INTERNATIONAL STANDARD

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# Air intake filter systems for rotary machinery — Test methods —

## Part 2: Filter element endurance test in fog and mist environments

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

*Partie 2: Essai d'endurance d'élément filtrant en brouillard et environnement brumeux*

Reference number
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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 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).

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This document was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 195, *Cleaning equipment for air and other gases*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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

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.

# Introduction

The ISO 29461 series provides a way to compare these products in a similar method and define what criteria are important for air intake filter systems for rotary machinery performance protection. The aim is to compare the performance of different filters and filter types with respect to the operating conditions in which they will be finally used.

Air intake filter system of rotary machinery is an important part of the whole gas turbine and air compressor systems. It usually consists of filter elements with a suitable way to be installed. The operating environment of rotary machinery including gas turbine and compressor and their air intake filtration units are complicated and challenging. Air filters intercept water mist and droplets when air passes through the air filter unit in case the equipment is working in rainy, foggy, hazy or other high-humidity environments or a local production environment which contains a large amount of water vapour, e.g. the cooling tower. If excessive water holds up, the performance of filters can be affected; pressure drop rises rapidly, causing a shut down in severe cases.

Reliability and non-break down operation of rotary machinery are regarded as a top priority for the end users, with the rapidly rising pressure drop under high-humidity conditions usually being their main concern. There are rotary machinery operating accidents caused by high-humidity conditions all over the world, whether it be inland or along the river or coastal.

To meet the requirements of production and operation, the water endurance performance of air filter elements needs to be considered besides assessing the performance of initial pressure drop, filtration efficiency and dust-holding capacity, especially when the air filter elements are used in high-humidity environments or intake air contains a large quantity of liquid droplets.

This document provides a water endurance test method for filter elements and can be used for evaluating performance variation trends of filter elements when encountering water and fog. This document can be used for:

— product development for filter manufacturers;

— supplier selection for end users;

— development of water endurance media by media manufacturers.

This document provides a repeatable, easy-to-conduct and economical test method, which is applicable to pulse-jet cleaning filter elements and filter elements for general ventilation.

# Air intake filter systems for rotary machinery — Test methods —

# Part 2:
# Filter element endurance test in fog and mist environments

## 1 Scope

This document specifies general test requirements, the test rig and equipment, the test materials and the test procedure and report for determining water endurance performance of air filter elements used in air intake filter systems for rotary machinery such as stationary gas turbines, compressors and other stationary internal combustion engines.

The test evaluates water endurance performance of air filter elements under laboratory conditions. The performance results obtained in accordance with this document cannot be quantitatively applied (by themselves) to predict performance in service with regard to water endurance and lifetime.

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

## 3 Terms and definitions

For the purposes of this document the following terms and definitions 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 Air flow and pressure drop

**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 airflow rate used for testing

[SOURCE: ISO 29464:2017, 3.3.2]

**3.1.3**
**pressure drop**
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* (3.1.3) of the clean filter operating at the test airflow rate

[SOURCE: ISO 29464:2017, 3.3.17]

**3.1.5**
**final test pressure drop**
maximum *pressure drop* (3.1.3) of the filter up to which the filtration performance is measured

[SOURCE: ISO 29464:2017, 3.3.15]

## 3.2 Filters

**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**
**upstream**
area or region from which fluid flows as it enters the *test device* (3.2.1)

[SOURCE: ISO 29464:2017, 3.1.39]

**3.2.4**
**downstream**
area or region into which fluid flows on leaving the *test device* (3.2.1)

[SOURCE: ISO 29464:2017, 3.1.11]

**3.2.5**
**static filter**
air filter that will be removed (exchanged) after it has reached its *final test pressure drop* (3.1.5) 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]

**3.2.6**
**pulse jet filter**
cleanable air filter, that typically is cleaned with air jet pulses to provide a longer service life

[SOURCE: ISO 29464:2017, 3.3.11]

**3.3**
**test duration**
period of reaching a certain *pressure drop* (3.1.3) or other termination conditions to end the test

### 3.4 Test materials

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

**3.4.2**
**saturated air**
air that contains the maximum amount of water vapour it can hold at its temperature and pressure

**3.4.3**
**water fog mass concentration**
mass of liquid water droplets per unit volume of air

**3.5**
**two-fluid nozzle**
nozzles capable of spraying fine mists by mixing fluid and air at the same time

**3.6**
**coefficient of variation**
**CV**
standard deviation of a group of measurements divided by the mean

[SOURCE: ISO 29464:2017, 3.2.31]

## 4 Symbols and abbreviated terms

| | |
|---|---|
| $c_{wm}$ | water fog mass concentration, g/m$^3$ |
| $d$ | saturated wet air moisture content, g/kg |
| $d_0$ | ambient air moisture content, g/kg |
| $m_p$ | water mass penetrated through tested filter at the end of the test, kg |
| $m_{tot}$ | total water fog generation amount, kg |
| $m_u$ | sedimentary water mass upstream of filter, kg |
| $m_{wm}$ | total water fog generation amount per hour, kg/h |
| $m_{wm,\,1}$ | water fog generation amount per hour at saturated humidifying air, kg/h |
| $m_{wm,\,2}$ | water fog generation amount per hour, kg/h |
| $p$ | atmospheric pressure, Pa |
| $p_a$ | absolute air pressure upstream of filter, Pa |
| $p_w$ | partial vapour pressure of water in air, Pa |
| $p_{ws}$ | saturated vapour pressure of humidifying air, Pa |
| $q_v$ | volumetric flow of non-humidifying air, m$^3$/h |
| $t_d$ | temperature downstream of filter, °C |

$t_0$ dry bulb temperature of ambient air, °C

$t_u$ temperature upstream of filter, °C

$t_{wb}$ wet bulb temperature of ambient air, °C

$T$ testing time, min

$T_{tot}$ total testing time, min

$\Delta p_b$ filter initial pressure drop at the test air flow rate, Pa

$\Delta p_f$ filter final test pressure drop at the test air flow rate, Pa

$\Delta p_T$ filter pressure drop at the test air flow rate at the $T$ time after spraying, Pa

$\eta_p$ water penetration ratio

$\rho$ ambient air density, kg/ m$^3$

$\rho_a$ air density upstream of filter, kg/m$^3$

$\rho_s$ saturated wet air density, kg/m$^3$

$\varphi$ relative humidity, %

$\varphi_u$ relative humidity upstream of filter, %

$\varphi_d$ relative humidity downstream of filter, %

$CV$ coefficient of variation

# 5 General requirements

Air filter systems normally use multiple stages of coarse and fine filter elements to protect the machinery. The scope of this document includes methods for a water endurance test of individual filter elements. It does not include methods for the direct measurement of the performance of entire systems as installed in service except in cases where they can meet the qualification criteria for the test assembly.

The test client can refer to the test results to rank the water endurance performance of multiple candidate filters.

# 6 Test conditions

## 6.1 Test air

Room air or outdoor air is used as the test air source. The air temperature shall be in the range of 10 °C to 38 °C (before wet equilibrium pre-treatment). The exhaust flow shall be discharged outdoors, indoors or re-circulated. Filtration of the exhaust flow is recommended when the test aerosol or loading dust is present.

## 6.2 Test water

The test water pH value shall be in the range of 6 to 8; alkalinity shall be no more than 50 mg/l; full hardness shall be no more than 70 mg/l. The temperature of the test water shall not be higher than the temperature of the test air.

