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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 — Détermination des performances

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 34, *Propulsion, powertrain and powertrain fluids*.

This fourth edition cancels and replaces the third edition (ISO 5011:2014), which has been technically revised. It also incorporates the Amendment ISO 5011:2014/Amd.1:2018. The main changes compared to the previous edition are as follows:

— added a validation procedure for verifying efficiency measurements;

— revised recommended ISO dust injector table;

— added formula for precleaner efficiency method;

— removed requirement for secondary element collapse test;

— added Annex H (Penetration sensitivity);

— added a new dust injector.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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

1 Scope

This document establishes and specifies 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 differential pressure, 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 document is applicable to air cleaners used on internal combustion engines and compressors generally used in automotive and industrial applications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

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

3 Terms, definitions and symbols

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Terms and definitions

3.1.1
air filter
air cleaner
device which removes particles suspended in the intake air as it is drawn into the engine

3.1.2
filter element
replaceable part of the *air filter* (3.1.1), consisting of the filter material and carrying frame

3.1.3
secondary element
air cleaner (3.1.1) element fitted downstream of the primary element for the purpose of providing the engine with protection against dust in the event of

a) certain types of primary element failure, or

b) dust being present during the removal of the primary element for servicing

3.1.4
unit under test
either a single *air cleaner* (3.1.1) element or a complete air cleaner assembly

3.1.5
single-stage air cleaner
air cleaner (3.1.1) which does not incorporate a separate *precleaner* (3.1.7)

3.1.6
multistage air cleaner
air cleaner (3.1.1) consisting of two or more stages, the first usually being a *precleaner* (3.1.7), followed by one or more *filter elements* (3.1.2)

Note 1 to entry: If two elements are used, the first is called the primary element and the second one is called the *secondary element* (3.1.3).

3.1.7
precleaner
device usually using inertial or centrifugal means to remove a portion of the test dust prior to reaching the *filter element* (3.1.2)

3.1.8
test air flow
measure of the quantity of air drawn through the *air cleaner* (3.1.1) outlet per unit time

Note 1 to entry: The flow rate is expressed in cubic metres per minute corrected to standard conditions.

3.1.9
rated air flow
flow rate specified by the user or manufacturer

Note 1 to entry: It may be used as the *test air flow* (3.1.8).

3.1.10
scavenged air flow
measure of the quantity of air used to remove the collected dust from a *precleaner* (3.1.7)

Note 1 to entry: It is expressed as a percentage of the *test air flow* (3.1.8).

3.1.11
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

Note 1 to entry: In the tests specified in this document, a static pressure is measured by a manometer (usually a liquid manometer) as a negative pressure difference against the atmospheric pressure and in the formula this is treated as a positive value.

3.1.12
restriction
static pressure (3.1.11) measured immediately downstream of the *unit under test* (3.1.4)

3.1.13
differential pressure
difference in *static pressure* (3.1.11) measured immediately upstream and downstream of the *unit under test* (3.1.4)

3.1.14
pressure loss
measure of the loss of energy caused by an *air cleaner* (3.1.1) at the observed air flow rate

Note 1 to entry: It is expressed as the *differential pressure* (3.1.13) corrected for any difference in the dynamic head at the measuring points.

Note 2 to entry: For further information, see Annex A.

3.1.15
absolute filter
filter downstream of the *unit under test* (3.1.4) that retains the contaminant passed by the unit under test

3.1.16
efficiency
ability of the *air cleaner* (3.1.1) or the unit to remove contaminant mass under specified test conditions

3.1.17
capacity
quantity of contaminant removed by the *unit under test* (3.1.4) in producing specified terminal conditions

3.1.18
oil carry-over
appearance of oil at the cleaner outlet

3.1.19
test terminal condition
condition, relating to an *air cleaner* (3.1.1), the occurrence of which signifies the end of the test

Note 1 to entry: A test terminal condition may be, for example, any one of the following: the *restriction* (3.1.12) or the *differential pressure* (3.1.13) reaches a specified or agreed terminal value; the dust-removing *efficiency* (3.1.16) or some other performance parameter falls to a specified or agreed value; *oil carry-over* (3.1.18) occurs; a dust pot becomes filled.

3.1.20
automotive application
air cleaner (3.1.1) generally used for internal combustion engines in passenger cars

3.1.21
industrial application
air cleaner (3.1.1) generally used for internal combustion engines in heavy-duty trucks, construction equipment and agricultural tractors

3.2 Symbols

The following applied units, according to ISO 80000-1, are used.

Name	Symbol	Unit
Density	ρ	kg/m^3
Differential pressure	Δp_d	Pa
Mass	m	g
Mass flow rate	q_m	kg/min
Pressure	p	Pa
Pressure loss	Δp_l	Pa
Restriction	Δp_r	Pa
Temperature	T	°C
Time	t	s

Name	Symbol	Unit
Velocity	v	m/s
Volume flow rate	q_V	m^3/min

4 Measurement accuracy and standard conditions

4.1 Measurement accuracy and precision

Measure the air flow rate to 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.

Measure the differential pressure and restriction to within 25 Pa for pressure readings up to 10 kPa, within 1 % of reading for higher pressures.

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

Measure the mass to within 0,1 g with the exception of absolute filter mass to be measured at 0,01 g and with the exception of the feeder mass to be measured at 1 %.

Measure the relative humidity (RH) with an accuracy of ±2 % RH.

Measure the barometric pressure to within 0,3 kPa.

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

Follow Annex H to determine the reporting precision of your efficiency measurement.

4.2 Standard conditions

All airflow measurements shall be corrected to a standard condition of 20 °C at 101,3 kPa.

See Annex G.

5 Test materials and test conditions

5.1 Test dust

5.1.1 Grade

The test dust to be used shall be ISO 12103-1, A.2 (ISO fine) or ISO 12103-1, A.4 (ISO coarse), subject to agreement between the filter manufacturer and client. The chemical analysis and the particle size distribution shall conform to ISO 12103-1.

In the absence of an agreement on the dust:

— for single-stage filters, use ISO fine test dust, and

— for multistage filters, use ISO coarse test dust.

5.1.2 Preparation

Before using the test dust, a quantity sufficient to cover the test requirements shall be mixed to ensure that no stratification / clumping has occurred. The test dust shall then be allowed to become acclimatised to a constant mass under the prevailing test conditions.

NOTE To ensure a constant rate of dust feed with some dust feeders, it can be found necessary to heat the dust prior to being acclimated to the environment.

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/differential pressure tests;

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

5.3 Absolute filter materials

5.3.1 Filter media

The absolute filter may 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 µm to 1,27 µm and the moisture absorption should be less than 1 % by mass after exposure to 50 °C and 95 % relative humidity for 96 h. The absolute filter media shall be installed with nap side facing upstream, in an airtight holder that adequately supports the media. The face velocity shall not exceed approximately 0,8 m/s to maintain media integrity.

As an alternative, a non-woven filter media with the efficiency described in 5.3.2 may be used.

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 a minimum of 5 min before the first (new) test weighing.

NOTE The use of an absolute filter with a backing will minimize fibre loss.

5.3.2 Validation of absolute filter media efficiency, E_a

Arrange two absolute filters in tandem. 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:

$$E_a = \frac{\Delta m_A}{\Delta m_A + \Delta m_B} \times 100 \quad (1)$$

where

E_a is the absolute filter efficiency, expressed as a percentage;

Δm_A is the mass increase of the upstream absolute filter;

Δm_B is the mass increase of the 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. Weight stabilization may be achieved by storage in a ventilated oven at a constant temperature of 105 °C ± 5 °C. The absolute filter shall be weighed inside the oven. Alternatively, air conditioned following 5.5 may be drawn through the absolute filter for 15 min and then the filter is weighed. Evaluate conditioning method per 5.4.1.

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

5.4.1 Validation of the absolute filter weighing method

Using the method of choice, the absolute pad weight method shall be performed once each day for three days and evaluate results per Annex H.

5.5 Temperature and humidity

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

The test results of an air cleaner will 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. The tests should be conducted within the narrowest range of temperature and humidity possible.

6 Test procedure for dry-type air cleaners for automotive applications

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/differential pressure 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 B, Figures B.1 and B.6 to B.11.

Use a dust feeder which when used with the dust injector in Figures B.2, B.3 and B.18 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 100 kPa minimum. The heavy-duty injector pressure shall be a gauge pressure of 280 kPa minimum.

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 the 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 the 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 %.

6.2.2 Use a dust-transfer tube between the dust feeder and the injector of a size suitable to maintain dust suspension. Sedimentation losses in the transfer tube should be avoided by having the tube as short as possible and grounded.

