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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
ISO 5011 : 1988 (E)

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 mm²/s for oil carry-over and restriction/pressure drop tests;

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[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 mm²/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/m³.[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.

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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.

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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/m³ of air; in special cases (e.g. small filters) 0,25, and 0,5 g/m³ 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 m³/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.
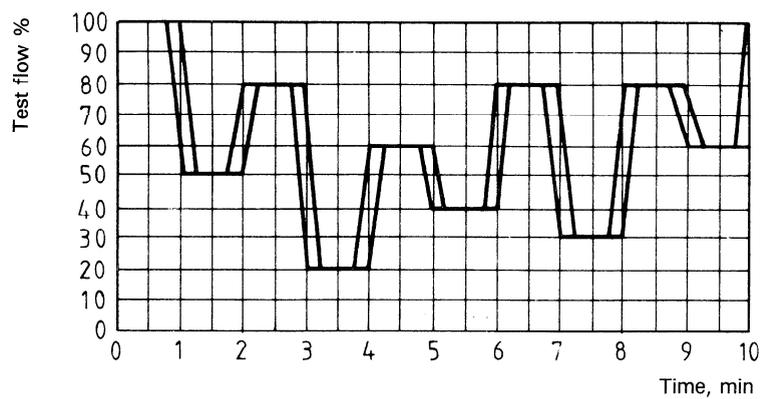
Figure 1 — Typical variable flow cycle (average flow 60 %)

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/m^3
Multistage	Coarse or fine	1 to 3 g/m^3

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/m^2 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.

7.4.1.8 Record temperature and relative humidity.

7.4.1.9 Brush any observed dust on the downstream side of the test unit onto the absolute filter. Carefully remove and reweigh the absolute filter pad as in 5.4 and calculate increase in mass by comparison with mass recorded in 7.4.1.2.

7.4.1.10 Collect all dust which has settled on exterior surface, inlet ducting, or test chamber or the inlet side of the test unit and transfer this dust to the dust feed system.

7.4.1.11 Reweigh dust feed system to within 1 % of actual value, and calculate mass of dust injected into the test cleaner by comparison with initial mass of dust feed system from 7.4.1.5.

7.4.1.12 If it is practicable, reweigh the complete unit under test.

7.4.1.13 Calculate the initial efficiency as follows:

$$\text{Initial efficiency} = \frac{\text{Mass of dust fed} - \begin{array}{c}\text{Increase in mass}\\\text{of absolute}\\\text{filter}\end{array}}{\text{Mass of dust fed}} \times 100\% \quad \dots (4)$$

7.4.1.14 If it was practicable to weigh and reweigh the complete unit under test, efficiency may be calculated with formula (2) in 6.4.3.17. Validation of test shall be carried out according to 6.4.3.16.

7.4.2 Test procedure — Direct weighing method

Where a suitable large, accurate balance is available, it is permissible to use a direct weighing method of assessing initial efficiency. In such cases the air cleaner under test shall be tested according to the procedure detailed under 7.4.1 with the following changes:

a) Weigh the air cleaner under test before and after the test and record the increase in mass of the test cleaner.

b) Disregard operations 7.4.1.2; 7.4.1.9 and 7.4.1.13.

c) Calculate initial efficiency as follows:

$$\text{Initial efficiency} = \frac{\begin{array}{c}\text{Increase in mass}\\\text{of test unit}\end{array}}{\text{Mass of dust fed}} \times 100\% \quad \dots (5)$$

7.5 Full life efficiency and capacity test

7.5.1 Air cleaner dust capacity is a function of air cleaner size, airflow test, terminal condition and grade of test dust employed. To permit a comparison between different air cleaners, the dust capacity is, therefore, determined at test air flow to the specified terminal condition with four intermediate points. In the absence of such a specification, a restriction of 60 mbar should be used as the terminal condition.

In case of the terminating condition being the restriction, it does not include the restriction added by the dust mixing duct

and test shroud. The test can be conducted with either constant or variable air flow according to 6.7.

7.5.2 Test procedure — Absolute filter method

7.5.2.1 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.

7.5.2.2 Weigh the absolute filter pad as specified in 5.4 and record mass before mounting it within absolute filter housing.

7.5.2.3 Prepare a sufficient quantity of test dust according to 5.2 of the selected grade and store in a suitable container in test area to stabilize to constant mass. The amount of dust, calculated according to the relevant concentration specified should be more than sufficient to cover the expected duration of the test. Record the mass.

7.5.2.4 If it is practicable, weigh the complete unit under test and record the mass.

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

7.5.2.6 Load dust feeder from dust container and adjust feed rate to coincide within the concentration specified in 7.1.2. Reload the dust feeder from the dust container as necessary throughout the test.

7.5.2.7 Record temperature and relative humidity.

7.5.2.8 Record at least four intermediate values of the mass of dust fed to the test unit (feed rate × time) and the corresponding restriction/pressure drop at approximately uniform time intervals.

7.5.2.9 Correct restriction/pressure drop/pressure loss values to standard conditions according to annex H and plot against dust fed to the air cleaner as shown in annex F. Label ordinate "restriction" or "pressure drop" or "pressure loss" as appropriate.

