



BUWAL Bundesamt für Umwelt, Wald und Landschaft
OFEFP Office fédéral de l'environnement, des forêts et du paysage
UFAPF Ufficio federale dell'ambiente, delle foreste e del paesaggio
UFAGC Uffizi federal d'ambient, gaud e cuntrada

Ordinance on the determination of the particle number emission level of passenger cars with compression ignition engines

Draft, 1 March 2004

Introduction

This draft version of the Ordinance on the determination of the particle number emission level of passenger cars with compression ignition engines has been prepared by the Swiss Agency for the Environment, Forests and Landscape (SAEFL) with the assistance of involved federal authorities and experts. It is based on the initial findings of the ECE-GRPE "Particle Measurement Programme (PMP)" experts' group. Practical trials of the testing procedure and an inter-laboratory test at the national level are to be carried out in spring and summer 2004, following which the draft will be revised and updated.

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Purpose

The purpose of this Ordinance is to specify the procedure for measuring the particle number emissions of passenger cars with compression ignition engines, and introduces a limit value for particle number of $10^{11}/\text{km}$ in the 20 to 500 nanometer range. With effect from 1 January 2006, this limit value supplements the existing EU limit value for particle mass specified in Directive 70/220/EEC¹⁾ and ECE Regulation 83 until the EU introduces a EURO 5 limit value for particle mass and particle number.

Scope of application, procedure

The procedure described in this Ordinance shall apply to all vehicles in categories $M_1^{2)}$ with compression ignition engines and an overall weight of up to 3.5 tonnes.

Vehicles are to be tested either by a recognised Swiss technical service or a foreign technical service that is responsible for carrying out exhaust gas emission tests in accordance with the relevant ECE Regulations or EC directives. All foreign test reports shall be presented to a recognised Swiss technical service in accordance with the "Ordinance governing the homologation of motor vehicles" (ORT)³⁾, which shall verify compliance with the Swiss requirements and, if this is the case, issue a certificate of compliance. Type approval will only be granted on the basis of a certificate issued by a recognised Swiss technical service.

Definitions

Empirical⁴⁾ *TPN* (total particle number) refers to the distance-based particle number in accordance with the procedure described in this Ordinance.

Penetration (P) of a component refers to the ratio between the particle concentration behind (c_a) and that in front (c_i) of the component: $P = c_a / c_i$.

Dilution factor (DF) refers to the ratio between the particle concentration in front of (c_i) and that behind (c_a) the dilution: $DF = c_i / c_a$

Particle diameter refers to the mobility diameter of the particle as measured using the electrostatic procedure.

¹ Directive 70/220/EEC dated 20 March 1970 to co-ordinate the legal provisions of member states governing measures to prevent air pollution due to emissions from motor vehicles; most recent amendment through Directive 2003/76/EC.

² In accordance with Appendix II, paragraph A, Directive 70/156/EEC dated 6 February 1970 to co-ordinate the legal provisions of member states governing operating licences for motor vehicles and their trailers; most recent amendment through Directive 2001/116/EC.

³ Ordinance dated 19 June 1995 governing the homologation of motor vehicles (ORT).

⁴ EURACHEM / CITAC Guide CG 4 (2000): Quantifying Uncertainty in Analytical Measurement, Second Edition; Chapter 5, Step 1: Specification of the Measurand

Measurement of TPN

Measurement of TPN is carried out in analogy to the measurement of particle mass in accordance with Directive 70/220/EEG on the basis of the following methodology:

The equipment for measuring TPN comprises a dilution tunnel, a sampling probe, a dilution unit, an evaporation unit and a particle counter.

All system components, from exhaust to measuring device, that come into contact with the undiluted and diluted aerosol must be arranged so that deposits of particles are minimised.

For measurement purposes, the individual components of the system may only be used with the aerosol flow, gas flow, and operating temperature (for the evaporation and dilution devices) settings for which they have been calibrated.