6.2.3 Use the dust injector described in Table 1 and shown in Figures B.2, B.3 and B.18.

Table 1 — Recommended ISO dust injectors (see Figures B.2 B.3 and B.18)

Dust feed rate per injector (g/min)	0 to 5	5 to 26	>26
Injector type	Light-duty injector	Light-duty injector or heavy-duty injectors (A or B)	Heavy-duty injectors (A or B)

If an array of injectors is used, special care shall be taken to make sure the dust fed is distributed evenly between each injector for two reasons: First, to get homogeneous dust distribution in the airstream and second, to make sure the maximum or minimum feed rate for the injectors being used is not exceeded.

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.

Injector nozzles are subject to natural erosion. Erosion may affect the distribution and delivery of test contaminant. Therefore, it is recommended to use a design with replaceable parts.

6.2.4 Use an inlet tube conforming to Figure B.4. The dust injector and inlet tube shall be positioned in such a way that there is a uniform dust distribution and no loss of dust.

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

6.2.6 For air cleaner assembly testing, use a housing and set-up agreed upon by the manufacturer and user conforming to Figure B.11. For air filter element testing, use a test set-up and shroud conforming to Figures B.1 and B.5 or an arrangement as shown in Figures B.6 or B.7. Where the test equipment is as shown in Figure B.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 so 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.

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

6.2.8 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 5167-1. 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 4.2).

6.2.9 Use an air flow rate control system capable of maintaining the indicated flow rate to within 2 % of the selected value during steady-state and variable air flow operation.

6.2.10 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.

6.2.11 Grounding is required for all test apparatus to reduce the effects of static charges and to improve the consistency of the test results. Grounding of metallic and non-metallic surfaces, housings, dust transport tubes, injectors and associated hardware is recommended.

6.3 Restriction and differential pressure test

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

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

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

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

6.3.5 Record the ambient temperature, barometric pressure and relative humidity.

6.3.6 Correct the recorded restriction and differential pressure to standard conditions in accordance with Annex G, Formula (G.1).

6.3.7 For pressure loss determination, use the formula given in Annex A.

6.3.8 Plot the results, for example as shown in Annex E, Figure E.1 or equivalent.

6.4 Efficiency test

6.4.1 Purpose

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 the 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 Types

Three types of efficiency tests can be performed, as follows:

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

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

c) initial efficiency determined after the addition of 20 g of contaminant or the number of grams numerically equivalent to six times the air flow in cubic metres per minute, whichever is the 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 g/m^3 or 0,5 g/m^3 may be allowed.

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

NOTE Conditioning of the absolute filter pad and air cleaner can be performed concurrently.

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

6.4.3.4 Set up test stand as shown in Figure B.11 for air cleaner assemblies, or as shown in Figure B.1, B.6 or B.7 for air filter elements. Seal all joints to prevent air leakage.

6.4.3.5 Record the temperature, barometric pressure and relative humidity.

6.4.3.6 Prepare the specified test dust according to 5.1 and weigh out the quantity required for test in a suitable test container. For full-life efficiency tests, the quantity should be approximately 125 % of the estimated capacity of the unit under test. Record the mass of the container and dust to the nearest 0,1 g. Specified in 4.1.

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

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

6.4.3.9 At specified time intervals (a minimum of five points is recommended), record the differential pressure in accordance with Annex A at the test flow and the elapsed test time.

6.4.3.10 Continue the test until the specified terminal condition is reached.

6.4.3.11 Record the temperature, barometric pressure 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 its weight recorded. This dust shall then be discarded due to potential change in distribution.

6.4.3.13 Reweigh the dust container and add the result to the weight recorded in 6.4.3.12. Subtract this sum from the mass recorded in 6.4.3.6. The difference is the mass of dust fed to the unit under test. The mass of dust fed to the unit under test can be determined from weight loss of the dust feeder directly.

6.4.3.14 Carefully remove the unit under test without losing any dust. Note any evidence of seal leakage or unusual conditions. Weigh the unit, per 4.1 in grams. 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 [see 6.4.2 a)] 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 step 6.4.3.3 per 4.1 and determine the difference in mass. This is the increase in mass of the absolute filter.

6.4.3.16 Calculate the material balance, *B*, of the test dust. For the test to be valid, this value shall be within the range 0,98 to 1,02:

$$B = \frac{\Delta m_F + \Delta m_u}{m_D} \tag{2}$$

where

Δm_F is the increase in mass of the absolute filter;

Δm_u is the increase in mass of the unit under test;

m_D is the total mass of the dust fed.

6.4.3.17 Calculate the efficiency, *E* (expressed as a percentage), by the following method:

$$E = \frac{\Delta m_u}{\Delta m_u + \Delta m_F} \times 100 \tag{3}$$

where the symbols are as in Formula (2).

6.4.4 Test procedure — Direct weighing method

NOTE This method is a less precise efficiency determination than the absolute filter method.

The direct weighing method may be used for cumulative efficiency determination where the humidity can be controlled to within ±1,0 % and the accuracy of the increase in mass of the filter determined to within 0,1 %.

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, *E* (expressed as a percentage), as follows:

$$E = \frac{\Delta m_u}{m_D} \times 100 \tag{4}$$

where the symbols are as in Formula (2).

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, the 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 the 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 the data and plot the curve of restriction versus mass gain, see reference plot in Annex F, Figure F1. Refer to 6.4.3.9 for restriction and time interval data.

Determine the mass gain values as follows:

$$\Delta m_t = \frac{t_1}{t_T} \times \Delta m_{UT} \quad (5)$$

where

Δm_t is the increase in mass at the end of each time interval;

t_1 is the total time at the end of interval;

t_T is the total time at the end of test;

Δm_{UT} is the total increase in mass of the unit under test at the end of test.

6.5.4 In the case of the terminal condition being the restriction, terminal condition shall 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 the test stand to perform the basic dust capacity test in accordance with Figure B.1, B.6, B.7 or B.11. Either the element from the prior capacity or efficiency test or a new element can be used for this test.

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

6.6.4 Record the maximum differential pressure attained, the reason for terminating the test, and the condition of the 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 that shown in 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.

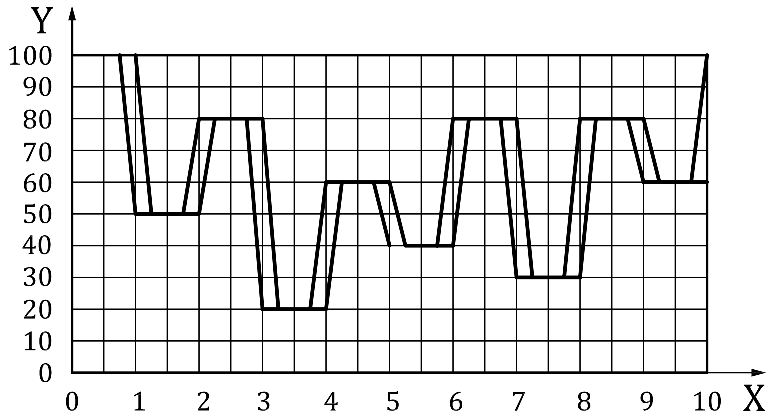
6.7.3 Based on the average test flow for the cycle being used, calculate the dust feed rate as in 6.4.3.1. The dust feed rate should remain constant.

6.7.4 All differential pressure 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 differential pressure shall be determined at the maximum flow, and

— the efficiency shall be determined at least after three 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.



Key

X time, min

Y test flow, %

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

6.8 Presentation of data

For the presentation of data, see examples in Annexes C, E and F or equivalent.

7 Test procedure for dry-type air cleaners for industrial applications

7.1 General

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/differential pressure test, an initial efficiency test, and a combined efficiency and dust capacity test.

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 2.

Table 2 — Test dust and concentration

Air cleaner type	Test dust [a]	Concentration
Single stage	Coarse or fine	1 g/m^3
Multistage	Coarse or fine	2 g/m^3

[a] In accordance with ISO 12103-1. See 5.1.1.

7.2 Test equipment

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

7.2.2 The dust feeding system shall be the same as described in 6.2.1.

7.2.3 The dust transfer tube shall be the same as described in 6.2.2. Concerning the dust feed rate, see also Table 1.

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 B.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 a minimum of 6 times the hydraulic diameter on the inlet and 4 times the hydraulic diameter on the outlet (hydraulic diameter = 4 times the area divided by 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 B.13.

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 B.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, such as increasing the inlet shroud length.

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 6.2.8, an air flow control system as described in 6.2.9 and a blower/exhauster as described in 6.2.10.

7.2.10 Grounding is required of all test apparatus to reduce the effects of static charges and to improve consistency of the test results. Grounding of metallic and non-metallic surfaces, housings, dust transport tubes, injectors and associated hardware is required.