# 7 Test rig and equipment

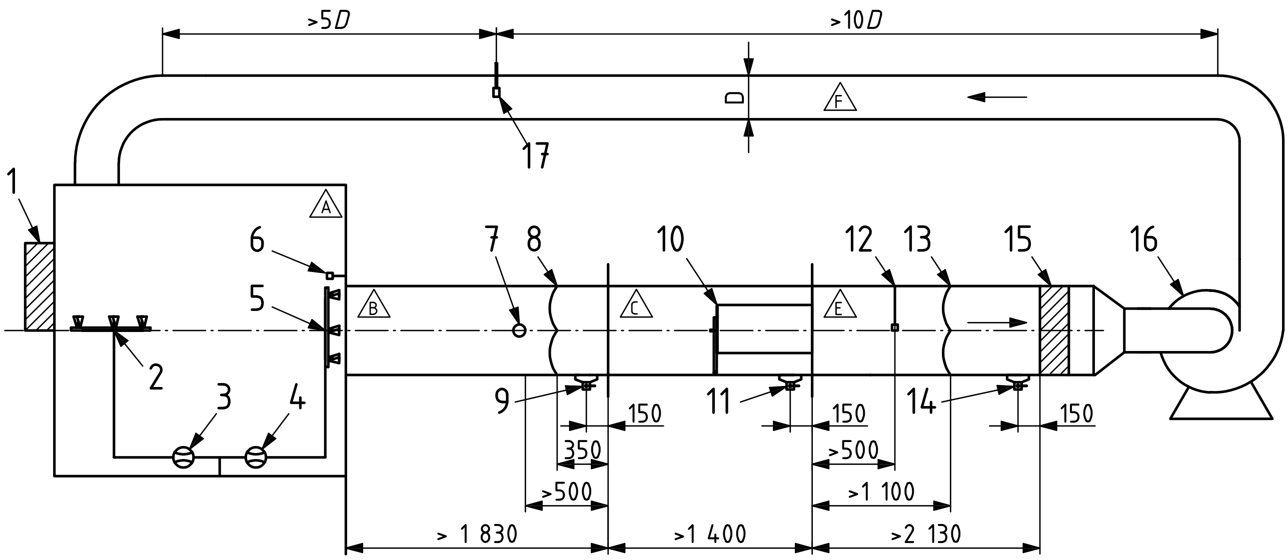
## 7.1 Test rig

The test rig consists of several square duct sections with typical 610 mm × 610 mm nominal inner dimensions except for the section where the filter is installed. This section has nominal inner dimensions between 616 mm and 622 mm. The length of this duct section shall be at least 1,1 times the length of the filter, with a minimum length of 1,5 m. A schematic diagram of the test rig is shown in Figure 1.

The test rig can be operated either in a negative or positive pressure air flow arrangement; and negative pressure operation is recommended. The test duct shall be sealed well to avoid water fog leakage if operated in positive pressure. A condensed water borehole should be provided at the lowest point in the fan housing in the event of formation of condensation.

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. Smaller parts of the test duct can be made in glass or plastic to expose the filter and equipment to view. Provision of windows to allow monitoring of test progress is desirable.

Dimensions in millimetres




**Key**

| | | | |
|---|---|---|---|
| A | duct section of the test rig (inlet plenum) | 7 | example of water droplet size instrument location |
| B | upstream duct section of the test rig | 8 | upstream pressure measuring point |
| C | duct section of filter to be tested | 9 | upstream water collecting groove |
| *D* | diameter of recirculated duct | 10 | filter to be tested |
| E | downstream duct section of the test rig | 11 | midstream water collecting groove |
| F | recirculated duct section of the test rig | 12 | downstream measuring point of temperature and humidity (secondary) |
| 1 | HEPA filter | 13 | downstream pressure measuring point |
| 2 | humidifying device | 14 | downstream water collecting groove |
| 3 | water mass flow metering device | 15 | final filter - eliminate water |
| 4 | water mass flow metering device | 16 | frequency converted fan |
| 5 | water spray device | 17 | air flow measuring point |
| 6 | upstream measuring point of temperature and humidity (primary) | | |

**Figure 1 — Schematic diagram of the test rig**

### 7.2 Water spray device

The water spray device is used to generate uniform water fog continuously to feed the filter to be tested during the test.

A two-fluid nozzle is recommended; and the spraying direction with respect to the inlet air flow shall be the same. The distance between the nozzle orifices and the duct section of filter to be tested shall be no less than 1 m.

The water fog particle can be adjusted by compressed air, or other means as called out by the nozzle manufacturer. The cumulative volume of water fog particles in the size range of 5 µm to 30 µm shall be more than 90 % of the total water fog volume.

Other types of water spray devices, such as ultrasonic humidifier and nozzle humidifier, can be used if these devices can achieve the same performance.

### 7.3 Humidifying device

The humidifying device shall maintain the required humidity in the test duct, which can be used for wet equilibrium pre-treatment. The optional humidifying devices, such as ultrasonic humidifier and atomizer, shall meet the requirements of 8.5.

### 7.4 Water collecting groove

The water collecting grooves shall be installed at the bottom of upstream and downstream of tested filter to collect water during the test.

## 8 Qualification of test rig and apparatus

### 8.1 Pressure system test

Carry out the pressure system test in accordance with ISO 16890-2:2022, 8.2.1.

### 8.2 Air leakage test

Carry out the air leakage test in accordance with ISO 16890-2:2022, 8.2.8.

### 8.3 Air velocity uniformity in the test duct

Carry out the air velocity uniformity test in the test duct in accordance with ISO 16890-2:2022, 8.2.9.

### 8.4 Pressure drop of test duct with no test filter installed

Carry out the test of pressure drop of test duct with no test filter installed in accordance with ISO 16890-2:2022, 8.2.12.

### 8.5 Stability of wet environment

The temperature measuring instrument used shall be capable of measuring temperature with an accuracy of ±1 °C. The relative humidity measuring instrument used shall be capable of measuring the relative humidity with an accuracy of ±2 %. The equipment shall be calibrated at regular intervals to ensure the required accuracy.

Turn on the humidifying device until the measured relative humidity of the upstream and downstream test duct exceeds 95 % at the qualification air flow rate of 3 400 $m^3/h$. Start to record the temperature and relative humidity of the upstream and downstream test duct every 2 min. The total test time is 30 min.

The relative humidity of upstream and downstream shall always exceed 95 % during the test.

To ensure the stability of the wet environment, it is important to limit the condensation and sediment water mass to a low level and thus minimize the effect on the water fog concentration and results of the test, therefore the total mass of water collected in the whole test duct section shall be less than 50 g after the test.

## 8.6 Water fog concentration and sedimentation check

This test is used to ensure that the water fog concentration, in the section where the filter is installed, can meet the requirements of this document.

Weigh and then install the final filter. Start to generate humidity at an air flow rate of 3 400 $m^3$/h. The relative humidity in the upstream duct shall not be less than 95 %.

Turn on the water spray device and adjust the water fog concentration to 6,0 g/$m^3$. The duration time is 30 min and the relative humidity in the upstream test duct shall not be less than 95 % during the test.

Turn off the water spray device after 30 min. Weigh the final filter.

Collect the water in the upstream test duct to the upstream groove. The collected water mass shall be less than 5 % of the total water mass.

## 8.7 Water tightness test with no test filter installed

This test is used to ensure the water tightness of the duct and that no leakage is found during the whole water endurance test.

This test is carried out along with the instructions in 8.5 and 8.6.

No droplets leakage shall be found from the test duct during the test.

Collect the water in the upstream and downstream test duct of the filter to be tested and final filter. The collected water mass shall not be less than 90 % of the total water mass.

## 8.8 Water droplet size distributions

This test is used to ensure that the water droplet size distribution, in the section where the filter is installed, can meet the requirements of this document.

A laser diffraction particle size analyser is recommended, which uses the technique of laser diffraction for measurement of the size of spray droplets and the accuracy shall be better than 3 %. The measuring point shall be located in the lateral centre of the upstream duct section, and as close as possible to the duct section of the filter to be tested.

Turn on the water spray device and adjust the water fog concentration to 6,0 g/$m^3$ at 3 400 $m^3$/h. The relative humidity in the upstream test duct shall not be less than 95 % during the test.

Measure the size and size distributions of water droplets by the laser particle size analyser. The cumulative volume of water droplets in the size range of 5 µm to 30 µm shall be more than 90 % of the total water fog volume.

## 8.9 Summary of qualification requirements

The test rig and apparatus qualification requirements are shown in Table 1.

**Table 1 — Summary of qualification requirements**

| Items | Subclause | Requirements |
|---|---|---|
| Pressure system test | 8.1 | No change in Pa |
| Air leakage test | 8.2 | < 1 % |
| Air velocity uniformity | 8.3 | CV < 10 % |
| Pressure drop of test duct with no test filter installed | 8.4 | < 5 Pa |
| Stability of wet environment | 8.5 | The relative humidity of upstream and downstream shall always exceed 95 % during the test |
| Water fog concentration and sedimentation check | 8.6 | The water mass collected in the upstream test duct shall be less than 5 % of the total water mass |
| Water tightness test with no test filter installed | 8.7 | No droplets leakage, the water mass collected in the test duct and the final filter shall not be less than 90 % of the total water mass |
| Water droplets size distributions | 8.8 | The cumulative volume of water droplets in the size range of 5 µm to 30 µm shall be more than 90 % of the total water fog volume |

## 8.10 Apparatus maintenance

The maintenance schedule is shown in Table 2.