For vehicles with constantly regenerating exhaust processing systems, it is necessary to carry out one cycle measurement. In the case of vehicles with periodically regenerating exhaust processing systems, two measurements have to be carried out: one with regeneration, and one without. The results of the measurement with regeneration should then be compared against the number of cycles specified by the manufacturer.⁵⁾

a) Sampling

Samples for measuring the TPN are taken at the same level as samples for measuring the particle mass⁶⁾, and both should be taken close to the middle of the tunnel. In order to ensure that they do not interfere with one another, the samples should be taken at a distance of at least 5 cm from one another, and the distance between both sampling points and the tunnel wall should also be at least 5 cm. Samples must be taken in such a manner as to ensure that a representative sample flow of the aerosol diluent mixture for the CVS tunnel is obtained.

The probe must take the form of a tube with an unobstructed aperture facing the flow. It must not contain any components (e.g. screens) that obstruct free flow. The inside diameter of the tube must be at least 4 mm.

b) Preparation of sample

Exhaust samples for measuring the TPN are fed into the measuring device at constant volume flow via a dilution device and subsequently via an evaporation device. All surfaces of the measurement equipment that is in contact with the aerosol must be made of electrically conductive and earthed material (with the exception of the adsorption material in the optional adsorption component). The exhaust sample may not at any time exceed the temperature of 723 K (450° C) inside the sample feeding device.

The length of the conduit between the intake of particles into the probe and entry into the dilution device may not exceed 1,000 mm, and the distance between intake into the probe and entry into the measuring device may not exceed 2,500 mm.

The calculated time between intake into probe and feed into measuring device may not exceed 10 seconds.

⁵⁾ For measuring particle mass in vehicles with periodically regenerating systems, ECE Regulation 83, Appendix 13; Rev. 1/Add. 82/Rev. 2/Amend.1 shall apply.

⁶⁾ Directive 70/220/EEC, Appendix III, paragraph 2.4, section 5

Dilution unit

The dilution unit dilutes the exhaust with particle-filtered dry air (HEPA filter, RH < 10%). The minimum dilution factor is 1 and the maximum is 1,000. The factor must remain constant. Throughout the entire duration of a TPN measurement, the empirical dispersion level (*standard deviation of readings in seconds*) may not exceed 10 % of the dilution factor.

Evaporation unit

The evaporation unit consists of a heated tube with a length of at least 350 mm and an unobstructed inside diameter of at least 6 mm, or in the case of concentric tubes, an unobstructed cross-sectional area of at least 80 mm². The temperature along the entire length of the tube must be controlled, and must be at least 473 K (200° C) but not more than 723 K (450° C), measured 50 mm from the intake, in the centre and 50 mm before the exit. For the operating conditions for temperature and aerosol flow, the aerosol must be present for at least 0.5 seconds.

The evaporation unit may also be equipped with an adsorption unit. The conduit from the heating to the adsorption unit may not be longer than 50 mm and must be electrically conductive, without valves, regulators, etc., and provide direct access to the adsorption unit. The adsorption unit itself must be a straight tube with an unobstructed inside diameter of at least 6 mm, or in the case of concentric tubes, an unobstructed cross-sectional area of at least 80 mm².

During measurement, the evaporation unit, including the adsorption unit (if applicable), must operate under conditions that guarantee a reduction of at least 99% of C40 particles (tetracontan) with a diameter of 30 nm and a concentration of at least 1,000 cm³. Under the same operating conditions, the penetration of solid particles with diameters of 30, 50 and 100 nm must be 90% or higher.

