DRAFT International Standard

ISO/DIS 29461-4

ISO/TC **142**

Secretariat: **UNI**

Voting begins on:
2024-02-07

Voting terminates on:
2024-05-01

Air intake filter systems for rotary machinery —

Part 4: Test methods for static filter systems in coastal and offshore environments

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

Partie 4: Méthodes d'essai des systèmes de filtration statique en milieu côtier et offshore

ICS: 29.160.99

This document is circulated as received from the committee secretariat.

ISO/CEN PARALLEL PROCESSING

Reference number
ISO/DIS 29461-4:2024(en)

Contents

Page

Foreword

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

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

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

This document was prepared by Technical Committee ISO/TC 142 *Cleaning equipment for air and other gases.*

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 use of gas turbines in the oil & gas industry represents one of the most challenging applications for this engine technology. The major constraint of the oil and gas business is to run 24/7 at full load with minimum downtime. In oil & gas activity, it is of prime importance to run the installation as close as possible to 100 % of the time with the highest level of efficiency (current production compared to nominal production).

An additional challenge for oil and gas applications lies in the absence of a back-up on site especially for mechanical-drive gas turbine configurations.

The coastal and offshore environment probably represents the harshest conditions for gas turbines. Humidity, rainfall and seasonal dust are the most obvious visible conditions that operators face on site. Hidden in the combustion air, alkali such as potassium, sodium or magnesium, as well as sulfur, soot, volatile hydrocarbons, oily vapors, and particles all generate gas turbine issues including compressor fouling, air-cooling passage fouling, vane and blade erosion, and compressor corrosion. Combined with sulfur in fuels, these alkali in combustion air create hot corrosion. Finally, heavy rainfall may induce filter washings that release filtered particles into the compressor. All these phenomena impact the gas turbine availability on site. An operating company aiming for excellence has to strive to minimize lack of availability and performance deterioration in order to make the asset more energy efficient.

The role of a highly efficient air filtration system is to maintain the engine cleanliness by preventing the introduction of contaminants into the gas turbine air intake. Achieving a high level of engine cleanliness helps maintain engine integrity and efficiency and reduces the need for water washes which generate avoidable downtime.

Currently, high efficiency filter elements are characterized by a limited number of parameters, namely filter efficiency and MPPS (Most Penetrating Particle Size). These parameters, related to a single filter element, are measured in laboratory conditions close to favorable inland conditions with synthetic dust. Consequently, these conditions are far from the reality observed on site, offshore or near coast, where filter elements are usually part of a system. The test results do not therefore provide a basis for predicting either operational filter performance or service life.

The objective of this document is to close the gap between the current filter element characterization conditions (e.g.: ISO 29641 – Part 1) and the site environment. As a first criterion, the standard considers the effect of humidity and alkali such as salt changing its structure with humidity. The tested air flow passing through the filter element is close to the air flow operated on site for the three different concepts: low, medium or high velocity filter elements.

Soot, volatile hydrocarbons, oily vapours and particles also have impact on filter characterization. Particles are covered in separate parts of ISO 29461, while soot, volatile hydrocarbons and oily vapours will have to be addressed in future revisions of this document. The work on the current revision has revealed that current test methods are not mature enough for inclusion of soot, volatile hydrocarbons and oily vapours.

The ageing of a filter element installed offshore and near coast is addressed to allow the prediction of operational filter performance and its associated service life. It is of paramount importance to understand how filter elements perform during different cycles representing typical site conditions such as heavy rainfall, low and high humidity, filter element unloaded and loaded.

Depending on the gas turbine applications, the service life of the filter element is also a criterion to take into consideration. A minimum service life of 3 years is required, especially for LNG applications. In this case the robustness, loading capacity and pressure drop characteristics of the filter elements become key parameters for design and testing.

Air intake filter systems for rotary machinery —

Part 4:
Test methods for static filter systems in coastal and offshore environments

1 Scope

This document defines test methods for performance testing of individual filter elements and of the complete filtration system[1)]. This procedure is intended for filter elements and filter systems which operate at flow rated up to 8 000 m^3/h per filter element.

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 2813, *Paints and varnishes — Determination of gloss value at 20°, 60° and 85°*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

ISO 16890-2:2016, *Air filters for general ventilation — Part 2: Measurement of fractional efficiency and air flow resistance*

ISO 29461-1:2021, *Air intake filter systems for rotary machinery — Test methods — Part 1: Static filter elements*

ISO 29461-2:2022, *Air intake filter systems for rotary machinery — Test methods — Part 2: Filter element endurance test in fog and mist environments*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29464 and the following apply.

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

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

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

1) Note: The Filters will be loaded with ultra-fine salt particles of a size mostly < 0,1 micron during variable humidity to simulate real offshore and costal conditions hence filter with an initial conditioned efficiency lower than 50 % for the $e\mathrm{PM}_1$ particles (filter class T7) are likely to under perform and would not be suited as a single stage filter.

3.1 Air flows

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
air flow rate used for testing

3.1.3
nominal air flow rate
air flow rate specified by the manufacturer

3.2 Efficiencies

3.2.1
salt removal efficiency
measure of the ability of a filter to remove salt from the air passing through it

3.2.2
water removal efficiency
ratio of water found downstream and upstream of filter element

3.3
salt
sodium chloride (NaCl)

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
dP	pressure drop, Pa
m_{p}	water mass penetrated through tested filter at the end of the test, kg
m_{tot}	total water fog generation amount, kg
CV	coefficient of variation
Na	sodium
NaCl	sodium chloride
RH	relative humidity
SFP	sodium flame photometer
SG	salt generator
SSA	solid salt aerosol

5 Description of test method

The following test method is designed to challenge the air intake test object (the test object could be a complete system, a single filter or a multi-stage filter system) with sub-micron salt to ensure that the fiber structure is challenged deep within the filter and not only on the surface. This allows simulation of salt loading, and the cycling of relative humidity allows simulation of aging because the salt particulates will transform from dry to liquid phase. In real life the filters are exposed to both sub-micron and larger salt particles and water droplets.

The main “failure” modes or weaknesses to be detected by using this test procedure/method are:

a) Bypass of salt and water through not properly sealed construction.

Example Too little glue between frame parts causing leakage.

b) Penetration of salt and water through the filter media.

Example Construction is sealed good, but the filter media has poor water repellency causing leaks through media.

c) Adverse pressure reaction to moisture and/or salt loading.

