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Road vehicles — Inlet air cleaning equipment for internal combustion engines and compressors —

Part 1:

Fractional efficiency testing with fine particles (0,3 µm to 5 µm optical diameter)

Véhicules routiers — Équipement d'épuration d'air d'entrée pour moteurs à combustion interne et compresseurs —

Partie 1: Contrôle d'efficacité fractionnelle avec particules fines (diamètre optique de 0,3 µm à 5 µm)

ICS 43.060.20

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Foreword

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ISO 19713-1 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 7, *Injection equipment and filters for use on road vehicles*.

ISO 19713 consists of the following parts, under the general title *Road vehicles — Inlet air cleaning equipment for internal combustion engines and compressors*:

- *Part 1: Fractional efficiency testing with fine particles (0,3 µm to 5 µm optical diameter)*
- *Part 2: Fractional efficiency testing with coarse particles (5 µm to 40 µm optical diameter)*

Introduction

The following Engine Air Cleaner/Filter Fractional Efficiency Test Standard has been developed to cover traditional and new particulate air filters to remove airborne contaminants specifically to protect the engine.

Air Cleaner Fractional Efficiency is one of the main air cleaner performance characteristics. This Test Standard has been established to address the measurement of this parameter. The objective of this procedure is to maintain a uniform test method for evaluating fractional efficiency of air cleaners and air filters on specified laboratory test stands.

The data collected according to this test standard can be used to establish fractional efficiency characteristic for air cleaners and filters tested in this manner. The actual field operating conditions, including contaminants, humidity, temperature, mechanical vibration, flow pulsation, etc. are difficult to duplicate. However, with the procedure and equipment set forth, comparison of air filter fractional efficiency may be made with a high degree of confidence.

Annexes, B, C, E, F, G, and H are normative. Annexes A, D, and I are informative.

Road vehicles — Inlet air cleaning equipment for internal combustion engines and compressors —

Part 1:
Fractional efficiency testing with fine particles (0,3 µm to 5 µm optical diameter)

1 Scope

This part of ISO 19713 describes laboratory test methods to measure engine air cleaner and filter performance by fractional efficiency test using particles from 0,3 µm to 5 µm. See ISO 19713-2 for fractional efficiency test with particles from 5 µm to 40 µm. Performance includes, but is not limited to, air flow restriction or pressure loss, initial and incremental fractional efficiencies during dust loading.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19713-2, *Inlet air cleaning equipment for internal combustion engines and compressors — Part 2: Fractional efficiency testing with coarse particles (5 to 40 µm optical diameter)*

ISO 5011:2000, *Inlet air cleaning equipment for internal combustion engines and compressors - performance testing*

ISO/DP 11 841-1, *Road vehicles and internal combustion engines - Filter vocabulary - Part 1: Definitions of filters and filter components*

ISO 12103-1, *Road vehicles – Test dust for filter evaluation – Part 1: Arizona test dust*

ISO/TS 11155-1, *Road vehicles - Air filters for passenger compartment - Part 1: Test for particulate filtration*

ASTM F 328, *Practice for determining counting and sizing accuracy of an airborne particle counter using near-mono-dispersed spherical particulate materials, (ASTM, 1916 Race Street, Philadelphia, PA. 19103-1187 USA)*

ASHRAE 52.2, *Method of testing general ventilation air-cleaning devices for removal efficiency by particulate size (ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA. 30329, USA)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
air cleaner assembly
assembly which includes the air cleaner housing and the air filter element

3.1.1
single stage air cleaner
air cleaner which does not incorporate a separate pre-cleaner

3.1.2
multistage air cleaner
air cleaner consisting of two or more stages, the first usually being a pre-cleaner, followed by one or more filter elements

NOTE If two elements are used, the first is called the primary element and the second one is called the secondary element.

3.1.3
pre-cleaner
device usually using inertial or centrifugal means to remove a portion of the test dust before reaching the filter element

3.2
air filter element
the actual filter supported and sealed within the air cleaner assembly

3.3
test air flow rates
a measure of the volume of air passing through the test duct per unit time

NOTE Expressed in cubic meters per second (m^3/s).