**Table 2 — Maintenance schedule**

| Maintenance items[a] | Subclause | Each test | Monthly | Quarterly | Annually | After any change that can alter performance |
|---|---|---|---|---|---|---|
| Pressure system test | 8.1 | | | | | X |
| Air leakage test | 8.2 | | | | | X |
| Air velocity uniformity | 8.3 | | | | | X |
| Pressure drop of test duct with no test filter installed | 8.4 | | | X | | X |
| Stability of wet environment | 8.5 | | | X | | X |
| Water fog concentration and sedimentation check | 8.6 | | | X | | X |
| Water tightness test with no test filter installed | 8.7 | | | X | | X |
| Water droplets size distributions | 8.8 | | | X | | X |

[a] Regular cleaning of all equipment shall be undertaken so that the performance of the test system is maintained.

# 9 Test procedure

## 9.1 Preparation of filter to be tested

Install the filter according to the recommendation of the test client or real application. Horizontal installation for cylindrical filter is recommended. A special vertical test duct can be used for vertical installation (see Annex B).

The filter shall be weighed to the nearest gram before installation.

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

Devices requiring external accessories shall be operated during the test with accessories having characteristics equivalent to those external accessories used in actual practice.

If for any reason, dimensions do not allow testing of a filter under standard test conditions, assembly of two or more filters of the same type or model is permitted, provided no leaks occur in the resulting filter. The operating conditions of such accessory equipment shall be recorded.

## 9.2 Initial pressure drop

The initial pressure drop is measured at the test air flow before wet equilibrium pre-treatment.

According to ISO 16890-2:2022, Annex B, all pressure loss measurements should be corrected to a reference air density of 1,20 kg/m$^3$, which corresponds to standard air conditions: temperature 20 °C, barometric pressure 101 325 kPa, relative humidity 50 %. However, as long as the air density is between 1,16 kg/m$^3$ and 1,24 kg/m$^3$, no corrections need to be made.

## 9.3 Test procedure for water endurance performance of filter elements

### 9.3.1 General

The test device shall be tested at its nominal air volume flow rate for which the device has been specified by the manufacturer.

If the rated air flow is not specified by manufacturer, the test air flow rate is established with the test client. The recommended test air flow rates are the following:

— for static filter: 4 250 m$^3$/h;

— for single cylindrical cartridge: 1 000 m$^3$/h;

— for cylindrical plus cylindrical (conical) combined cartridges: 2 500 m$^3$/h.

Carry out wet equilibrium pre-treatment in a set time before water spray. The relative humidity of suction air through the tested filter shall exceed 95 %. Start water fog test after wet equilibrium pre-treatment.

For the test rigs without wet equilibrium device, pre-treatment can be omitted if approved by the test client, but an interpretation shall be noted in the test report. The brief test rig and test procedures are specified in Annex C.

The water fog used shall meet the requirements of 7.2. Discontinuous air supply and water fog can change the water endurance performance of the filter to be tested. Once the test starts, the air supply and water fog spray process shall not be stopped until the end of the test.

### 9.3.2 Wet equilibrium pre-treatment

Adjust the humidifying device to increase the humidity at the test air flow rate. Carry out wet equilibrium pre-treatment and start timing when the relative humidity of the air upstream and downstream of the tested filter exceeds 95 %.

The time of wet equilibrium pre-treatment is 60 min and the relative humidity of the air in the test duct shall not be less than 95 % during the test.

The pressure drop is recorded at the beginning, end, and every 15 min during the test. If the pressure drop varies significantly, increase records to achieve a smooth curve of the pressure drop as the function of time.

#### 9.3.3 Water fog test

The water fog test shall be carried out immediately after wet equilibrium pre-treatment.

Increase the water fog mass by the water spray device based on saturated wet air and carry out the water fog test at a saturated air loading with water fog at concentration of $c_{wm}$ under the test air flow rate. The medium in the test duct is a gas-liquid two-phase flow of saturated air and water fog. A water fog concentration should be 6,0 g/m$^3$.

The pressure drop change during the test time is measured and recorded. The record interval shall not exceed 5 min and corresponding pressure drop increases shall not exceed 20 Pa. For a test filter with a fast-increasing pressure drop, more recordings are needed.

Stop the water fog test after the predetermined time or predefined pressure drop are reached. The final test pressure drop value can be set by the test client. The water spray time should be 180 min and the final test pressure drop should be 1 000 Pa. Then stop the test, whichever comes first and record the data.

### 9.4 Water penetration ratio

Collect the water accumulated in the downstream of tested filter and record the water penetration in accordance with Annex D.

For the evaluation of a filter water leakage, see Annex E.

## 10 Test report

### 10.1 General

The test report shall include at least the following items:

— general interpretation of test reports (see 10.2);

— type of water spray device;

— description of the test method;

— summaries of test results (see 10.3);

— data and results of air flow rate and pressure drop measurements (see 10.4).

Test results shall be reported using the test report format used in this document. Annex F gives examples of the test reporting format. Exact formats are not requested but the report shall include the items shown. The legend of each table and graph should include the following:

— type of filter;

— number of this document, i.e. ISO 29461-2:2022;

— test number;

— test air flow rate.

### 10.2 Interpretation of test reports

A brief digest shall be included in the test reports. The interpretation shall be included after the issued report and shall be a one-page addition.

A brief review of the test procedures is provided to explain ISO procedures. It is intended to assist in understanding and interpreting the results in the test reports/summaries.

The environments and particle matters are various in different locations. The water fog endurance performance in the test cannot be used to quantitatively evaluate the real-life behaviour of filters. The test results can be used as a comparison and classification of filter performance, but the real-life performance of the filter depends on actual site environment conditions.

### 10.3 Summaries of test results

Summaries of the performance report shall include the following items:

a) general:

    1) testing organization;

    2) date of test;

    3) name of test operator;

    4) report number;

    5) test client;

    6) device delivered by;

    7) device receiving date;

b) manufacturer’s data of the tested device:

    1) description of the device;

    2) type, identification and marking;

    3) manufacturer;

    4) physical description of construction;

    5) dimensions;

    6) type of media;

    7) the pictures of raw air and clean air sides of the device;

    8) additional information needed for correct filter recognition;

c) parameters of water spray device:

    1) type;

    2) compressed air pressure;

    3) air flow rate;

    4) water pressure;

   5) water particle size;

d) test data:

   1) test air flow rate;

   2) test air upstream temperature and upstream relative humidity, and barometric pressure;

   3) water fog concentration;

   4) initial and final test pressure drop;

   5) the water penetration ratio (if necessary);

   6) the pressure drop curve of the tested filter as the function of test time in the condition of wet equilibrium and spray pattern;

e) statement:

   1) the results relate only to the tested item;

   2) the performance results cannot be quantitatively applied to predict filter performance in service.

All data shall be rounded to the nearest integer in the summaries of the test report.

### 10.4 Water fog mass and pressure drop

All data and results about the needed water spray mass and pressure drop measurements shall be listed in the report as a tabular form. A pressure drop curve of the tested filter as the function of test time is shown in a summary page. The water fog mass in the report is the measured value. The initial pressure drop measured during the test shall be corrected to a reference air density of 1,20 kg/m$^3$ as described in 9.2.

### 10.5 Marking

The filter shall be marked with the following identifying marking provided by the client:

— name, trademark or other means of identification of the manufacturer;

— type and reference number of the filter;

— number of this document, i.e. ISO 29461-2:2022;

— flow rate at which the filter has been classified.

If the correct mounting cannot be deduced, marking is necessary for correct fitting in the ventilation duct (e.g. "top”, “direction of flow"). The marking shall be as clearly visible and durable as possible.