6 Test rig and equipment

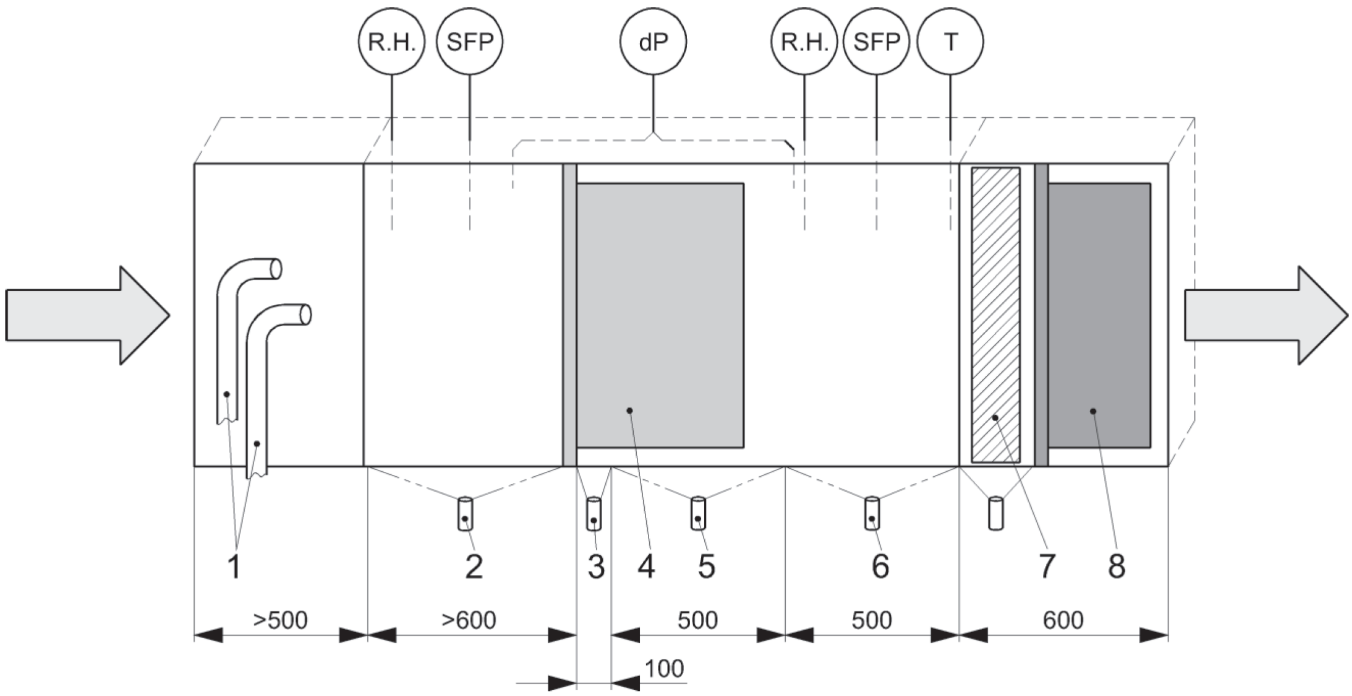
6.1 General

6.1.1 Test rig

The test rig can be configured in multiple different ways depending on the object being tested, the main part of the standard is aimed at testing individual filter elements.

NOTE To perform a multi-stage test an appropriate test procedure is under preparation and will be defined later.

In case of circular cartridges, the test setup (mounting of the filters in the test duct) shall be as close to the real application as possible. This must however be analyzed specifically for each construction, taking into consideration possible jetting effect that can affect the velocity and aerosol concentration in the test duct cross section (see ISO 29461-1:2021, 5). The intended orientation (horizontal/vertical) should be noted in the report.



key

1 injection of aerosol and water spay nozzles
2 upstream drain
3 1st downstream drain
4 test object
5 2nd downstream drain
6 3rd downstream drain
7 droplet separator
8 final filter

Figure 1 — Test duct for testing of single filter element

6.2 Test duct

6.2.1 Test rig layout

The test rig (see Figure 1) shall consist of several duct sections with 650 mm x 650 mm (25,6” x 25,6”) nominal inner dimensions. If the cross section dimensions deviates from this it shall be stated in the report. The section where the test filter is installed shall be representative of the cross-sectional area and geometry for a single filter within the proposed inlet system.

Each rig module should have central drain installed in the floor of the duct in order to collect any water upstream or downstream of the filter, to further aid collection of water the floor should slope towards the drain with a slope angle of 1-3°.

The floor of the duct downstream of the test element should be black (gloss level 20 % according to ISO 2813) in order to aid detection of any salt bypass and a minimum of two walls per module should be transparent.

The test rig is to be operated in a negative pressure airflow arrangement, which represents the typical air flow condition for a gas turbine. A positive pressure arrangement is not typically encountered in gas turbine air inlet systems.

6.2.2 Test air conditioning

A filter with an efficiency of ISO 25 E (ISO 29463-1) shall be placed in the loop to ensure high quality air is entering in the measurement area. If a non-recirculating rig is used the inlet air should instead be pre-filtered with an efficiency of ISO 25 E.

Depending on numerus external factors such as the ambient relative humidity of the test lab etc. additional equipment might need to be installed in the test rig in order to adjust the conditions of the test air to within specification as described in 8.1

6.2.3 Measurement of the air flow rate

Flow measurement shall be made by standardized flow measuring devices in accordance with ISO 5167-1. The uncertainty of measurement shall not exceed ±5 % of the measured value.

6.2.4 Measurement of pressure drop

The measuring points for pressure drop, *dP*, shall be so arranged that the mean value of the static pressure in the flow upstream and downstream of the filter can be measured. The planes of the pressure measurements upstream and downstream shall be positioned in regions of an even flow with a uniform flow profile, minimum distance 350 mm from the forward and rearward most protruding part of the test object.

Smooth holes with a diameter of 2 mm ± 0,5 mm for the pressure measurements shall be bored in the middle three of the channel walls, the hole in the floor should be left out as there is a high risk of that hole clogging with water and/or salt. The holes should be bored normal to the direction of flow. The three holes shall be interconnected with a circular pipe/tube.

The pressure measuring equipment used shall be capable of measuring pressure differences with an accuracy of ±2 Pa in the range of 0 Pa to 70 Pa. Above 70 Pa, the accuracy shall be ±3 % of the measured value.

6.2.5 Aerosol mixing section

The aerosol input and the mixing section shall be so constructed that the aerosol uniformity meets requirements set in 7.2.2

6.2.6 Measurement of temperature and relative humidity

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.

6.3 Measurement equipment

6.3.1 Test rig instrumentation

The test rig shall be equipped with:

— pressure transducers for measuring atmospheric pressure as well as pressure drop over filters, flow devices, droplet separators etc.

— humidity sensors

— temperature sensors

6.3.2 Sodium Flame Photometer

When a solution of metallic salt is sprayed as fine droplets into a flame, due to the heat of the flame, the droplets dry leaving a fine residue of salt. This fine residue converts into neutral atoms.

Due to the thermal energy of the flame, the atoms get excited and after that return to ground state. In this process of return to ground state, excited atoms emit radiation of specific wavelength. This wavelength of radiation emitted is specific for every element.

This specificity of the wavelength of light emitted makes it a qualitative aspect, while the intensity of radiation depends on the concentration of element. This makes it a quantitative aspect.

The radiation emitted in the process is of a specific wavelength. Like for Sodium (Na) 589 nm radiation, Potassium 767 nm range radiation.

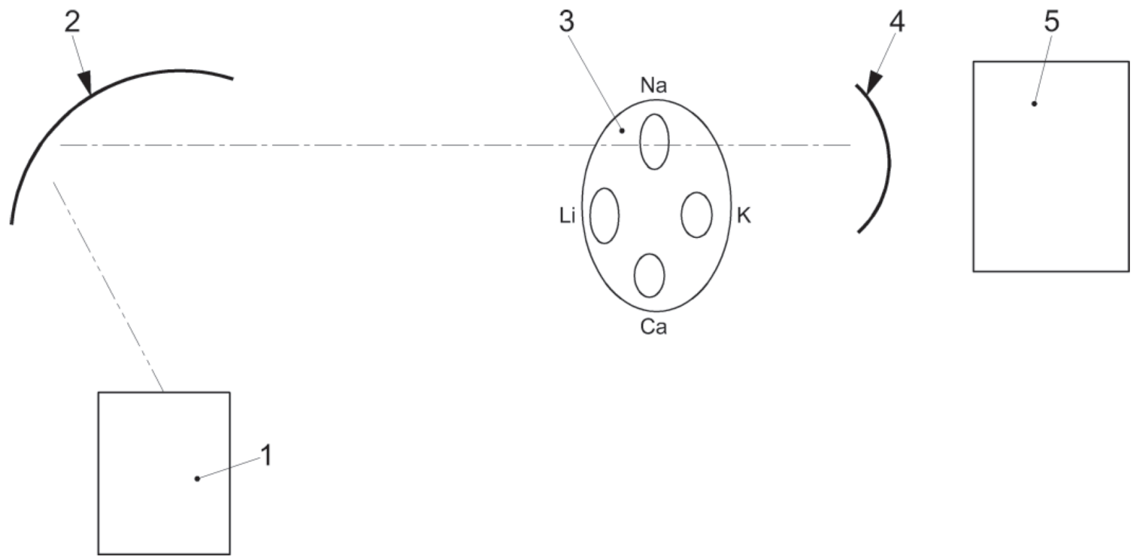
The sensitivity of the sodium flame photometer shall be 10 ng/m^3 or better.

