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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

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Foreword

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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 use of gas turbines in the oil and gas industry represents one of the most challenging applications for this engine technology. The major constraint of the oil and gas industry is to run 24/7 at full load with minimum downtime. In oil and gas activity, the installation must be run 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 turbine 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 vapours, 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 can induce filter washings that release filtered particles into the compressor. All these phenomena impact the gas turbine availability on site.

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 most penetrating particle size (MPPS). These parameters, related to a single filter element, are measured in laboratory conditions close to favourable 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 consider how the effect of water spray, humidity and salt affects the performance of an air filter. The tested air flow passing through the filter element is close to the air flow rate 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 and performance. The separate parts of ISO 29461 cover particles, while soot, volatile hydrocarbons and oily vapours are yet to be addressed. Current test methods are not mature enough for the inclusion of soot, volatile hydrocarbons and oily vapours.

The ageing of a filter element installed offshore and near the coast is addressed to allow the prediction of operational filter performance and its associated service life. It must be understood 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. 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 16890-2:2022, *Air filters for general ventilation — Part 2: Measurement of fractional efficiency and air flow resistance*

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, *Cleaning of air and other gases — Vocabulary*

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 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/

1) The filters will be loaded with ultra-fine salt particles of a size mostly sub micron during variable humidity to simulate real offshore and coastal conditions hence filters with an initial conditioned efficiency lower than 50 % for the ePM_1 particles (filter class T7) are likely to underperform 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 29464:2024, 3.1.29]

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

Note 1 to entry: The flow rate is usually expressed in volumetric units [m^3/h (cfm)].

Note 2 to entry: Test flow rate may differ from the manufacturer's specified flow through the air cleaner.

[SOURCE: ISO 29464:2024, 3.1.32]

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

[SOURCE: ISO 29464:2024, 3.1.30]

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
measure of the ability of a filter to remove water from the air passing through it

3.3
test device
air filter or device to be tested

4 Symbols and abbreviated terms

CV	coefficient of variation
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
E_{salt}	salt removal efficiency
E_w	water removal efficiency
m_{p}	water mass penetrated through tested filter at the end of the test, kg
m_{tot}	total water fog generation amount, kg
Na	sodium

NaCl sodium chloride

RH relative humidity

SFP sodium flame photometer

5 Principle

The test method is designed to challenge the air intake test object (the test object can be a complete system, a single filter or a multi-stage filter system) with sub-micron salt in order to ensure that the fibre 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 field operating conditions, 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 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 well, but the filter media has poor water repellence, causing leaks through media.

c) adverse pressure reaction to either moisture or salt loading, or both.