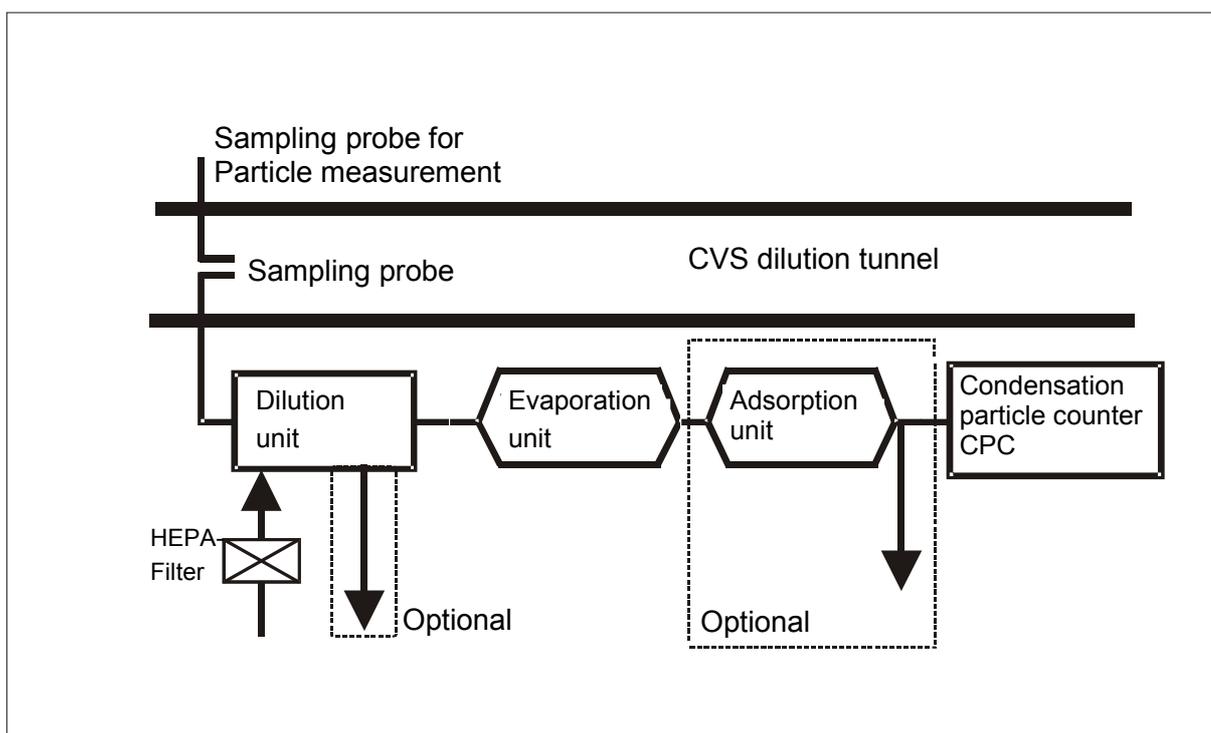


Fig. 1: Diagram of equipment for measurement of TPN

c) Particle counter

Measurement of particle concentration is carried out using a condensation particle counter (CPC)⁷. The aerosol is fed into this device via a supersaturated alcohol vapour bath (n-butanol), in order to enlarge the particles through condensation of the vapour on the surface. The particles are then counted using an optical detector (laser diode). The alcohol used for TPN measurement must be changed on the day of the test before measurement may be carried out.

The CPC must meet the following requirements:

- It must be able to detect at least 50% of particles with a diameter of 10 nm or greater, and at least 90% of particles with a diameter greater than 20 nm but less than 500 nm.
- Measurement range: 0.1 to 10⁴ particles/cm³
- Measurement must be based on the single particle counting method.
- Response time t_{10} up to t_{90} : < 15 seconds
- Measuring frequency: ≥ 0.5 Hz
- Automatic data processing of the device may only include data averaging (sliding average) and adjustments of insensitive time and coincidence.

d) Evaluation of TPN measurement

Evaluation of TPN measurement is carried out by adding together the readings from the CPC using the following formula:

$$TPN = \frac{V_{mix}}{d} \times DF \times \frac{1}{n} \times \sum_{i=1}^{tn} C_{CPCi}$$

Key:

- TPN : Particle number emission expressed in particles/km.
- V_{mix} : Volume of diluted exhaust gas expressed in litres per test and adjusted to standard temperature and pressure (273.15 K; 101.325 kPa).
- C_{CPCi} : Particle concentration measured in CPC in time interval i under normal conditions (273.15 K; 101.325 kPa).
- DF : Dilution factor.
- d : Distance equivalent to driving cycle.
- $t1...tn$: Testing time divided into n intervals (intervals must be equal in length and extend over a period of 2 seconds or less).
- n : No. of readings.

