nanoparticles per unit volume, specified per cubic centimeter (#/cm3)

Efficiency (E): Quotient of the concentration of the number of particles shown by the equipment and the concentration of the number of particles entering the measuring instrument.

Total Particles: Diesel particles consist mainly of carbonaceous material (soot or solid particles) generated during combustion, on which organic compounds are absorbed/adsorbed from the exhaust gas. Their composition at room temperature includes unburned hydrocarbons from fuel and lubricating oil, oxygenated hydrocarbons such as ketones, esters, ethers and organic acids, and polycyclic aromatic compounds. Depending on the sulfur content of the fuel, species such as sulfur oxides and sulfuric acid (Maricq, ,M. Chemical characterization of particulate emissions from diesel engines: A review. Journal of Aerosol Science. 38 (2007) 1079-1118).

Solid particles: They are the solid fraction of the total particles, those whose size is greater or equal to 23 nm are considered.

Volatile particles: They are the volatile fraction of the total particles, usually less than 23 nm in size. They are usually formed from the condensation of organic compounds of high molecular weight.

Periodic technical inspection of vehicles: Technical-mechanical and pollutant emissions inspection that is carried out periodically to verify compliance with the maximum permissible pollutant emission limits defined by law for vehicles in use. Terminology by country: Mexico: Vehicle Technical Inspection (ITV), Mexico: Vehicle emissions verification. Chile: Technical and emissions review of motor vehicles. Colombia: Automotive diagnostics. Peru: Vehicle Technical Inspection.

On-road Inspection: Review of pollutant emissions by the competent authority on vehicles on public roads, to verify compliance with the maximum permissible emission limits defined by law for vehicles in circulation.

Gross Vehicle Weight: Maximum design weight of the loaded vehicle, specified by its manufacturer.

Low idle: stationary minimum engine speed with no load

High idle: stationary maximum engine speed with no load

Particle filter: It is a filter that reduces the emission of particles generated in the engine combustion process. For filters installed in vehicles that use compression-ignition engines, they are identified with the acronym DPF (Diesel particle filter), while for induced-ignition

engines, they are identified as GPF (Gasoline particle filter). The material in which they are manufactured is usually ceramic or sintered metal.
EGR (Exhaust gas recycle): Fraction of exhaust gas that is recirculated to the intake manifold to dilute the mixture entering the cylinder and lower the temperature inside the combustion chamber. It is used to reduce nitrogen oxides.

Compression-ignition engine: Internal combustion engine whose operation is based on a thermodynamic cycle in which fuel is injected directly into the chamber. Combustion occurs by self-ignition of the fuel in an environment of compressed air at high pressure and temperature.

Spark Ignition Engine: internal combustion engine whose operation is based on a thermodynamic cycle in which the combustion of the air-fuel mixture at high pressure and temperature is produced by a spark plug.

Condensation Particle Counting (CPC): This measure provides a method of counting particles emitted in which each particle that has been previously devolatilized and saturated with a working fluid, normally isopropyl alcohol, is counted, whose function is to increase the size of the condensed particle. Since drops are produced after the condensation process, the counting is not sensitive to particle size. The concentration of the number of particles is obtained by counting the number of pulses and the volumetric sample flow.

Diffusional Charge (DC) Particle Counting: In this method of particle counting, the sample from the exhaust stream is forced through a confined space where the particles are electrostatically charged. The particles pass into the measurement chamber, which consists of one or more positively charged high voltage electrodes surrounded by one or more electrometers. In the latter case, the particles change their trajectory as a result of repulsive forces and end up in each electrometer as a function of their size (discrete measurement of the number of particles as a function of their size). The measured quantity is the active surface area of the charged particle. The current measured in the electrometer is proportional to the diameter of mobility of the particle raised to an exponent that usually varies between 1.1 and 1.4. These equipments require to know the average diameter of particles, to convert the measured current to the concentration of the number of particles (Giechaskiel, B., Riccobono, F., Bonnel, P. (2014). Feasibility study on the extension of the Real Driving Emissions (RDE) procedure to particle number (PN): Experimental evaluation of portable emission measurement systems (PEMS) with diffusion chargers (DCs) to measure particle number (PN) concentration. JRC Science and Policy Reports. Joint Research Centre, European Commission. Brussels: Publications Office of the European Union. Retrieved from http://publications.jrc.ec.europa.eu/repository/handle/JRC93743)

Eddy current (IC) particle counting: see: M. Fierz et al. Aerosol measurement by induced currents, Aerosol Science and Technology 48 (4), 350-357, 2014.