6 Test rig and equipment

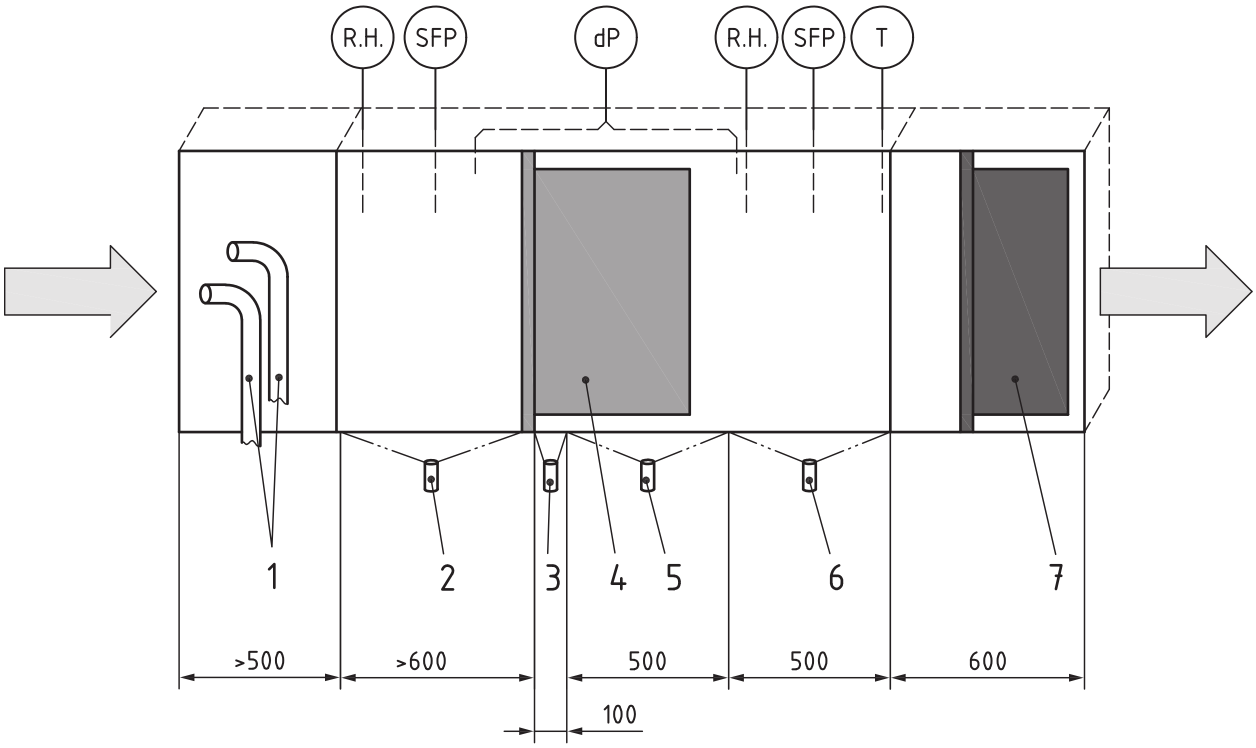
6.1 Test rig

The test rig can be configured in multiple different ways depending on the object being tested, this document defines testing individual filter elements.

NOTE To perform a multi-stage test, an appropriate test procedure is under preparation for a later revision of this document.

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

Dimensions in millimetres



Key

1 injection of solid salt aerosol and water spray device
2 upstream drain
3 1st downstream drain
4 test device
5 2nd downstream drain
6 3rd downstream drain
7 ISO 25E filter

Figure 1 — Test duct measurement section of single filter element

6.2 Test duct

6.2.1 Test rig layout

The test rig (see Figure 1) should consist of several duct sections with 650 mm × 650 mm (25,6” × 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 filter arrangement within the proposed inlet system.

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

The bottom wall of the test duct downstream of the test device shall be black (gloss level 20 % at 60° in accordance with ISO 2813) to aid detection of any salt bypass. A minimum of two walls per module shall be transparent or include windows. Additionally, cameras can be used to aid detection of water by-pass.

The test rig shall be operated in a negative pressure air flow 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 in accordance with ISO 29463-1 shall be placed in the loop to ensure high quality air is entering in the measurement section. If a non-recirculating rig is used, the inlet air shall 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 can potentially 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 ±100 m^3/h of the measured value. The equipment shall be calibrated at regular intervals to ensure the required accuracy.

6.2.4 Measurement of pressure drop

The measuring points for pressure drop, *dP*, shall be arranged so 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, at a minimum distance of 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 drilled in three of the test duct walls, the hole in the floor shall be left out as there is a high risk of that hole clogging with either water or salt, or both. The holes shall be drilled perpendicular to the direction of flow. The three holes shall be interconnected with a circular pipe or 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. The equipment shall be calibrated at regular intervals to ensure the required accuracy.

6.2.5 Solid salt aerosol mixing section

The solid salt aerosol input and the mixing section shall be constructed so that the aerosol uniformity meets the requirements set out 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 etc.;

— humidity sensors;

— temperature sensors.

6.3.2 Sodium flame photometer

A sodium flame photometer (SFP) works by analysing the light emitted from sodium atoms when they are excited in a flame, see Figure 2.

