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Inlet air cleaning equipment for internal combustion engines and compressors — Performance testing

Séparateurs aérauliques placés à l'entrée des moteurs à combustion interne et des compresseurs — Essai de rendement

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 5011 was prepared by Technical Committee ISO/TC 22, *Road vehicles*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Contents

Inlet air cleaning equipment for internal combustion engines and compressors — Performance testing

1 Scope and field of application

The purpose of this International Standard is to establish and specify uniform test procedures, conditions, equipment, and a performance report to permit the direct laboratory performance comparison of air cleaners.

The basic performance characteristics of greatest interest are air flow restriction or pressure drop, dust collection efficiency, dust capacity, and oil carry-over on oil bath air cleaners. This test code therefore deals with the measurement of these parameters.

This International Standard applies to air cleaners used on internal combustion engines and compressors, and is subdivided into two sections:

Section one: Automotive air cleaner test procedure

Section two: Industrial air cleaner test procedure

2 References

ISO 789-8, *Agricultural tractors — Test procedures — Part 8: Engine air cleaner*.[1)]

ISO 5167, *Measurement of fluid flow by means of orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full*.

3 Definitions and units

See annex A.

4 Measurement accuracy

4.1 Measure air flow rate within ±2 % of the actual value except for the variable air flow test when accuracy may be ±2 % of the maximum value of the cyclic flow rate through the cleaner.

4.2 Measure pressure drop and restriction within 0,25 mbar of the actual value.

4.3 Measure temperature within 0,5 °C of the actual value.

4.4 Measure mass within 1 % of the actual value except where noted.

4.5 Measure relative humidity with an accuracy of ±2 % R.H.

4.6 Measure barometric pressure within 3 mbar.

4.7 The measurement equipment shall be calibrated at regular intervals to ensure the required accuracy.

5 Test materials and test conditions

5.1 Test dust

5.1.1 Grade

The test dust shall be of two grades labelled fine and coarse. The chemical analysis and the particle size distribution shall conform to annex B.

5.1.2 Preparation

Before using the test dust, a quantity sufficient to cover the test requirements shall be mixed in a sealed container for a minimum of 15 min. This test dust shall then be dried to a constant mass at a temperature of 105 ± 5 °C. The test dust shall then be allowed to become acclimatized to a constant mass under the prevailing test conditions.

NOTE — To ensure a constant rate of dust feed with some dust feeders, it may be found necessary to heat the dust prior to being fed to the injector.

5.2 Test oil for oil bath air cleaners

The oil used for testing oil bath air cleaners shall be that specified by the filter manufacturer and agreed by the user for use at the appropriate ambient temperature. If an oil is not specified, the test oil shall be a heavy-duty oil and the viscosity at the temperature of the test shall be adjusted as follows:

85 mm^2/s for oil carry-over and restriction/pressure drop tests;

1) At present at the stage of draft. ISO 789-8 is referenced only for when ISO 5011 is applied to performance testing of agricultural tractors.

330 mm^2/s for efficiency and capacity tests, including an oil carry-over test after capacity test.

5.3 Absolute filter materials

5.3.1 Filter media

The absolute filter shall consist of fibreglass media with a minimum thickness of 12,7 mm and a minimum density of 9,5 kg/m^3.[1)] The fibre diameter shall be 0,76 to 1,27 µm and the moisture absorption shall be less than 1 % by mass after exposure of 50 °C and 95 % relative humidity for 96 h. The filter shall be installed with nap side facing upstream in an air-tight holder that adequately supports the media. The face velocity shall not exceed ≈ 0,8 m/s to maintain media integrity.

To reduce any subsequent errors in the measurements caused by losses of fibres or materials, the absolute filter shall be subject to a flow of at least 110 % of the rated flow of ambient air for 15 min before the test weighings.

5.3.2 Validation of absolute filter media efficiency

5.3.2.1 Arrange two absolute filters in tandem.

5.3.2.2 Perform a filter efficiency test and determine the mass increase of each absolute filter according to the test procedure given in 6.4.3 or 7.5.2.

$$\text{Absolute filter efficiency} = \frac{A}{A + B} \times 100 \ \% \qquad \ldots (1)$$

where

A is the mass increase of upstream absolute filter;

B is the mass increase of downstream absolute filter.

The absolute filter efficiency should be a minimum of 99 % for the contaminant presented to it.

5.4 Absolute filter mass

The absolute filter shall be weighed, to the nearest 0,01 g after the mass has stabilized and while in a ventilated oven at 105 ± 5 °C.

