International Standard

ISO 29461-3

Air intake filter systems for rotary machinery — Test methods —

Part 3:
Mechanical integrity of filter elements

Systèmes de filtration d'air d'admission pour machines tournantes — Méthodes d'essai —

Partie 3: Intégrité mécanique des éléments filtrants

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Foreword

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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 document 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).

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A list of all parts in the ISO 29461 series can be found on the ISO website.

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Introduction

In rotating machinery applications, the filtering system, typically a set of filter elements arranged in a suitable manner, is an important part of the whole turbine/compressor system. The development of turbine machinery used for energy production or others has led to more sophisticated equipment and therefore, the importance of effective protection of these systems has become more important in the recent years. It is known that particulate contamination can deteriorate a turbine power system quite substantially if not taken care of.

This process is often described as "erosion", "fouling" and "hot corrosion" where salt and other corrosive particles are known as potential problems. Other particulate matters can also cause significant reduction of efficiency of the systems. It is important to understand that air filter devices in such systems are located in various environmental conditions. The range of climate and particulate contamination is very wide, ranging from deserts to humid rain forests to arctic environments. The requirements on these filter systems are obviously different depending on where they are operated.

This document has based the performance of the air intake filter systems not only upon heavy dust collection but also particulate efficiency in a size range that is considered to be the problematic field for these applications. Both ultra-fine and fine particles, as well as larger particles should be considered when evaluating turbine fouling. In typical outdoor air, ultra-fine and fine particles in the size range from 0,01 µm to 1 µm are contributing to > 99 % of the number concentration and to > 90 % of the surface contamination. The majority of the mass normally results from larger particles (> 1,0 µm).

Turbo-machinery filters comprise a wide range of products, ranging from filters preventing from coarse particles to filters for very fine and even sub-micrometre particles. The range of products varies from self-cleaning to depth and surface loading systems. The filters and the systems have to withstand a wide temperature and humidity range, very low to very high dust concentration and mechanical stress. The shape of products existing today can be of many different types and have different functions such as droplet separators, coalescing products, filter pads, metal filters, inertial filters, filter cells, bag filters, panel filters, self-cleanable and depth loading filter cartridges or pleated media surface filter elements.

The ISO 29461 series provides a way to compare these products in a standardized way and defines the criteria important for air filter intake systems for rotary machinery performance protection. The performance of products in this broad range needs to be compared according to a standardized procedure. Comparing different filters and filter types needs to be done with respect to the overall conditions they finally operate in.

If a filter or a filter system is meant to operate in an extreme, very dusty environment, the real particulate efficiency of this filter cannot be predicted since the dust loading of the filter becomes important.

In an ideal filtration process, each particle would be permanently arrested at its first contact with a media fibre, but incoming particles can impact on a captured particle and detach it into the air stream. Fibres or particles from the filter itself can also be released, due to mechanical forces.

Another worst-case scenario in abnormal operating environments which leads to unusual high-pressure drops is the burst or damage of the filter element accompanied with a sudden release of parts of the filter element or high amounts of dust captured.

This document specifies a method and procedure to test the mechanical integrity ("burst test") of individual filter elements up to an abnormal final test pressure drop of maximum 6 250 Pa. Any other customer defined final pressure drop up to a higher pressure drop shall be reported as variation from the standard. Nevertheless, it is within the ability of the user to define the maximum possible value (lower or higher) for a certain application and to define the burst strength requirements for this test procedure. As the pressure drops under typical operating conditions are on a much lower level, it is not intended to specify a final pressure drop for any application within this procedure.

For multi-stage systems which use a number of components (e.g. equipment for cleaning, filters), each filter element needs to be tested separately.

In general, it is possible to use this procedure also after any previous ageing procedure if it is clearly described as a variation from the standard test procedure. An ageing procedure is defined as an appropriate customer defined durability test which can affect the stability of media, adhesives, construction and the like, and is important for the evaluation at its real application. Test results of filter elements after different ageing procedures cannot be quantitively compared.

Examples of conditioning are:

— climatic conditioning at high or low temperatures and/or defined relative humidity levels;

— wet conditions with water droplets or condensing water over a defined time period;

— any kind of dust loading and pulsing procedure over a certain duration or number of pulses;

— operation at real conditions, etc.

The “burst test” itself is considered as an independent procedure to evaluate the integrity of a filter element to resist a defined high pressure drop without collapsing, losing or releasing any parts of its construction into the downstream while keeping its filtration efficiency.

The test procedure does not include methods for the direct measurement of the performance of entire systems as installed (e.g. systems with use of multiple stages of coarse and fine filter elements).

Note For example, can a damaged, vertically installed pulse-jet filter perform differently in real operation conditions compared to what can be detected by a horizontal, non-pulsing test as described in this document.

Air intake filter systems for rotary machinery — Test methods —

Part 3: Mechanical integrity of filter elements

1 Scope

This document specifies methods to determine the mechanical integrity of filters under defined conditions that can be encountered in abnormal operating environments. It describes the test methods for filter elements, independent of any ageing procedures like pulsing, loading, temperature cycles, wet conditions or others.

The test procedure is intended for filters operating in the range of 0,24 m^3/s (850 m^3/h) up to 2,36 m^3/s (8 500 m^3/h). Filter elements with a lower efficiency than ISO T5 ($e\mathrm{PM}_{10}$) according to ISO 29461-1 are excluded.

To ensure the comparability of the test results, only new filter elements or those loaded up to 625 Pa or maximum 800 Pa according to ISO 29461-1 are tested.

This document does not describe a standardized method to measure the fractional or gravimetric efficiency. The efficiency of the filter element can be tested according to ISO 29461-1.

The performance results obtained according to this document cannot be quantitatively applied (by themselves) to predict performance in real use.

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 (all parts), *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduit running full*

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

ISO 16890-2:2022, *Air filters for general ventilation — Part 2: Measurement of fractional efficiency and air flow resistance*

ISO 29461-1, *Air intake filter systems for rotary machinery — Test methods — Part 1: Static filter elements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29461-1 and the following apply.

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

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

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

3.1 Test parameter

3.1.1
air flow rate
volume of air flowing through the filter per unit time

[SOURCE: ISO 29464:2017, 3.1.24]

3.1.2
test air flow rate
volumetric air flow rate used for testing

[SOURCE: ISO 29464:2017, 3.3.2]

3.1.3
resistance to air flow
difference in absolute (static) pressure between two points in a system

Note 1 to entry: Resistance to air flow is measured in Pa.