Depending on the model of SFP it may output either sodium content or have onboard conversion into a corresponding sodium chloride value. Should the selected SFP output only sodium this value needs to be converted into sodium chloride as follows: Elements of Group IA

$$Sodium\,Chloride\,(NaCl) = (\frac{Sodium\,content\,(Na)}{0{,}3935})$$

NOTE Since the test duct is operated in negative pressure the pressure condition at the sample inlet of the photometer may affect the measurement depending on the design. Make sure that the photometer is operated according to the manufacturer’s specification and that it is suited for the test setup in this standard.

Also make sure that the selected SFP is suited for sampling airborne salt.



key

1 burner

2 concave mirror

3 filter

4 detector

5 display and recorder

Figure 2 — Flame photometry for Schematic Diagram

6.4 Aerosol sampling

6.4.1 Sample probes

Tapered sharp-edged sampling probes are placed in the center of the upstream and downstream measuring sections. The sampling heads shall be centrally located on the line with the inlet tip facing the inlet of the test rig parallel to the air flow. The sampling probe tip diameter shall be sized to provide isokinetic sampling within 10 % in the test rig for a test air flow rate of 4 250 m^3/h. Changing sampling probe tip diameters to maintain isokinetic sampling in the test rig at other test air flow rates is recommended. The probe diameter shall be 6 mm or larger.

6.4.2 Sampling air flow

The air flow of the sampling pump used (onboard or external) shall be sufficient to provide isokinetic sampling while meeting the requirements of 6.4.1. It is important that the sampling air flow must be within the tolerances of the instrument specification (range) during aerosol measurement.

6.5 Aerosol generation

The SSA shall be generated using an aerosol generator. An example of the technical specifications is included in Annex A.

6.5.1 Salt generation

The saline solution used in the salt generator is made by mixing salt and water (concentration 30 g salt/100 g water). This solution is used in the salt generator (Annex A) to produce an aerosol with a concentration of 4 mg salt per cubic meter of test air (tolerance +0,2/-0 mg). The output concentration of the salt generator is adjusted by regulating the air pressure to the Laskin nozzles. Should the test be interrupted the Laskin nozzles are to be checked and cleaned to ensure the correct output. The saline solution level in the salt generator shall be 50 mm +30/-0 above the holes in the Laskin nozzle.

6.5.2 Aerosol injection

The aerosol should be injected into the airstream from one injection point located in the center of the cross-section of the duct, the injection point shall be facing against the airstream and have a diameter of 100 mm.

6.6 Water spray device

Water spray device is used to generate a uniform water fog. The device shall fulfill the requirements specified in ISO 29461-2, 7.2.

6.7 Water collection device

The collection basins connected to the drains shall be built and configured in such a way that they can be closed off from the rig and removed while keeping the rig free from leaks (i.e by using ball valves), the volume of each basin shall be 10 L. To ensure free flow of water into the basins and to make sure that there is no pressure difference between the basin and the rig the basin shall be fitted with a ventilation that is connected back to the same duct section as the drain.

7 Qualification of test rig and apparatus

7.1 Pressure system testing

7.1.1 Pressure system test protocol

Carefully seal the pressure sample points in the test rig to be able to withstand a negative pressure of 5 000 Pa (20,0 inch H_2O). Disconnect the pressure sensor(s) and apply the negative pressure to each individual sample line until all sample pressure lines have been tested.

For each pressure sensor connected to the system, apply the maximum pressure allowed by the manufacturer to the sensor. This test shall be carried out sequentially on all pressure lines attached to the test rig.

NOTE The pressure system test is to verify the lines, connectors and equipment used to measure pressure in the test rig do not significantly affect the accuracy of the measurements of air flow rate or resistance to air flow.

7.1.2 Pressure system test results

Fulfil the requirements specified in ISO 16890-2, 8.2.1

7.2 Aerosol uniformity

7.2.1 Aerosol uniformity parameters

The uniformity of the challenge aerosol concentration across the test rig cross section shall be determined by a nine-point traverse in the 650 mm × 650 mm (25,6“× 25,6”) test rig immediately upstream of the test device location using the grid points as shown in Figure 3.

The traverse measurements shall be performed at air flow rates of 4 250, 6 000 and 8 000 m^3/h (or the maximum design flow rate for the test rig). The traverse shall be made by repositioning a single probe to maintain the same sample line configuration for each of the nine grid points. The inlet nozzle of the sample probe shall be a tapered sharp edged sample probe and meet the requirements of 6.4.1 for isokinetic sampling at 4 250 m^3/h. This same inlet nozzle diameter shall be used at all air flow rates.

7.2.2 Aerosol uniformity protocol

A minimum of a one-minute sample shall be taken at each grid point with the aerosol generator operating. After sampling all nine points, the traverse shall be repeated four more times to provide a total of five samples from each point. The five values for each point shall then be averaged. The measurements shall be made with an SFP meeting the criteria set in 6.3.2.

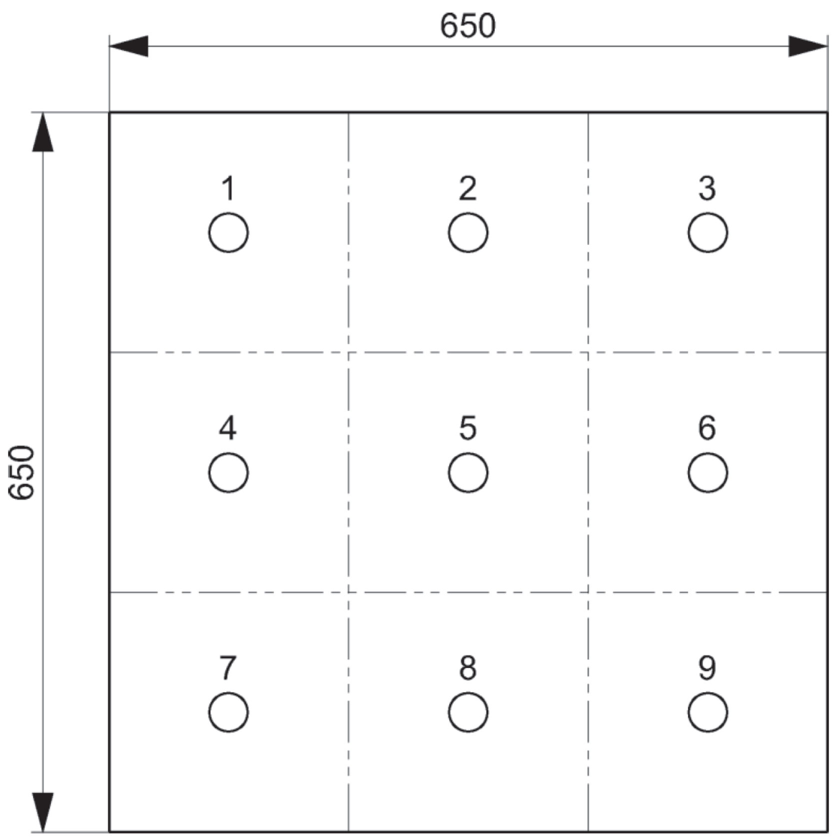


Figure 3 — Test points for aerosol uniformity testing

7.2.3 Aerosol uniformity results

The CV of the corresponding nine grid point salt concentrations shall be less than 20 % for each of the three standard air flow rates.