# Annex A
(informative)

# Resistance to air flow and water generation mass calculation

## A.1 Resistance to air flow calculation

The resistance to air flow shall be calculated according to ISO 16890-2:2022, Annex B.

## A.2 Water generation mass calculation

The relative humidity of air, $\varphi$, is made to reach saturation by adding water and water generation mass shall be calculated in accordance with Formula (A.1) to Formula (A.4).

$$m_{\mathrm{wm},1} = \rho \times q_{\mathrm{v}} \times (d - d_0) \tag{A.1}$$

where

$q_{\mathrm{v}}$ is the volumetric flow of non-humidifying air, $\mathrm{m}^3/\mathrm{h}$;

$d_0$ is the ambient air moisture content, g/kg;

$d$ is the saturated wet air moisture content, g/kg;

$\rho$ is the ambient air density, kg/ $\mathrm{m}^3$.

$$d_0 = 0{,}622 \times \frac{\varphi p_{\mathrm{ws}}}{p - \varphi p_{\mathrm{ws}}} \tag{A.2}$$

$$d = 0{,}622 \times \frac{p_{ws}}{p - p_{ws}} \tag{A.3}$$

$$\rho = \frac{p - 0{,}378\, p_{\mathrm{w}}}{287{,}06 \times (t_0 + 273{,}15)} \tag{A.4}$$

where $p_{\mathrm{w}}$ is the partial vapour pressure of water in air given in Formula (A.5):

$$p_{\mathrm{w}} = \frac{\varphi}{100} \times p_{\mathrm{ws}} \tag{A.5}$$

where $p_{\mathrm{ws}}$ is the saturation vapour pressure of water in air at temperature $t_0$ (°C) obtained from Formula (A.6):

$$p_{\mathrm{ws}} = \exp\left[59{,}484\,085 - \frac{6\,790{,}498\,5}{t_0 + 273{,}15} - 5{,}028\,02 \times \ln(t_0 + 273{,}15)\right] \tag{A.6}$$

# Annex B
(informative)

# Water endurance test for vertical installed air filters

## B.1 General

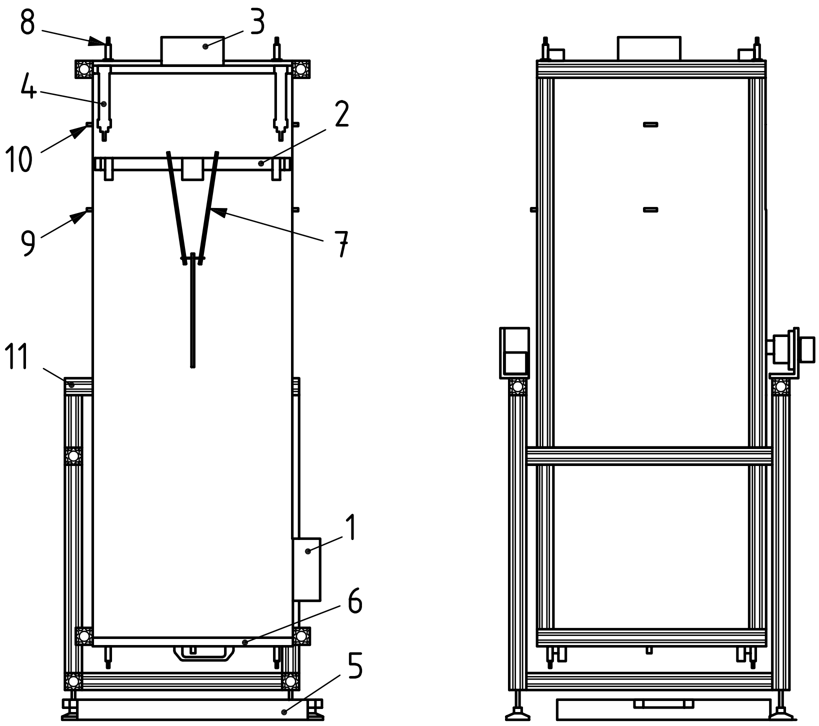
There are two types of air intake filter systems with horizontally or vertically installed air filter elements for rotary machinery. Compared with the horizontal installed filter elements, the vertical installed filter elements can have less accumulated water due to gravity and lower sensitive water endurance performance. Therefore, the water endurance results of the above two types of installed air filter elements can be different.

This procedure is used to test water endurance for vertically installed pulse jet filters.

## B.2 Test method

### B.2.1 Equipment

A schematic diagram of the vertical test duct can be seen in Figure B.1. Unless otherwise specified, the vertical test rig, except for the duct where the filter is installed, is the same as the test rig of this document.




**Key**

| | | | |
|---|---|---|---|
| 1 | air inlet duct | 7 | installation stand |
| 2 | installation plate | 8 | clamp |
| 3 | air outlet duct | 9 | upstream pressure measuring point |
| 4 | pressure cylinder | 10 | downstream pressure measuring point |
| 5 | water collecting device | 11 | test duct frame |
| 6 | water spray device | | |

**Figure B.1 — Schematic diagram of the vertical test duct**

### B.2.2 Preparation of filter to be tested

The filter shall be vertically mounted in accordance with the test client's recommendations and after the equilibration with the test air weighted to the nearest gram. A device requiring external accessories shall be operated during the test with accessories having characteristics equivalent to those used in actual practice. The filter, including any normal mounting frame, shall be sealed into the duct in a manner that prevents leakages.

NOTE This test method does not test the filter sealing mechanism.

### B.2.3 Test conditions

Test conditions shall be the same as specified in Clause 6.

### B.2.4 Initial pressure drop

Initial pressure drop shall be tested as specified in 9.2

### B.2.5 Test procedure for water endurance performance of filter elements

Water endurance performance of filter elements shall be tested as specified in 9.3.

### B.2.6 Test report

The test report shall be the same as specified in Clause 10. Vertical installation shall be noted in the test report.

# Annex C
(informative)

# Water endurance of air filter elements without wet equilibrium pre-treatment

## C.1 General

For the test rigs without humidifying device or recirculated air design, wet equilibrium pre-treatment can be omitted if approved by the test client, but an interpretation shall be noted in the test report. This procedure is used to test water endurance of air filter elements without wet equilibrium pre-treatment.

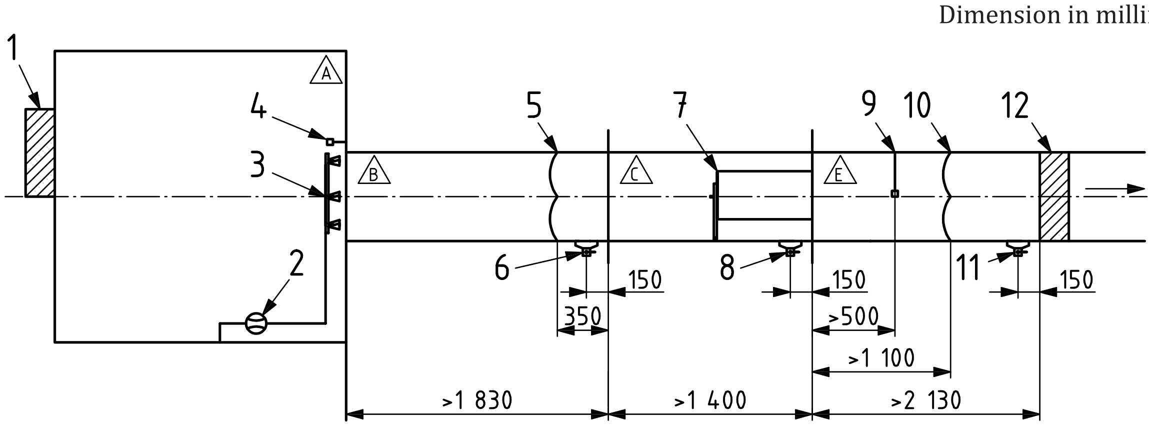
## C.2 Test method

### C.2.1 Equipment

A schematic diagram of the test rig is shown in Figure C.1.

The test rig has no available humidifying device or recirculated air design. Unless otherwise specified, the other parts of test rig shall be the same as the test rig of this document.