[SOURCE: ISO 29464:2017, 3.1.36]

3.1.4
initial pressure drop
pressure drop of the clean filter operating at the test air flow rate

[SOURCE: ISO 29464:2017, 3.3.17]

3.1.5
initial test pressure drop
pressure drop of the filter element operating at the test air flow rate at start of the test

3.1.6
final pressure drop
maximum test pressure drop of the filter specified by the requestor of the test

3.1.7
final test pressure drop
maximum operating pressure drop of the filter to terminate the test as recommended at rated air flow

3.1.8
leakage
damage of the structure of a filter element, which allows particles to pass through the filter element without passing through the filter medium

3.2 Filter to be tested

3.2.1
test device
filter element (3.2.2) being subjected to performance testing

[SOURCE: ISO 29464:2017, 3.1.38]

3.2.2
filter element
structure made of the filtering material, its supports and its interfaces with the filter housing

[SOURCE: ISO 29464:2017, 3.2.77]

3.2.3
static filter
air filter that will be removed (exchanged) after it has reached its final test pressure drop and that is not cleaned with jet pulses or other means in order to fully, or partially, retrieve its initial performance (pressure drop and efficiency)

[SOURCE: ISO 29464:2017, 3.3.12]

3.3 Test duration

3.3.1
test duration
time between starting a test and achieving a terminal condition (e.g. pressure drop)

3.4 Test materials

3.4.1
water fog
water droplets and fog generated by water spray device

3.4.2
test dust
synthetic dust used for the loading up to the final pressure drop

4 Test rig, conditions and equipment

4.1 Test conditions

Room air or outdoor air can be used as a test air source. Relative humidity of supply air (before water spraying nozzles) shall be in the range of > 30 % during the tests. The air temperature shall be in the range of 25 °C ± 10 °C. Other conditions may be used upon customer request.

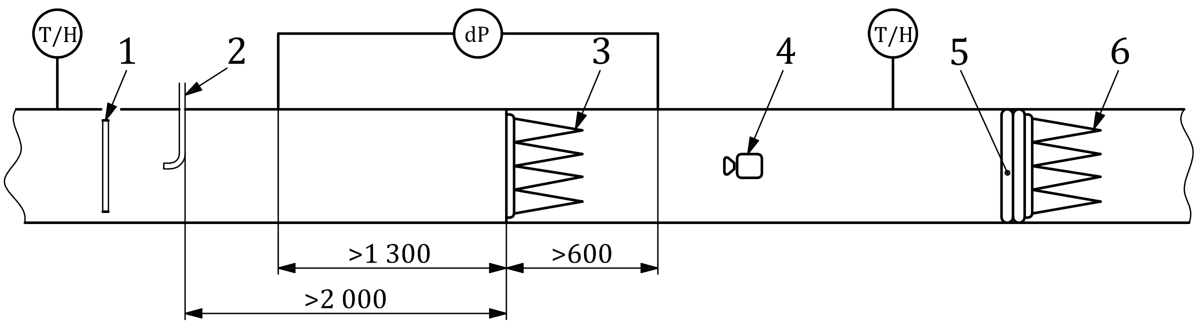
4.2 Test rig – General requirements

The test rig shall be operated in negative pressure air flow configuration. The duct material shall be electrically conductive and electrically grounded and shall have a smooth interior finish and be sufficiently rigid to maintain its shape at the operating pressure (designed to withstand the negative pressure of at least 6 500 Pa). Parts of the test duct can be made in glass or plastic material to see the filter and equipment. Provision of windows to allow monitoring of the test progress is desirable. At least the upstream side of the filter element under test shall be observable from outside the test rig through a window as a camera is polluted very fast by the high dust/water concentration.

Test rigs according to ISO 16890-2 can be used for static filter elements, but it is recommended to use a larger test rig designed for pulse cleaning tests, because of its optimized construction for higher pressure drop, more powerful ventilators, higher dust feeding possibilities and the option to simulate ageing procedures like pulsing and/or wet conditioning prior to the burst test procedure.

The test rig (see Figure 1) dimensions shall be large enough to prevent the outside of the filter elements (e.g. V-bank filter) from touching the test rig walls. Hence, if the elements would be deformed during the test, the test rig shall not be an additional support for the test device.

The test rig section where the filter is installed should preferably have inner dimensions of ≥ 50 mm larger than the nominal face dimensions of the test device, especially for V-bank filter elements. For a 600 mm × 600 mm filter element, a test rig section of minimum 650 mm × 650 mm can be used.



Key

1 fogging nozzles
2 dust injection
3 test device
4 camera
5 coarse filter/grid
6 final filter

Figure 1 — Schematic diagram of the test rig (only main sections)

It is recommended but optional to install water collecting grooves or drains at the bottom side upstream (and downstream) of the tested filter. The fogging nozzles can be either before or after or at the same position as the dust injection position.

4.3 Camera

In the test rig downstream side of the filter element, a camera shall be installed in a suitable manner for the visual observation of the test device during the whole test procedure. A special position or type of the camera is not compulsory, but the test laboratory shall ensure that it is possible to observe the complete filter element during the test in an appropriate quality. It is recommended to:

— position the camera in such a way that it shows the area below the installed filter element to visualize any water breakthroughs or detached parts;

— install an adequate light source in the test duct on the upstream side and the downstream side of the filter element;

— use a second optional camera, for example outside of the test rig pointed at the side of the filter, if the filter design prevents an appropriate observation of the downstream side;

— use a third optional camera to look at the coarse filter/grid to see structural failures and filter pieces captured by the grid.

4.4 Differential pressure measurement

Measurements of pressure drop shall be taken between measuring points located in the duct wall upstream and downstream of the test device. Each measuring point shall comprise minimum three interconnected static taps distributed around the periphery of the duct cross section. If a static tap on the bottom side is used, the laboratory should make sure that it will not be blocked by water. More details can be found for example in ISO 16890-2.

The pressure measuring equipment and data recording used shall be capable of measuring pressure differences with an accuracy of ±3 % of the measured value at least every minute to get a continuous reading of the pressure drop curve versus time/dust load.