The coefficient of variation CV shall be calculated at each flow as follows:

$$CV = \frac{\delta}{Avg}$$

where

δ is the standard deviation of the nine measuring points

Avg is the arithmetic average of the nine measuring points

7.2.4 Water droplet size distributions

Shall fulfil the requirements set in ISO 29461-2, 8.8.

7.2.5 Water fog sedimentation check

With no test filter installed, adjust the airflow to 4 250 m^3/h and increase the relative humidity, the relative humidity shall not be less than 95 %.

Turn on the water spray device and adjust the water fog concentration to 3,4 g/m^3. The test duration is 30 min under which the relative humidity shall be no less than 95 %.

Turn off the water spray device after 30 minutes and collect the water from the upstream collection basin; the collected mass shall be no more than 5 % of the total mass injected during the test.

8 Test conditions

8.1 Test air

Room air or outdoor air may be used as the test air source. The air temperature shall be in the range of 10 °C to 45 °C. The exhaust flow may be discharged outdoors, indoors or re-circulated. If the rig is configured in a non-recirculating way the ambient room air needs to be conditioned in such a way that the relative humidity and temperature conforms with each of the test cycles.

8.2 Test water

The test water pH value shall be in the range of 6-8, alkalinity ≤ 50 mg/dm^3, full hardness ≤ 70 mg/dm^3. The temperature of the test water shall not exceed the temperature of the test air.

9 Test method

9.1 Stop criteria

The size and weight of salt particles changes drastically during periods of high and low relative humidity. It is therefore important to transfer this into the lab test by cycling the RH from low to high while introducing the salt particles from the salt generator, the accelerated cycling will cause accelerated aging. The tested filter will be challenged by salt in all phases as it transforms with relative humidity levels. A fine water spray is used to determine the water repellency of the filter and visually allows detection of any leakages. The process is repeated until one of the ‘stop-test’ criteria below are met:

— water bypasses and test object: droplets or pools of water is visible downstream of the test object on the duct floor, in the basins or on the test object itself. Document the water leak by adding a picture to the report and note the amount of water that bypassed;

— total runtime of test exceeds 120 hours;

— pressure drop of the test object exceeds 1 000 Pa at any point during the test.

9.2 Adjustment of the test air flow rate

Filters to be tested at one of the three default airflows or to customer specific air flow. It shall be possible to adjust the volume flow rate by means of a suitable provision (e.g. by changing the speed of the fan, or with dampers) to a value ±5 % of the test air flow rate which shall then remain constant within ±5 % throughout each test.

Depending on the intended use of the filter, three default test airflow rates are recommended:

a. nominal airflow 4 250 m^3/h

b. increased airflow 6 000 m^3/h

c. high velocity 8 000 m^3/h

9.3 Preparatory checks

9.3.1 Operational readiness of the measuring instruments

Before each measurement the sodium flame photometer needs to be turned on and warmed-up as specified by the instrument manufacturer

9.3.2 Zero level check measurement of the sodium flame photometer

The measurement of the zero level (no salt particles detected) level shall be carried out using flushing air which is free of particles. This can be achieved by sampling through an ISO 45 H filter on the upstream/downstream probe or by using the “flush” setting on the SFP if available. The photometer reading shall be < 0,01 mg/m^3.

9.3.3 Absolute pressure, temperature and relative humidity of the test air

These parameters shall be checked to ensure that they comply with the specifications described in 8.1.

9.3.4 Starting up the aerosol generator

Before turning on the heater, start by checking the level in the tank containing the saline solution to see that it is at the appropriate level as specified in Annex A.

Remove the water container and rinse it completely in order to remove any salt build-up that may have occurred due to evaporation of the saline solution. Inspect that the holes in the Laskin nozzles are not clogged. The test shall always be started with a fresh saline solution.

After adjusting the operating parameters of the dry salt generator and observing an appropriate warming-up period, the salt concentration shall be checked to ensure that it complies with the requirements specified in 6.5.1. The salt concentration shall be verified by sampling with the SFP through the upstream sampling probe.

9.3.5 Installation of the test filter

The test filter shall be installed in the mounting assembly with regard to air flow direction and gasketing side as it is foreseen for use.

The interface between the filter element and the duct shall be sealed by compressing the filter gasket to the filter manufacturers recommended setting. The interface shall not be sealed by any other means (i.e. tape). The tightness shall be checked by visual inspection and no visible leaks are acceptable.

9.3.6 Flushing the test filter

In order to reduce emission of any deposited particles and to equalize the temperatures of the test filter and the test air, the test filter shall be flushed with test air for 10 minutes at the test air flow rate prior to the start of the test.

9.4 Measurements

9.4.1 Measurement of pressure drop

The initial pressure drop at test air flow rate across the test filter shall be measured in the unloaded (clean) state with no salt generation present. The nominal air flow rate shall be set, as specified in 6.2.4. The measurements shall be made when a stable operating state has been reached. The pressure drop across the test filter shall be continuously measured and recorded for the complete duration of the test.

9.4.2 Measurement of the salt removal efficiency

Efficiency shall be measured with the SFP by sampling the salt concentration upstream and downstream of the filter repeatedly five (5) times. The salt removal efficiency is calculated as follows:

$$E = \left(1 - \frac{C_{\text{downstream}}}{C_{upstream}}\right)100$$

where

$C_{downstream}$ is the average mass (five measurements) of salt downstream of the filter.

$C_{upstream}$ is the average mass (five measurements) of salt upstream of the filter.

Test sequence for measurement of salt removal efficiency:

a) Start the SFP, allow for warm-up period according to manufacturer's specification.

b) Measure the background concentration and adjust the zero of the SFP.

c) Measure the salt concentration repeatedly until 5 upstream and 5 downstream concentration have been sampled as follows:

   1) Purge the upstream lines.

   2) Sample the upstream concentration until the reading is stabilized.

   3) Purge the downstream lines.

   4) Sample the downstream concentration until the reading is stabilized.

d) Shut down the SFP according to the manufacturer's specification.

9.4.3 Measurement of the water removal efficiency

Measure the water removal efficiency by collecting the water at each of the drains and note how much water each drain has collected in relation to the water injected into the test rig. In the event that the volume of the water found downstream of the filter is very small and will not reach the drain, weigh a piece of paper or similar before and after drying out the duct with said paper.

The water removal efficiency is calculated as follows:

$$E_w = \left(1 - \frac{W_{\text{downstream}}}{W_{\text{upstream}}}\right)100$$

where

$W_{downstrean}$ is the mass of water collected downstream of the filter

$W_{upstream}$ is the mass of water injected upstream of the filter

9.4.4 Cumulative salt penetration

The cumulative salt penetration is calculated as follows:

$$Cumulative\ salt\ penetation\,(g) = \left(\frac{Q \times t \times C_{upstream} \times (100 - E)}{100} \right)$$

where

Q is the airflow in m^3/h

t is the time in hours

$C_{upstream}$ is the salt concentration upstream used to calculate salt removal efficiency

E is the salt removal efficiency

10 Test procedure

10.1 Preparation of Test rig (no test object installed)

1. With an empty test rig (no test object), turn on the airflow.
2. Allow the air flow to stabilize (variation of +/- 100 m^3/h) at the desired test air flow rate.
3. Turn on the sodium flame photometer (SFP), salt generator (SG) and allow the SFP to warm up according to the manufacturer's specification. Measure background concentration and zero the SFP.
4. Measure the salt concentration with the SFP, salt concentration shall be 4 mg per m^3 of air.
5. When the salt concentration has been verified turn off the SFP and the SG.
6. Turn on the water challenge, water mass flow shall be 1,7 g per m^3 of air.
7. Visually check the dispersion plumes to make sure no nozzles are clogged.
8. When the water challenge dispersion plumes have been verified, increase the water mass flow to 3,4 g per m^3 of air.
9. Visually check the dispersion plumes to make sure no nozzles are clogged.
10. When the water challenge dispersion plumes have been verified, turn off the water challenge and air flow.