7.3 Restriction and differential pressure test

Test shall be performed according to 6.3.

7.4 Initial efficiency test procedure — Absolute filter method

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

NOTE Conditioning of the absolute filter pad and air cleaner can be performed concurrently.

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

7.4.3 Prepare the test dust according to 5.1.1 and weigh out a quantity equal to 11 g/m^2 of the primary element media area. Place the preweighed dust in the dust feeder.

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

7.4.5 Weigh the dust feed system with the dust and record the mass.

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

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

7.4.8 Record the temperature, barometric pressure and relative humidity.

7.4.9 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. Calculate the increase in mass by comparison with the mass recorded in 7.4.2.

7.4.10 Collect all dust which has settled on the exterior surface, inlet ducting or test chamber, or the inlet side of the test unit and record the weight. This dust shall then be discarded due to potential change in distribution.

7.4.11 Reweigh the dust feed system per 4.1, add the recorded weight from 7.4.10 and calculate the mass of dust injected into the test cleaner by comparison with the initial mass of the dust feed system from 7.4.5.

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

7.4.13 Calculate the initial efficiency, E_i (expressed as a percentage), as follows:

$$E_i = \frac{m_D - \Delta m_F}{m_D} \times 100 \quad (6)$$

where the symbols are as in Formula (2).

7.4.14 If it was practicable to weigh and reweigh the complete unit under test, the efficiency may be calculated from Formula (3) in 6.4.3.17. Validation of the test shall be carried out according to 6.4.3.16.

7.5 Full-life efficiency and capacity test

7.5.1 Air cleaner dust capacity

Air cleaner dust capacity is a function of air cleaner size, airflow test, terminal condition, grade of test dust employed and environmental conditions. 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 6 kPa should be used as the terminal condition.

In the 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.

NOTE Conditioning of the absolute filter pad and air cleaner can be performed concurrently.

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

7.5.2.3 Prepare a sufficient quantity of test dust according to 5.1 of the selected grade and store in a suitable container in the 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 B.12, sealing all connections to prevent air leakage, and maintain the air flow at the test flow rate.

7.5.2.6 Load the dust feeder from the dust container and adjust the feed rate to coincide within the concentration specified in Table 2. Reload the dust feeder from the dust container as necessary throughout the test.

7.5.2.7 Record the temperature, barometric pressure 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/differential pressure at approximately uniform time intervals.

7.5.2.9 Correct the restriction/differential pressure/pressure loss values to standard conditions according to Annex G and plot them against dust fed to the air cleaner. Label the ordinate “restriction” or “differential pressure” or “pressure loss” as appropriate.

7.5.2.10 Continue the test until the specified terminal condition is attained. In the case of air cleaners having no limiting dust capacity, for example cyclone air cleaners, 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 the mass recorded in 7.5.2.2.

7.5.2.12 Collect all the dust which has settled on exterior surfaces/ducting/test chamber or the inlet side of the test unit and record the weight. This dust shall be discarded after weighing due to potential change in distribution. Transfer all unused dust in the dust feed device to the original dust container and reweigh the container. Add the weight of the container and the dust collected on the inlet side of the dust unit and record. 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. The mass of dust fed to the unit under test can be determined from weight loss of the dust feeder directly.

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

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

$$C = m_D - \Delta m_F \tag{7}$$

where

m_D is the mass of dust fed;

Δm_F is the increase in mass of the absolute filter.

7.5.2.15 Calculate the full-life efficiency, E_f (expressed as a percentage), as follows:

$$E_f = \frac{m_D - \Delta m_F}{m_D} \times 100 \qquad (8)$$

where the symbols are as in Formula (7).

7.5.2.16 If it was practicable to weigh and reweigh the complete unit under test, the efficiency may be calculated using Formula (3) in 6.4.3.17. Validation of the test shall be carried out according to 6.4.3.16.

7.5.3 Test procedure — Direct weighing method

NOTE This method is a less precise efficiency determination than the absolute filter method.

The direct weighing method may be used for cumulative efficiency determination where the humidity can be controlled to within ±1,0 % and the accuracy of the mass increase of the filter determined within 0,1 %.

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 the full-life efficiency, E_f (expressed as a percentage), as follows:

$$E_f = \frac{\Delta m_U}{m_D} \times 100 \qquad (9)$$

where

Δm_U is the increase in mass of the unit under test;

m_D is the total mass of dust fed.

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

7.6 Presentation of data

Data should be presented as given in Annexes D, E and F or equivalents.

7.7 Scavenged air cleaner performance test

7.7.1 General

This subclause describes those variations in the test procedures specified in this document 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.

The flow formula is as follows:

$$q_{VA} = q_{VB} + q_{VC} \qquad (10)$$

where

q_{VA} is the inlet air flow rate;

q_{VB} is the cleaned air flow rate;

q_{VC} is the scavenged air flow rate.

7.7.2 Additional equipment

A typical test arrangement is shown in Figure B.16 and shall comprise the following.

a) 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.

b) 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.

c) Pressure tappings: the pressure tappings used shall conform to Figure B.4.

d) 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.

e) The test arrangement shall not use any vibration devices in order to modify the test results.

7.7.3 Restriction and differential pressure 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 requires 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 purpose 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 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 full-life efficiency, E_f (expressed as a percentage), of the air cleaner shall be calculated as follows:

$$E_f = \frac{d_1 - d_2}{d_1} \times 100 \quad (11)$$

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 (air flow corrected to standard conditions);

V_2 is the volume of air leaving the clean side of the air cleaner (air flow corrected to standard conditions).

7.7.4.7 The capacity, C, of the unit shall be calculated in accordance with Formula (12) as follows:

$$C = \left(m_D \times \frac{q_{VB}}{q_{VA}} \right) - \Delta m_F \quad (12)$$

where

q_{VA} is the inlet air flow rate;

q_{VB} is the cleaned air flow rate;

m_D is the total mass of dust fed;

Δm_F is the increase in mass of the absolute filter.

7.7.5 Presentation of data

Data should be presented as given in Annexes D, E and F or equivalents.

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 shall be made. For precleaners that are scavenged, see 7.7.

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

b) Dust cup: the dust shall not be emptied during the dust capacity test until at least two-thirds full. Also, the number of servicing intervals shall be noted in the performance report.

The user should be aware that the above provisions ensure optimum air cleaner performance and it is advisable 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 is defined by the dust removed from the air stream prior to the primary filter housing. Precleaner efficiency (E_{p1}) shall be determined during the dust capacity test, based on the total mass of dust fed to the air cleaner and the sum of the gain in mass of the primary, secondary elements, housing and the absolute filter. Calculate the precleaner full life efficiency, E_{p1} (expressed as a percentage), as follows:

$$E_{p1} = \frac{m_D - (\Delta m_P + \Delta m_S + \Delta m_F)}{m_D} 100 \tag{13}$$

where

m_D is the total mass of dust fed;

Δm_P is the increase in mass of the, primary element and primary housing, if present;

Δm_S is the increase in mass of the secondary element, if present;

Δm_F is the increase in mass of the absolute filter.

7.8.3 Presentation of data

Data should be presented as given in Annexes D, E and F or equivalents.

7.9 Secondary element test procedure

7.9.1 General

The requirement for a secondary element is that it should block rapidly in the event of a leak occurring in the primary element, passing a minimum of dust in the process. To evaluate this, a specific efficiency test shall be performed. During normal and correct operation of the air cleaning system, it is desirable that the secondary element should not block during the lives of one or more primary elements. To evaluate this, a secondary element blocking test shall be performed. This may be carried out as part of the full-life efficiency and capacity test as specified in 7.5.

7.9.2 Specific efficiency test

7.9.2.1 Preparation

Using the housing normally employed to retain the secondary elements, prepare a “dummy” primary element, i.e. a complete element skeleton lacking only the media but including any swirl vane present. Place the secondary element and the dummy primary element into the housing.

7.9.2.2 Test procedure

7.9.2.2.1 The test shall be conducted in accordance with the full-life efficiency and capacity test given in 7.5, but with the following specifications.

7.9.2.2.2 The terminating condition for dust feeding shall be a differential pressure across the housing of 10 kPa or as agreed upon between the user and manufacturer.

7.9.2.2.3 The dust used shall be in accordance with 5.1.

7.9.2.2.4 The airflow shall be the full rated airflow as agreed between the customer and supplier.

7.9.2.2.5 The test dust concentration shall be 0,1 g/m^3 in the absence of customer requirements.

7.9.2.2.6 Where applicable, the requirements of 7.8.1 and 7.8.1 a) (pre-cleaner dust removal) shall be adhered to. The precleaning efficiency will be different from normal during this test. However, should a large reduction be noted, the reasons for this should be checked and any observations recorded.