3.4
pressure loss
permanent pressure reduction due to a decrease in the flow energy (velocity head) caused by the filter (Pa at standard conditions of 20 ºC and 101,3 kPa)

3.5
term fractional efficiency, $E_{f,i}$ (%)
ability of the air filter to remove particles of a specified size expressed as a percentage for particle size i

$$E_{f,i} = \frac{C_{1i} - C_{2i}}{C_{1i}} \times 100 \qquad (1)$$

where: C_{1i} = number of particles per unit volume of specified size, i upstream
C_{2i} = number of particles per unit volume of specified size, i downstream

3.6
definition of different fractional efficiencies

3.6.1
fractional efficiency before dust loading
efficiency before the collected particles have any measurable effect on the efficiency of the filter under test

NOTE The collected particles can affect the measured filter efficiency before enough aerosol is collected to have any measurable effect on the filter pressure loss.

3.6.2
incremental fractional efficiency
efficiency, determined at the specified flow rate as a function of particle size at 10 %, 25 %, 50 % and 100 % of filter life, which is determined by pressure loss across the filter as the filter is loaded with ISO 12103-1 test dust.

NOTE 1 The filter pressure loss (ΔP_i) values at which the incremental fractional efficiencies are measured can be calculated from: the initial pressure loss (ΔP_o), the fraction of filter life (ΔL_i), and the specified terminal pressure loss (ΔP_d). See Equation 2.

$$\Delta P_i = \Delta P_o + \Delta L_i \times (\Delta P_d - \Delta P_o) \tag{2}$$

NOTE 2 If necessary, the requester and the tester may agree upon different criteria for incremental fractional efficiency.

3.7
fractional penetration, $P_{f,i}$ (%)
ratio of the concentration of particles of specified size exiting the filter to the concentration of particles of specified size entering the filter expressed in a percentage for particle size i

$$P_{f,i} = 100 - E_{f,i} \tag{3}$$

3.8
test dust loading
mass of test dust collected by the air cleaner assembly or air filter element at a specified flow rate expressed in grams

3.9
particle measurement device / aerosol spectrometer
instrument for sizing and/or counting aerosol particles

NOTE Recommended particle counters are optical particle counters (OPC) or other counters demonstrating good correlation in measuring particle sizes such as aerodynamic particle counters (APC).

3.10
test aerosol
particles suspended in air, used for filter efficiency evaluation or dust loading

3.10.1
fractional efficiency test aerosol
aerosol used to measure the efficiency of the test filter, the concentration of which is low enough to prevent coincidence related errors in the particle counters, and does not change the filter efficiency due to loading; for this part of ISO 19713, the KCl (potassium chloride) test aerosol shall be used

NOTE The aerosol charge is reduced so that it approximates a Boltzman equilibrium charge distribution. The requirements for the efficiency challenge aerosol are given in sections 5.2.9 and 5.2.10.

3.10.2
loading test aerosol
aerosol used to load the filter, the concentration of which is high enough to allow loading of the filter in a reasonable amount of time; for this part of ISO 19713 for single-stage air cleaner assemblies and air filter elements, ISO 12103-1 A2 test dust and for pre-cleaners and multistage air cleaner assemblies ISO 12103-1 A4 test dust shall be used

NOTE The requirements for the loading test aerosol are given in section 5.2.12.1.

3.11
correlation ratio, R
ratio of the number of particles observed at the downstream sampling location to the number of particles at the upstream sampling location when no filter is installed in the test system

NOTE 1 This number may be greater or less than 1.

NOTE 2 The method of calculating the correlation ratio is given in Annex B.

3.12
Log mean diameter, $D_{l,i}$
weighted mean diameter calculated by

$$D_{li} = \left(D_i \times D_{i+1}\right)^{1/2} \quad (4)$$

where

$D_{l,i}$ = log mean diameter

D_i = lower threshold of particle size range

D_{i+1} = upper threshold of particle size range

3.13
geometric (volume equivalent) diameter, $D_{g,i}$
diameter of a sphere with the same volume as the particle being measured

NOTE For a spherical particle, it is the diameter of the sphere.