10.2 Cleaning of test rig

11. With the air flow turned off, thoroughly clean the test rig, ensuring no salt, condensation, moisture or free standing water is on any of the test rig or installed equipment surfaces, including measuring probes etc. Also ensure that all drainage points are clean and free to drain.

10.3 Primary weighing of the 'test object'

12. Prior to installation into the test rig, the 'test object' is to be weighed in a new and dry condition (the test object to be stored in an air environment of 25 °C ± 5 °C and 40 % RH +0/-10 % for at least 12 hours).

If the laboratory room conditions are significantly different to the conditions above, the test object shall be installed in the test rig with air flow turned on at nominal airflow in order to condition the test object. This conditioning shall be done for minimum of 1 hour.

10.4 Installation of the 'test object'

13. If not already done so to accommodate cleaning of the test rig as per 10.2 above, remove any test rig components i.e. removable panels, viewing windows etc. that are required to be removed to accommodate the installation of the 'test object'.

14. Install the 'test object' into the test rig. The installation configuration shall be as intended to be supplied or as actually installed in the offshore application i.e. orientation, retention, gasket sealing and compression.

15. Re-install any test rig components i.e. removable panels, viewing windows etc. that were removed to accommodate the installation of the 'test object'.

10.5 Primary Water deluge challenge

16. Turn on the air flow.

17. Allow the air flow to stabilize (variation of ±100 m3/h) at the desired test air flow, air temperature to be 25 °C ± -5 °C and 40 % RH +0/-10 %.

18. Turn on the water challenge with a water mass flow 3,4 g water /m3 of air and run for a period of 1 hour.

19. Turn off the water droplet challenge. Measure the water collected in each basin.

20. Allow the 'test object' to dry at an air temperature to be 25 °C ± 5 °C and 40 % RH +0/-10 % for a period of 1 hour and return to the initial dP.

10.6 Salt loading

21. Turn on the SG for the remaining entirety of the test.

22. 1 hour salt loading of salt.

23. Measure the salt removal efficiency using the SFP.

10.7 Water deluge challenge

24. Increase the air RH to > 95 % with the temperature remaining at 25 °C ± 5 °C. The RH ramp up duration from 40 % +0/-10 % to > 95 % is to be 15 minutes.

25. Turn on the water deluge challenge, water mass flow 1,7 g water /m^3 of air and run for a period of 60 minutes.

26. At the end of the 60 minutes period turn off the water deluge challenge. Measure the water collected in each basin.

27. Decrease the air RH from > 95 % to 40 % +0/-10 % with the temperature remaining at 25 °C ± -5 °C. The RH ramp down duration from > 95 % to 40 % +0/-10 % is to be 30 minutes.

28. Run for a period of 90 minutes at RH 40 % +0/-10 %.

Note Any deviation from the target ramp up duration shall be added or subtracted to the time of the next step in the test procedure.

10.8 Relative humidity cycles

29. Measure the salt removal efficiency using the SFP.

30. Increase the air RH to > 95 % with the temperature remaining at 25 °C ± 5 °C.

The RH ramp up duration from 40 % +0/-10 % to > 95 % is to be 15 minutes.

31. Run for a period of 60 minutes at RH > 95 %.

32. Decrease the air RH from > 95 % to 40 % +0/-10 % with the temperature remaining at 25 °C +/-5 °C. The RH ramp down duration from > 95 % to 40 % +0/-10 % is to be 30 minutes.

33. Run for a period of 90 minutes at RH 40 % +0/-10 %.

34. Increase the air RH to > 95 % with the temperature remaining at 25 °C ± 5 °C. The RH ramp up duration from 40 % +0/-10 % to > 95 % is to be 15 minutes.

35. Turn on the water deluge challenge, water mass flow 1,7 g water/m^3 of air, and run for a period of 60 minutes.

36. At the end of the 60 minutes period turn off the water deluge challenge. Measure the water collected in each basin.

37. Decrease the air RH from > 95 % to 40 % +0/-10 % with the temperature remaining at 25 °C ± -5 °C. The RH ramp down duration from > 95 % to 40 % +0/-10 % is to be 30 minutes.

38. Run for a period of 90 minutes at RH 40 % +0/-10 %.

Repeat step 29 to 38 until one of the stop-test criteria in **Errore. L'origine riferimento non è stata trovata.** is met. After completing the first relative humidity cycle it is permitted to skip step 29 for subsequent cycles in order to make the cycling automated under the condition that a minimum of one (1) salt removal efficiency measurement is taken per 24 hour period.

10.9 End of test

39. Measure the final salt removal efficiency using the SFP.

40. Stop the SG.

41. Run the filter for an additional 60 minutes at RH 40 % +0/-10 %.

10.10 Secondary weighing of the ‘test object’

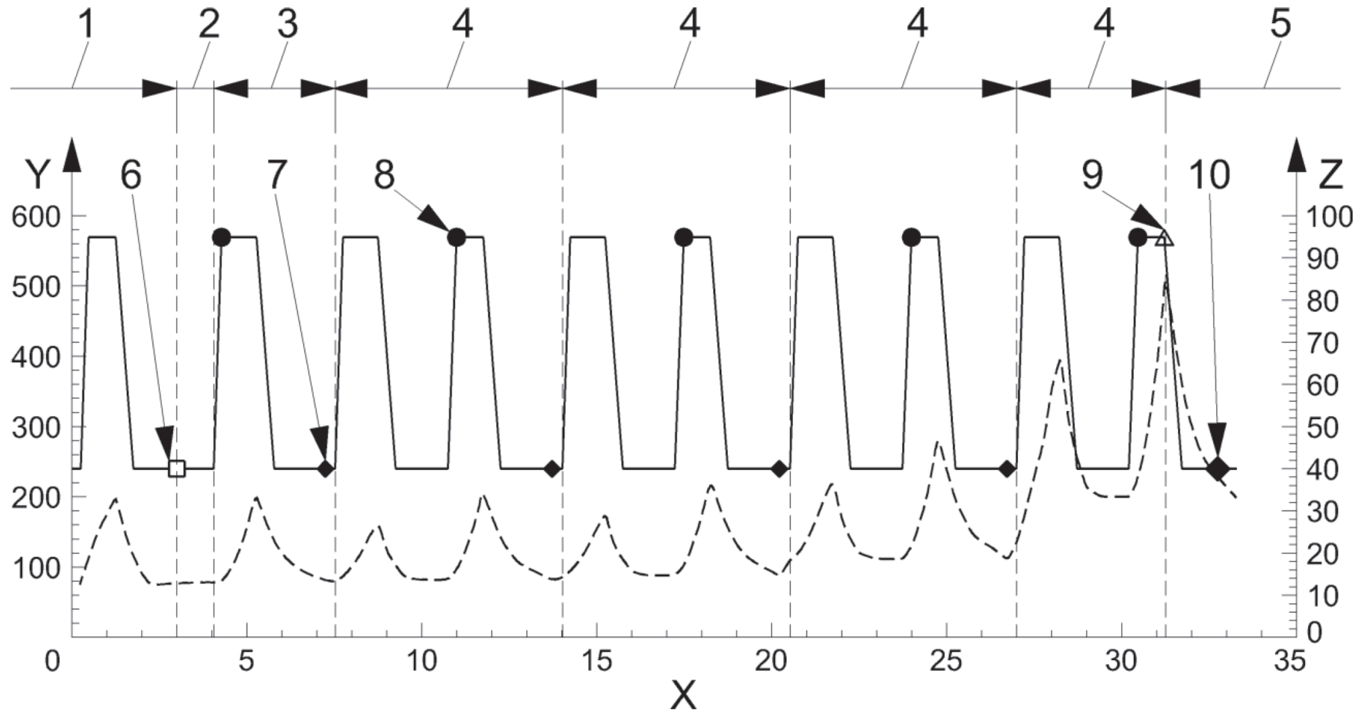
1. Extract the ‘test object’ from the test rig.