7.9.3 Expression of results

Calculate the efficiency as in 7.5.2.15 or 7.5.3 c).

8 Test procedure for industrial applications of oil bath air cleaners

8.1 General

Performance tests shall be performed on a complete oil bath air cleaner. The tests shall consist of a restriction/differential pressure 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 the oil in accordance with 5.2.

8.2.2 Test dusts prepared according to 5.1.2 shall be used at a concentration of 1 g/m^3 air flow. Either fine or coarse test dust may be specified.

8.2.3 All tests shall be carried out with the air cleaner at a level position unless otherwise specified by the user or by the particular clause 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 the rated air flow for 15 min;

d) stop the 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 B.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 setting occurs, then a compressed air jet may be used to re-entrain the test dust. Typical examples of chambers are shown in Figure B.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.

Grounding is required for all test apparatus to reduce the effects of static charges and to improve the consistency of the test results. Grounding of metallic and non-metallic surfaces, housings, dust transport tubes, injectors and associated hardware is recommended.

8.3 Restriction and differential pressure test

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

a) perform the restriction/differential pressure 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 differential pressure 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 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 B, Figure B.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 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 may 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/differential pressure 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

Data should be presented as given in Annexes D, E and F or equivalents.

Annex A
(normative)

Explanation of restriction, differential pressure and pressure loss of an air cleaner

When differential pressure across a separator has been measured ($p_2 - p_1$ in Table A.1), any difference in the cross-sectional area of the ducts at the upstream and downstream pressure tapping points shall be taken into account in determining the pressure loss across the separator. The pressure loss, Δp_l across the separator is given by the Formula (A.1):

$$\Delta p_l = \Delta p_d - \Delta p_c \tag{A.1}$$

where Δp_d is the measured differential pressure.

$$\Delta p_c = \frac{\rho_2 \cdot v_2^2}{2} - \frac{\rho_1 \cdot v_1^2}{2} \tag{A.2}$$

where

ρ_1 is the density of the air at the upstream pressure tapping point;

ρ_2 is the density of the air at the downstream pressure tapping point;

v_1 is 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, p_{dyn}, required to accelerate the air from rest to its velocity in the downstream duct. The pressure loss Δp_l across the cleaner is then given by the Formula (A.3):

$$\Delta p_l = \Delta p_r - p_{dyn} \tag{A.3}$$

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

NOTE 1 In the tests specified in this document, a static pressure is measured by a manometer (usually as a liquid manometer) as a negative pressure difference against the atmospheric pressure; in the formulae, this is treated as a positive value.

Table A.1 — Illustration of restriction, differential pressure and pressure loss of an air cleaner

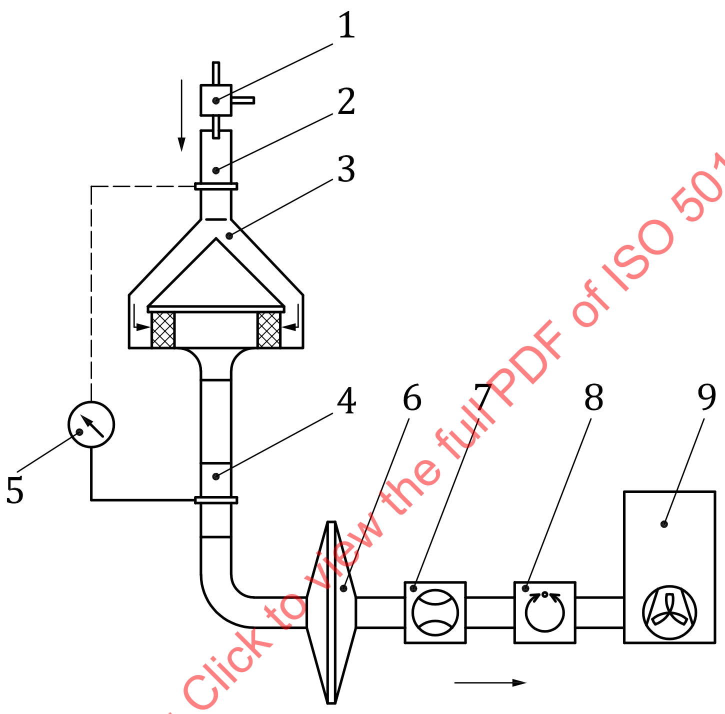
Term	Air cleaner drawing air from the atmosphere	Air cleaner drawing air through an inlet duct	Explanation
Static pressure upstream of air cleaner	—	p_1	Used to measure restriction of inlet tube.
Static pressure downstream air cleaner = restriction	$\Delta p_r = p_2$	$\Delta p_r = p_2$	Used when no inlet tube. See Figures B.8, B.9 and B.15.
Differential pressure	—	$\Delta p_d = \Delta p_r - p_1$ $= p_2 - p_1$	
Pressure loss	$\Delta p_l = \Delta p_r - p_{dyn} = p_2 - \frac{\rho_2 \cdot v_2^2}{2}$	$\Delta p = \Delta p_d - \Delta p_c$ $= (p_2 - p_1) - \frac{(\rho_2 \cdot v_2^2) - (\rho_1 \cdot v_1^2)}{2}$	

NOTE 2 This document is written for tests conducted by pulling air through the unit under test. The pressures in the inlet and outlet tubes are below ambient. Restriction is reported as a positive value. Therefore, for the formulae in Table A.1 to be correct, the gauge pressures p_1 and p_2 are assumed to measure as positive values when the pressure in the inlet and outlet tubes (upstream and downstream piezometers) is below ambient pressure.

Annex B
(normative)

Test equipment

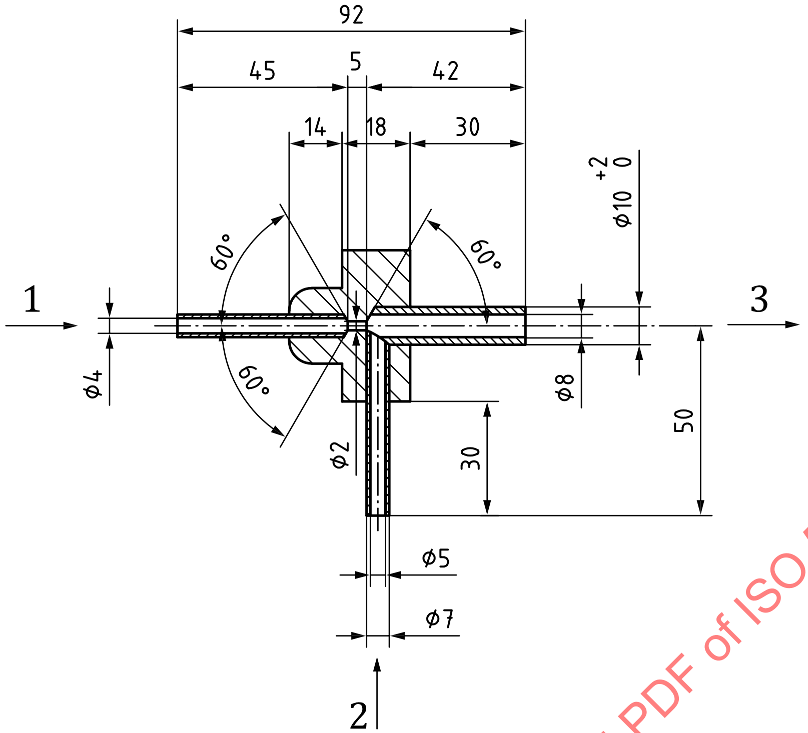
See Figures B.1 to B.17.