3.14
optical (equivalent) diameter, $D_{o,i}$
diameter of a particle of the type used to calibrate an optical sizing instrument that scatters the same amount of light as the particle being measured

NOTE Optical diameter depends on the instrument, the type of particle used to calibrate the instrument (usually polystyrene latex spheres), the optical properties of the particle being measured, and the size of the particle.

3.15
aerodynamic (equivalent) diameter, D_{ae}
diameter of a sphere of density 1 g/cm^3 with the same terminal velocity due to gravitational force in calm air, as the particle being measured

NOTE 1 The aerodynamic diameter will be used to report results to avoid different diameter measures due to different sizing and counting techniques.

NOTE 2 Annex F provides additional information about aerodynamic diameter.

3.16
High Efficiency Particulate Air
HEPA
for this part of ISO 19713, HEPA is defined as a filter having 99,95 % efficiency at most penetrating particle size (class H13 according to EN 1822) or 99,97 % (or higher) fractional efficiency at 0,3 µm using DOP aerosol as defined by IEST RPCC001 recommended practice

3.17
neutralization
aerosol whose charge distribution is reduced until it provides a Boltzman equilibrium charge distribution

4 Purpose

The purpose of this test code is to establish and specify consistent test procedures, conditions, equipment, and performance reports to enable comparison of filter performances of air cleaners and air filter elements used in engine air induction systems. It specifies the critical characteristics of equipment, test procedure and report format required for the consistent assessment of filter elements in a laboratory test stand with particle sizes in the range of 0,3 µm to 5 µm (optical diameter). The test procedure enables an assessment of air cleaners for pressure loss and fractional efficiency against standardized laboratory particulate challenges. Because the test methods exclude the full range of possible particulate challenges and environmental effects, the relative ranking of filters may change in service. Note that absolute comparability is only possible with air cleaners the same shape and size as well as the same position in the test duct. In order to get comparable results to the dust loading capacity, gravimetric efficiency and air flow restriction/pressure loss tests, the fractional efficiency test can be done simultaneously. (Refer to ISO 5011).

5 Test equipment, accuracy and validation

5.1 Measurement accuracy

Accuracy requirements are given in Annex E, Table E.1

5.2 Test stand configuration

Complete vehicle manufacturers air cleaner assemblies or individual air filter elements may be tested. The test stand shall consist of the following major components and shall be arranged as shown in Figure 2.

NOTE 1 Depending on configuration results may vary.

NOTE 2 Air cleaner assembly orientation will affect performance. It is recommended that air cleaner assemblies will be oriented and tested as installed in the vehicle.

Figure 2 shows a set up to measure the performance of an air cleaner assembly.

Figure 3 shows a recommended air cleaner housing to measure the performance of a panel type air filter element.

Figure 4 shows a recommended air cleaner housing to measure the performance of a cylindrical type air filter element.

5.2.1 Unit under test

The unit under test may be an air cleaner housing with filter element or elements or it may be a housing designed to hold a filter element with appropriate inlet and outlets. The unit under test may be or may include a pre-cleaner. The scope of this test procedure does not include the testing of air cleaner systems without tubular inlet and outlet connections. However designs such as perforated or louvered inlet systems could be tested with the unit under test inside a plenum that would include a tubular inlet. Non-tubular air cleaner systems outside the scope of this test procedure may still be evaluated as agreed upon between the tester and customer.

5.2.1.1 Air cleaner assembly

Air cleaner assemblies will be evaluated using the set up shown in Figure 2.

5.2.1.2 Evaluating panel air filter elements

In general, panel type air filter elements may be tested using the recommended housing shown in Figure 3.

5.2.1.3 Evaluating cylindrical/round air filter elements

Figure 4 shows a recommended housing to test cylindrical type air filter elements. This housing design is similar to the one recommended in ISO 5011.