Note Take care when removing the test object, there may be water present.

2. Dry the filter in ambient air for 24 hours. During the drying the temperature shall be 25 °C +/-5 °C and 50 % +10/-10 % RH.

3. The extracted ‘test object’ is to be weighed in a loaded condition (ambient air temperature 25 °C +/-5 °C and 40 % +0/-10 % RH).

4. Record final weight.



key

1	primary deluge challenge (10.5)	6	start SFP
2	salt loading (10.6)	7	measure salt removal efficiency
3	water deluge challenge (10.7)	8	water deluge challenge
4	relative humidity cycles (10.8)	9	leakage detected
5	end of test (10.9)	10	final salt removal efficiency measurement

Figure 4 — Test procedure

11 Reporting results

11.1 General

The report shall describe all deviations from the test setup specified in this standard.

11.2 Observations

Observations to be made during test:

a) Media bulging

b) Filter breaking

c) Pleat deformations

d) Water penetration and location

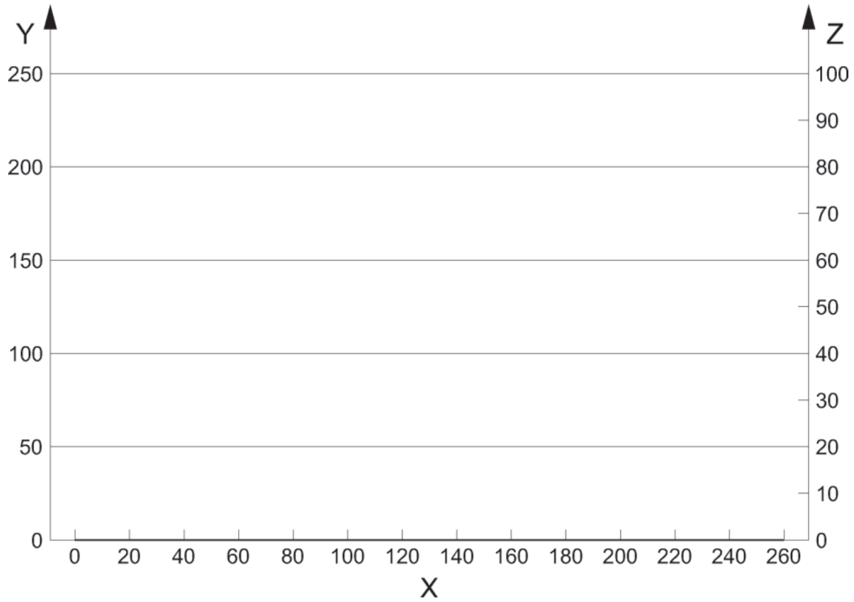
e) Penetration of salt through filter.

f) High dP spikes

11.3 Report Template

ISO 29461-4 Reporting Template			
Testing organization		Report Number	
GENERAL			
Test number		Test date	
Test performed by		Test requestor	
Filter supplied by		Filter receipt date	
FILTER INFORMATION			
Filter model		Manufacturer	
Filter media type		Effective media area	
Filter type		Nominal filter dimension	
TEST EQUIPMENT			
Nozzle type		Nozzle quantity	
Compressed air pressure		Air flow rate	
Water pressure			
TEST DATA			
Airflow rate		Ambient temperature	
Ambient relative humidity		Water concentration	
Salt concentration		Total water mass	
RESULTS			
Initial pressure drop		Number of cycles	
Max pressure drop		Total testing time	
Initial filter weight		Final filter weight (dry)	
Reason for stop			
Comments			

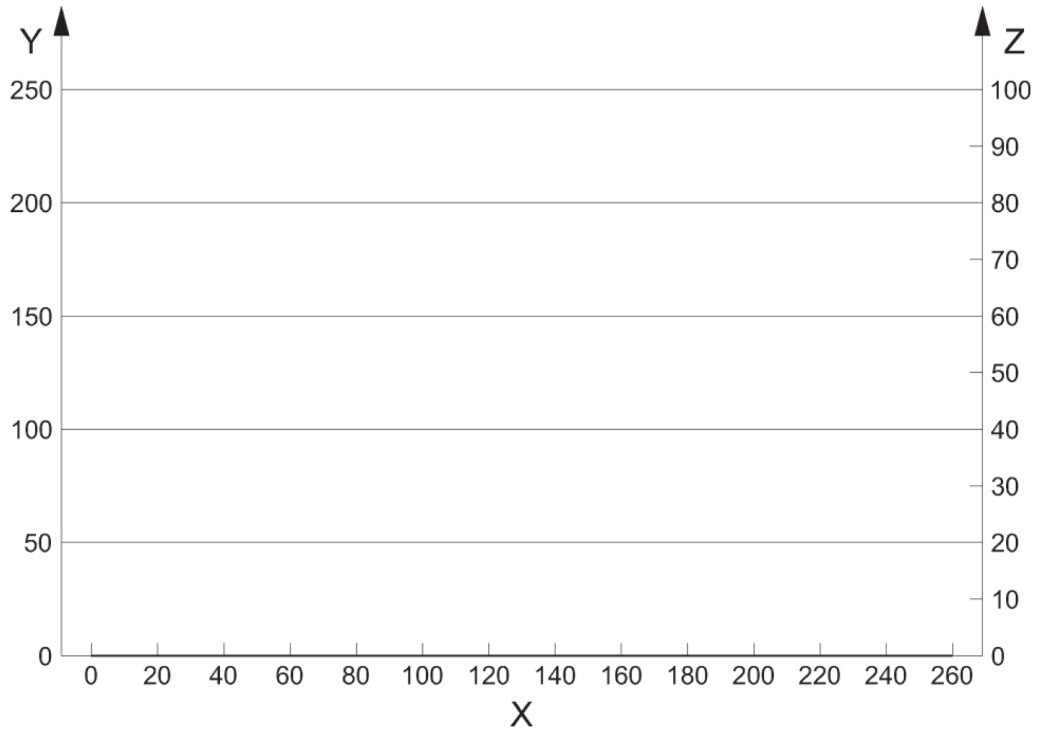
Salt and water mass vs. time



x = time (min)
y = water mass (g)
z = salt mass (g)

Figure 5 — Report template page 1

Differential pressure and RH vs. time



x = time (min)
y = dP (Pa)
z = RH (%)

ISO 29461-4 Reporting template			
Air Filter		Test number	
Water Concentration		Salt concentration	
Airflow rate			

Table of results

Cycle Number	T(min)	dP (Pa)	Cumulative Water mass (g)	Water Penetration Mass (g)	Cumulative Salt Mass (g)	Salt penetration Mass (g)	Salt removal Efficiency (%)

Figure 6 — Report template page 2

Annex A
(informative)