5. References

The following normative documents contain provisions which, by reference in this text, constitute provisions of this guide.

Subsequent amendments or revisions of dated references do not apply. However, parties to agreements based on this proposed standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents listed below. In the case of undated references, the latest edition of the aforementioned normative document applies.

ISO, IEC and OIML members maintain registers of currently valid international standards. The current status of the Standards referred to can also be found on the Internet:

■ IEC Publications: http://www.iec.ch

■ ISO Publications: http://www.iso.org

■ OIML Publications: http://www.oiml.org (with free download of PDF files)

- Proposal for a particle filter test with a particle counter, at the ITP in the Netherlands, version 2019-11-26

- Particle number counter. Version 2019-06-28. Instruments to measure the number of particles in vehicle exhaust. Part 1: Metrological and technical requirements.

- Particulate Number Counter. Version 2019-06-28. Instruments for measuring the number of particles in vehicle exhaust gases. Part 2: Metrological controls and performance tests.

To delve into the background and evolution of particle number counting tests, the following references are recommended:

1998: The VERT-Filterlist, edited officially by Swiss FOEN and SUVA, first in April 1998, defines filtration quality according to particle number in the mobility size range of 10-500 nm and defines how DPF must be measured in order to become certified.

2000: SAE-paper 2000-01-1998 by Kasper et al, published the technology of the first counting instrument (NanoMet) for DPF control.

2002: With the FOEN document Baurichtlinie LUFT, DPF of construction machines became mandatory in Switzerland and a periodic test was required for all vehicles and machines equipped with particle filters, first by opacity, later modified to number counting.

2004: VERT developed a testing method by number count to detect small failures of DPF. Published in SAE 2008-01-0759.

2007: the SNR 277205 Swiss Technical standard is published, it described in detail how filtration quality of DPF must be measured, insisting on eliminating volatile particles.

2007: UN-ECE adopted the Swiss PN-rules during the PMP process, documented by ECE/324/Rev.1/Add.48/Rev.5/Amend.083, basis for the introduction of DPF; metrology was already described and published by Kasper et al 2006 at SAE F2006P342

2010: METAS, the Swiss metrology authority, as the leading member of a Swiss working group developed (2006-2009) a method to check the quality of a DPF in the field by PN counting at stand still at either high idle or low idle or during a transient at no load (Dr. Schlatter published the result at IAC 2010 in Helsinki).

2012: METAS published VAMV: metrology regulation for emission measurements of ICE including number count measurement for PTI purposes.

2016: VERT was invited as testimony at the hearing of the German Parliament on the Diesel scandal, and recommended the introduction of a new PTI metrology by number count at low idle. The German law StVZO was accordingly adapted in January 2017.

2020 Belgium adopted the NMI standards and implemented the respective PN-PTI process

2021 Germany published type approval documents, slightly different from the Dutch basis (see Annex 3).

6. Test equipment

The specifications of this measuring instrument have been developed by the Dutch Institute of Metrology (NMi) in consultation with manufacturers of particle counting equipment. The relevant specifications have been established by NMi. Germany proposed the worldwide harmonization of particle counter specifications for vehicle ITP within the framework of the International Organization of Legal Metrology (OIML). The German metrology institute PTB (Physikalisch-Technische Bundesanstalt) and the NMi have taken on the task of initiating this global harmonization.