5.2.2 Ducting

Upstream and downstream cylindrical ducting shall be made of conductive material and all components shall be commonly grounded from the aerosol inlet section to the downstream sampling section.

5.2.3 Air flow conditioning

Inlet air shall be conditioned according to the requirements of ISO 5011, (23 ± 5 °C and 55 ± 15% RH). The inlet air shall be filtered with a HEPA filter if the background particle concentration exceeds the requirements in 7.6.2.3 and 7.6.4.3.

5.2.4 Test configurations

The upstream and downstream ducting can be constructed vertically (recommended), horizontally or a combination based on space constraints. The example in this procedure shows a vertical configuration to test both air cleaners and panel type air filters. The particle samplers are located vertically in each test section, which reduces the probability of particle loss and enable sampling of large particle sizes of interest. The underlying test system design will reduce particle losses and meet the requirements of Table E.1 and E.2 in Annex E.

5.2.5 Air flow ducting

The test system should be capable of handling user specified flow rates. Further, the test system will maintain the required flow rates with air cleaner assembly pressure loss up to 10 kPa. Primary duct sizing shall conform to the following 'nominal' duct diameter and flow ranges in Table 1 below. Higher and lower flow rates may use duct sizes scaled appropriately.

Table 1 — Duct diameter vs. flow range

Nominal duct diameter mm	Area m^2	Velocity m/s	Flow range low m^3/hr	Flow range high m^3/hr	Reynolds number at low flow	 at high flow
50	0,00202	*11,6*	85	425	40407	202034
100	0,0081	*5,8*	170	850	40407	202034
150	0,0182	*5,2*	340	1700	53876	269378
200	0,0324	*5,8*	680	3400	80813	404067

NOTE A 10 µm particle with a specific gravity of 2 settles at about 6 x10^{-3} m/s in still air. At the minimum velocity of approximately 5,1 m/s this would result in only a 10 mm drop in that 10 µm particle over a 3 m run.

5.2.6 Inlet filtration

Test inlet air flow shall be filtered with a HEPA filter to remove the majority of ambient aerosol if required according to Annex E.

5.2.7 Flow uniformity

The test system shall be designed to provide uniform and steady air flow to the air cleaner assembly or to the air filter element under test as stated in the test set up.

NOTE Uniform air flow is required in sections where isokinetic samplers are located when evaluating air cleaner assemblies. Proper flow distribution will facilitate a representative aerosol sample being drawn by the isokinetic samplers. Refer to 5.2.9.3 for flow uniformity measurements.

5.2.8 Leakage

It is important to minimize leakage into the test system to obtain good data. Depending on where the leakage occurs, it can cause major errors in particle counting.

As a minimum all connections and joints should be checked for visual leakage using soap bubbles. Any known soap solution can be used for the test. Preferably, the soap solution [foam] will be applied using a brush at all connections and joints. Leaks are especially important on the clean side of the air cleaner. See Annex H for more information.

5.2.9 Fractional efficiency test aerosol generator

The aerosol generator for fractional efficiency tests shall provide a stable and homogenous aerosol concentration and size distribution. The size distribution of the aerosol shall have sufficient particles for statistical evaluation in each size class as explained in Section 7. If high-resolution particle spectrometers are used, size classes may be combined to achieve the required counts using the size ranges in 5.2.13. The total concentration of the aerosol in the test duct shall not exceed the limit of the particle counter as discussed in 5.2.13.3. The efficiency test aerosol concentration shall be low enough so there is no change in efficiency during the test as measured by the penetration data acceptance criteria in 7.6.4 (i.e. no loading effects). The size distribution and concentration stability requirements are established by the data quality requirements in clause 7.