Dimension in millimetres




**Key**

| | | | |
|---|---|---|---|
| A | duct section of the test rig (entry plenum) | 5 | upstream pressure measuring point |
| B | upstream duct section of the test rig | 6 | upstream water collecting groove |
| C | duct section of filter to be tested | 7 | filter to be tested |
| E | downstream duct section of the test rig | 8 | midstream water collecting groove |
| 1 | HEPA filter | 9 | downstream measuring point of temperature and humidity |
| 2 | water mass flow metering device | 10 | downstream pressure measuring point |
| 3 | water spray device | 11 | downstream water collecting groove |
| 4 | upstream measuring point of temperature and humidity | 12 | final filter - eliminate water |

**Figure C.1 — Schematic diagram of the test rig**

### C.2.2 Water endurance test

Adjusting the water mass flow by the water spray device at the test air flow rate, the water fog test is carried out at a saturated air loading with water fog at concentration of $c_{wm}$. The gas-liquid two phase flow medium contains the saturated air and water fog. The water fog concentration should be 6 g/m$^3$.

The mass of total water shall be calculated in accordance with Formula (C.1) and Formula (C.2).

$$m_{\mathrm{wm}} = m_{\mathrm{wm,\,1}} + m_{\mathrm{wm,\,2}} \tag{C.1}$$

$$m_{\mathrm{wm,\,2}} = \frac{c_{\mathrm{wm}}}{1\,000} q_{\mathrm{v}} \tag{C.2}$$

where

| | |
|---|---|
| $m_{\mathrm{wm}}$ | is the water fog total mass per hour, kg/h; |
| $m_{\mathrm{wm,\,1}}$ | is the water fog generation mass per hour at the saturated humidifying air, kg/h; $m_{wm,\,1}$ shall be calculated as shown in Annex A, where the relative humidity, $\varphi$, is 100 %; |
| $m_{\mathrm{wm,\,2}}$ | is the water fog generation mass per hour, kg/h; |
| $q_{\mathrm{v}}$ | is the air flow, m$^3$/h; |
| $c_{\mathrm{wm}}$ | is the water fog concentration, g/m$^3$. |

Pressure drops changing with test time are measured and recorded when the filter is tested in a gas-liquid two phase flow medium. The record interval shall not exceed 5 min and corresponding pressure drop increases shall not exceed 20 Pa. For test filters with fast increasing pressure drop, more data recordings are needed.

The final test pressure drop can be the water endurance pressure drop value recommended by the manufacturer or the pressure drop value required by the test client. If no above-mentioned restrictions exist, the water spray time should be 180 min and the final test pressure drop should be 1 000 Pa.

Stop the test and record the data.

## C.3 Test report

The test report shall be the same as specified in Clause 10. No wet equilibrium pre-treatment shall then be noted in the test report.

# Annex D
(normative)

# Water penetration ratio test

## D.1 General

Water penetration ratio is an important factor in water endurance tests. To determine the water penetration ratio, gravimetric weighing of accumulated downstream water is typically used.

## D.2 Test method

### D.2.1 Equipment

The water collecting grooves are installed at the bottom of upstream and downstream of the tested filter to collect water during the test, shown in Figure D.1. The water can be collected into the grooves by the glass scraper and discharged from the bottom of the grooves.

Dimensions in millimetres

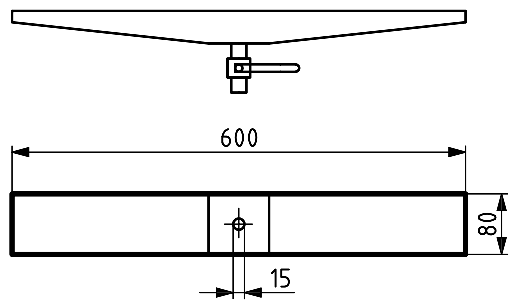



**Figure D.1 — Schematic diagram of water collecting groove**

### D.2.2 Test method

When the water fog test finishes, turn off the water spray device and fan.

The water deposited in the downstream duct of the tested filter is collected and weighed (with an accuracy of ±1 g) to achieve the water penetration ratio during the test.

The water penetration ratio shall be calculated in accordance with Formula (D.1).

$$\eta_p = \frac{m_p}{m_{tot}} \times 100\ \% \qquad \text{(D.1)}$$

where

$\eta_p$ is the water penetration ratio;

$m_p$ is the water mass penetrated through the tested filter at the end of the test, kg;

$m_{tot}$ is the total water fog generation amount, kg.

# Annex E
(informative)

# Leak detection and first water droplet detection procedure

## E.1 General

In order to verify that no water penetrates through a filter during a water endurance test, the following procedure defines a method for reliably detecting the penetration of even minor amounts of water downstream a filter.

This is accomplished by mixing a small amount of fluorescent dye with the water used for the water endurance test, illuminating downstream of the filter with a UV light, and recording downstream of the filter with a camera so that the first droplet to penetrate can be detected.

## E.2 Test method for detecting droplet penetration

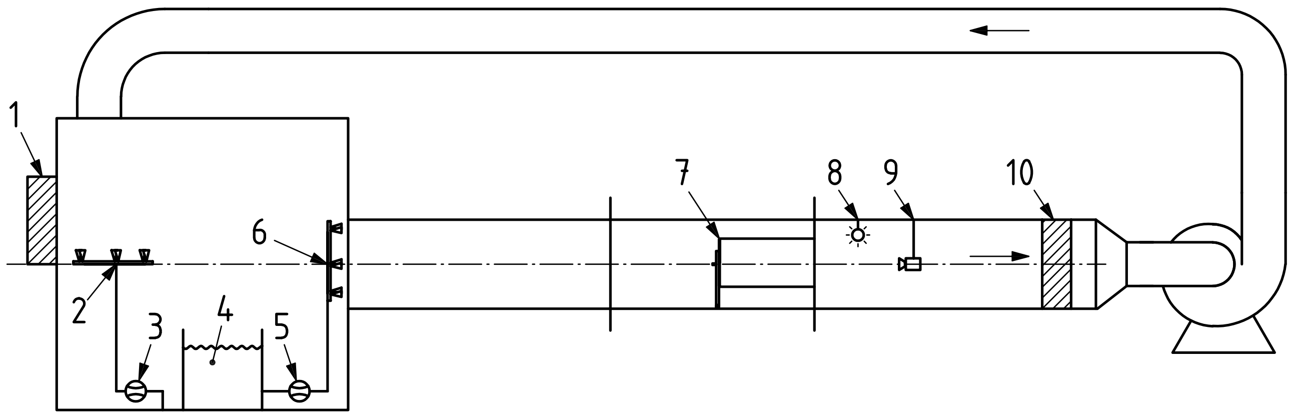
### E.2.1 Equipment

There are three main systems for detecting droplets (see Figure E.1):

a) a water/dye mixing system;

b) a UV light source;

c) a video recording device.



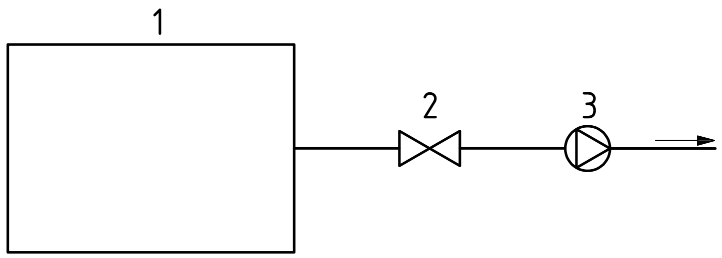

**Key**

| | | | |
|---|---|---|---|
| 1 | HEPA filter | 6 | water spray device |
| 2 | humidifying device | 7 | filter to be tested |
| 3 | water mass flow metering device | 8 | UV light source |
| 4 | water-UV dye mixture tank | 9 | video recording device |
| 5 | water mass flow metering device | 10 | final filter - eliminate water |

**Figure E.1 — Schematic diagram of the test rig**

The water/dye mixing system can either take the form of a large holding tank containing enough water for the entire water endurance test where the UV tracer dye is pre-mixed, or it can be a smaller tank where a concentrated solution of water/dye is premixed and then injected into the water line as the test is conducted so as to limit the size of the water reservoir needed.

A diagram of the premixed water solution is shown in Figure E.2, while a diagram of the concentrated water/dye injection system is shown in Figure E.3.