⁷ VDI 3489 (1995) Measurement of particles; methods of characterising and monitoring testing aerosols; condensation core counters with constant flowthrough

Periodical calibration of measuring system

a) Condensation particle counter (CPC)

The CPC must be traceable⁸⁾ to a national standard⁹⁾.

It must be calibrated every 12 months.

As a rule, calibration is carried out with solid particles¹⁰⁾ with nominal diameters of 30, 50, 100 and 300 nm for at least five concentrations that are distributed as equally as possible over the measurement range of the CPC.

The error limits¹¹⁾ of the CPC refer to an average of at least 20 readings. These are 5 particles/cm³ for a particle concentration of up to 50 particles/cm³, and 10% of the displayed reading for higher concentrations.

The empirical standard deviation of the CPC must not exceed 20% of the average figure.

b) Dilution unit

The dilution unit must have been calibrated with a traceable calibration gas and concentration measurement device no longer than 6 months before the date of test measurement.

Calibration must be carried out by measuring the concentration at the exit while the calibration gas is fed at the intake and the concentration of the measured gas in the dilution air is negligible. Dilution units with a variable dilution factor must be calibrated at a minimum of five dilution rates that are distributed over the range as evenly as possible. The measured dilution rates must be within $\pm 10\%$ of the nominal dilution settings.

c) Evaporation unit

Testing of penetration of solid particles into the evaporation unit must have been carried out within 6 months. The test must be carried out under the same operating conditions for temperature and aerosol flow as for TPN measurement. Three aerosols must be used with solid particles with diameters of 30, 50 and 100 nm (most-frequent diameters) and with a minimum concentration of 1,000 particles/cm³. Penetration must be calculated by measuring the particle concentration before and after the evaporation unit, including the adsorption unit if applicable, and must be at least 90% for all tested particle sizes.

⁸ International Vocabulary of Basic and General Terms in Metrology (VIM) (1993) ISO: section 6.10

⁹ International Vocabulary of Basic and General Terms in Metrology (VIM) (1993) ISO: section 6.1

¹⁰ NaCl particles are often used for this purpose. Diameter sizes are mobility diameters.

¹¹ International Vocabulary of Basic and General Terms in Metrology (VIM) (1993) ISO: section 5.21

Tests to be carried out prior to TPN measurement

a) On day of measurement

On the day on which TPN measurement is to be carried out, the CPC must be tested to make sure it is operating correctly. The aerosol to be used must consist of solid particles with a most-frequent diameter of between 30 and 150 nm¹²). The test must be carried out with a stable concentration of between 5,000 and 10,000 particles/cm³.

Testing should be carried out on the basis of one of the following procedures:

- The CPC must be tested by comparing it with a second, traceable particle counter with the same specifications. The measured concentrations may not deviate from one another by more than 20%.
- The CPC is compared with a traceable aerosol standard. The uncertainty factor of the aerosol standard may not exceed 10% (standard deviation). The difference between measurement with the CPC and the aerosol standard may not exceed 20% of the reading.

On the day of the TPN measurement, the particle measurement system must be tested to verify its proper operation. This system, comprising a dilution unit, an evaporation unit and the CPC, should be able to measure a concentration of less than 1 particle/cm³ when an HEPA filter is attached to the intake of the dilution unit. The temperature of the evaporation unit must be at least 50° C higher than the temperature set during the emission test.

b) Before each TPN measurement

The following tests should be carried out before each TPN measurement:

- The particle measurement system, comprising a dilution unit, an evaporation unit and the CPC, must be able to measure a concentration of less than 1 particle/cm³ when an HEPA filter is attached to the intake of the dilution unit. The evaporation unit should be at operating temperature.
- The CPC must be able to measure a concentration of more than 1,000 particles/cm³ when a suitable aerosol is fed in.
- The flow rate of the CPC has to be tested.

Appendix

HEPA filter: filter that reduces the TPN of a 0.3 µm dioctylphthalate aerosol by at least 99.87%.

HEPA filter: filter with a filtration efficiency of at least 99.95% of the particle-size-related filtration curve

HEPA filter: filter in category H13 (standard EN1822) or better

¹² Of the total number of particles, > 90% must lie within the diameter interval.