A particle number (PN) analyzer measures the volumetric concentration of PN (solid particles) in the exhaust gas. The main features of the NP analyzer, as described in the proposed specific standard for particle counting equipment, are as follows:

- Applicable to compression-ignition and induced-ignition engines.
- The analyser contains a sampling probe, a volatile particle removal (VPR) and a particle number (PN) counter.
- The VPR has an efficiency of more than 95%.
- The analyzer features particle at least above 23 nm.
- The particle size for calibration and linearity verification is > 50 nm.
- Measuring range: 0 - 5,000,000 #/cm3.
- Measurement accuracy +/- 25%.
- Stabilization time (T0 - T95) of the PN counter (including the sample line) is less than 15 seconds.
- Response time: 5.5 s to 10 s
- The measurement frequency of the PN meter is at least 1 Hz.
  - Climatic, mechanical and electromagnetic environmental conditions: The following nominal operating conditions must be fulfilled:
- Ambient temperature range from 0 °C to 40 °C
- Environmental pressure range from 750 hPa to 1060 hPa
- Class M2 mechanical environment (typical of PTI workshops)
- Class E2 electromagnetic environment (typical of PTI workshops)

In the case of Latin America, it will be necessary to use particle counting equipment approved by the metrology entity designated by each country, or by a metrology entity of those countries involved in the development of the particle counting standard. This guide proposes the procedure for prototype homologation, first inspection and periodic re-inspection of particle-counting equipment for stationary vehicles with the engine idling.

It is suggested that each country's metrology body issue national type approval certificates for particle counting equipment. In case there are no national standards, it is suggested to accept the certificates of origin, as long as there are recognition agreements between the metrological entities, according to the legislation of each member country. Several manufacturers have indicated that they are working on the development of prototypes of particle counters for use in automotive workshops dedicated to performing vehicle TPD. If these manufacturers pass the certification procedure of the internationally recognized metrology entity, the instruments developed can be made available to the Latin American market as approved instruments for verifying particle emissions in vehicle TPD tests or for roadside inspection.

Another option would be to allow the use of particle counters approved by an independent international inspection body, provided that the admission requirements are at least at the same level as national requirements. As long as equipment certified according to this document is not available, it is suggested to recognize as technically suitable those that are approved by the Swiss Institute of Metrology (METAS) according to the Swiss regulation SR941.242 (2014) or its most recent versions.

The proposed approval scheme for the test equipment will be developed in 2021 and will serve as a reference framework for each member country (Guide No. 2 part 1 and part 2 under development).

7. TPI Emissions Test and Roadside Inspection

The DPF test during vehicle ITP is carried out by measuring the concentration of the number of particles per cubic centimeter (#/cm3) over a period of at least 15 seconds, preceded by a period of 15 seconds for stabilization of the measurement signal.

The measurement period of at least 15 seconds can be divided into several parts with intermediate periods without measurement. If the average measurement is below the limit value for the number of particles, the vehicle passes the test.

A well-functioning DPF is very effective for particle filtration. The particulate emissions of a well-functioning diesel vehicle with filter do not exceed 5,000 #/cm3.

The DPF test can be done under any engine temperature condition from cold to normal operating temperature. This is advantageous since, for example, it is not necessary to make a warm-up run to bring the engine to operating temperature before starting the test. Another important factor is whether or not the exhaust gas recirculation (EGR) system is activated. When the EGR system is activated (EGR valve open) it leads to higher particulate emissions. It is recommended that the particulate count test be performed with the EGR system off (EGR valve closed). This can be done by running the vehicle with the engine idling for some time (cab mode) or through the OBD connector with an engine diagnostic device (Appendix 1).

Pre-test considerations

- Before the emissions test for the ITP, a zero check of the PN counter equipment should be performed with a HEPA filter in the sample line. The PN concentration must be less than 5,000 # / cm3. Per day, only one zero check is required.

• The status of the exhaust pipe and particulate filter, and if possible, the operation of the DPF and the status of the EGR valve should be visually checked through parameters such as alerts from the OBD vehicle information system.

With the approach described above, you have the following test procedure:

- The vehicle's engine is started and left at idle (low idle).
- The particulate number analyzer sampling probe is placed in the exhaust pipe and a representative sample of the engine exhaust gas must be taken at idle.
- After stabilization of the measuring equipment (15 seconds), the vehicle's particulate matter emission (#/cm3) is determined for a measuring time of 15 seconds (measuring frequency is 1 Hz). If the PN emission is below the PN limit value of the vehicle's ITP, the test has been exceeded. If the PN emission is above the limit value, the test is considered failed. The test can be performed with a warm engine and the EGR valve closed. Appendix 2 contains a schematic summary of the DPF test procedure for the ITP.
- In case of a PN emission of twice the limit value the ITP test must be stopped immediately and the vehicle must be marked as not passed.
- The procedure only applies to diesel vehicles and not to positive (provoked) ignition vehicles. The need for conditioning of the vehicle with regard to engine temperature and EGR status is illustrated by an example in Annex 1.
- If the vehicle does not pass the test because the engine is cold and the EGR is operational, it would have to be re-tested after a warm-up run/cycle and wait a few minutes (Taxi mode), or actively close the EGR valve with an OBD analyzer.