NOTE — If stabilization cannot be determined, a minimum time of 4 h is required.

5.5 Temperature and humidity

All tests shall be conducted with air entering the air cleaner at a temperature of 23 ± 5 °C. Tests shall be conducted in a relative humidity of (55 ± 15) %, the permissible variation at each weighing stage throughout each single test being ± 2 %.

NOTE — The test results of an air cleaner may be affected by the relative humidity of the air passing through it and the results of otherwise identical tests carried out near the two extremes of the permitted range of relative humidity may not be directly comparable.

1) A suitable material is commercially available. Details may be obtained from the secretariat of ISO/TC 22 or from the ISO Central Secretariat.

Section one : Automotive air cleaner test procedure

6 Dry-type air cleaner test procedure for automotive applications

This section covers dry-type air cleaners generally used in automotive applications, e.g. for internal combustion engines in passenger cars. In the case of oil bath air cleaners, use procedure according to clause 8.

6.1 General

Performance tests shall be performed on a complete air cleaner assembly or on a single air cleaner element; tests on a complete air cleaner assembly are preferred. The tests shall consist of an air flow restriction/pressure drop test, an efficiency test and a capacity test. In addition a pressure collapse test shall be performed on the air filter element.

6.2 Test equipment

6.2.1 Typical arrangements to determine resistance to air flow, dust capacity, dust removal characteristics and rupture collapse characteristics are shown in annex C, figures 2, 6, 7, 8, 9 and 11.

6.2.1.1 Use a dust feeder which when used with the dust injector in figure 3 is capable of metering dust over the range of delivery rates required. This dust feed system shall not change the primary particle size distribution of the contaminant. The air feed pressure shall be 1 bar[1)].

The dust feed system shall be validated as follows:

a) Charge the dust feeder with a pre-weighed amount of test dust.

b) Simultaneously start dust feed system and timer.

c) At 5 min intervals, determine the mass of dust dispensed. Continue mass determinations of dust increments for 30 min.

d) Adjust dust feeder until the average delivery rate is within 5 % of the desired rate and the deviation in delivery rate from the average is not more than 5 %.

6.2.1.2 Use a dust transfer tube between the dust feeder and the injector of a suitable size to maintain dust suspension.

6.2.1.3 Use the dust injector described in figure 3. The specified injector has been shown satisfactorily to feed test dust at rates up to 40 g/min. Where dust feed rates greater than this are required, more than one injector will have to be used.

It should be noted that the design of the system feeding test dust to the injector may affect this maximum rate of dust feed. The maximum attainable dust feed rate should therefore be determined prior to the dust feed/injector system being used for tests.

NOTE — Injector nozzles are subject to natural erosion. Therefore, it is recommended to use a design with replaceable parts.

6.2.1.4 Use an inlet tube conforming to figure 4. The dust injector and inlet tube shall be positioned in such a way that there is no loss of dust.

6.2.1.5 Use a manometer or other differential pressure-measuring device with the specified accuracy.

6.2.1.6 For air cleaner assembly testing, use a housing and set-up agreed upon by manufacturer and user conforming to figure 11. For air filter element testing, use a test set-up and shroud conforming to figures 2 and 5 or an arrangement as shown in figures 6 or 7. Where the test equipment is as shown in figure 6, the dust is fed into the chamber and, to ensure that it does not adhere to the walls and is evenly distributed, dry compressed air jets on flexible tubing should be provided in the test chamber, arranged to agitate any dust that settles out.

When using compressed air for agitating dust, care shall be taken not to eject any dust out of the chamber. To ensure that no dust is ejected from the chamber, a negative pressure should be maintained between the chamber and the atmosphere.

6.2.1.7 Use an outlet tube conforming to figure 4. The cross-section shall be the same as the air cleaner outlet. In case of non-uniform flow conditions caused by special outlet tubes, special precautions may be required.

6.2.1.8 Use an air flow rate measuring system having the accuracy described in 4.1.

Validate the air flow rate measuring system. The air flow meter shall be of an acceptable design such as a calibrated orifice and manometer conforming to ISO 5167. The orifice unit shall be permanently marked such that it can be identified after calibration. Corrections shall be made for variations in absolute pressure and temperature at the meter inlet and the air flow rate shall be expressed in cubic metres per minute corrected to Standard Conditions (see annex A, clause A.1.19).

6.2.1.9 Use an air flow rate control system capable of maintaining the indicated flow rate within 1 % of the selected value during steady-state and variable air flow operation.