7.5.2.10 Continue the test until the specified terminal condition is attained.

NOTE — Certain types of air cleaner, e.g. cyclone air cleaners, have no limiting dust capacity. In such cases, the test shall not be stopped before the cleaner has been fed with a sufficient quantity of dust for its efficiency to be determined as accurately as required. The minimum quantity shall be 50 g of dust.

7.5.2.11 Brush any observed dust on the downstream side of the test unit onto the absolute filter. Carefully remove and reweigh the absolute filter pad and determine the increase in mass by comparison with mass recorded in 7.5.2.2.

7.5.2.12 Collect all dust which has settled on exterior surfaces/ducting/test chamber or the inlet side of the test unit and transfer this dust to the original dust container.

Transfer all unused dust in the dust feed device to the original dust container and reweigh the container and dust. By subtraction of this mass from the mass recorded in 7.5.2.3, determine the total mass of dust injected into the test unit.

7.5.2.13 If it is practicable, reweigh the complete unit under test.

7.5.2.14 Calculate the capacity of the unit under test as follows:

$$\text{Capacity} = \frac{\text{Total mass of}}{\text{dust fed}} - \frac{\text{Increase in mass of}}{\text{absolute filter}} \quad \ldots (6)$$

7.5.2.15 Calculate the efficiency as follows:

$$\text{Full life efficiency} = \frac{\text{Mass of dust fed} - \text{Increase in mass of absolute filter}}{\text{Mass of dust fed}} \times 100\% \quad \ldots (7)$$

7.5.2.16 If it was practicable to weigh and reweigh the complete unit under test, efficiency may be calculated with formula (2) in 6.4.3.17. Validation of test shall be carried out according to 6.4.3.16.

7.5.3 Test procedure — Direct weighing method

Where a suitably large, accurate balance is available, it is permissible to use a direct weighing method of assessing capacity and accumulative efficiency. In such cases the air cleaner under test shall be tested according to the procedure detailed in 7.5.2 with the following changes:

a) Weigh the air cleaner under test before and after the test and record the increase in mass of the test unit. This mass is the capacity of the unit under test.

b) Disregard operations 7.5.2.2; 7.5.2.11; 7.5.2.14 and 7.5.2.15.

c) Calculate efficiency as follows:

$$\text{Full life efficiency} = \frac{\text{Increase in mass of unit under test}}{\text{Total mass of dust fed}} \times 100\% \quad \ldots (8)$$

7.6 Presentation of data

For presentation of data, use annexes E, F and G or equivalent.

7.7 Scavenged air cleaner performance test

7.7.1 General

7.7.1.1 This clause describes those variations in the test procedures specified in this International Standard that are

necessary for the testing of air cleaners that are scavenged in operation by a proportion of the air input that is bled off for this purpose.

7.7.1.2 The flow equation is as follows:

$$\dot{V}_B = \dot{V}_A - \dot{V}_C$$

where

$\dot{V}_A$ is the inlet air flow;

$\dot{V}_B$ is the cleaned air flow;

$\dot{V}_C$ is the scavenged air flow.

7.7.2 Additional equipment

A typical test arrangement is shown in figure 16.

7.7.2.1 Exhauster

An exhauster shall be provided to handle the scavenged flow and shall be capable of maintaining it at a steady state during the whole test.

7.7.2.2 Air flow meter

An air flow meter shall be provided to measure the scavenged air flow rate having an accuracy in accordance with 4.1.

7.7.2.3 Pressure tapping

The pressure tappings used shall conform to figure 4.

7.7.2.4 Scavenged air filter

A filter shall be provided in the scavenged air flow of sufficient efficiency and capacity to protect the apparatus downstream of it against the effects of the dust in the scavenged air flow.

7.7.3 Restriction and pressure drop test

The test shall be conducted in accordance with 6.3 with the following changes:

a) The scavenged air flow shall be started before the cleaned air flow.

b) The scavenged air flow shall preferably be stopped at the same time as the cleaned air flow; it shall not be stopped before the cleaned air flow.

c) Measurements shall be made with the scavenged air flow adjusted to be a specified proportion of the cleaned air flow (interaction between the scavenged air flow and the cleaned air flow may require some re-adjustment to be made to maintain this proportion).

7.7.4 Full life efficiency and capacity test

7.7.4.1 Most of the air cleaners that are scavenged in operation by a proportion of the air input that is bled off for this pur-

pose are comparatively large in size. The absolute filter test method is therefore recommended.

7.7.4.2 Unless otherwise specified, the scavenged air flow shall be maintained at a fixed proportion of the cleaned air flow, as agreed between the manufacturer and the user.

7.7.4.3 The test dust concentration shall be that in the inlet air flow.

7.7.4.4 The scavenged air flow shall be started before the cleaned air flow.

7.7.4.5 The scavenged air flow should preferably be stopped at the same time as the cleaned air flow; it shall not be stopped before the cleaned air flow.

7.7.4.6 The efficiency of the air cleaner shall be calculated in accordance with formula (9) as follows:

$$\text{Full life efficiency} = \frac{d_1 - d_2}{d_1} \times 100 \text{ \%} \qquad \ldots (9)$$

where

d_1 is the average dust concentration at the inlet of the air cleaner $= M_1/V_1$

d_2 is the average dust concentration at the outlet of the air cleaner $= M_2/V_2$

in which

M_1 is the mass of dust fed to the air cleaner;

M_2 is the mass of dust leaving the clean side of the air cleaner;

V_1 is the volume of air fed to the air cleaner;

V_2 is the volume of air leaving the clean side of the air cleaner.