4.5 Flow measurement

Flow measurement shall be made by standardized or calibrated flow measuring devices in accordance with the ISO 5167 series. Examples of standardized or calibrated flow measuring devices are orifice plates, nozzles, Venturi tubes. The uncertainty of measurement shall not exceed 5 % of the measured value at 95 % confidence level.

4.6 Dust feeder

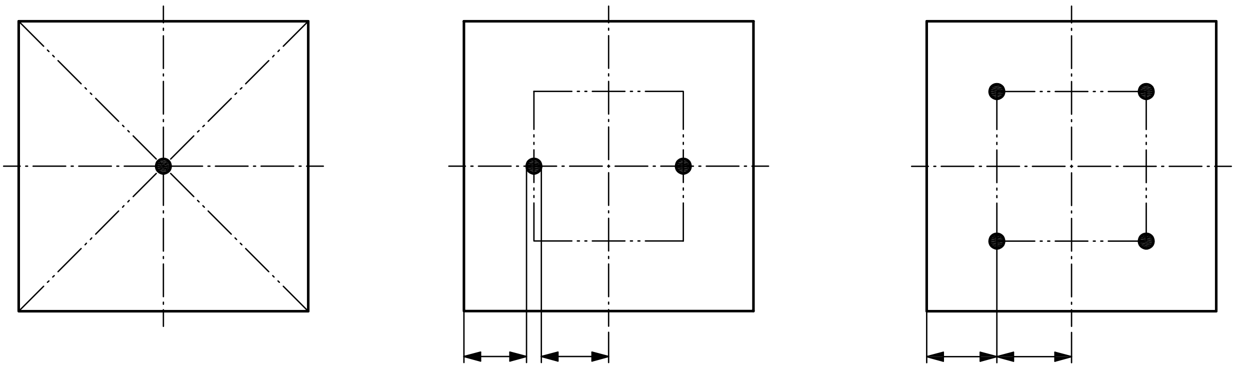
The dust injection nozzle(s) or tube(s) is (are) located as shown in Figure 2.

Any commercial dust feeder which is designed for air filter loading tests (e.g. ISO 16890-3 and ISO 5011) can be chosen. The purpose of the dust feeder is to supply the synthetic dust to the filter under test at a constant rate over the test period. These dust feeders disperse the dust with compressed air through a dust injection nozzle into the test rig through the dust feed tube. All tubing, nozzles and the like, that are in direct contact with the dust during the operation should be electrically conductive and grounded.

The dust feeder shall be able to produce a mass concentration between 100 mg/m^3 and 600 mg/m^3 at the rated air flow. If necessary, more than one dust feeder or dust nozzles can be used.

Averaged over an interval of 5 min, the feeder shall be able to produce an upstream dust mass concentration within ±20 % over the testing time (4 h).

It is recommended to place the dust feeder with dust reservoir on a scale to get a continuous recording of the dust fed (e.g. in intervals of 1 min to 5 min). It shall be possible to record the mass of dust fed versus time with at least ±10 g accuracy.



a) Single nozzle positioning **b) Double nozzle positioning** **c) Positioning for four nozzles**

Figure 2 — Positioning of feeding nozzles

4.7 Water spraying nozzles (fogging nozzles)

The fogging nozzle(s) are located and positioned as described in Figure 2.

One or two-substance nozzle(s) capable of producing in total 10 g/min to 160 g/min (= 0,6 g/m^3 at 1 000 m^3/h to 1,2 g/m^3 at 8 000 m^3/h) mass flow of water (droplets) are recommended to be used (similar range like ISO 29461-2). The quantity can be adjusted by the compressed air pressure and number of nozzles used (e.g. one to four nozzles). Examples of nozzles are described in ISO 29461-2, but it is not intended to specify a certain manufacturer or type.

An exact definition of the water aerosol (amount and size distribution) is not necessary for this document as it is only needed to accelerate the increase of pressure drop.

The water spraying system shall have a constant mass flow with a tolerance of ±20 % of the selected flow during the complete test (4 h). It is recommended to place the water reservoir on a scale to get a continuous recording of the water fed. Alternatively a constant water flow rate within ±20 % over testing time should be validated in preliminary tests. It shall be possible to record the mass flow of water fed versus time with at least ±20 g accuracy.

Exact amount of water and droplet size at filter position also depends on air flow rate, temperature and relative humidity of inlet air. It is not intended to restrict this test method to a full climatic conditioned test rig.

The water mass flow shall be 4 ± 0,5 times greater than the dust mass flow to ensure a sufficient mix of dust and water in the test air.

NOTE A noticeable amount of the injected water will evaporate and increase the relative humidity. This is neglected because of the reasons detailed in 4.7.

4.8 Final filter/coarse filter mat or grid

A final filter is recommended to capture any loading dust that passes through the test device during the dust loading procedure. It should be installed after the test device. It is recommended to use a filter of filter class T8 or higher according to ISO 29461-1. To be able to detect released parts or components of the test sample in the downstream area by visual inspection, a fine grid (maximum 3 mm open mesh size) or a flat shaped coarse particle filter mat shall be installed after the test device upstream of the optional final filter.

4.9 Temperature, relative humidity

The temperature measurement device shall be accurate to within ±1 °C (1,8 °F). The relative humidity measurement device shall be accurate to within ±2 %. The temperature and relative humidity measurement devices shall be calibrated yearly.

5 Qualification of test rig and apparatus

5.1 Pressure system test

The requirements specified in ISO 16890-2:2022, 8.2.1 shall be met.

5.2 Test rig — Pressure drop of test duct with no test device installed

The requirements specified in ISO 16890-2:2022, 8.2.12 shall be met.

5.3 Test rig — Pressure drop reference test

A perforated plate (or other object) with known pressure drop values at a minimum of four measured air flow rate data points shall be used as a reference. The data points shall be in the range of 1 700 m^3/h to 5 000 m^3/h.

The measured resistance to air flow across the reference shall be within ±5 % of the reference value. If the resistance to air flow deviates by more than ±5 %, system maintenance shall be performed to restore the resistance to air flow to within ±5 % of the reference value.

5.4 Summary of qualification requirements and schedule

The test rig and apparatus qualification requirements are shown in Table 1. System qualification testing shall take place every two years or sooner if any change is made to the system that may alter performance, such as changing a major component of the system.