6.2.1.10 Use a blower/exhauster, for inducing air flow through the system, which has adequate flow rate and pressure characteristics for the filters to be tested. Pulsation of flow rate shall be so low that it is not measurable by the flow rate measuring system.

1) 1 bar = 10^2 kPa = 10^5 Pa

6.2.2 Requirements only if using absolute filter method

6.2.2.1 Use an oven capable of maintaining the temperature for stabilizing absolute filter mass (see 5.4).

6.2.2.2 Use a balance mounted on the oven (balance pan inside oven) having the required accuracy for weighing absolute filters (see 5.4).

6.3 Restriction and pressure drop test

6.3.1 The purpose of this test is to determine the restriction/pressure drop/pressure loss across the unit under test which will result when air is passed through under predetermined conditions. Airflow restriction or pressure drop is measured with a clean filter element, or elements at five equally spaced airflows between 50 % and 150 % of rated air flow or as agreed upon between the user and the manufacturer. This data is presented in curve form.

6.3.2 Condition the unit at the airflow at which the unit is tested for at least 15 min under temperature and humidity conditions as specified in 5.5 until mass stabilization has been reached.

6.3.3 Set up test stand as shown in figures 8 or 9 and 14 or 15. Seal all joints to prevent air leaks. Connect pressure taps.

6.3.4 Measure and record the restriction and the pressure drop versus flow rate at approximately 50 %, 75 %, 100 %, 125 % and 150 % of rated air flow or as agreed upon between user and manufacturer.

6.3.5 Record ambient temperature, pressure and relative humidity.

6.3.6 Correct recorded restriction and pressure drop to standard conditions in accordance with annex H.

6.3.7 For pressure loss determination, use the formulae given in annex A clause A.1.13.

6.3.8 Plot the results as shown in annex F or equivalent.

6.4 Efficiency test

6.4.1 The purpose of this test is to determine the retention capabilities of the unit under test. This test can be conducted with either constant or variable air flow and with coarse dust or fine test dust. If desired, efficiency tests can be performed concurrently with capacity tests (see 6.5). Determination of efficiency at constant test air flow can be performed at the rated air flow or any percentage thereof as agreed upon by the user and manufacturer. Determination of efficiency at variable air flow can be performed using variable air flow cycle according to 6.7.

6.4.2 Three types of efficiency tests can be performed:

a) full life efficiency determined when the terminal condition, i.e. the terminating pressure drop, is reached;

b) incremental efficiency determined when, for example, 10 %, 25 % and 50 % of the terminating pressure drop minus the initial pressure drop are reached;

c) initial efficiency determined after the addition of 20 g of contaminant or the number of grams numerically equivalent to 6 times the air flow in cubic metres per minute, whichever is greater.

6.4.3 Test procedure — Absolute filter method

6.4.3.1 Based on the test flow, calculate the test dust feed rate using a dust concentration of 1,0 g/m^3 of air; in special cases (e.g. small filters) 0,25, and 0,5 g/m^3 may be allowed.

6.4.3.2 Condition unit under test according to 6.3.2, measure and record the mass.

6.4.3.3 Weigh the absolute filter after the mass has stabilized.

6.4.3.4 Set up test stand as shown in figure 11 for air cleaner assemblies, or as shown in figure 2, 6 or 7 for air filter elements. Seal all joints to prevent air leakage.

6.4.3.5 Record temperature and relative humidity.

6.4.3.6 Prepare specified test dust according to 5.1 and weigh out quantity required for test in a suitable test container. For full life efficiency tests, the quantity should be approximately 125 % of estimated capacity of unit under test. Record mass of container and dust to nearest 0,1 g.

6.4.3.7 Start air flow through the test stand and stabilize at test flow rate. Record pressure drop.

6.4.3.8 Load dust feeder from dust container and adjust feed rate to inject dust at the concentration calculated in 6.4.3.1. Reload dust feeder from dust container throughout test as necessary.

6.4.3.9 At prescribed time intervals (a minimum of five points is recommended), record pressure drop at test flow and elapsed test time.

6.4.3.10 Continue test until the specified terminal condition is reached.

6.4.3.11 Record temperature and relative humidity.

6.4.3.12 The dust on the exterior surfaces of a cleaner assembly or any which may have settled in the test chamber/ducting on the inlet side of a test element shall be collected carefully and transferred to the preweighed dust container together with any dust remaining in the dust feeder.

6.4.3.13 Reweigh the dust container and subtract the result from the mass recorded in 6.4.3.6. The difference is the mass of dust fed to the unit under test.