5.2.9.1 Aerosol generation

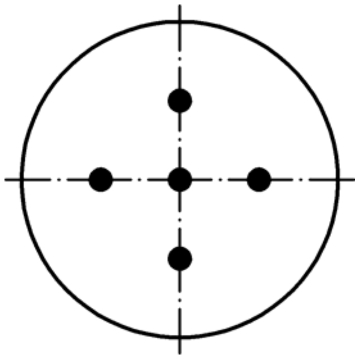
The potassium chloride aerosol generator for fractional efficiency tests shall nebulize a saline solution to produce a homogeneous mist aerosol with stable concentration and size distribution. The droplets shall be dried to form salt particles by using e.g. dry dilution air, heat, or desiccant. The efficiency test aerosol generator shall be capable of dispersing KCl (potassium chloride aerosol) at a concentration low enough to meet coincidence error requirements for the particle counter used. Compressed air used to operate and transport the challenge aerosol should be HEPA filtered and dried before entering the feeding system.

5.2.9.2 Aerosol dispersion

The efficiency test aerosol should be injected against the air flow coming from the inlet HEPA filter(s). Care should be taken to keep the injection velocity low enough to keep the larger particles in the challenge aerosol from impacting on the walls of the inlet aerosol ductwork. The objective is to allow the inlet air to turn the challenge aerosol and result in a more uniform distribution of concentration and particles size distribution across the duct even before it enters the upstream static mixer.

5.2.9.3 Aerosol uniformity

During validation of uniformity and concentration of the efficiency test aerosol, no air cleaner shall be installed in the location of the test filter (see Figure 2). Instead, a smooth straight pipe or an elbow may be used. The uniformity of the particle size distribution and the concentration of the test aerosol used for fractional efficiency tests may be verified by use of a particle-sizing instrument that will also be used in the test system. This particle-sizing instrument shall draw samples upstream and downstream of the air cleaner mounting position using the isokinetic samplers. For each test duct the minimum and maximum flow rate will be used for this evaluation [refer Table 1]. Samples shall be drawn by the isokinetic samplers along a diameter at 3 locations. Locations will be 0,15 D, 0,5 D and 0,85 D [refer to Figure 1]. The measurements will be performed in a plane along two perpendicular diameters. A minimum of 3 samples shall be drawn at each sampling location, and the resulting number distribution shall be averaged. As far as possible, the samples will be taken at random. The average values for each reported particle-size range shall not vary by more than ± 10 % for channels less than 5 μm particles among the 5 locations. This indicates that the efficiency test aerosol is uniformly distributed across the test duct, and that the centreline sample is representative of the overall challenge.



NOTE Sampling positions horizontal: 0,15 × tube diameter; 0,5 × tube diameter; 0,85 × tube diameter
Sampling positions vertical: 0,15 × tube diameter; 0,85 × tube diameter

Figure 1 — Location of isokinetic sampling points for validation

5.2.10 Aerosol neutralizer

The efficiency test aerosol shall be neutralized by passing it through a radioactive (5 millicurie minimum) or other ion generating device. The feed aerosol shall be neutralized to approach a Boltzman equilibrium charge distribution.

Generated and dispersed particles often obtain a high level of electrical charge. To obtain comparable results for different aerosols and different generation methods, the aerosol's charge distribution shall be reduced until it provides a Boltzman equilibrium charge distribution. A Boltzman equilibrium charge distribution is the minimum stable charge level and is reached by an aerosol when it is aged. This state of an aerosol cannot be generated artificially in a comparably short time. For many applications, e.g. filter testing; it is sufficient to reduce the charges, utilizing ionized air, to a minimum level. To reach this charge level quickly in a test system the efficiency aerosol is mixed with a high concentration of air ions. To create a high level of air ions, an electrostatic corona (ion blower) or radioactive air ionizer shall be used. The ionizer shall produce a sufficient concentration of bipolar air ions to mix with the aerosol so that the resulting aerosol has a charge distribution that approximates a Boltzman distribution. An aerosol that has Boltzman equilibrium charge distribution is said to be neutralized. The aerosol is not neutral in the sense that all of the particles are neutral.

- The level of neutralization shall be optimised by methods described in Annex G.
- Aerosol may become charged in transport through tubing and test duct, so the neutralization should take place as close as practical to the filter under test.
- A neutralizer is required for fractional-efficiency tests and is optional for dust-holding capacity tests.