Table 1 — Summary of qualification requirements and schedule

Items	Subclause	Requirements	Frequency
Pressure system test	5.1	No change in Pa	Every two years or after system changes
Pressure drop of duct with no filter installed	5.2	< 5 Pa	Quarterly
Pressure drop reference test	5.3	within 5 % of the reference value	Monthly

6 Test materials

6.1 Test dust

ISO 12103-1 Fine (A2) ATD (Arizona test dust) or another dust with comparable characteristics and properties shall be used for the test procedure.

The loading test dust “fine” is defined in ISO 12103-1, and consists of natural occurring silica particles.

6.2 Water

Normal tap water with a PH value in the range of 6 to 8 and a recommended hardness of < 2,5 mmol/l may be used for the test.

6.3 Coarse filter

A fine grid (maximum 3 mm open mesh size) or a flat shaped coarse particle filter mat shall be installed after the test device, upstream of the optional final filter. This filter is intended to detect by visual inspection released parts/components of the test sample in the downstream area. Pleated filter elements should not be used as it is difficult to detect small released parts.

7 Test procedure

7.1 General

The test device shall be tested for initial efficiency in accordance with ISO 29461-1 in new state (a discharging procedure according to the ISO 16890 series is not necessary) prior to the dust loading procedure or any conditioning, regardless of whether the filter model has been previously tested with another filter sample.

This procedure shall be used for new filter elements or after a test in accordance with ISO 29461-1 with a loading up to 625 Pa (maximum 800 Pa). Any other prior ageing procedure shall be clearly described as variation in the test report. Preconditioning of filter elements for “wet burst” test shall be made according to Annex A.

After the initial efficiency test according to ISO 29461-1, the test procedure continues with the test preparation described in 7.3 and the loading procedure described in 7.5.

The dust loading is conducted at rated air flow up to a standard pressure drop of 6 250 Pa, if not specified to another value and clearly indicated in the test report.

In order to prevent noticeable different loading times, which can result in completely different mechanical stress on the element, the dust loading concentration shall be adjusted depending on the pressure drop increase rather than the dust loading behaviour of the filter element (e.g. dependent on media area or dust holding capacity), see 7.4.

Recommended test duration time is 3 h to 4 h (loading time inclusive holding time at maximum pressure drop), but can be exceeded based on the performance of the test sample.

7.2 Test result evaluation

7.2.1 General

The main target is an objective evaluation if a filter element meets the pass criteria of a laboratory mechanical integrity test (“burst test”) up to a maximum defined pressure drop (standard 6 250 Pa).

This evaluation comprises four parts as defined in the following subclauses.

7.2.2 Measurement of pressure drop

The pressure drop measurement of the test sample shall be performed to detect a spontaneous decrease of the pressure drop as a result of a leakage.

A clear indication of a break within the filter element or filter medium is a sudden significant decrease of the pressure drop. A significant decrease of pressure drop is defined as > 50 Pa up to a measured pressure drop level of 2 500 Pa and > 2,0 % above a pressure drop level of 2 500 Pa, between two pressure drop recordings in a standard time interval of 1 min. However, the test laboratory should ensure that this is not a result of detaching the dust cake on the upstream side.

If the dust fed is constant, a leakage can also be present if the pressure drop is not increasing at the same rate as measured before. The operator shall observe visually very carefully the further loading.

7.2.3 Visual inspection of filter

The visual inspection of the filter shall be performed to detect obvious leakages and/or damages of the test sample during or after the test. For this reason, a camera shall be installed behind the test sample.

Potential leakages and/or damages shall be evaluated by qualified personnel. A minor structural change as for example, the deformation of a pleat pack shall not be rated as a damage as long the tested filter efficiency is not lower than the initial reported efficiency (see 7.6.5).

7.2.4 Visual inspection downstream of the test device

The visual inspection downstream of the test device shall be performed to detect released parts/components of the test sample in the downstream area.

For this reason, a fine grid (maximum 3 mm open mesh size) or a flat shaped coarse particle filter mat shall be installed after the test device, upstream of the optional final filter.

The release of solid parts/components of the tested sample that are visible to the naked-eye necessarily leads to a failed test.

7.2.5 Final test in accordance with ISO 29461-1

A final efficiency test of the test device shall be made in accordance with ISO 29461-1 if the condition of the filter after dust loading is acceptable for such a test (the filter is not collapsed or for any other reason unsuitable for a test according to ISO 29461-1).

If the filter has failed according to 7.2.2 or 7.2.4 this test is not mandatory.

If the results are showing lower efficiency compared to the initial efficiency (clean filter) in any particle size range, this shall be regarded as a failure.

A discharging procedure (according to the ISO 16890 series) of the dust loaded filter element is not needed for this fail/pass check.

The filters are dust loaded to 6 250 Pa before performing the efficiency test. Since not every rig according to ISO 29461-1 would be able to operate at that pressure drop, the test air flow shall be reduced to a value corresponding to a pressure drop between 2 500 Pa and 3 000 Pa of the dust loaded filter. This is still above the running conditions for most practical applications.

Some filters can initially shed particles and affect the test results negatively. For this reason (prior to the efficiency test), the laboratory shall measure the upstream and downstream concentration of the filter element at the test air flow only with the background concentration (without the aerosol generator running). If in any particle size range relevant for the fail/pass check criteria the downstream concentration minus the upstream concentration exceeds 2 % of the used upstream concentration for the new filter element test (see 7.1) the filter shall be conditioned for an additional 15 min at the test air flow before the efficiency test.

NOTE For example, if the upstream concentration used in the initial efficiency test was 1 000 000 particles per cubic metre for a particle size, the 15 min of conditioning is done if the shedding (downstream concentration minus the upstream concentration with no aerosol) is exceeding 20 000 particles per cubic metre (1 000 000 × 0,02).

7.3 Test preparation

The following steps shall be executed during the test preparation:

— The test sample shall be visually checked for any damages according to the checklist in Table 4 and for dirt residues on the downstream side. Solid dirt pieces as from packaging material shall be detached from the test sample. All findings shall be documented.

— All relevant product information shall be documented (including type of filter, type of filter medium, installed filter area, sealant, etc.)