6.4.3.14 Carefully remove the unit under test without losing any dust. Note any evidence of seal leakage or unusual conditions. Weigh, in grams, to within 1 % of the actual value. The increase in mass of the unit under test is this mass minus the mass determined in 6.4.3.2. In the full life efficiency test, this increase in mass is the capacity of the unit under test.

6.4.3.15 Brush any observed dust on the downstream side of the test unit onto the absolute filter. Carefully remove the absolute filter. Repeat 6.4.3.3 and determine the difference in mass. This is the increase in mass of the absolute filter.

6.4.3.16 Calculate the material balance of the test dust. This value must be within the range of 0,98 to 1,02 to be a valid test.

$$\text{Material balance of test dust} = \frac{\text{Increase in mass of absolute filter} + \text{Increase in mass of unit under test}}{\text{Total mass of dust fed}}$$

6.4.3.17 Calculate the efficiency by the following method:

$$\text{Efficiency} = \frac{\text{Increase in mass of unit under test}}{\text{Increase in mass of unit under test} + \text{Increase in mass of absolute filter}} \times 100\,\% \qquad \ldots (2)$$

6.4.4 Test procedure — Direct weighing method

Where a suitable large, accurate balance is available it is permissible to use a direct weighing method of assessing the performance of the unit under test. In such cases the air cleaner under test shall be tested according to the procedure in 6.4.3 omitting the operations described in 6.4.3.3; 6.4.3.15; 6.4.3.16 and 6.4.3.17. Calculate the efficiency as follows:

$$\text{Efficiency} = \frac{\text{Increase in mass of unit under test}}{\text{Total mass of dust fed}} \times 100\,\% \qquad \ldots (3)$$

The test report should indicate the method of efficiency determination used.

6.5 Capacity test

6.5.1 The purpose of this test is to determine the total mass gain of the unit under test at the terminating condition. This test can be conducted with either constant or variable air flow and with coarse or fine test dust contaminant. If desired, capacity determination can be performed concurrently with the efficiency test (see 6.4).

6.5.2 Condition the unit according to 6.3.2. Perform test as described in 6.4.3 or 6.4.4.

6.5.3 Assuming a constant ratio of elapsed time versus dust feed of the test unit, record data, plot curve of restriction versus mass gain. Refer to 6.4.3.9 for restriction and time interval data. Use the following formula to determine the mass gain values:

$$\text{Increase in mass at end of each time interval} = \frac{\text{Total time to end of interval}}{\text{Total time to end of test}} \times \text{Total increase in mass of unit under test}$$

6.5.4 In the case of the terminal condition being the restriction, it does not include the restriction added by the dust mixing device and test shroud.

6.6 Filter element pressure collapse test

6.6.1 The purpose of this test is to determine the ability of an air filter element to withstand a specified differential pressure and/or to determine the differential pressure at which collapse occurs.

6.6.2 Set up test stand to perform the basic dust capacity test in accordance with figures 2, 6, 7 or 11. The element from the prior capacity or efficiency test or a new element can be used for this test.

6.6.3 Increase air flow through stand and if necessary, feed dust at any convenient rate until the specified pressure drop is reached or until element collapse is indicated by a decrease in pressure drop or increase in air flow.

6.6.4 Record maximum pressure drop attained, reason for terminating test and condition of element after test.

6.7 Variable air flow test

6.7.1 As an option to the constant air flow test, a variable air flow test can be carried out by using a variable air flow cycle similar to figure 1.

6.7.2 In the case of oil bath air cleaners and large air cleaners (e.g. flow rate > 5 m^3/min), the duration of every partial flow section may be 5 min instead of 1 min.

6.7.3 Based on the avarage test flow for the cycle being used, calculate the dust feed rate as in 6.4.3.1. Dust feed rate should remain constant.

6.7.4 All pressure drop determinations shall be made at maximum air flow.

6.7.5 Perform tests using variable air flow in place of the constant air flow, however, with the following changes:

After the end of each cycle the pressure drop shall be determined at the maximum flow. The efficiency shall be determined at least after 3 cycles if the duration of partial flow section is 1 min. and after every cycle if the duration of partial flow section is 5 min., and after the end of test.