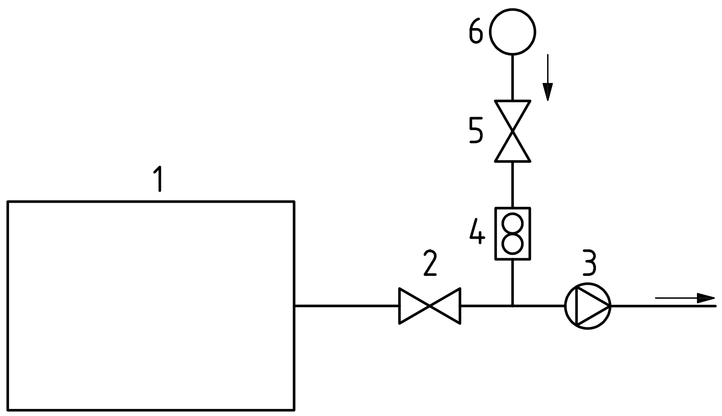

**Key**

1 water-UV dye mixture tank

2 valve

3 pump

**Figure E.2 — Premixed water reservoir**




**Key**

1 water tank

2 valve

3 pump

4 flowmeter

5 valve

6 UV tracer dye

**Figure E.3 — Suction line injection of UV tracer dye**

The UV light source shall be located so as to illuminate downstream of the air filter. In case a transparent duct section is used, the UV light source can be placed outside the test rig. In the case of an opaque duct section, the UV light source should be IP66 rated or greater and placed downstream of the filter.

A video recording device shall be mounted downstream of the filter inside the duct, so as to minimize reflections and condensed water that can obstruct the video of the filter during the test. A video of the entire test duration shall be captured and a physical timer shall be placed so as to remain visible throughout the test.

### E.2.2 Test procedure

Complete the leak detection and first water droplet detection test according to the procedure in 9.3.

When starting the water fog test, turn on the UV light and video recording device. Start the physical timer as soon as water starts to spray in order to provide a timestamp for verification of water penetration.

After the test is completed, the video recording shall be searched through for signs of water penetration downstream which appear illuminated in bright fluorescence.

## E.3 Test report

The test report shall be the same as specified in Clause 10. Two readings shall be reported:

a) Was water found downstream of the filter during the water endurance test? Yes/No.

b) When did water start to penetrate through the filter? Time in minutes shall be provided.

# Annex F
(informative)

# Examples of completed test reports

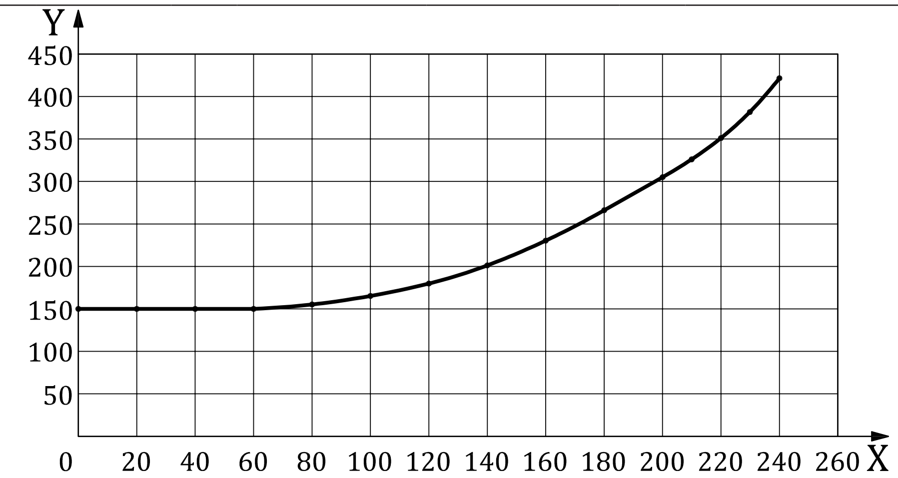
## F.1 Example of the test report

An example of a test report is given in Table F.1 and Table F.2. Some pictures are given in Figure F.1.

**Table F.1 — Example of test report summary page**

<table>
<tr><td colspan="7">ISO 29461-2</td></tr>
<tr><td colspan="4">Testing organization: Any Filter Test Lab</td><td colspan="3">Report#: 001-202x</td></tr>
<tr><td colspan="7">GENERAL</td></tr>
<tr><td colspan="3">Test no.: Unique Number</td><td colspan="2">Date of test: 10 July 202x</td><td colspan="2">Supervisor: A</td></tr>
<tr><td colspan="4">Test client: B</td><td colspan="3" rowspan="2">Device receiving date: 1 July 202x</td></tr>
<tr><td colspan="4">Device supplied by: C</td></tr>
<tr><td colspan="7">DEVICE TESTED</td></tr>
<tr><td colspan="3">Model: Leader1</td><td colspan="2">Manufacturer: D</td><td colspan="2">Construction:<br>cylindrical cartridge</td></tr>
<tr><td colspan="3">Type of media: Material</td><td colspan="2">Effective filtering area: 18 $m^2$</td><td colspan="2">Actual filter dimension:<br>$\phi$ 325 × $\phi$215 × H658</td></tr>
<tr><td colspan="7">WATER SPRAY DEVICE</td></tr>
<tr><td colspan="5">Type: Two-fluid nozzle, YB1/8QF+SU4.5N-SS</td><td colspan="2">Quantities: 6</td></tr>
<tr><td colspan="3">Compressed air pressure: 0,3 MPa</td><td colspan="2">Air flow rate per nozzle: 2,4 $m^3$/h</td><td colspan="2">Water pressure: 0,3 MPa</td></tr>
<tr><td colspan="7">TEST DATA</td></tr>
<tr><td colspan="2">Test air flow rate: 1 000 $m^3$/h</td><td colspan="2">Ambient temperature: 20 °C</td><td colspan="2">Ambient relative humidity: 60 %</td><td>Water concentration: 6 g/$m^3$</td></tr>
<tr><td colspan="7">RESULTS</td></tr>
<tr><td colspan="2">Initial pressure drop: 150 Pa</td><td colspan="2">Final test pressure drop: 420 Pa</td><td colspan="2">Total testing time: 240 min</td><td>Water total mass: 18 kg</td></tr>
<tr><td>Remark:</td><td colspan="6">1. Test duration of wet equilibrium pre-treatment is 60 min;<br>2. Water penetration ratio: 0.</td></tr>
<tr><td colspan="7">NOTE The performance results are only valid for the tested item and cannot by themselves be quantitatively applied to predict filter performance in service.</td></tr>
</table>

**Table F.1** *(continued)*




Key

Y pressure drop, Pa

X time, min

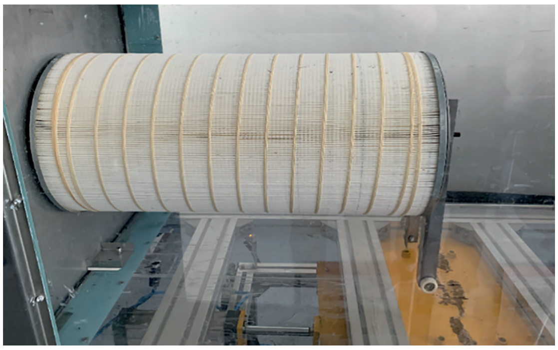
NOTE The performance results are only valid for the tested item and cannot by themselves be quantitatively applied to predict filter performance in service.