Mk II. Salt generator

A.1 Ultrafine dry salt generator Mk. II

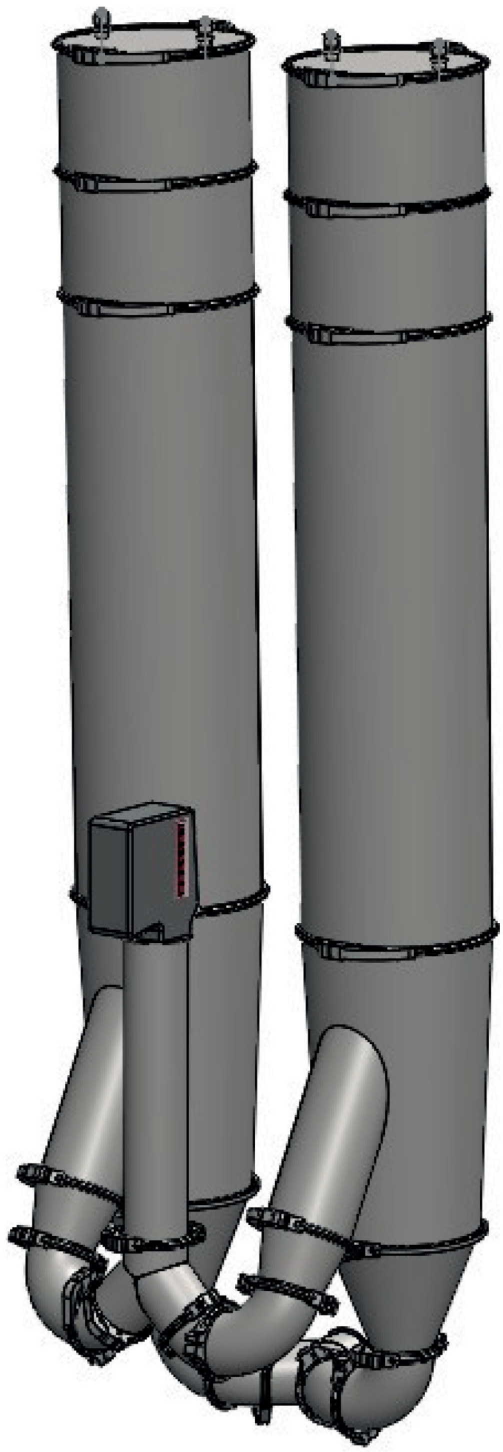
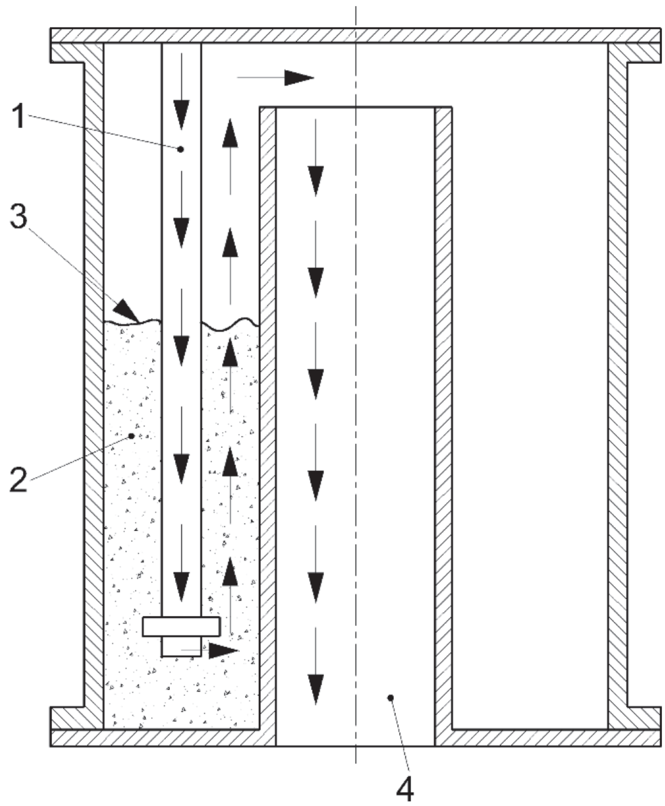


Figure A.1 — 3D model of salt generator

A.1.1 Principle

Sea-salt aerosol is produced from bursting bubbles created by white wash and breaking waves from which droplets get ejected. These droplets dry in the wind resulting in ultrafine dry salt particles with sizes down to 0,01 µm. To replicate this phenomenon and generate small salt particles the salt generator is built around the principle of bubbling a saline solution and then drying these droplets in a drying tower to generate dry ultrafine salt particles.



key

1 compressed air through Laskin nozzle

2 salt water

3 bubbles bursting creating droplets

4 exit pipe to air dryer

Figure A.2 — Working principle of salt generator

A.1.2 Design

A.1.2.1 Parts

Parts from Jacob GmbH: Pipe, blank covers, Quick connect clamps					
Pcs	**Diameter**	**Length**	**Material**	**Artnr**	**Comment**
2	300	200	2 mm SS [a)]	12303040	
1	300	1 000	1 mm SS [a)]	11303020	
1	100	200	2 mm SS [a)]	12103130	Push in pipe
1	300-250-140	390	1 mm SS [a)]	11303288	Branch to connect heater
3	100	-	1 mm SS [a)]	11103339	90 degree bends
1	100-250	200	1 mm SS [a)]	11003454	Cone piece to connect 90 dg bends
1	100	28	1,5 mm SS [a)]	11103431	Connection flange to test rig
1,1	300,140	-	1,5 mm SS [a)]		Blank covers for top lid & heater
3	300	-		10303780	Pipe clamp for mounting
1	140	-	1,5 mm SS [a)]	111437151	Blank cover to fit heater
3,1,1,4	300,250,140,100	-	SS [a)]	-	Quick connect pull-ring clamps

Silicone U-seal gaskets will also be needed for each of the pull ring fittings.