Key

1 dust injector (see Figures B.2, B.3 and B.18)
2 inlet tube (see Figure B.4)
3 test shroud (see Figure B.5)
4 outlet tube (see Figure B.4)
5 pressure measuring device
6 absolute filter
7 air flow meter
8 air flow control
9 exhauster

Figure B.1 — Filter element efficiency/capacity test set-up



Key

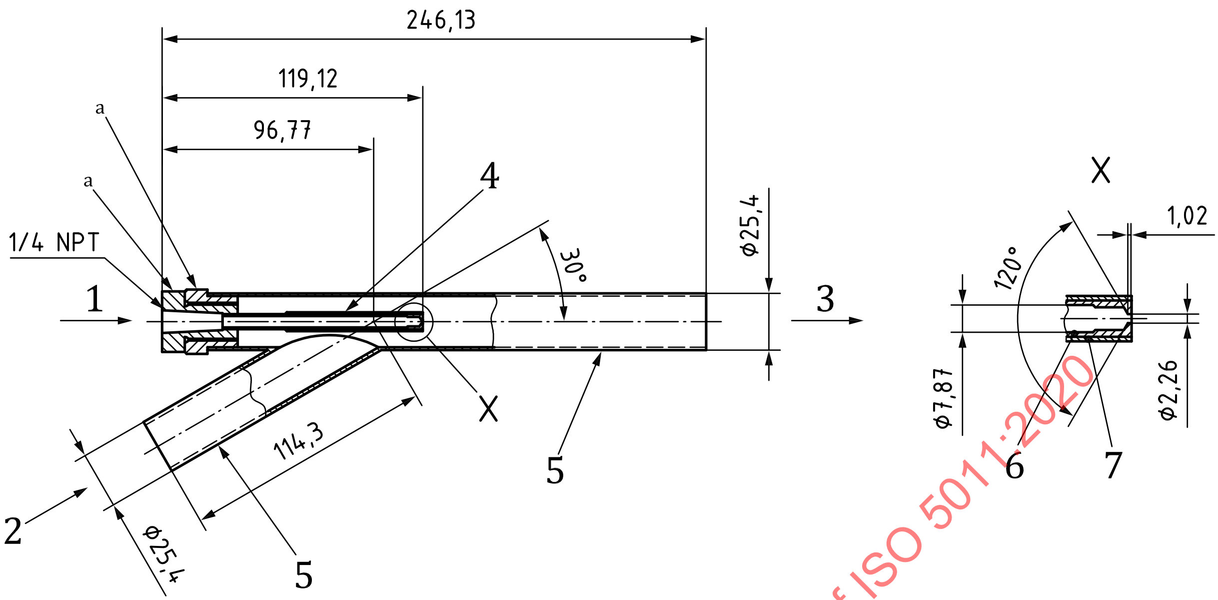
1 air entry

2 dust entry

3 dust/air exit

Figure B.2 — Light-duty dust injector

Dimensions in millimetres



Key

1 air entry

2 dust entry

3 dust/air exit

4 tubing erosion shield

5 stainless-steel tubing of wall thickness 1,65 mm

6 stainless-steel tubing of wall thickness 0,81 mm

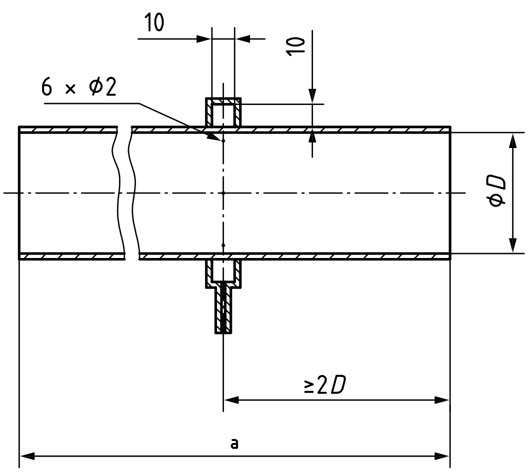
7 tubing of diameter 9,53 mm that does not affect particle charge

a Make from a 3/4 – 16 hexagonal HD bolt.

NOTE See Table 1.

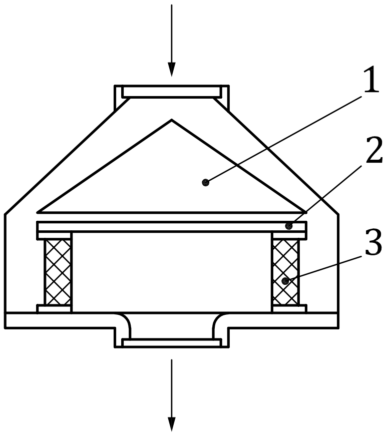
Figure B.3 — Heavy-duty dust injector A

Dimensions in millimetres



a Outlet tube: 4*D* min; inlet tube: 6*D* min.

Figure B.4 — Inlet/outlet piezometer tube



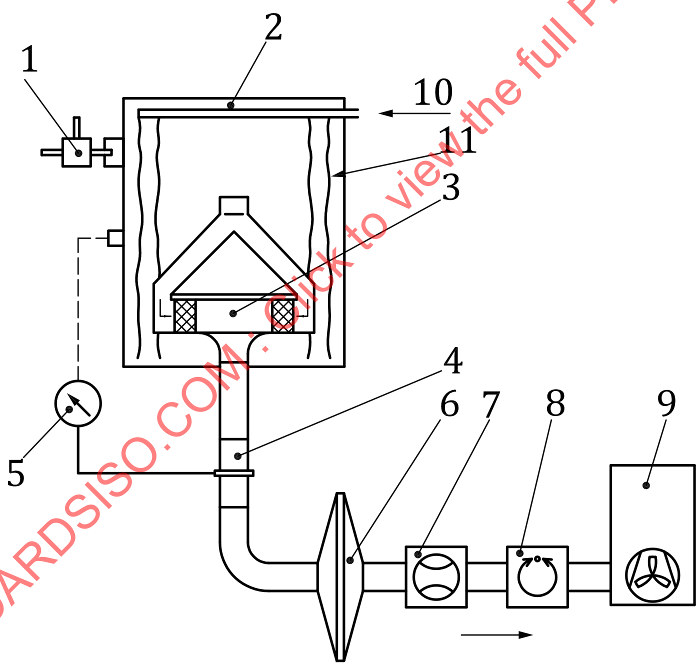
Key

1 diffusor surface

2 sealing plate

3 unit under test

Figure B.5 — Filter element test shroud



Key

1 dust injector (see Figures B.2, B.3 and B.18)

2 dust chamber

3 unit under test with diffusor (see Figure B.5)

4 outlet tube (see Figure B.4)

5 pressure measuring device

6 absolute filter

7 air flow meter

8 air flow control

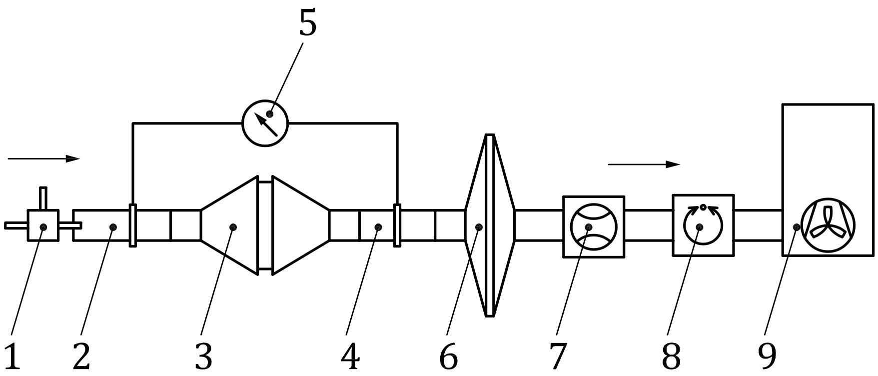
9 exhauster

10 compressed air feed

11 compressed air feed flexible tubes

NOTE In this figure, a single air cleaner element is installed.

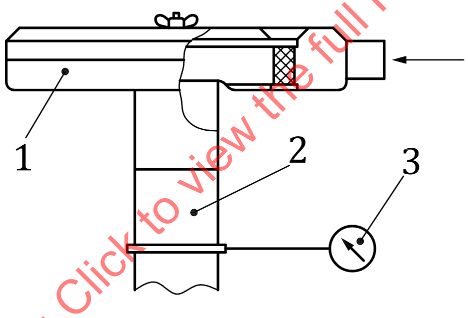
Figure B.6 — Efficiency/capacity test set-up using a dust chamber



Key

1 dust injector (see Figures B.2, B.3 and B.18)
2 inlet tube (see Figure B.4)
3 panel filter chamber
4 outlet tube (see Figure B.4)
5 pressure measuring device
6 absolute filter
7 air flow meter
8 air flow control
9 exhauster

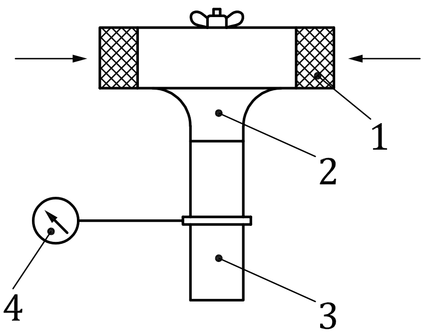
Figure B.7 — Set-up for panel filter element efficiency/capacity test



Key

1 unit under test
2 outlet tube (see Figure B.4)
3 restriction measuring device

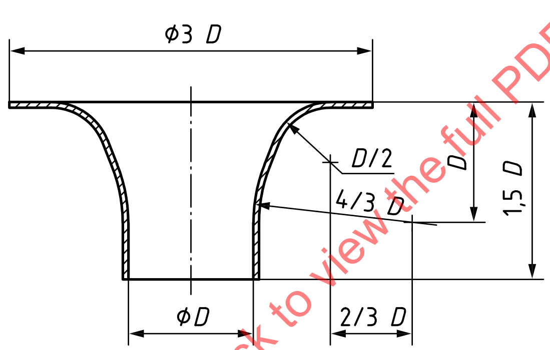
Figure B.8 — Set-up for restriction test