**Table F.2 — Example of test report details page**

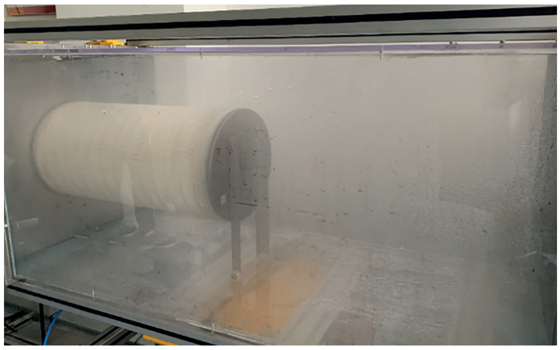
| **ISO 29461-2** | | | | | | |
|---|---|---|---|---|---|---|
| Air filter: Leader1 | | | | | | |
| Test no.: Unique Number | | | | | | |
| Water content: 6 g/m$^3$ | | | | | | |
| Test air flow rate: 1 000 m$^3$/h | | | | | | |
| Data | $T$ , min | $\Delta p_T$ , Pa | $m_{tot}$ , kg | $t_u$ , °C | $\varphi_u$ , % | $T_{tot}$ , min |
| The stage of wet equilibrium pre-treatment | | | | | | |
| 202x-07-10 | 0 | 150 | 0 | 16 | 95 | |
| | 20 | 150 | 0 | 16 | 95 | |
| | 40 | 151 | 0 | 16 | 97 | |
| | 60 | 151 | 0 | 16 | 96 | |
| The stage of water fog endurance | | | | | | |
| | 80 | 155 | 2 | 16 | 95 | |
| | 100 | 165 | 4 | 16 | 95 | |
| | 120 | 180 | 6 | 16 | 97 | |
| | 140 | 200 | 8 | 16 | 96 | |
| | 160 | 230 | 10 | 16 | 95 | |
| | 180 | 265 | 12 | 16 | 95 | |
| | 200 | 305 | 14 | 16 | 97 | |
| | 210 | 325 | 15 | 16 | 96 | |
| | 220 | 350 | 16 | 16 | 95 | |
| | 230 | 380 | 17 | 16 | 95 | |
| | 240 | 420 | 18 | 16 | 97 | 240 |
| Water penetration ratio | | | | | | |
| $m_{tot}$ : 18 kg | | | | | | |
| $m_p$ : 0 g | | | | | | |

**Table F.2** *(continued)*

| |
|---|
| Did water penetrate through filter? (☐Yes; ☒No) (Optional)<br>Penetration started after ___ mins at dP of ___ Pa.<br>Water penetration ratio is 0. |
| **SYMBOLS AND UNIT** |
| $T$ , testing time, min |
| $T_{tot}$ , total testing time, min |
| $t_u$ , temperature upstream of filter, °C |
| $\Delta p_T$ , filter pressure drop, Pa |
| $m_{tot}$ , total mass of water, g |
| $m_p$ , water mass penetrated through tested filter, g |
| $\varphi$ , relative humidity upstream of filter, % |



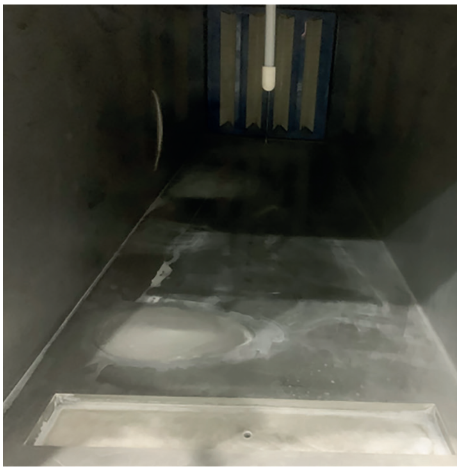
a) The filter to be tested



b) Test in process

c) The filter tested

d) Upstream duct after fog test



e) Downstream duct after fog test

**Figure F.1 — Test device pictures**

## F.2 Example of test report for comparisons

Example of test report for comparisons is given in Table F.3 and Table F.4. An image of Filter #1 to be tested is given in Figure F.2.

**Table F.3 — Example of test report summary page**

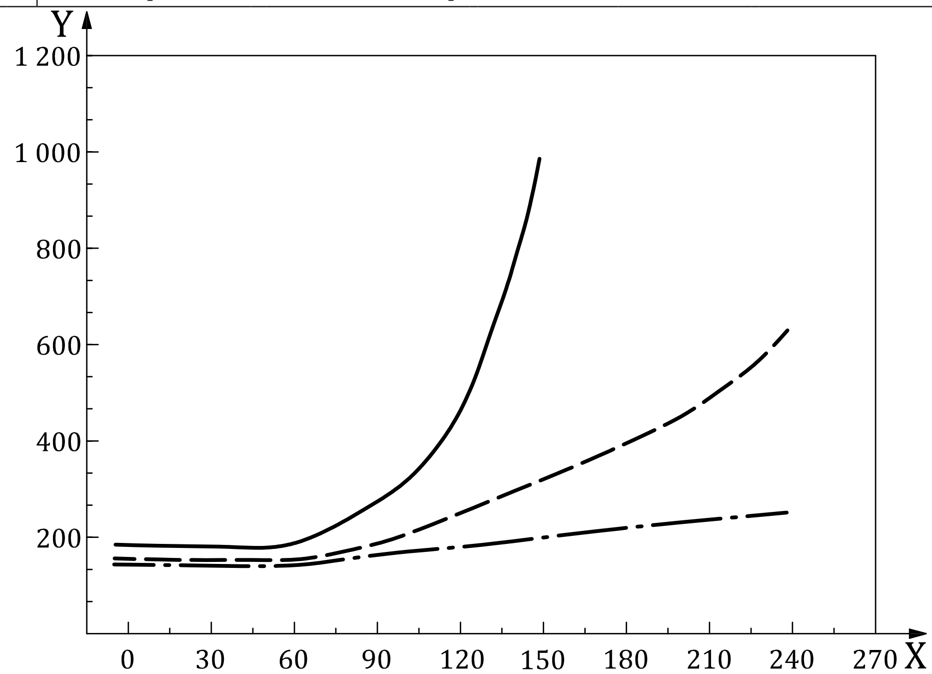
<table>
<tr><td colspan="4">ISO 29461-2</td></tr>
<tr><td colspan="3">Testing organization: Any Filter Test Lab</td><td>Report#: 001-202X</td></tr>
<tr><td colspan="4">GENERAL</td></tr>
<tr><td colspan="2">Test no.: Unique Number</td><td>Date of test: 10 Aug 202x</td><td>Supervisor: ZH</td></tr>
<tr><td colspan="3">Test client: B</td><td rowspan="2">Device receiving date: 1 Aug 202x</td></tr>
<tr><td colspan="3">Device supplied by: C</td></tr>
<tr><td colspan="4">DEVICE TESTED</td></tr>
<tr><td rowspan="2">#1</td><td>Model: Leader1</td><td>Manufacturer: D</td><td>Construction:<br>cylindrical plus conical combined cartridges</td></tr>
<tr><td>Type of media: Material</td><td>Effective filtering area:<br>38 m²</td><td>Actual filter dimension:<br>ϕ 325 x ϕ215 x× H660+<br>ϕ215/330× ϕ325/445× H660</td></tr>
<tr><td rowspan="2">#2</td><td>Model: Leader1</td><td>Manufacturer:<br>D</td><td>Construction:<br>cylindrical plus conical combined cartridges</td></tr>
<tr><td>Type of media: Material</td><td>Effective filtering area:<br>38 m²</td><td>Actual filter dimension:<br>ϕ 325 × ϕ215 × H660+<br>ϕ215/330× ϕ325/445× H660</td></tr>
<tr><td colspan="4">NOTE The performance results are only valid for the tested item and cannot by themselves be quantitatively applied to predict filter performance in service.</td></tr>
</table>

**Table F.3** *(continued)*

| | | | |
|---|---|---|---|
| #3 | Model: Leader1 | Manufacturer:<br>D | Construction:<br>cylindrical plus conical combined cartridges |
| | Type of media:<br>Material | Effective filtering area:<br>38 $m^2$ | Actual filter dimension:<br>ϕ 325 × ϕ215 × H660+<br>ϕ215/330× ϕ325/445× H660 |

| | | |
|---|---|---|
| **WATER SPRAY DEVICE** | | |
| Type: Two-fluid nozzle, YB1/8QF+SU4.5N-SS | | Quantities: 6 |
| Compressed air pressure: 0,3 MPa | Air flow rate per nozzle: 2,4 $m^3$/h | Water pressure: 0,3 MPa |

| | | | | |
|---|---|---|---|---|
| **TEST DATA** | | | | |
| #1 | Test air flow rate: 2 500 $m^3$/h | Ambient temperature: 20 °C | Ambient RH: 60 % | Water concentration: 6 g/$m^3$ |
| | RESULTS | | | |
| | Initial pressure drop: 184 Pa | Final test pressure drop: 1 000 Pa | Total testing time: 151 min | Water total mass: 22,6 kg |
| #2 | Test air flow rate: 2 500 $m^3$/h | Ambient temperature: 20 °C | Ambient RH: 60 % | Water concentration: 6 g/$m^3$ |
| | RESULTS | | | |
| | Initial pressure drop: 155 Pa | Final test pressure drop: 629 Pa | Total testing time: 240 min | Water total mass: 45,2 kg |
| #3 | Test air flow rate: 2 500 $m^3$/h | Ambient temperature: 20 °C | Ambient RH: 60 % | Water concentration: 6 g/$m^3$ |
| | RESULTS | | | |
| | Initial pressure drop: 150 Pa | Final test pressure drop: 250 Pa | Total testing time: 240 min | Water total mass: 45,2 kg |
| Remark: | 1. Test duration of wet equilibrium pre-treatment is 60 min;<br>2. Water penetration ratio of 3 samples: 0. | | | |




NOTE The performance results are only valid for the tested item and cannot by themselves be quantitatively applied to predict filter performance in service.