— The output of the dust and water feeder shall be measured and if necessary, adjusted to the intended concentration within ±15 % to prevent re-adjustments after start of the loading.

— The test sample shall be mounted in accordance with the manufacturer’s recommendations and should be close to the real application, if possible.

— The test sample, including any normal mounting frame and mounting accessories, shall be sealed into the duct in a manner that prevents leakages. The tightness shall be checked by visual inspection. No visible leaks are acceptable.

— The test rig shall have a fine grid or a flat shaped coarse particle filter mat installed downstream the test device, upstream of the optional final filter.

— The initial pressure drop shall be recorded at the rated air flow.

— The installed camera shall record and show the full downstream filter area. If necessary, the camera position shall be adjusted and/or the camera shall be cleaned.

7.4 Determination of the initial loading concentration of test dust and water

The ratio of the mass concentration of test dust and water shall be 1:4 (e.g. 250 mg/m^3 A2 test dust and 1 000 mg/m^3 water flow through the spraying nozzles).

Recommendations for initial concentrations as a function of filter media surface area are given in Table 2.

Table 2 — Recommended dust/water flow mass concentration

Media area, approximately [m^2]	**Dust concentration** [mg/m^3]	**Water flow** [mg/m^3]
10	150	600
20	250	1 000
30	300	1 200
40	400	1 600

The target is a minimum of 2 h loading up to the final pressure drop and a maximum of 4 h. If this has not been achieved from any reasons, it shall be recorded in the documentation.

If test data of same or similar filter design are available, chose an appropriate constant test concentration to meet the target loading time. Otherwise refer to the recommended start concentrations in Table 2. If in doubt, choose the lower concentration.

NOTE It is assumed that the increase of pressure drop versus dust/water loading is not linear. Especially at the beginning of the loading, the pressure drop will increase much slower. Therefore, it will need some experience and judgment of the laboratory operator.

7.5 Loading procedure

The test device is progressively loaded at rated test air flow rate with the concentration determined in 7.4 of the test dust and water until the maximum final pressure drop of 6 250 Pa is achieved. The amount of dust and water fed shall be recorded versus time and pressure drop as specified in 4.6 and 4.7. The pressure drop shall be recorded every minute.

Once dust loading is started, interruptions in the air flow can change the filter characteristics such as pressure drop. Therefore, the air flow through the filter shall be constant at nominal air flow until the loading procedure is completed. If it is necessary for any reason to interrupt the test, it shall be documented and reported.

If after two hours loading an extrapolation of the pressure drop versus time curve indicates that the final pressure drop cannot be finished within 4 h, the concentration should be increased by factor 1,5 or other experience-based value during the loading procedure. If necessary, the same will be performed again after 3 h.

The test device shall be regularly observed visually. At least at every 500 Pa increment, the filter element shall be visually checked through the window at the upstream side and with all available cameras. This inspection shall be recorded and documented in the test report with pictures and notes describing the status of the test device.

A sudden decrease of the pressure drop is a clear indication of a leak. But also, a very slow or no increase of pressure drop (compared to the gradient before) can indicate a leak. In this case, the operator should observe the further loading thoroughly with the installed camera(s).

Stop the test if one of the fail criteria in 7.6.2 or 7.6.3 is met.

After reaching the final test pressure drop:

— document the loading time and stop the dust and water loading;

— maintain the air flow up to a total time of minimum 3 h (e.g. 2 h loading time plus 1 h holding time);

— if the pressure drop decreases > 250 Pa and time is < 3 h, start again loading up to the final pressure drop.

Before removal, the test device may be dried with a clean air flow.

If not positioned on a scale with continuous reading, the weight of the water reservoir shall be determined with an accuracy of ±20 g.

The operator shall carefully search for any parts released by the filter in the duct between the test device and the coarse filter. Any parts or fragments found which can be related to the test device shall be documented.

The test device shall be thoroughly visually inspected for any leaks or damages.
See 7.6 for fail/pass criteria.

After the test procedure has been carried out, the filter shall be dried and then tested according to the efficiency test method it has been rated by (see 7.2.5) and the results should be included in the reporting. The test device shall be conditioned to a dry condition prior to such a test.

A final test according to ISO 29461-1 after the dust loading is not necessary if it fails in any other fail criteria (7.6.2, 7.6.3). This shall be described in the final report. The documentation shall include pictures of the test device after the test from the up- and downstream side and all areas of leaks (if any).

7.6 Fail/pass criteria

7.6.1 General

The filter will fail if any of the criteria in 7.6.2, 7.6.3 or 7.6.5 are met. The filter can fail at any point of time during the test. The filter can pass only after the test in 7.6.5 has been conducted at the end of test procedure (6 250 Pa).

The evaluation criteria are listed in 7.6.2 to 7.6.5.

7.6.2 Release of parts

The filter fails if a release of any parts of the filter element (e.g. adhesive, media, grid) into the downstream area is detected, see Table 3.

7.6.3 Pressure drop decrease

The filter fails if the pressure drop decrease > 50 Pa in the lower measurement range (0 Pa to 2 500 Pa) and > 2,0 % of the measured value in the higher range (2 500 Pa to 6 250 Pa), in combination with a visual confirmation of a damage (e.g. not a result of detaching the dust cake on the upstream side or other explainable reasons, see 7.2.2).

7.6.4 Visual inspection during test

A visual inspection shall be conducted and documented at each 500 Pa increment or when damages are detected. This shall be performed according (but not limited) to the checklist in Table 3 and Table 4 and shall be documented and reported in the final report.

7.6.5 Final test in accordance with ISO 29461-1

The filter fails if the tested filter has a lower measured efficiency in any particle size range than the new filter according to ISO 29461-1 (see 7.2.5).

Table 3 — Checklist for failing damages

Description	Fail (end of test)	To be documented
Any component of the filter separating from the rest and coming loose (media/scrim/grid/adhesive, etc.)	Yes	Yes

Table 4 — Checklist for visual inspections, to be reported

Description	To be documented
Separation of media pack and frame/adhesive even if no parts come loose	Yes
Any cracks in the media pack (e.g. either on one pleat along the tips or on multiple pleats in a line perpendicular to the pleat tips)	Yes
A visible lack of sealing to test rig frame or defects and cracks in filter mounting frame/body	Yes
Bypass through (if applicable and depending on the filter design) — damage of the filter medium by stress fractures — damage of the filter medium by detached spacers — open weld seams/stitched seams — a gap between frame and pocket — ripped out frame parts — any broken frame parts — a gap between frame gasket and mounting frame due to frame bending	Yes
Any other damage found in dependence of the filter design	Yes
Blown up pockets by detached spacers (without bypass)	Yes

At higher pressure drop, pleats can be deformed, the grid and/or outer shape of the filter can be bended or even the compound/adhesive between the frame and the pleats can be separated in small areas.