Key

1 unit under test
2 nozzle (see Figure B.10)
3 outlet tube (see Figure B.4)
4 restriction measuring device

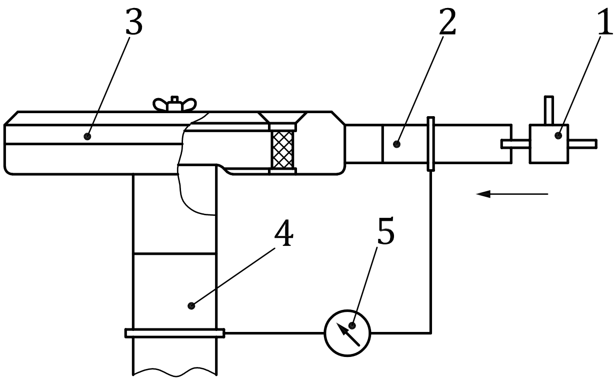
Figure B.9 — Set-up for restriction test



Key

$ØD$ = $ØD$ in Figure B.4

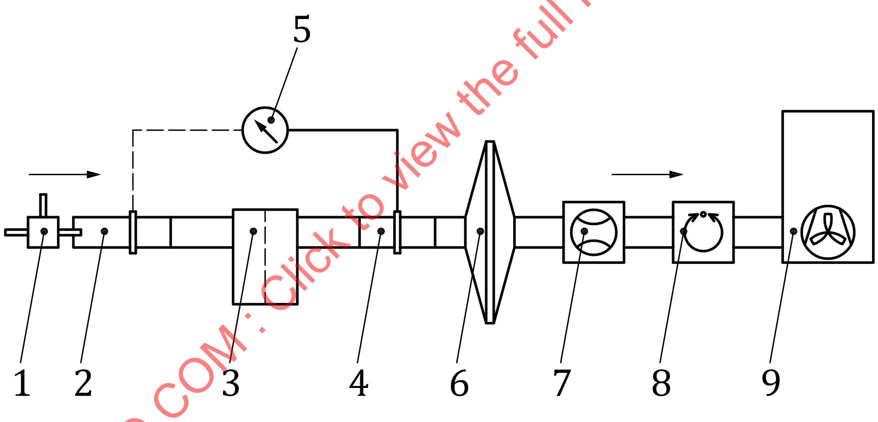
Figure B.10 — Ideal flow nozzle



Key

1 dust injector (see Figures B.2, B.3 and B.18)
2 inlet tube (see Figure B.4)
3 unit under test
4 outlet tube (see Figure B.4)
5 pressure measuring device

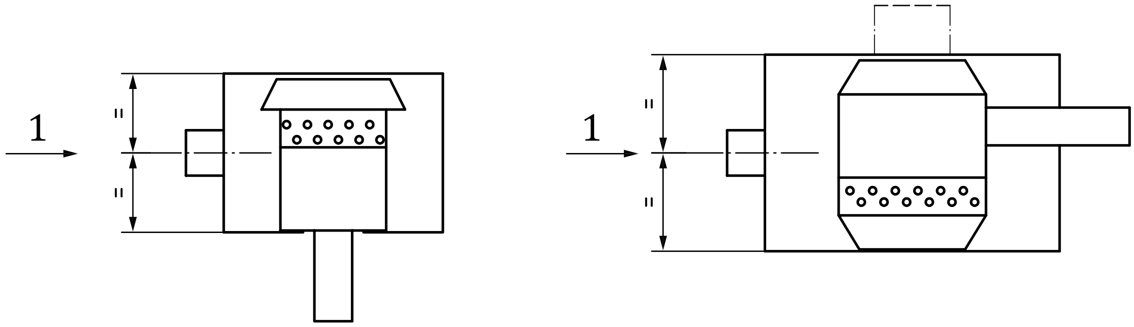
Figure B.11 — Set-up for efficiency/capacity test



Key

1 dust injector (see Figures B.2, B.3 and B.18)
2 inlet tube (see Figure B.4)
3 unit under test
4 outlet tube (see Figure B.4)
5 pressure measuring device
6 absolute filter
7 air flow meter
8 air flow control
9 exhauster

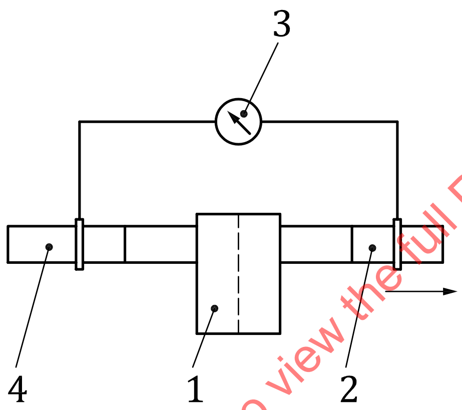
Figure B.12 — Set-up for tubular air cleaner efficiency/capacity test



Key

1 dust/air entry

Figure B.13 — Arrangement for non-tubular inlet air cleaner test chamber



Key

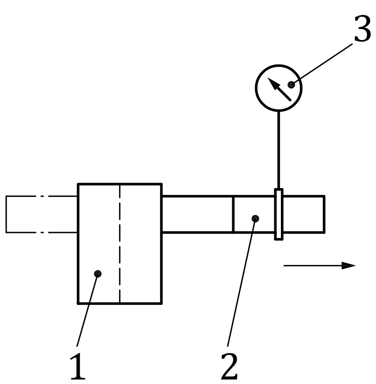
1 unit under test

2 outlet tube (see Figure B.4)

3 differential pressure measuring device

4 inlet tube (see Figure B.4)

Figure B.14 — Set-up for differential pressure test



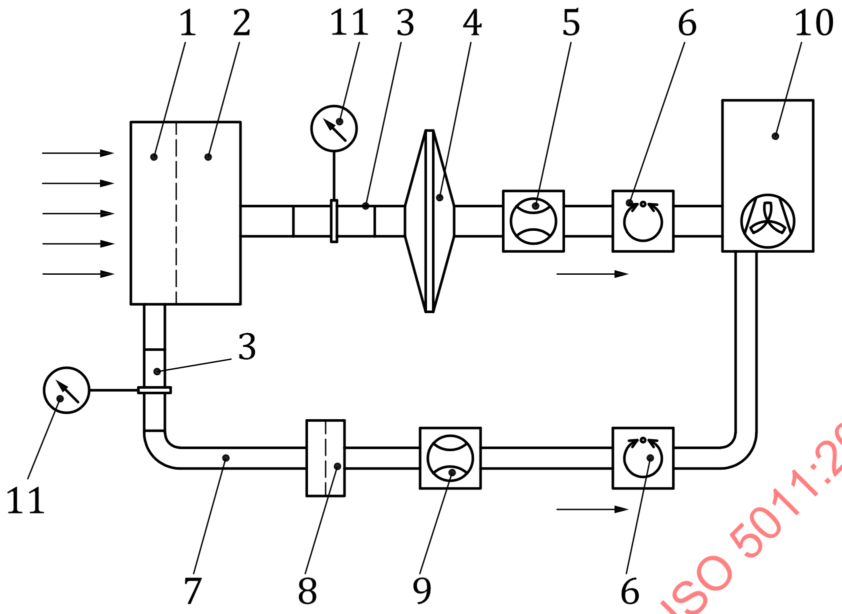
Key

1 unit under test

2 outlet tube (see Figure B.4)

3 restriction measuring device

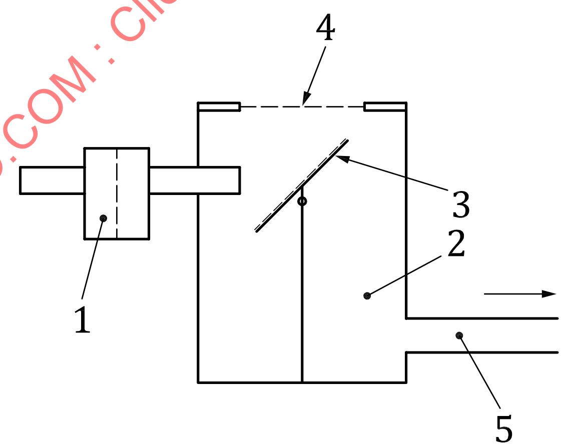
Figure B.15 — Set-up for restriction test