**Table F.3** *(continued)*

| | | | |
|---|---|---|---|
| Key | | | |
| Y | pressure drop, Pa | ———— | # 1 |
| X | time, min | — — — | # 2 |
| | | —·— | # 3 |
| NOTE The performance results are only valid for the tested item and cannot by themselves be quantitatively applied to predict filter performance in service. | | | |

**Table F.4 — Example of test report details page**

| | | | | | | |
|---|---|---|---|---|---|---|
| **ISO 29461-2** | | | | | | |
| **AIR FILTER: #1** | | | | | | |
| Test no.: Unique Number | | | | | | |
| Water content: 6 g/m$^3$ | | | | | | |
| Test air flow rate: 2 500 m$^3$/h | | | | | | |
| Data | $T$ , min | $\Delta p_T$ , Pa | $m_{tot}$ , kg | $t_u$ , °C | $\varphi_u$ , % | $T_{tot}$ , min |
| The stage of wet equilibrium pre-treatment | | | | | | |
| 202x-8-10 | 0 | 184 | 0 | 18 | 95 | |
| | 20 | 182 | 0 | 16 | 95 | |
| | 40 | 183 | 0 | 17 | 97 | |
| | 60 | 184 | 0 | 16 | 96 | |
| The stage of water fog endurance | | | | | | |
| | 80 | 229 | 5,0 | 16 | 95 | |
| | 100 | 303 | 10,0 | 16 | 95 | |
| | 120 | 437 | 15,0 | 18 | 97 | |
| | 140 | 730 | 19,9 | 16 | 96 | |
| | 151 | 1 000 | 22,6 | 16 | 95 | 151 |
| Water penetration ratio | | | | | | |
| $m_{tot}$ : 22,6 kg | | | | | | |
| $m_p$ : 0 g | | | | | | |
| Did water penetrate through filter? (☐Yes; ☒ No) (Optional)<br>Penetration started after ___ mins at dP of ___Pa.<br>Water penetration ratio is 0. | | | | | | |
| **AIR FILTER: #2** | | | | | | |
| Test no.: Unique Number | | | | | | |
| Water content: 6 g/m$^3$ | | | | | | |
| Test air flow rate: 2 500 m$^3$/h | | | | | | |
| Data | $T$ , min | $\Delta p_T$ , Pa | $m_{tot}$ , kg | $t_u$ , °C | $\varphi_u$ , % | $T_{tot}$ , min |
| The stage of wet equilibrium pre-treatment | | | | | | |
| 202x-8-10 | 0 | 156 | 0 | 17 | 97 | |
| | 20 | 154 | 0 | 18 | 98 | |
| | 40 | 154 | 0 | 19 | 96 | |
| | 60 | 154 | 0 | 21 | 95 | |
| The stage of water fog endurance | | | | | | |
| | 80 | 170 | 5,0 | 22 | 92 | |
| | 100 | 199 | 10,0 | 24 | 96 | |

**Table F.4** *(continued)*

| | | | | | | |
|---|---|---|---|---|---|---|
| | 120 | 246 | 15,0 | 20 | 97 | |
| | 140 | 291 | 20,1 | 20 | 98 | |
| | 160 | 343 | 25,1 | 21 | 96 | |
| | 180 | 391 | 30,1 | 21 | 90 | |
| | 200 | 445 | 35,1 | 22 | 97 | |
| | 220 | 528 | 40,2 | 22 | 98 | |
| | 240 | 629 | 45,2 | 22 | 96 | 240 |
| Water penetration ratio | | | | | | |
| $m_{tot}$ : 45,2 kg | | | | | | |
| $m_p$ : 0 g | | | | | | |
| Did water penetrate through filter? (☐Yes; ☒No) (Optional)<br>Penetration started after ___ mins at dP of ___Pa.<br>Water penetration ratio is 0. | | | | | | |
| **AIR FILTER: #3** | | | | | | |
| Test no.: Unique Number | | | | | | |
| Water content: 6 g/m$^3$ | | | | | | |
| Test air flow rate: 2 500 m$^3$/h | | | | | | |
| Data | $T$ , min | $\Delta p_T$ , Pa | $m_{tot}$ , kg | $t_u$ , °C | $\varphi_u$ , % | $T_{tot}$ , min |
| The stage of wet equilibrium pre-treatment | | | | | | |
| 202x-8-10 | 0 | 145 | 0 | 27 | 100 | |
| | 20 | 144 | 0 | 24 | 99 | |
| | 40 | 144 | 0 | 26 | 97 | |
| | 60 | 144 | 0 | 28 | 98 | |
| The stage of water fog endurance | | | | | | |
| | 80 | 150 | 5,0 | 34 | 100 | |
| | 100 | 169 | 10,0 | 30 | 98 | |
| | 120 | 180 | 15,0 | 28 | 96 | |
| | 140 | 193 | 20,1 | 27 | 96 | |
| | 160 | 206 | 25,1 | 26 | 96 | |
| | 180 | 221 | 30,1 | 26 | 96 | |
| | 200 | 229 | 35,1 | 26 | 96 | |
| | 220 | 244 | 40,1 | 25 | 96 | |
| | 240 | 255 | 45,2 | 25 | 96 | 240 |
| Water penetration ratio | | | | | | |
| $m_{tot}$ : 45,2 kg | | | | | | |
| $m_p$ : 0 g | | | | | | |
| Did water penetrate through filter? (☐Yes; ☒ No) (Optional)<br>Penetration started after ___ mins at dP of ___Pa.<br>Water penetration ratio is 0. | | | | | | |
| **SYMBOLS AND UNITS** | | | | | | |
| $T$ , testing time, min | | | | | | |
| $T_{tot}$ , total testing time, min | | | | | | |
| $t_u$ , temperature upstream of filter, °C | | | | | | |

**Table F.4** *(continued)*

| |
|---|
| $\Delta p_T$ , filter pressure drop, Pa |
| $m_{tot}$ , total mass of water, g |
| $m_p$ , water mass penetrated through tested filter, g |
| $\varphi$ , relative humidity upstream of filter, % |

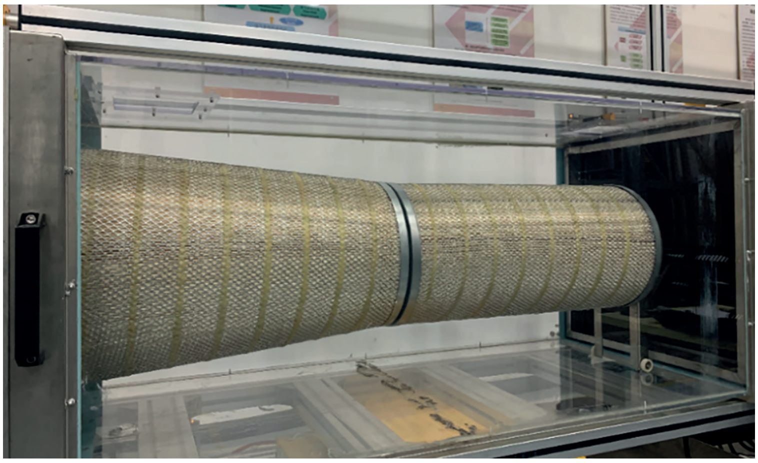


**Figure F.2 — Filter #1 to be tested**

# Bibliography

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

**ICS 29.160.99**

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