7.7.4.7 The capacity of the unit shall be calculated in accordance with formula (10) as follows:

$$\text{Capacity} = \left(\begin{array}{c}\text{Total mass of} \\ \text{dust fed}\end{array} \times \frac{\text{Cleaned air flow}}{\text{Inlet air flow}}\right)$$
$$- \text{ Increase in mass of absolute filter} \qquad \ldots (10)$$

7.7.5 Presentation of data

For presentation of data, use annexes E, F and G or equivalent.

7.8 Precleaner performance test

7.8.1 Precleaner dust removal

When testing with precleaners that employ either an automatic dust unloading valve, or a dust cup, the following provisions

with respect to dust removal are to be made. For precleaners that are scavenged see 7.7.

7.8.1.1 Automatic unloader valve

For test purposes, a sealed jar or container may be substituted for the unloader valve.

7.8.1.2 Dust cup

The dust shall not be emptied during the dust capacity test until at least two-thirds full. Also, the number of servicings shall be noted in the performance report.

NOTE — The user should be aware that the above provisions ensure optimum air cleaner performance and is advised to consult the air cleaner manufacturer for specific instructions or test procedures for any given air cleaner installation.

7.8.2 Precleaner efficiency

The precleaner efficiency shall be determined during the dust capacity test based on the total mass of dust fed to the air cleaner and either the sum of the gain in mass of the primary and secondary elements and absolute filter, or the mass of dust removed by the precleaner.

7.8.3 Presentation of data

For presentation of data, use annexes E, F and G or equivalent.

8 Oil bath air cleaner test procedure for industrial application

8.1 General

Performance tests shall be performed on a complete oil bath air cleaner. The tests shall consist of a restriction/pressure drop test, an oil carry-over test, a combined capacity and efficiency test and a recovery test.

8.2 Test equipment and conditions

8.2.1 Test oil in accordance with 5.2.

8.2.2 Test dusts, prepared according to 5.11, shall be used at a concentration of 1 g/m^3 air flow. Either fine or coarse test dust may be prescribed.

8.2.3 All tests shall be carried out with the air cleaner in a level position unless otherwise specified by the user or the particular section of the test procedure. Before the test the air cleaner shall be prepared in the following manner.

a) Thoroughly wash and dry the air cleaner.

b) Fill the oil cup/reservoir to the indicated level with the specified oil.

c) Allow air to flow through the cleaner at rated air flow for 15 min.

d) Stop air flow or allow a draining period of 15 min.

e) Refill the cup/reservoir with oil to the specified level for the particular test.

8.2.4 A typical arrangement for testing oil bath air cleaners of the tubular inlet type is shown in figure 12.

8.2.5 Air cleaners of the peripheral inlet type 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 a compressed air jet 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.

8.2.6 All tests shall be carried out under the conditions detailed in 5.5.

8.3 Restriction and pressure drop test

Tests shall be performed according to 6.3 with the following changes.

a) Perform the restriction/pressure drop test versus flow rate at more than 100 % only as long as no oil carry-over occurs.

b) The air flow shall be maintained until the pressure drop across the air cleaner has stabilized.

8.4 Oil carry-over test

8.4.1 Dust shall not be fed to the cleaner during this test.

8.4.2 The cleaner, prepared in accordance with 8.2.3, shall be assembled, weighed and attached to the test rig. The room temperature and humidity shall be recorded. The recommended oil shall be used for the test and the test shall be conducted at a temperature to be agreed between the user and manufacturer.

8.4.3 Each oil bath air cleaner tested in accordance with this clause shall be tested in one of two ways, as agreed between the manufacturer and the purchaser. The two ways are as follows :

a) a test at a single flow rate, above the rated flow, as agreed between the manufacturer and the purchaser, to determine whether or not oil carry-over occurs at that flow rate;

b) a test at increasing flow rates, starting at 80 % of the rated flow and increasing in increments of 10 % of the rated flow, to determine the air flow rate at which oil carry-over occurs.

8.4.4 The test in 8.4.3 a) shall be conducted for a minimum of 60 min for each filter tested. The test in 8.4.3 b) shall be conducted for at least 10 min at each flow rate.

8.4.5 At the end of the test at each flow rate, the air cleaner outlet shall be examined for signs of oil carry-over using an observation chamber with a target plate covered with a suitable paper which turns transparent at the impact of oil droplets (see annex C, figure 17).

8.4.6 At the end of the test described in 8.4.3, the air cleaner shall be removed and weighed again and the loss of oil by mass shall be recorded.

8.4.7 If an oil bath air cleaner is to be or may be operated in an inclined position, the tests described in 8.4.3 shall be repeated in full with the cleaner inclined at the angles and directions in which it may be required to operate, with such additional margins as may be agreed between the manufacturer and the purchaser.