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 dependent on the element. For sodium (Na) this wavelength is in the range of 589 nm, for potassium (K) it is around 767 nm.

The sensitivity of the SFP shall be ≤ 10 ng/m^3.

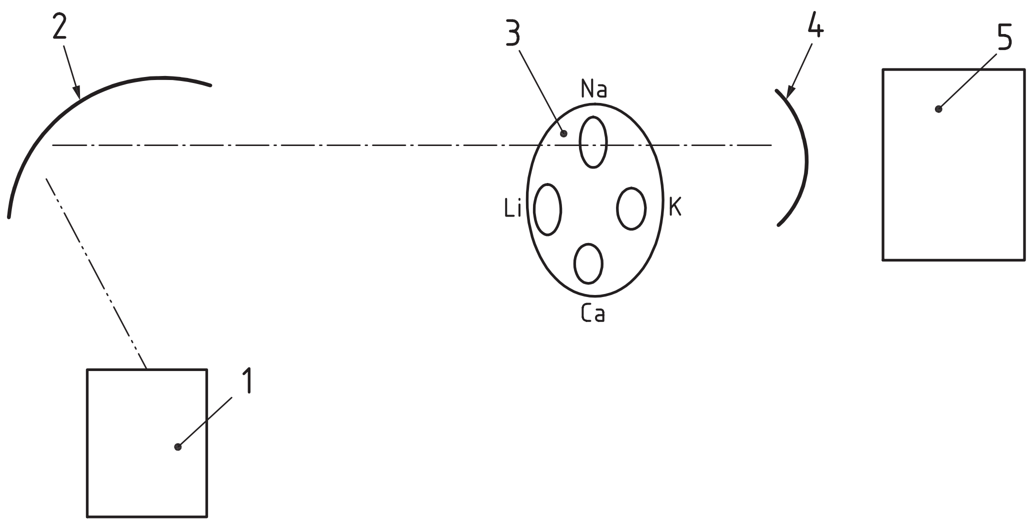
Depending on the model of SFP, the output can either be of measured sodium content or a converted sodium chloride value. If the output is sodium content only, this shall be converted into sodium chloride as follows:

$$c_{\mathrm{NaCl}} = \left(\frac{c_{\mathrm{Na}}}{0{,}393\,5}\right)$$

Since the test duct is operated in negative pressure, the pressure condition at the sample inlet of the SFP can affect the measurement depending on the design.

The SFP shall be operated according to the manufacturer's specification and be of suitable design for the test setup in this document.

The SFP shall be suitable for sampling airborne salt.



Key

1 burner
2 concave mirror
3 optical filter
4 detector
5 display and recorder

Figure 2 — Flame photometry — Schematic diagram

6.4 Solid salt aerosol sampling

6.4.1 Sample probes

Tapered sharp-edged sampling probes are placed in the centre 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. The sampling probe tip diameter shall be sized to provide isokinetic sampling within 10 % in the test rig for either all three default test flow rates or the actual test air flow rate, or both. The probe diameter shall be 6 mm or larger.

6.4.2 Sampling air flow

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

6.5 Solid salt aerosol generation

6.5.1 Salt generation

The SSA shall be generated using a salt generator. An example of the technical specification is included in Annex A. The salt used for tests according to this document is sodium chloride (NaCl).

The saline solution used in the salt generator is made by mixing NaCl and water (concentration 30 g NaCl/100 g water). This solution is used in the salt generator (Annex A) to produce an aerosol with a concentration of 4 mg NaCl 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. If the test is interrupted, the Laskin nozzles shall be checked and, if needed, cleaned to ensure the correct output once the test is restarted. The saline solution level in the salt generator shall be 50 mm +30/-0 above the holes in the Laskin nozzle.

An auxiliary heater is connected to the salt generator to dry the aerosol, the heater shall be adjustable for air flow and temperature and set to an air flow of 200 l/min ±10 %, the air temperature in the salt generator shall be 35 °C ± 5 °C in the centre of part 11 in the generator, see Figure A.6.