These observations should be recorded but they do not indicate a broken filter element, even if the deformation will possibly not be fully reversible. The filter elements can still be fully functional.

All deformations will possibly return to their initial shape position when the pressure drop or air flow is reduced.

A clear indication that a filter is destructed can be seen in the pressure drop curve which would be recorded at any time. A disintegration of a filter element will be accompanied by a sudden Δp drop. A drop of Δp can also be stealthy, or the Δp just rises very slowly.

NOTE The pressure drop of the filter element to be tested can drop during the visual inspection. This does not necessarily indicate a crack, it can also be caused by effects such as water evaporation.

8 Reporting results

8.1 General and descriptive information

An example of a test report can be found in Annex B. The test report shall include but not be limited to the following items:

a) laboratory information

- laboratory name;
- laboratory location and contact information;
- test operator’s and supervisor name(s);

b) test information

- a reference to this document, i.e. ISO 29461-3:2024;
- additional description of the test method (where necessary)

— unique test report identification;

— date of the test;

— device receiving date;

— test client and device delivered by;

— manufacturer name of the device;

c) test device information

— description of the device/physical description of construction;

— brand, identification/model number of the device;

— marking of the device;

— test device condition/history (new, any prior performed tests like filter efficiency and/or prior loadings according to ISO 29461-1 or any other ageing/durability procedures);

— dimensions (height, width and depth);

— type of media/media identification;

— additional information if available (device or media);

— net effective filtering area according to ISO 29461-1;

— the pictures of raw air and clean air sides of the device;

— initial pressure drop and efficiency according to ISO 29461-1;

d) details of instrumentation

— type of water spray device, number of nozzles and operating pressure of the nozzles;

— type of dust feeder, number of injection nozzles;

— method of air flow measurement;

e) test conditions

— test air flow rate;

— test air temperature and relative humidity;

— type of dust;

— loading dust concentration;

— water fog concentration during loading;

— specified final test pressure drop (if different from the standard value of 6 250 Pa).

8.2 Test data and results

An example of a test report can be found in Annex B. The test report shall include but not be limited to the following items:

— weight of test device before installation in test rig;

— condition of new test sample prior to the test procedure (e.g. “new filter, from original package, no prior loading or treatment, no damage, clean”). Any other special observations;

- total mass of dust and water fed during the loading;
- initial test pressure drop as measured at the test air flow rate;
- final test pressure drop at the test air flow rate;
- a graph and tabular form of pressure drop versus dust fed and time at least every 250 Pa;
- a graph and tabular form of the efficiency results according to ISO 29461-1 (see 7.1 and 7.2.5) before and after the test procedure has been conducted for all measured particle size ranges, including a statement if the requirement in 7.6.5 is met;
- visual observation documentation at each 500 Pa (see 7.6.4) in tabular format;
- pictures and description of any observations (not only fail criteria) during the test with corresponding pressure drop value;
- pictures of test device at start of test before and after installation in the test rig at least from up- and downstream side;
- pictures of test device installed in test rig at final test pressure drop;
- pictures of test device after removal at least from up- and downstream side;
- final statement if the filters have passed or failed;
- final summary statement of the test result.

EXAMPLE An example of a final test result statement is as follows:

The filter element resisted up to a pressure drop of 6 250 Pa without visible break or damage. The final test according to ISO 29461-1 on the dust loaded test device was not showing a decrease in filter efficiency.

All data values shall be reported as whole number values only (no decimal or fractions) when displayed in SI units (Pa, g).

If a test device failed before reaching the final pressure drop, the pressure drop value shall be rounded downwards to the nearest multiple of 100 Pa when reporting.

8.3 Concluding statement

The results of this test relate only to the test device in the condition stated herein. The endurance performance results cannot by themselves be quantitatively applied to predict filtration performance or to evaluate the behaviour of filters in all "real life" environments. The real-life performance and mechanical integrity of filters depends on actual site environment conditions.

Annex A
(normative)

Wet burst testing

A.1 General

This preconditioning procedure of the test devices is used on requests for a so-called “wet burst testing”. Wet burst testing has relevance for extreme wet and humid operation conditions since the mechanical integrity of the filter components can be altered in the presence of water over a longer period.

Therefore, the filter element shall be pre-soaked in water before a “burst test” according to this document. This soaking challenge can reduce the burst pressure for the filter.

A.2 Preconditioning procedure

For this procedure, only new filter elements shall be used. Any other prior done ageing or loading procedure shall be clearly described as variation in the test report.

The test sample shall be visually checked for any damages according to the checklist in Table 4 and for dirt residues on the downstream side. Solid dirt pieces as from packaging material shall be detached from the test sample.

The entire filter shall be submersed under normal tap water for minimum 12 h.

During the storage of the filter element, the test rig shall be prepared according to 7.3 (e.g. output of the dust and water feeder, camera, fine grid or flat shaped coarse filter).

The filter shall be surfaced and drained of free water before installed in the test duct. The drainage of water shall be carried out for 5 min (minimum) from each side (upstream and downstream side up). The transition and installation in the test rig shall be done within 15 min.

The dust and water loading phase shall be started within 10 min after installation (see 7.4 and 7.5).

A.3 Documentation

Filters tested according to this annex shall be reported according to this document with the additional text (wet/Annex A) listed after the actual burst pressure and clearly stated in the test data and results (see 8.2).