8.5 Full life efficiency and capacity test

The dust capacity/efficiency characteristics of oil bath air cleaners shall be assessed by the methods described in 7.5 for industrial air cleaners with the exceptions detailed below. It is essential, when testing oil bath cleaners, to ensure that no oil carry-over occurs at the rated test air flow. Significant oil losses of this kind will affect the masses recorded for the absolute filter and/or unit under test, which will influence the final test results. The tests can be conducted with either constant or variable air flow according to 6.7. The exceptions in test procedures are the following.

a) Condition the unit under test according to 8.2.3, measure and record the mass.

b) Use the test dust at the concentration detailed in 8.2.2.

c) At the end perform an oil carry-over test according to 8.4.3 b).

8.6 Recovery test

After the capacity test, drain and clean the unit under test to the precise instructions recommended by the cleaner manufacturer and resume the test without dust feed for 20 min, noting the restriction/pressure drop at 5 min intervals during this period. The recovery capabilities of the test unit will be assessed by comparison of these results with those obtained for a new, unused test cleaner.

8.7 Presentation of data

For presentation of data, use annexes E, F and G or equivalent.

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Annex A

Definitions and units

A.1 Definitions

A.1.1 air filter; air cleaner: Device which removes particles suspended in the fresh charge as it is drawn into the engine.

A.1.2 filter element: Replaceable part of the air filter, consisting of the filter material and carrying frame.

A.1.3 unit under test: Either a single air cleaner element or a complete air cleaner assembly.

A.1.4 single stage air cleaner: Air cleaner which does not incorporate a separate precleaner.

A.1.5 multistage air cleaner: Air cleaner consisting of two or more stages, the first usually being a precleaner followed by one or more filter elements. If two elements are employed, the first shall be called the primary element and the second one shall be called the secondary element.

A.1.6 precleaner: Device usually employing inertial or centrifugal means to remove a portion of the test dust prior to reaching the filter element.

A.1.7 test air flow: Measure of the quantity of air drawn through the air cleaner outlet per unit time. The flow rate shall be expressed in cubic metres per minute corrected to standard conditions.

A.1.8 rated air flow: Flow rate specified by the user or manufacturer; it may be used as the test air flow.

A.1.9 scavenge air flow: Measure of the quantity of air employed to remove the collected dust from a precleaner, expressed as a percentage of test air flow.

A.1.10 static pressure: Pressure in a duct, at the observed air flow rate, measured by connecting a pressure gauge to a hole or holes drilled in the wall of the duct.

In the tests specified in this International Standard, a static pressure is measured by a manometer (usually a liquid manometer) as a negative pressure difference against the atmospheric pressure and in the formulae is treated as a positive value.

A.1.11 restriction: Static pressure measured immediately downstream of the unit under test.

A.1.12 pressure drop: Difference in static pressure measured immediately upstream and downstream of the unit under test.

A.1.13 pressure loss: Measure of the loss of energy caused by an air cleaner at the observed air flow rate, expressed as the pressure drop corrected for any difference in the dynamic head at the measuring points.

When pressure drop across an air cleaner has been measured ($p_2 - p_1$ in table 2), any difference in the cross-sectional area of the ducts at the upstream and downstream pressure tapping points must be taken into account in determining the pressure loss across the air cleaner. The pressure loss across the cleaner is given by the equation:

$$\Delta p_l = \Delta p_d - \Delta p_c$$

where

Δp_d is the measured pressure drop

$$\Delta p_c = \frac{\varrho \cdot v_2^2}{2} - \frac{\varrho \cdot v_1^2}{2}$$

in which

ϱ is the density of the air;

v_1 the velocity of the air in the duct at the upstream pressure tapping point;

v_2 is the velocity of the air in the duct at the downstream pressure tapping point.

When the upstream pressure is equal to atmospheric and therefore only the static pressure in the downstream duct has been measured, the pressure loss across the air cleaner can be calculated from the dynamic head required to accelerate the air from rest to its velocity in the downstream duct. The pressure loss across the cleaner is then given by the equation:

$$\Delta p_l = \Delta p_r - p_{dynamic}$$

$$= p_2 - \frac{\varrho \cdot v_2^2}{2}$$

where

$\Delta p_r = p_2$ is the restriction/static pressure at the downstream pressure tapping point;

ϱ is the density of the air;

v_2 the velocity of the air at the downstream pressure tapping point.

Table 2 — Illustration of restriction, pressure drop and pressure loss of an air cleaner

Term	Air cleaner drawing air from the atmosphere	Air cleaner drawing air through an inlet duct
Static pressure upstream of air cleaner	—	p_1
Restriction = Static pressure downstream of air cleaner	$\Delta p_r = p_2$	$\Delta p_r = p_2$
Pressure drop	—	$\Delta p_d = \Delta p_r - p_1$ $= p_2 - p_1$
Pressure loss	$\Delta p_l = \Delta p_r - p_{dynamic}$ $= p_2 - \dfrac{\varrho \cdot v_2^2}{2}$	$\Delta p_l = \Delta p_d - \Delta p_c$ $= (p_2 - p_1) - \dfrac{(\varrho \cdot v_2^2) - (\varrho \cdot v_1^2)}{2}$

A.1.14 absolute filter: Filter downstream of the unit under test to retain the contaminant passed by the unit under test.

A.1.15 efficiency: Ability of the air cleaner or the unit under specified test conditions to remove contaminant.

A.1.16 capacity: Quantity of contaminant removed by the unit under test in producing specified terminal conditions; e.g. restriction, oil carry-over.