Key

1+2	unit under test
1	precleaner, scavenged
2	main cleaner
3	outlet tube (see Figure B.4)
4	absolute filter
5	air flow meter
6	air flow control
7	scavenged air duct
8	scavenged air duct filter
9	scavenged air duct flow meter
10	exhauster
11	restriction measuring device

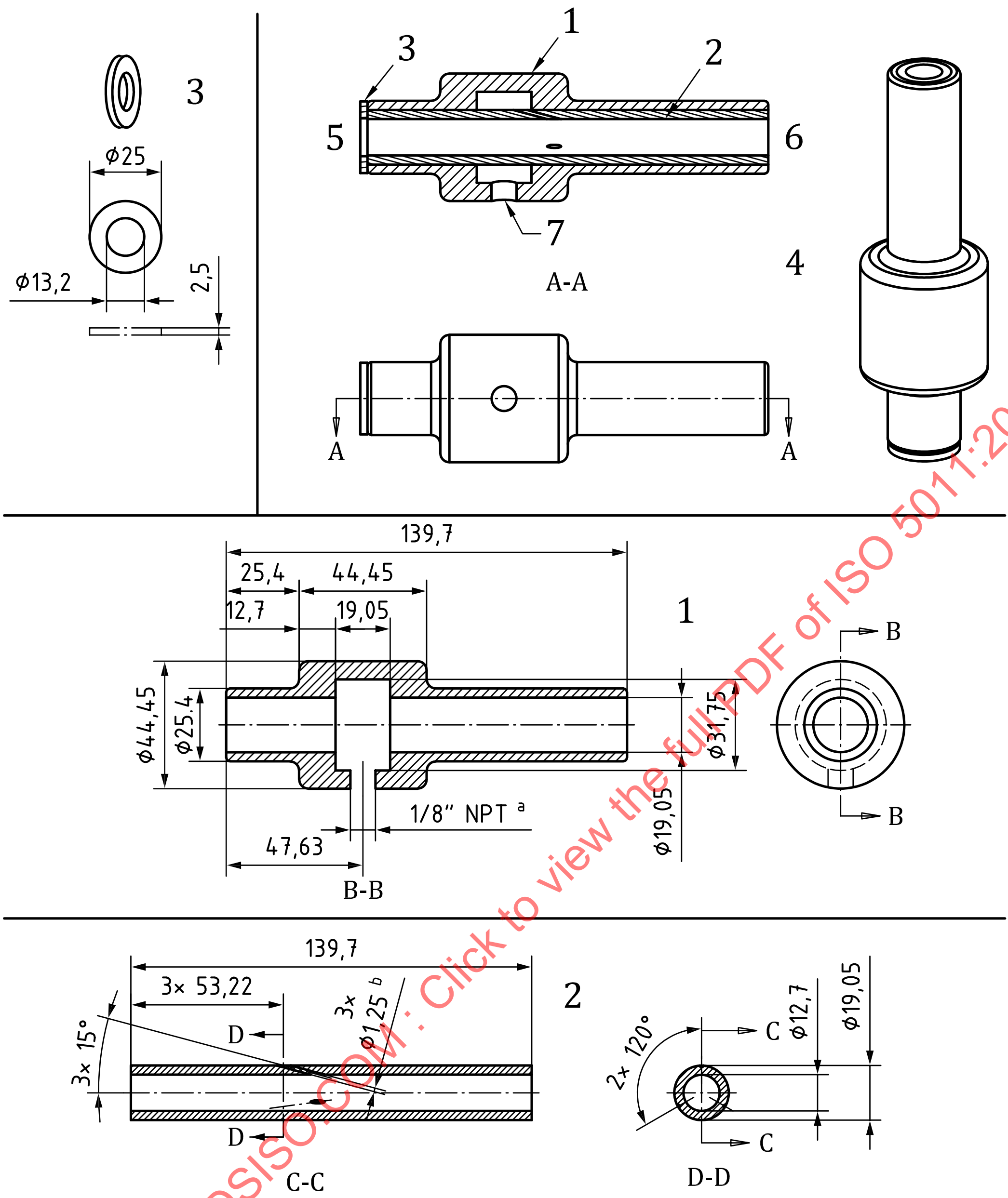
Figure B.16 — Set-up for scavenged air cleaner efficiency/capacity test



Key

1	unit under test
2	observation chamber
3	target plate covered with paper
4	observation window
5	outlet to air exhauster

Figure B.17 — Oil carry-over test — Observation chamber



Key

1 injector outer body

2 ceramic insert

3 steel erosion shield

4 assembled part

5 dust entry

6 air/dust exit

7 air entry

a Or equivalent threads.

b Thru hole.

Figure B.18 — Heavy duty dust injector B

Annex C
(informative)

Report sheet on performance testing of air cleaner equipment according to ISO 5011 — Automotive application

1.Test unit:	Model/Type No.:		
Manufacturer:			
Assembly:			
Precleaner:			
Filter element:			
Dust cup ☐:		/Unloader valve ☐:	
Tubular inlet ☐:		/Non-tubular inlet ☐:	
Outlet:			
2. Test conditions			
Test dust:	fine ☐ / coarse ☐	Batch No.:	
Barometric pressure			
- before test:	kPa,	after test:	kPa
Temperature			
-before test:	°C,	after test:	°C
Relative humidity			
-before test:	%,	after test:	%
Rated air flow			m³/min
Test air flow:	steady ☐	/variable ☐:	m³/min
Applied method:	Direct weighing method ☐	Absolute filter method ☐	
Test terminal condition:			
Dust Concentration:			g/m³
Air feed pressure:			kPa
Number of dust injectors used:			
3. Test results	**Diagrams- see:**		
Restriction (at test air flow):			kPa
Differential pressure (at test air flow)			kPa
Pressure loss (at test air flow):			kPa
Initial efficiency (after dust fed):	g	%	
Incremental efficiency:	at 10 % pressure diff. rise:		%
	at 25 % pressure diff. rise:		%
	at 50 % pressure diff. rise:		%
Full-life efficiency:			%
Precleaner efficiency:			%
Capacity (at test terminal condition):			g
4. General Comments			
Date:	Test conducted by:		

Annex D
(informative)

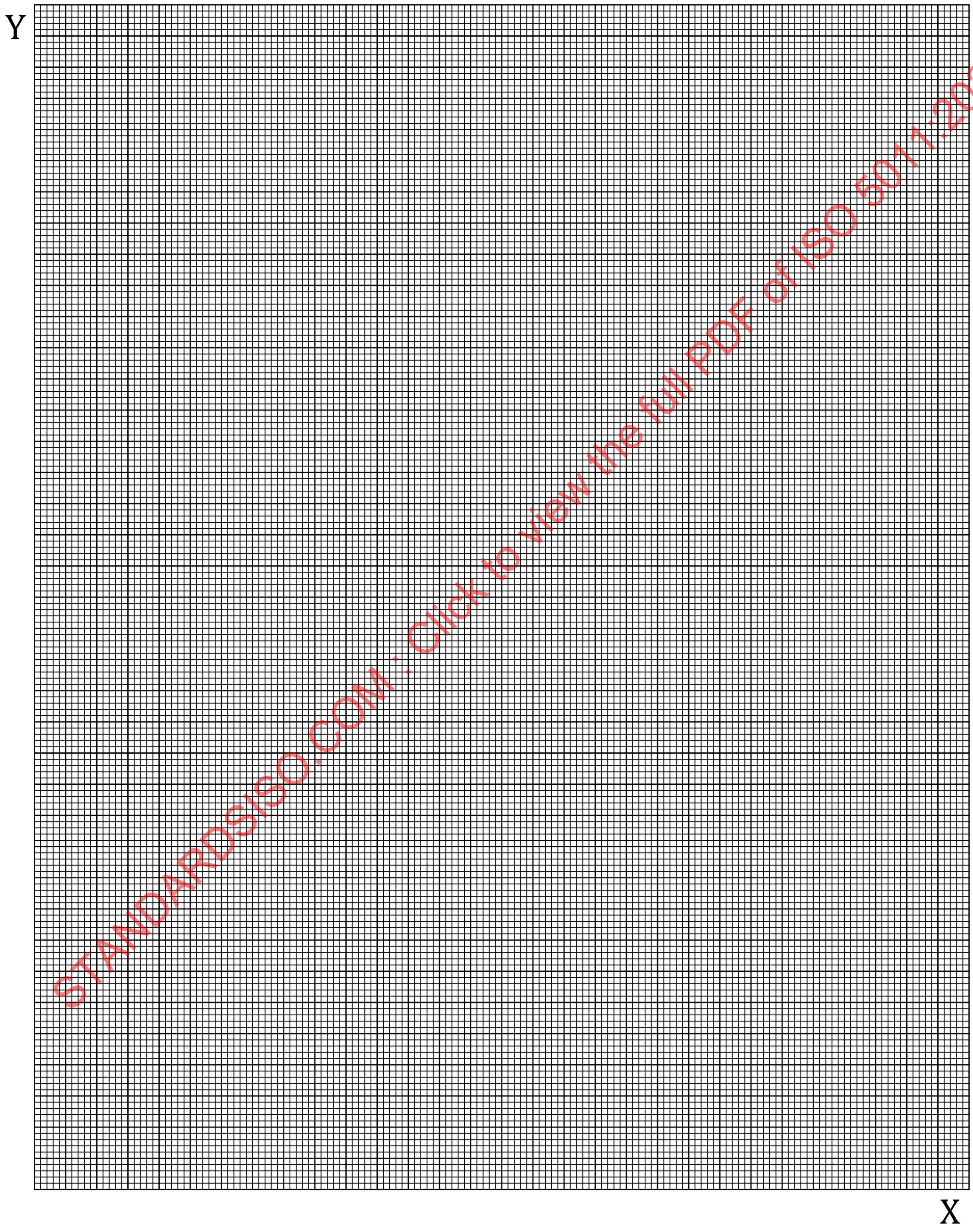
Report sheet on performance testing of air cleaner equipment according to ISO 5011 — Industrial application