Annex B
(informative)

Test report example

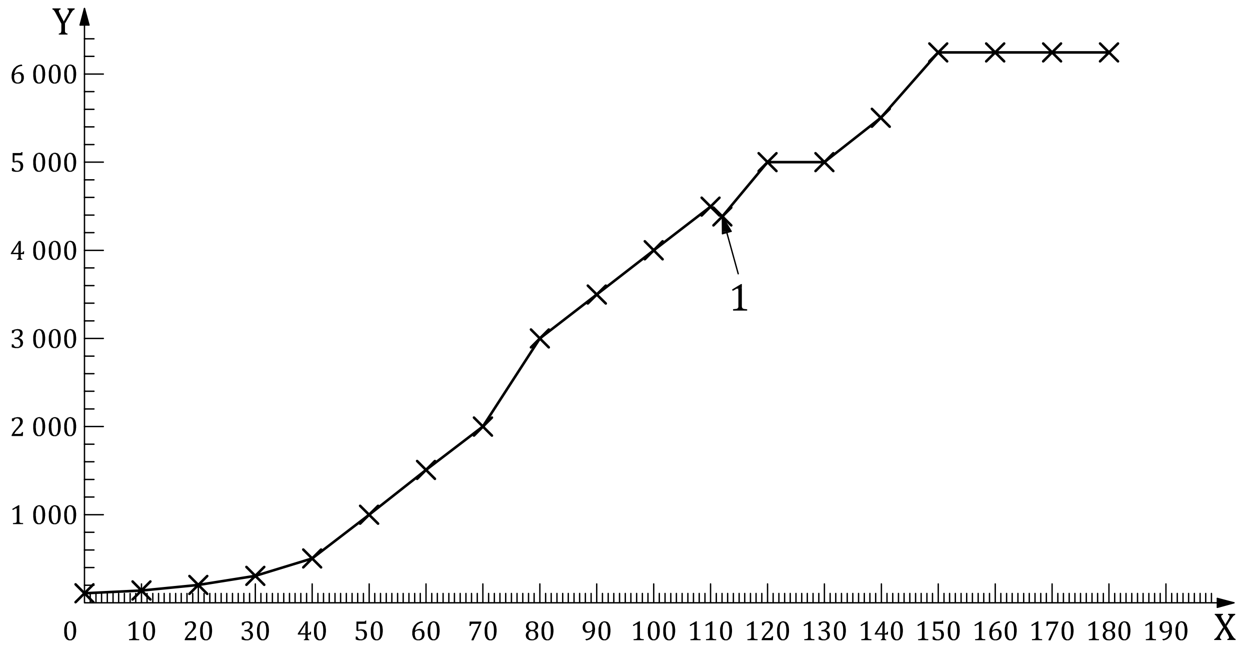
STANDARD/TEST ORGANISATION			
Test organisation	Filter laboratory Inc.	Report no: 001-YYMMDD	
Address/email	L street 29, City, Region, Country / email address		
GENERAL			
Test no: Unique number	Date of test: YYYY-MM-DD	Supervisor: Name of supervisor	
Test client: X-Corporation Device supplied by:	Device receiving date: YYYY-MM-DD	Test operator: Name of operator	
DEVICE – MANUFACTURER'S DATA			
Model: GT Filter Q GT-XYZ-592-592-295-T9	Manufacturer: X-Corporation	Construction: V-Bed	
Type of media: Synthetic, pleated, XYZ	Effective filtering area: 16 m^2	Filter dimensions (W × H × D): 592 mm × 592 mm × 292 mm	
Rated air flow: 3 400 m^3/h	Rated pressure drop: 100 Pa	Rated filter class: T9 (see ISO 29461-1)	
TEST EQUIPMENT			
Test rig	XYZ rig, range 500 m^3/h to 8 000 m^3/h		
Water spray device	ABC-spray device, air/liquid type, 4 nozzles, operating pressure X bar		
Dust feeder	XYZ-dust feeder, 2 injection nozzles		
Air flow measurement	Orifice plate XYZ		
DEVICE TESTED - CLEAN FILTER			
Device condition (prior to test): New filter, from original package (box). No prior loading or treatment			
Effective filtering area: 15,4 m^2 (see ISO 29461-1)	Dimension (W × H × D): 592 mm × 592 mm × 295 mm	Initial pressure drop: 108 Pa	Efficiency[a]: ePM_1=91 % $ePM_{2,5}$=94 %
TEST CONDITIONS			
Test air flow: 3 405 m^3/h	Temperature: 23 °C	Relative humidity: 95 %	
Type of dust: ISO A2 Fine	Dust concentration: 200 mg/m^3	Fog concentration: 800 mg/m^3	Final test pressure drop: 6 250 Pa
TEST RESULTS (7.2.5)			
Weight of test device before test: 2,1 kg	Total water load: XXX g	Total dust load: YYY g	
Test Air flow[b]: 3 000 m^3/h	Test pressure drop[b]: 2 500 Pa	Efficiency[c]: ePM_1=79 % $ePM_{2,5}$=84 %	Comment: See enclosed test report XYZ (see ISO 29461-1)

OBSERVATIONS
No comments up to 4 500 Pa. After 4 500 Pa, the backplates started to move (slightly). At 4 500 Pa, a slight decrease in pressure drop was observed, less than 5 % of the measured value. No clear visible damage was observed. This bending of the backplate was monitored during the test but no major damage was identified for the remainder of the test. The test was conducted up to 6 250 Pa and ended after 3 h duration. The filter was then tested according to ISO 29461-1.
SUMMARY
The tested device showed no signs of damage up to 4 500 Pa. At 4 500 Pa, a decrease in pressure drop was observed (< 5 % of measured value). A slight bend of one of the backplates was observed, but no visual signs of a major damage. After the dust loading phase was finalized, the filter was tested (after conditioning) for efficiency according to ISO 29461-1. The efficiency was lower than the initial test (clean device), see report XYZ.
CONCLUSION
Filter has failed the test. The final efficiency test (7.2.5) showed lower efficiency compared to the initial (clean device) test data and therefore the filter failed from the 7.6.5 criteria.
[a] The test results from report XYZ. [b] The ISO 16890 series test rig was only able to reach the 2 500 Pa pressure drop. [c] The efficiency was measured on the dust loaded, conditioned filter, no additional treatment.