In addition, the following conditions should be considered:

The DPF status must allow full use of the vehicle throughout its speed range.

8. Limit values

The European standard for prototype approval and sustainability for the number of particles emitted by passenger cars and delivery vans from Euro 5b, and for trucks and buses from Euro VI is 250,000 #/cm3. Studies by the Dutch research institute TNO and the Joint Research Commission for Europe (JRC) show that the 250,000 #/cm3 requirement is three to five times less strict than the Euro 5b standard for 6 x 10^{11} #/km particulate emissions.

Figure 1 shows the correlation between the emission of the number of solid idle particles (NPS 23, greater than 23 nm) measured by the prototype particle counters and the instruments that comply with the portable emission measurement systems (PEMS) of the NPS (limit value 6x1011 #/km). The JRC study summarized the results of three different studies, Figure 1: (1) idling TNO study with three vehicles; (2) pre-evaluation of JRC's NPTI instruments with an idling bypass DPF equipped vehicle; and (3) evaluation study of NPS PEMS using idling data from the NEDC and WLTC driving cycles.

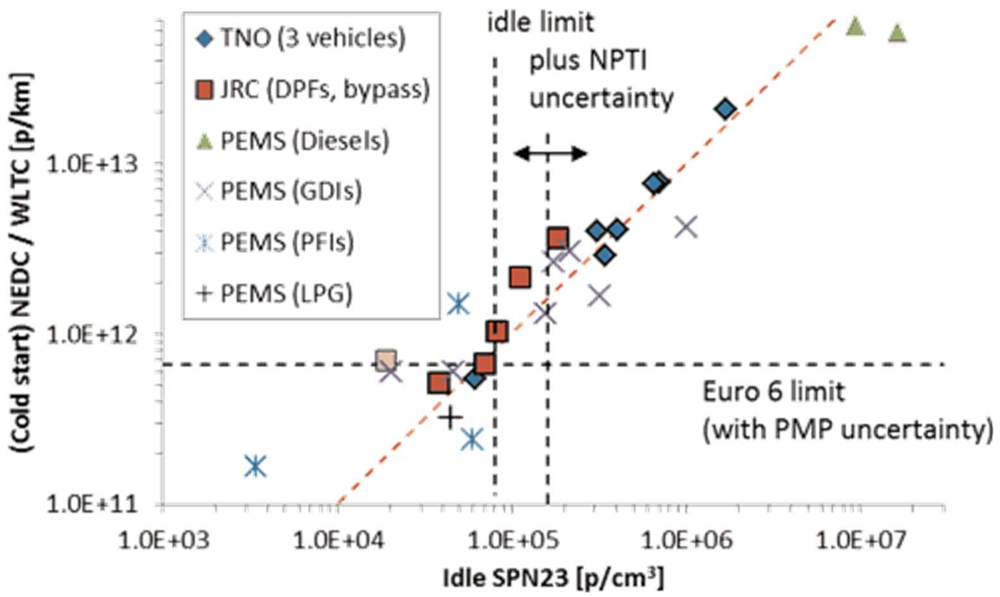

Figure 1. Emission factor (#/km) during the NEDC or WLTC driving cycle as a function of the raw exhaust gas concentration (#/cm3) measured at idle with different PMP or NPS PEMS instruments (Source: JRC)

Each country would have the task of setting the maximum permissible limit(s). A proposal to set the limit could be based on the explicit European standard, pilot measurement campaigns could be carried out, and the percentiles of pass/fail testing of the fleet that meets the requirements described in the scope of this guide could be verified.