5.2.11 Upstream and downstream sample probes

Sampling probes shall be isokinetic (local velocity of duct and probe to be equal) to within ± 20 %. The same probe design should be used before and after the filter. Sampling probes shall be located on the centreline of the test duct. Sample probes shall be located at least 7 diameters downstream of any bends, reducers, expanders etc.. The sampling probe shall be at least 4 diameters upstream of any bends, reducers, expanders etc. The samplers will also be located in the centre of duct. The probes shall be made of electrically conductive metallic tubing with a smooth inside surface. The design of the probes and sampling lines will reduce particle losses. The inlet of the sampling probes shall be sharp edged and shall be located near the centre of the duct. Both the upstream/downstream sampling lines should be identical, straight (or no more than one bend) and as short as possible. Refer to Annex I for details on isokinetic sampling. A short (≤ 50 mm) flexible connection to the particle counter may be used to allow some flexibility and reduce stress on the counter inlet. PTFE may not be used as flexible tubing. Use conductive tubing [e.g. plasticized PVC] instead. For more information on tubing, refer to Bibliography.

Sampling probe ducting to the particle counter must be set up in a way that no sedimentation of large particles takes place. i.e.

— vertical orientation of the tubing;

— sufficient flow velocity;

— short connection length between particle counter and sampling probe;

— avoidance of bends in the tubing;

— no sharp angles if bends are necessary.

5.2.12 Loading test aerosol generator (refer to ISO 5011)

Loading aerosol generation shall follow ISO 5011, 6.2.1 – 6.2.4.

5.2.12.1 Loading test aerosol (air cleaner assembly only)

A dust injector (reference ISO 5011, Figure B.2 or B.3) shall be used to disperse the loading test aerosol (ISO 12103-1 A2 test dust). Dust feeder location is shown in Figure 2. Test Dust shall be injected downstream from the upstream sample probe in order to reduce upstream optics contamination problems. The injector nozzle shall extend into the duct so that dust is injected at a point beyond the adjacent sample probe. The nozzle will extend into the duct to the entrance of the piezometer tube. The inside diameter of the extension tube will be the same as the outside diameter of the Injector nozzle. A slight offset (but close to the centre as possible) of either or both the probe and the injector extension may be required so they can extend past each other inside the duct elbow. The extension nozzle shall be centred in the duct.

5.2.12.2 Loading test aerosol dust feeder

A dust feeder capable of feeding a stable (within ± 5 %) concentration of 1g/m^3 of air at the test flow rate shall be used. Reference the dust feeder specifications and validation procedure in ISO 5011.

5.2.13 Upstream and downstream particle counters

Upstream and downstream particle counters shall be of the same model and matched as closely as possible. A single particle counter can also be used for efficiency measurements using sequential measurements alternately sampling upstream and downstream. The use of a single particle counter sampling downstream only is not allowed. The airborne particle counters shall be capable of counting particles in the 0,3 to 5 µm optical size range and 0,5 to 10,0 µm aerodynamic size range. It is also desirable for the Particle Counters to have a design incorporating clean sheath air to protect and keep the optics clean. The Particle Counters may also need to be adapted with an exhaust port that can be routed back to the test system vacuum. Without this exhaust set up the Particle Counters may not be able to perform at the rated flow. Counters must be calibrated using NIST traceable PSL (polystyrene latex) spheres (Reference ASTM F328 calibration procedure.). Correlation shall be done according to clauses 6 and 7 with an elbow and/or tube the same size as the test ducting in place of the air cleaner assembly. The inlet/outlet duct orientation shall be maintained during correlation measurements and testing. Data should also be reported in equivalent aerodynamic size ranges. Most laboratories currently use optical particle counters, however the technical advantages of using aerodynamic particle counters is also well recognized. The particle counter shall be able at a minimum, to discriminate 8 logarithmically spaced particle size classes.

There is a finite measurable delay for particle transport from the upstream sample probe to the downstream sample probe. It is possible to improve data quality by starting the downstream sample count after a delay equal to the transport time between the sample probes. The transport time can be measured or calculated.