PICTURES			
Graphic 1: New filter upstream	Graphic 2: New filter downstream	Graphic 3: Filter at 500 Pa, no observations	Graphic 4: Filter at 1 000 Pa, no observations
Graphic 5: Filter at 1 500 Pa, no observations	Graphic 6: Filter at 2 000 Pa, no observations	Graphic 7: Filter at 2 500 Pa, no observations	Graphic 8: Filter at 3 000 Pa, no observations
Graphic 9: Filter at 3 500 Pa, no observations	Graphic 10: Filter at 4 000 Pa, no observations	Graphic 11: Filter at 4 500 Pa, no observations	Graphic 12: Filter at 4 520 Pa, backplate deformation
Graphic 13: Filter at 5 000 Pa, backplate deformation	Graphic 14: Filter at 5 500 Pa, backplate deformation	Graphic 15: Filter at 6 000 Pa, backplate deformation	Graphic 16: Filter at 6 250 Pa, backplate deformation
Graphic 17: Filter at 6 250 Pa, at end of test, upstream side	Graphic 18: Filter at 6 250 Pa, at end of test, downstream side	Graphic 19: Backplate deformation, downstream side	

TEST DATA			
Test started YYYY-MM-DD, 09:00 Test ended YYYY-MM-DD, 12:05			
Time elapsed [min]	**Dust load** [g]	**Δ*p*** [Pa]	**Observation**
0	0	108	Start of test
10	114	140	-
20	227	200	-
30	341	300	-
40	454	500	Check of filter – no deformations
50	568	1 000	Check of filter – no deformations
60	600	1 500	Check of filter – no deformations
70	700	2 000	Check of filter – no deformations
80	908	3 000	Check of filter – no deformations
90	1 100	3 500	Check of filter – no deformations
100	1 135	4 000	Check of filter – no deformations
110	1 249	4 500	Check of filter – no deformations
112	1 271	4 385	Pressure drop decrease, back plate bent, 3 % decrease of pressure drop (from 4 520 Pa)
120	1 362	5 000	Monitoring – back plate bent
130	1 476	5 500	Monitoring – back plate bent
140	1 589	6 250	Monitoring – back plate bent
150	1 703	6 250	Dust feeder stopped
160	1 816	6 250	Holding at 6 250 Pa
170	1 930	6 250	Holding at 6 250 Pa
180	2 043	6 250	Test end (3 h)

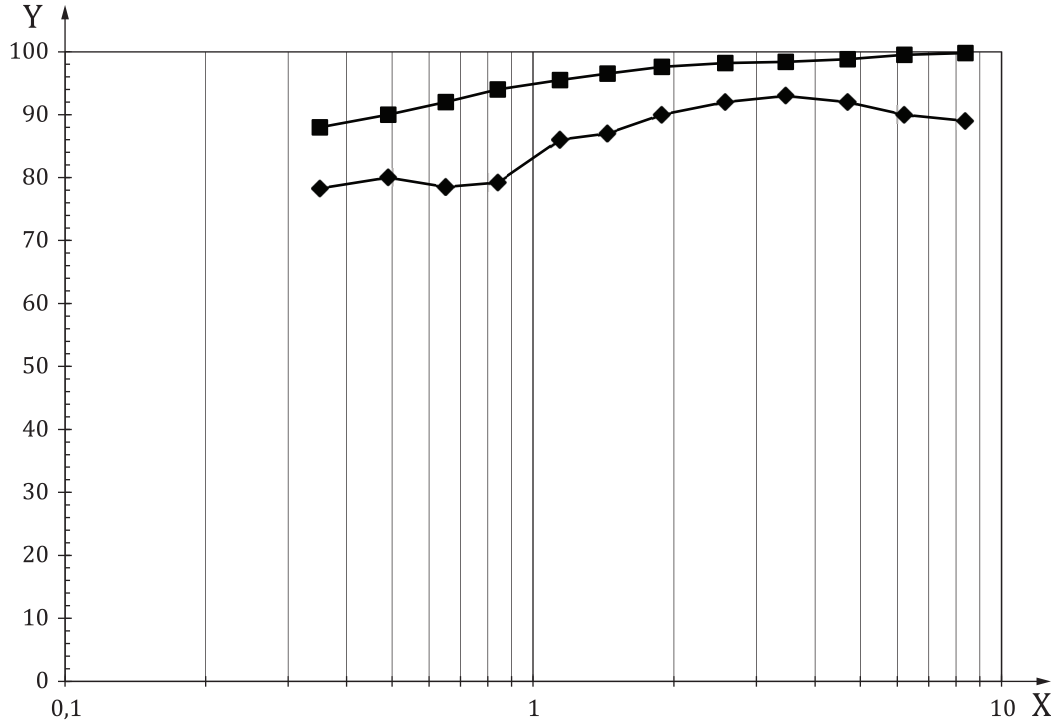
Pressure drop versus time (Q = 3 400 m³/h)



X time [min] Y pressure drop [Pa] 1 observed pressure decrease during test

TEST DATA efficiency 29461-1 (ISO 16890)				
		Measured efficiency		
Particle size range [µm]	$d_{m,i}$ [µm]	Clean filter	Dust loaded filter	Test aerosol
0,30 to 0,40	0,35	88	78,3	DEHS
0,40 to 0,60	0,49	90	80	DEHS
0,60 to 0,70	0,65	92	78,5	DEHS
0,70 to 1,00	0,84	94	79,2	DEHS
1,00 to 1,30	1,14	95,5	86	KCl
1,30 to 1,60	1,44	96,5	87	KCl
1,60 to 2,20	1,88	97,6	90	KCl
2,20 to 3,00	2,57	98,2	92	KCl
3,00 to 4,00	3,46	98,4	93	KCl
4,00 to 5,50	4,69	98,8	92	KCl
5,50 to 7,00	6,2	99,5	90	KCl
7,00 to 10,0	8,37	99,8	89	KCl
$d_{m,i}$ is the diameter of particle size range *i*. DEHS is Di-Ethyl-Hexyl-Sebacate and KCl is Potassium chloride.				

Fractional efficiencies by particle size



X particle size [µm]

Y fractional efficiency [%]

dust loaded filter

clean filter

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[1] ISO 5011, *Inlet air cleaning equipment for internal combustion engines and compressors — Performance testing*

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[4] ISO 29461-2, *Air intake filter systems for rotary machinery — Test methods — Part 2: Filter element endurance test in fog and mist environments*

[5] ISO 29463-1, *High efficiency filters and filter media for removing particles from air — Part 1: Classification, performance, testing and marking*

[6] ISO 29464:2017, *Cleaning of air and other gases — Terminology*

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