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10. List of abbreviations

DPF Diesel particulate filter
EGR Exhaust gas recirculation
GPF Gasoline particulate filter
HEPA High Efficiency Particulate Air Filter
ITV Vehicle Technical Inspection (Periodic Technical Inspection)
JRC Joint Research Centre
NEDC New European Driving Cycle
NMi Dutch Metrology Institute (Nederlands Meetinstituut)

NPTI New Periodic Technical Inspection
OBD On-board diagnostics
OIML International Organization of Legal Metrology
PEMS Portable Emissions Measurement System
PMP Particle Measurement Programme
PN Particle number
PTB German National Institute of Metrology (Physikalisch-Technische Bundesanstalt)
RDW Dutch Type Approval Authority (Rijksdienst voor Wegverkeer)
RSI Road Side Inspection
SPN Solid Particle Number
TNO Netherlands Organisation for Applied Research
VPR Volatile Particle Remover
WLTC Worldwide harmonized light vehicles test procedure

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ASTM E2456-06 (2020) Standard Terminology Relating to Nanotechnology

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Annex 1. Vehicle Conditioning

A properly functioning DPF can significantly reduce particulate emissions. A well-functioning filter allows about one in a thousand particles to pass through it.

Therefore, if the idle measurement values on a vehicle are 5,000,000 #/ cm^3, the particulate concentration after the DPF will be about 5,000,000 / 1,000 = 5,000 #/ cm^3.

However, if the filter efficiency is lower, a clear decision must be made about whether a vehicle passes the test or not. To do this, the conditioning of the vehicle with respect to engine temperature and EGR status (EGR valve closed) is important. This is illustrated with the following example.

A vehicle has an idle emission value of 15,000,000 #/ cm^3 with the engine cold and the EGR valve open, and with the engine warm and the EGR valve closed, the emission value is 5,000,000 #/ cm^3. In addition, the vehicle's filter has a small crack, so 10% of the particles pass through the filter. Finally, the vehicle was registered before 2015, so the limit value of the number of particles for the ITP is 1,000,000 #/ cm^3.

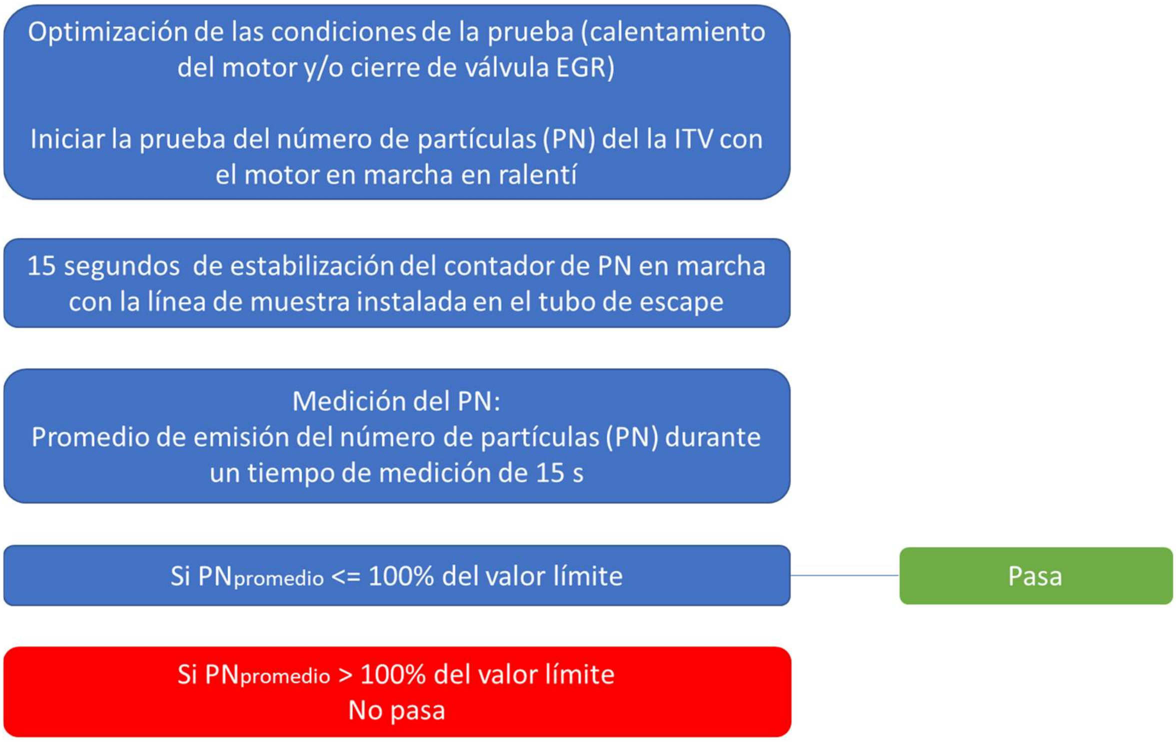
With a cold engine and the EGR valve open (EGR in operation), the concentration of the number of particles after the DPF will be 15,000,000 / 10 = 1,500,000 #/ cm^3. Therefore, the vehicle will not pass the first test. With the engine warm and the EGR valve closed (EGR not running, cab mode), the particle number concentration after the DPF will be 5,000,000 / 10 = 500,000 #/ cm^3. So the vehicle will pass the second test. Normally, the filter will work well in most cases (> 90%). Therefore, also with a cold engine and an unknown EGR state a vehicle will pass the test. However, in the case of a DPF with a small crack, the engine temperature and the EGR state will also determine whether a vehicle passes the test or not.