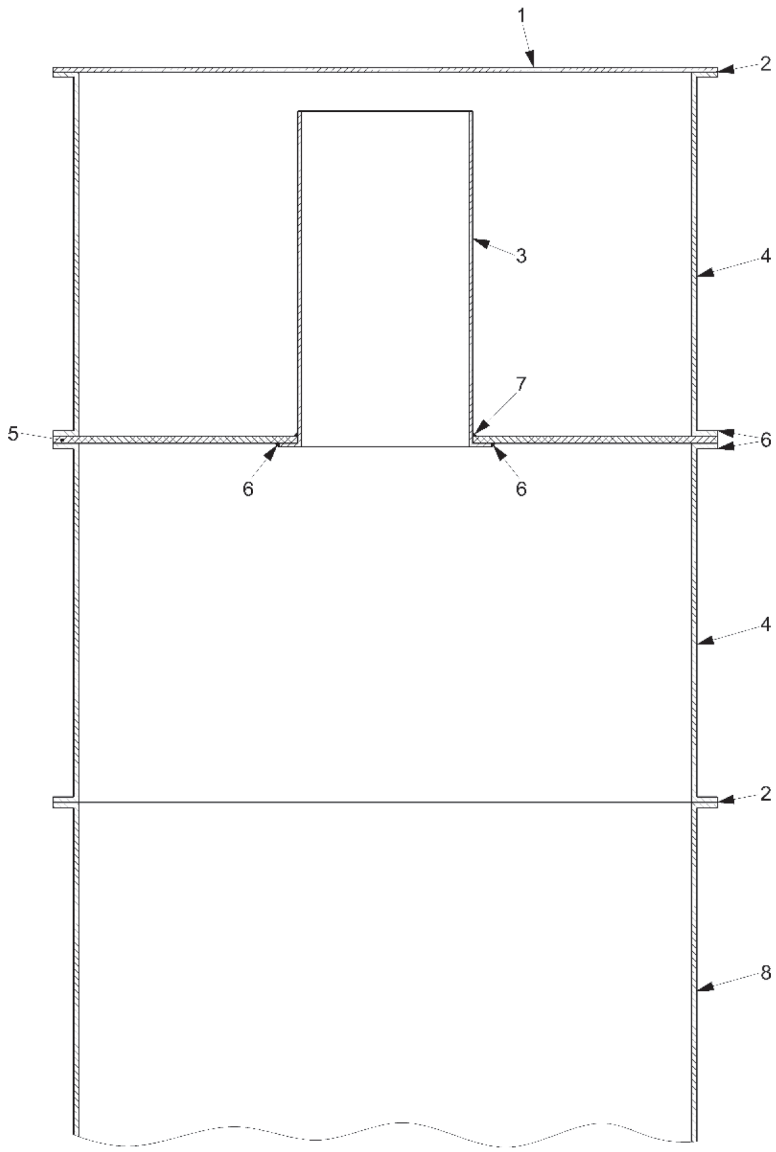
a) SS = stainless steel

Other parts: Heater, nozzles etc.					
Pcs	**Type**	**Manufacturer**	**Model**	**Artnr**	**Comment**
Choose one	Heater	Leister	LHS 21S PREMIUM 2kW	139.909	Heater without internal fan. Use combines with fan of choice.
	Heater	Leister	HOTWIND SYSTEM 2300W	140.096	Heater with internal fan and LCD, possibility to connect temp probe.
Opt.	Temp probe	Leister	-	106.956	Temp probe for HOTWIND. Makes it possible to set temperature
Opt.	Flange connector	Leister	-	125.317	Push-fit flange for HOTWIND
6	Nozzles	-	Laskin	-	Laskin nozzles for aerosol generation. Dimensions described below. Use stainless steel.

Various pipe parts, fittings, compressed air tubes, connectors etc. will not be specified at this moment and can be chosen by personal preference.

A.1.2.2 Aerosol generator

The generator consists of two 200 mm long pipes with a 3 mm thick disc of stainless steel welded between them in order to make it watertight, the upper 200 mm holds the saltwater and the lower 200 mm connects to the rest of the drying tower with a quick connect clamp so the generator can be easily cleaned. In the center of the disc a hole needs to be cut and the exit pipe to the dryer need to be welded from below, see illustration below.



key

1	2 mm lid, fitted with clamps. Article number: 113037151	5	3 mm disc of stainless
2	quick connect clamp	6	weld
3	push-in pipe cut to length 170 mm	7	alternative weld
4	D:300 L:200 stainless pipe. Article number: 12303040	8	D:300 L:200 stainless pipe

Figure A.3 — Section view of salt generator

A.1.2.3 Laskin nozzles

Machine 6 laskin nozzles out of stainless steel using dimensions below. Save approx. 2 mm of material at the bottom of the nozzle, the other end can be cut short and then be internally threaded. Or left long and externally threaded.

Dimension in mm

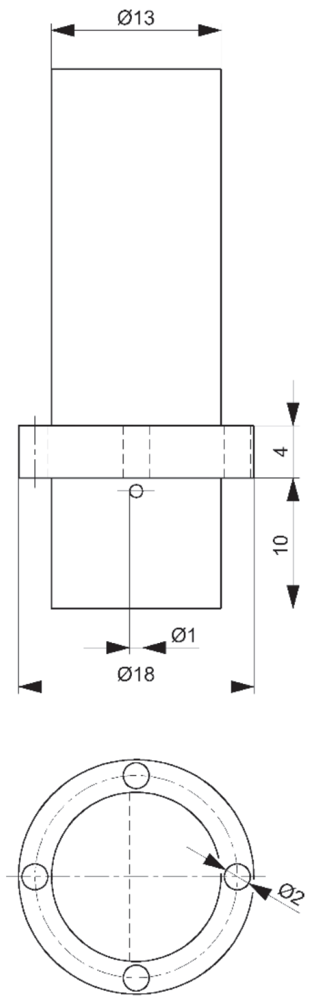


Figure A.4 — Laskin nozzle dimensions

A.1.2.4 Assembly

Assemble the pipe parts according to the sketch to the left, use silicone U-seal between each of the fittings that use the Quick connect clamps.

Take the Ø 300 mm blank cover and drill 6 holes evenly displaced and 50 mm in from the outer edge. Use pipe couplings and compressed air couplings to fit a Laskin nozzle in each of the 6 holes. Leave approximately 10 mm between the nozzle and the bottom of the container.

Attach the heater to the 140 mm blank cover, if using the HOTWIND then drill a hole in the blank cover and fit the push-fit flange by welding or sealant.

Use the 90° bends to fit the generator to the test rig.

Optional:

Construct a support structure (cage) around the complete salt generator to aid in mounting the generator and to prevent anyone from touching the potentially hot pipes.

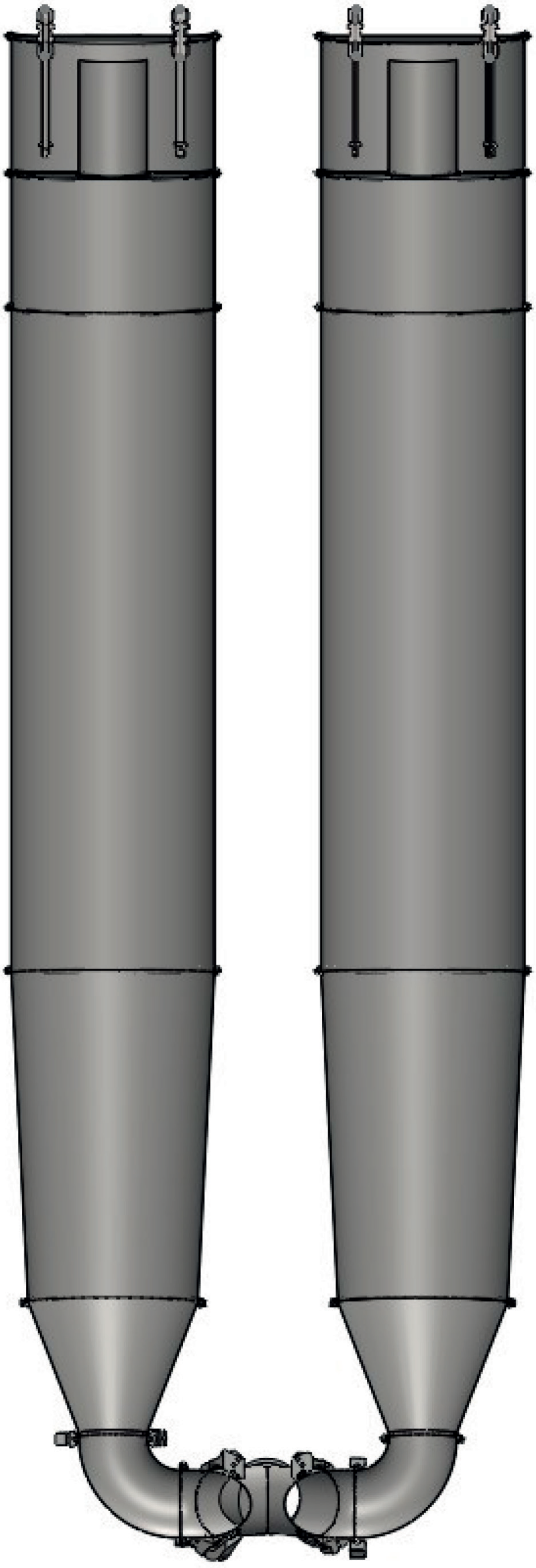


Figure A.5 — Section view