1.Test unit:		Model/Type No.:	
Manufacturer:			
Assembly:			
Precleaner:			
Primary element:			
Secondary element:			
Dust cup ☐:		Unloader valve ☐:	
Tubular inlet ☐:		Non-tubular inlet ☐:	
Outlet:			
2. Test conditions			
Test dust:	fine ☐ / coarse ☐	Batch No.:	
Test oil:			
Barometric pressure			
- before test:	kPa,	after test:	kPa
Temperature			
-before test:	°C,	after test:	°C
Relative humidity			
-before test:	%,	after test:	%
Applied method:	Direct weighing method ☐	Absolute filter method ☐	
Rated air flow:			m^3/min
Test air flow:	steady ☐ /variable ☐:		m^3/min
Scavenge air flow:			m^3/min
Test terminal condition:			
ISO dust injector: ☐		ISO heavy duty dust injector: ☐	
Dust concentration:			g/m^3
Air feed pressure:			kPa
Number of dust injectors used:			
3. Test results		**Diagrams- see:**	
Restriction (at test air flow):			kPa
Differential pressure (at test air flow)			kPa
Pressure loss (at test air flow):			kPa
Initial efficiency (after dust fed):	g		%
Full-life efficiency:			%
Pre-cleaner efficiency:			%
Capacity (at test terminal condition):			g
Dust cup served:			times
Oil carry-over: yes ☐ no ☐ at single flow rate:			m^3/min
Oil carry-over (increasing flow rates) at flow rate:			m^3/min

4. General Comments	
Date:	Test conducted by:

Annex E
(informative)

Presentation of results — Air cleaner restriction/differential pressure versus flow



Key

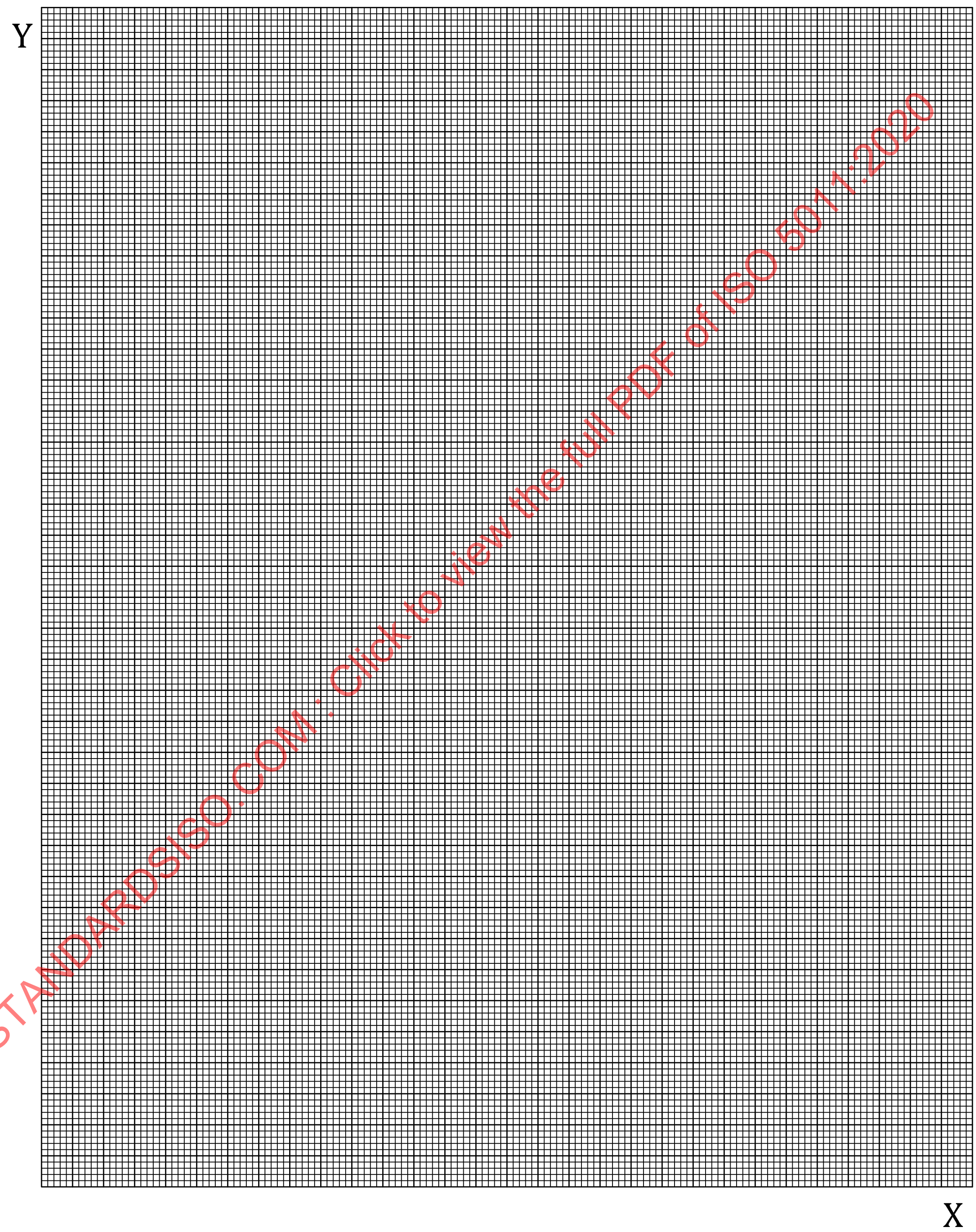
X airflow rate, m^3/min

Y restriction/differential pressure/pressure loss, kPa

Figure E.1 — Air cleaner restriction vs. flow

Annex F
(informative)

Presentation of results — Air cleaner capacity



Key

X dust capacity, g

Y restriction/differential pressure/pressure loss, kPa

Figure F.1 — Differential pressure vs. dust capacity

Annex G
(normative)

Airflow and resistance corrections to standard conditions

Airflow restriction/differential pressure/pressure loss and dust capacity data shall be reported for standard conditions of 20 °C and 1 01,3 kPa. The resistance, Δp, of the air cleaner can be represented by the following expression:

$$\Delta p = K_1 \mu q_V + K_2 \rho q_V^2$$

where

K_1 is an empirical constant;

K_2 is an empirical constant;

μ is the dynamic viscosity, in millipascal seconds;

ρ is the air density, in kilograms per cubic metre;

q_V is the volume flow rate, in cubic metres per minute;

q_m is the mass flow rate, in kilograms per minute.

Substituting $\frac{q_m}{\rho}$ for q_V:

$$\Delta p = K_1 \mu \left(\frac{q_m}{\rho} \right) + K_2 \rho \left(\frac{q_m}{\rho} \right)^2$$

Rearranging terms gives:

$$\rho \Delta p = K_1 \mu q_m + K_2 q_m^2$$

Thus by maintaining the mass flow constant and limiting the variation in ambient temperature to keep the change in viscosity small, $\rho \Delta p$ will remain constant. Therefore:

$$\rho_0 \Delta p_0 = \rho \Delta p$$

$$\Delta p_0 = \frac{\rho}{\rho_0} \Delta p$$

where subscript 0 indicates standard conditions.

Observed restriction/differential pressure/pressure loss values shall therefore be corrected to standard conditions by using the following formula:

$$\Delta p_0 = \frac{p}{1\,013} \times \frac{293}{T + 273} \times \Delta p_r \text{, or } \Delta p_d \text{, or } \Delta p_l \qquad (G.1)$$