A.1.17 oil carry-over: Appearance of oil at the cleaner outlet.

A.1.18 test terminal condition: Condition, relating to an air cleaner, the occurrence of which signifies the end of the test.

A test terminal condition may be, for example, any one of the following:

— the restriction or the pressure drop reaches a specified or agreed value;

— the dust-removing efficiency or some other performance parameter falls to a specified or agreed value;

— oil carry-over occurs;

— a dust pot becomes filled.

A.1.19 standard condition: All air flow measurements are to be corrected to a standard condition of 20 °C at 1 013 mbar.

A.2 Units

The following applied units, according to ISO 1000, are used:

	Symbol	Unit
flow	$\dot{V}$	m³/min
velocity	v	m/s
density	ϱ	kg/m³
mass flow rate	$\dot{m}$	kg/min
pressure	p	bar[1]
restriction	Δp_r	mbar
pressure drop	Δp_d	mbar
pressure loss	Δp_l	mbar
area	A	m²
volume	V	m³

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[1] 1 bar = 10^5 Pa = 100 kPa; 1 mbar = 100 Pa

Annex B

Test dust [1]

B.1 Typical chemical analysis

See table 3.

Table 3 — Chemical analysis of test dust

Chemical	Percentage of mass %
SiO_2	67 to 69
Fe_2O_3	3 to 5
Al_2O_3	15 to 17
CaO	2 to 4
MgO	0,5 to 1,5
Total alkalis	3 to 5
Ignition loss	2 to 3

B.2 Particle size distribution

**B.2.1** The particle size distribution by mass as measured with a Roller analyser is given in table 4.

Table 4 — Particle size distribution, Roller analyser percentage by mass

Size μm	Fine grade %	Coarse grade %
0 to 5	39 ± 2	12 ± 2
5 to 10	18 ± 3	12 ± 3
10 to 20	16 ± 3	14 ± 3
20 to 40	18 ± 3	23 ± 3
40 to 80	9 ± 3	30 ± 3
80 to 200	—	9 ± 3

B.2.2 The particle size distribution by mass as measured by the Andreason method is given in table 5.

Table 5 — Particle size distribution, Andreason method percentage by mass

Size μm	Fine grade %	Coarse grade %
< 125	—	98,5 ± 1,5
< 75	98 ± 2	84,5 ± 5,5
< 40	84 ± 3	51 ± 2
< 20	67 ± 3	32 ± 2
< 10	49 ± 3	19,5 ± 1,5
< 5	35 ± 3	10 ± 1
< 2	17,5 ± 2,5	—

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1) This test dust is commercially available. Details may be obtained from the Secretariat of ISO/TC 22 or from the ISO Central Secretariat.

Annex C

Test equipment
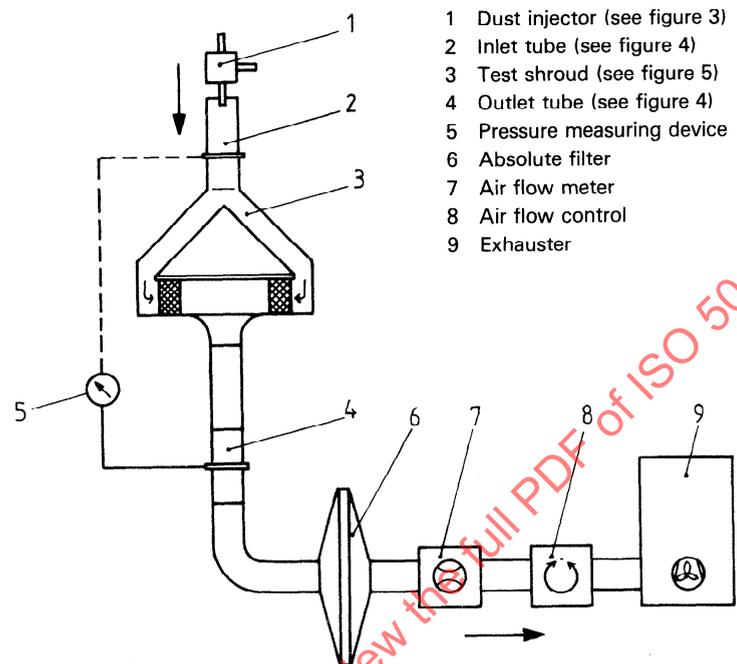
1 Dust injector (see figure 3)
2 Inlet tube (see figure 4)
3 Test shroud (see figure 5)
4 Outlet tube (see figure 4)
5 Pressure measuring device
6 Absolute filter
7 Air flow meter
8 Air flow control
9 Exhauster

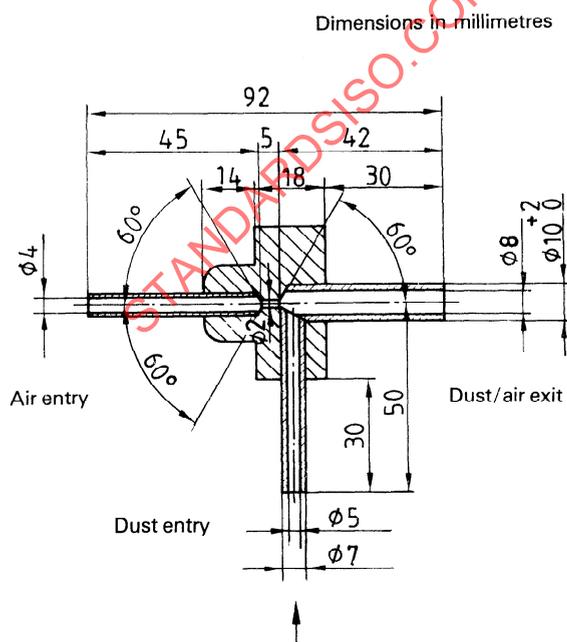**Figure 2 — Filter element efficiency/capacity test set-up**