If a vehicle fails a test (less than 10% of the time), a new test can be done with the engine warm and the engine running at idle for some time so that the vehicle has a chance to enter cab mode (EGR valve closed). With only a small crack in the filter, the vehicle will pass the new test.

However, with a removed or completely damaged filter, the vehicle will also fail the new test.

The possibility of retesting with a warm engine in cab mode is of particular interest when testing ITP in service workshops. In the Netherlands, in many cases the DPF checks for ITP will be done with a cold engine. With the proposed procedure, the ITP inspectors do not have to do a warm-up run and wait a few minutes before they can do the DPF check with a particle counter. Only when a vehicle fails the test (less than 10% of the time), would they have to do a new test after a warm-up run and wait a few minutes or actively close the EGR valve with an OBD analyzer.

Annex 2. Summary of DPF Testing Procedure for Vehicle ITP



Annex 3. Comparison between PTI test requirements

Comparison between several PTI test procedure and PN instrument characteristics. Adapted from [VERT "PTI by Particle Count PN at Low Idle," *Tecnhical Instruction Technique TA-024/21*. pp. 1–12, 2021]				
	Switzerland	The Netherlands	Germany	VERT
Standard/regulation	SR 941.210	IENW/BSK-2020/125046	PTB-A 12.16	Recomendation 2021
Test				
Tipo vehículos	Maquinaria with DPF	Euro 4-6/VI with DPF	Euro 6/VI	Internal Combustion Engines
Limit value (#/cm^3)	2.5 x 10^5	1 x 10^6	2.5 x10^5	50.000
Fast approval (#/cm^3)	-	-	50.000	50.000
Fuel	Diesel	Diesel	Diesel	Hydrocarbons
Type of test (ralenti)	high	low	low	low
Sampling time (s)	3 x 5	15	3 x 35	3 x 15
PN zero daily	-	yes	yes	yes
PN environment daily	-	-	optional	yes
Instrument				
PN range (#/cm^3)	5 x10^4 - 5 x10^6	5 x10^3 - 5 x10^6	5 x10^3 - 5 x10^6	3 x10^3 – 1.5 x10^6
Efficiency VPR (%)	> 95	> 95	> 90	> 95
Max. error homologatión (% @ (#/cm^3))	-	25 @25.000	25 @5.000	25 @5.000
Max. error calibración anual (% @(#/cm^3))	-	25 @25.000	75 @10.000	50 @10.000
Range of particle size (nm)	23 – 300	23 – 200	23 – 200	23 – 200
Counting efficiency (%) @ 23 nm @ 50 nm @ 80 nm @ 200 nm	 < 50 - 70 – 130 < 300	 20 – 60 60 – 130 70 – 130 -	 20 – 60 60 – 130 - 50 – 200	 20 – 60 60 – 130 70 – 130 < 200

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