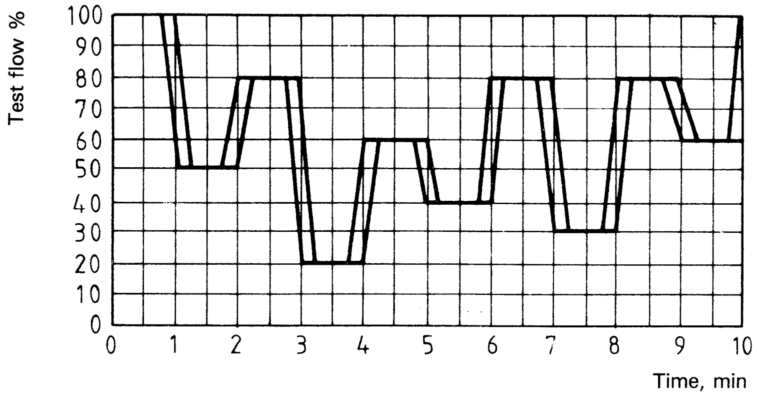

Figure 1 — Typical variable flow cycle (average flow 60 %)

6.8 Presentation of data

For presentation of data, use annex D, F and G or equivalent.

Section two: Industrial air cleaner test procedure

7 Dry-type air cleaner test procedure for industrial applications

This section covers air cleaners generally used in non-automotive or industrial applications.

NOTE — Additional specific test procedures for air cleaners fitted to agricultural tractors (see ISO 789-8) may be necessary.

7.1 General

7.1.1 Performance tests shall be performed on a complete air cleaner including precleaner, primary element, and secondary element, if normally provided. The tests shall consist of an airflow restriction/pressure drop test, an initial efficiency test and a combined efficiency and dust capacity test.

7.1.2 It is difficult, if not impossible, to select a test dust size distribution and concentration which will be representative of all service conditions. Therefore, based on primarily practical considerations, the different types of air cleaners have been classified as to their most probable service conditions, and the test dust grade and concentration selected accordingly from table 1.

Table 1 — Test dust and concentration

Air cleaner type	Test dust	Concentration
Single stage	Coarse or fine	1 g/m³
Multistage	Coarse or fine	1 to 3 g/m³

7.2 Test equipment

7.2.1 Typical test arrangements are shown in figures 12, 14 and 15.

7.2.2 The dust feeding system shall be the same as described in 6.2.1.1.

7.2.3 The dust transfer tube and dust injector shall be the same as described in 6.2.1.2 and 6.2.1.3.

7.2.4 Tubular air cleaner inlet: the cross-sectional area of the upstream piezometer tube shall be the same as the air cleaner inlet (see figure 4).

7.2.5 Rectangular or open face inlet: the same as 7.2.4 except the overall length and placement of the piezometer shall be 24 and 16 times the hydraulic radius respectively (hydraulic radius = area divided through perimeter).

7.2.6 The peripheral air inlet or stack type precleaners shall be tested in a chamber which ensures the even distribution and delivery of test dust to the inlet of the unit. Care should be taken in the design of the chamber to ensure that all the test dust is fed to the filter. If dust settling occurs, then compressed air jets may be used to re-entrain the test dust. Typical examples of chambers are shown in figure 13.

When using compressed air for agitating dust, care should be taken not to eject dust out of the chamber. To ensure that no dust is ejected, a negative pressure should be maintained between the chamber interior and the atmosphere.

7.2.7 The outlet downstream piezometer tube shall be as shown in figure 4: the inside diameter of the outlet downstream piezometer tube shall be the same as the air cleaner outlet tube. In the case of non-uniform flow conditions caused by special outlet tubes, special precautions may be required.

7.2.8 The absolute filter shall comprise the material specified in 5.3.

7.2.9 Use an air flow measuring system as described in 6.2.1.8, an air flow control system as described in 6.2.1.9 and a blower/exhauster as described in 6.2.1.10.

7.3 Restriction and pressure drop test

Test shall be performed according to 6.3.

7.4 Initial efficiency test

7.4.1 Test procedure — Absolute filter method

7.4.1.1 Condition the unit to the air flow at which the unit is tested for at least 15 min under temperature and humidity conditions as specified in 5.5.

If desired, absolute filter pad and air cleaner conditioning can be performed concurrently.

7.4.1.2 Weigh the absolute filter pad as specified in 5.4 and record mass before assembly within absolute filter housing.

7.4.1.3 Prepare test dust according to 5.1.1 of the fine grade and weigh out a quantity equal to 11 g/m² of primary element media area. Place the preweighed dust in the dust feeder.

7.4.1.4 If it is practicable, weigh the complete unit under test.

7.4.1.5 Weigh dust feed system with dust and record mass.

7.4.1.6 Set up air cleaner as shown in figure 12 or 13, sealing all connections to prevent air leakage, and maintain air flow at test flow rate.

7.4.1.7 Start dust feeder and adjust feed rate to maintain continuous injection of complete quantity of test dust over a period of 30 min.