Dimensions in millimetres
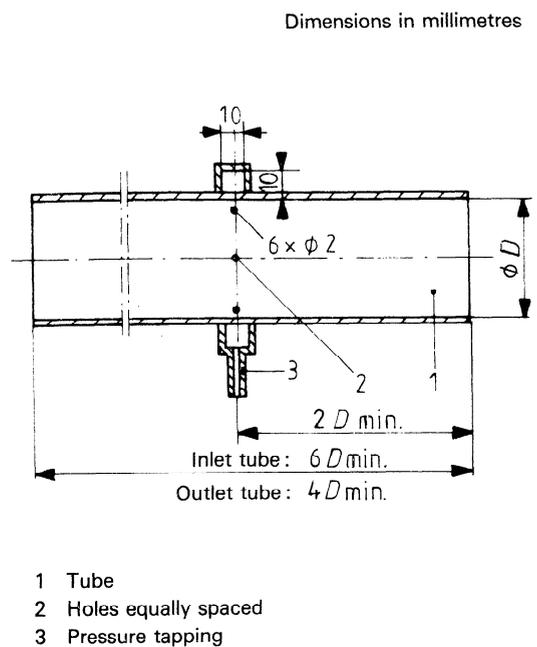

Air entry

Dust/air exit

Dust entry

Figure 3 — Dust injector

Dimensions in millimetres

$6 \times \phi 2$

$2 D$ min.

Inlet tube : $6 D$ min.
Outlet tube : $4 D$ min.

1 Tube
2 Holes equally spaced
3 Pressure tapping

Figure 4 — Inlet outlet piezometer tube

1 Diffusor cone
2 Sealing plate
3 Unit under test
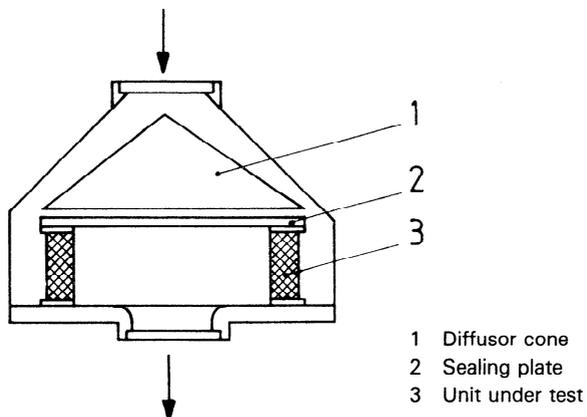
Figure 5 — Filter element test shroud

1 Dust injector
2 Dust chamber
3 Unit under test with diffusor cone (see figure 5)
4 Outlet tube (see figure 4)
5 Pressure drop measuring device
6 Absolute filter
7 Air flow meter
8 Air flow control
9 Exhauster
10 Compressed air feeding
11 Compressed air feeding flexible tubes
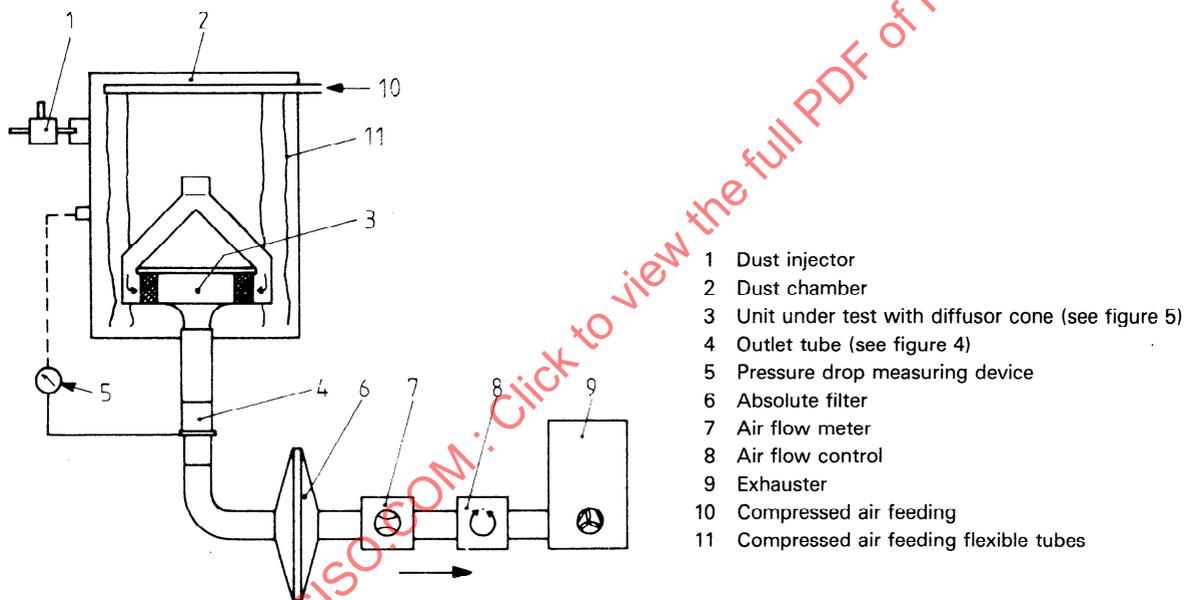
NOTE — In this figure a single air cleaner element is installed.

Figure 6 — Efficiency/capacity test set-up using a dust chamber

1 Dust injector (see figure 3)
2 Inlet tube (see figure 4)
3 Panel filter chamber
4 Outlet tube (see figure 4)
5 Pressure measuring device
6 Absolute filter
7 Air flow meter
8 Air flow control
9 Exhauster
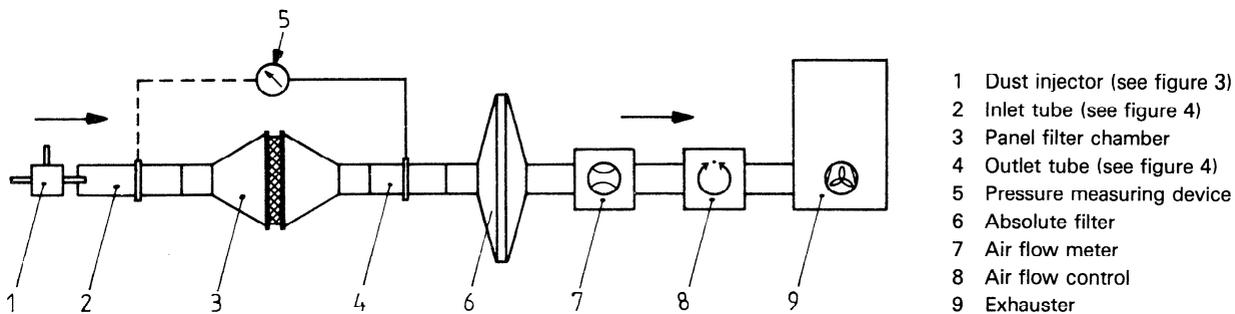
Figure 7 — Panel filter element efficiency/capacity test set-up

1 Unit under test
2 Outlet tube (see figure 4)
3 Restriction measuring device
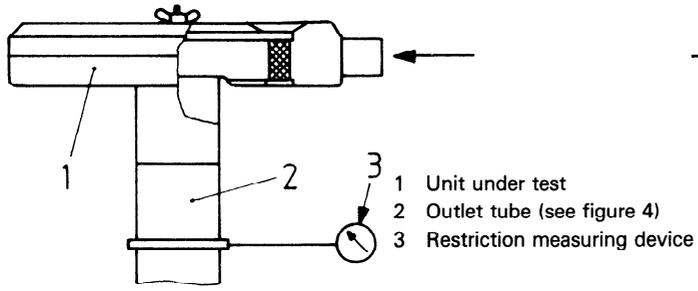
Figure 8 — Assembly restriction test set-up

1 Unit under test
2 Orifice (see figure 10)
3 Outlet tube (see figure 4)
4 Restriction measuring device
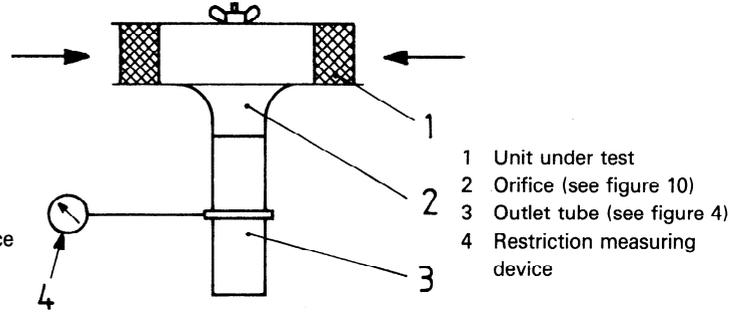
Figure 9 — Filter element restriction test set-up
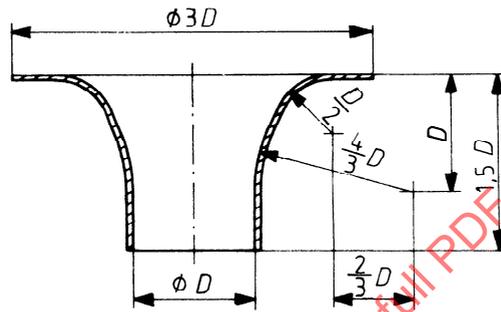
(øD = øD in figure 4)

Figure 10 — Ideal flow orifice

1 Dust injector (see figure 3)
2 Inlet tube (see figure 4)
3 Unit under test
4 Outlet tube (see figure 4)
5 Pressure measuring device
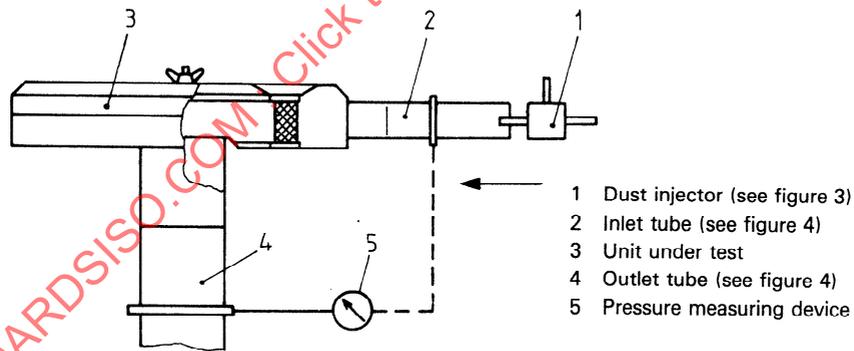
Figure 11 — Assembly efficiency/capacity test set-up

1 Dust injector (see figure 3)
2 Inlet tube (see figure 4)
3 Unit under test
4 Outlet tube (see figure 4)
5 Pressure measuring device
6 Absolute filter
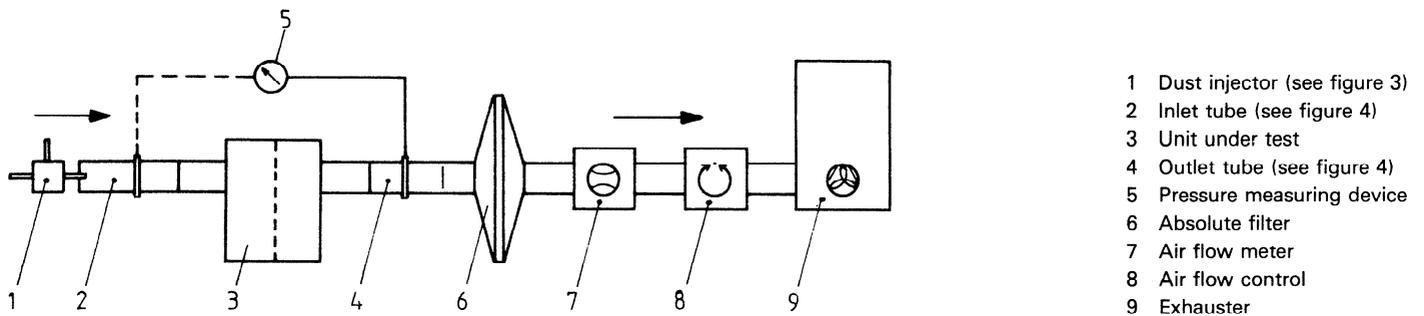7 Air flow meter
8 Air flow control
9 Exhauster

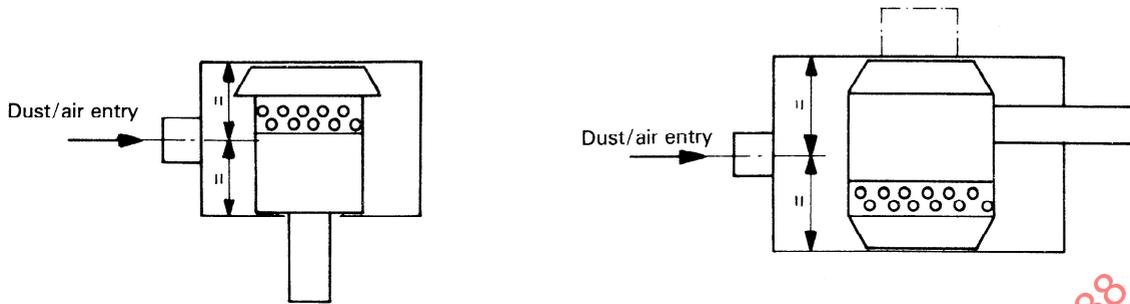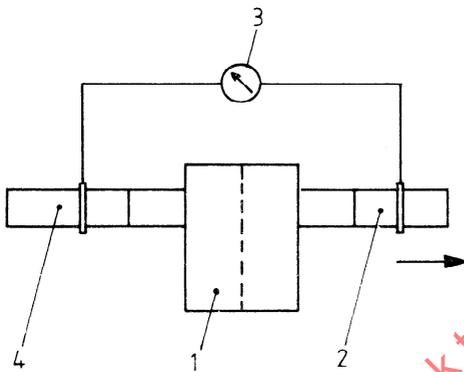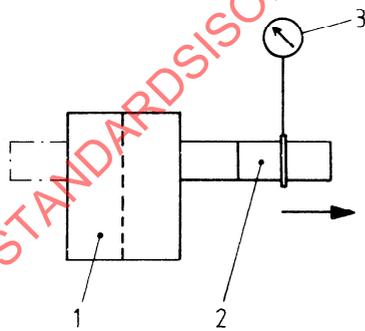**Figure 12 — Tubular inlet air cleaner efficiency/capacity test set-up**

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Figure 13 — Non-tubular inlet air cleaner test chamber arrangement

1 Unit under test
2 Outlet tube (see figure 4)
3 Pressure drop measuring device
4 Inlet tube (see figure 4)

Figure 14 — Assembly pressure drop test set-up

1 Unit under test
2 Outlet tube (see figure 4)
3 Restriction measuring device

Figure 15 — Assembly restriction test set-up