6.5.2 Aerosol injection

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

6.6 Water spray device

A water spray device is used to generate a uniform water fog. The device shall fulfil the requirements specified in ISO 29461-2:2022, 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 test duct section as the drain.

7 Qualification of test rig and apparatus

7.1 Pressure system testing

Pressure system testing shall meet the requirements specified in ISO 16890-2:2022, 8.2.1

7.2 Solid salt 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 m^3/h, 6 000 m^3/h 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.

7.2.2 Aerosol uniformity protocol

A minimum of a one-minute sample shall be taken at each grid point with the salt 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.

Dimensions in millimetres

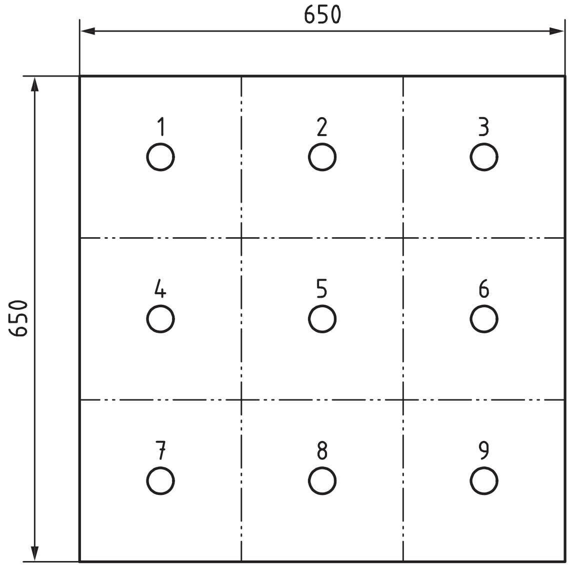


Figure 3 — Test points for aerosol uniformity testing

7.2.3 Aerosol uniformity results

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

The CV shall be calculated at each flow rate as follows:

$$c_V = \frac{\delta}{a}$$

where

c_V is the coefficient of variation;

δ is the standard deviation of the nine measuring points;

a is the arithmetic average of the nine measuring points.

7.2.4 Water droplet size distributions

The water droplet size distributions shall fulfil the requirements set in ISO 29461-2:2022, 8.8.

7.2.5 Water fog sedimentation check

With no test filter installed, adjust the air flow rate 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 min 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.

7.2.6 Schedule of qualification

The test rig owner or operator shall always have a qualification testing report available documenting the results of the latest qualification testing. The qualification shall be made in accordance with the schedule in Table 1.

Table 1 — Qualification schedule

Maintenance items[a]	Subclause	Each test	Quarterly	Annually	After any change that can alter performance
Pressure system testing	7.1		X		X
Solid salt aerosol uniformity	7.2		X		X
Water droplet size distributions	7.2.4		X		X
Water fog sedimentation check	7.2.5		X		X

[a] Regular maintenance and calibration of equipment shall be undertaken so the performance of the test system is maintained.

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-recirculation arrangement, the ambient room air shall 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 shall be ≤ 50 /dm^3. Full hardness shall be ≤ 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. This shall, therefore, be transferred into the lab test by cycling the RH from low to high value while introducing the salt particles from the salt generator. The accelerated cycling causes accelerated aging. The tested filter is 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 following stop-test criteria are met:

— droplets or pools of water are visible downstream of the test object on the test duct bottom wall, 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 has bypassed;

— total runtime of test exceeds 120 h;

— 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 are tested at one of the three default air flow rates or to customer specific air flow rate. 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 air flow rates are recommended:

a) design 4 250 m^3/h

b) increased 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 SFP shall be turned on and warmed-up as specified by the instrument manufacturer

9.3.2 Zero level check measurement of the sodium flame photometer (SFP)

The measurement of the zero level (no salt particles detected) 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 and 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 conform to the requirements specified in 8.1.

9.3.4 Starting up the salt generator

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

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 6.5.1. 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 conforms to 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 test duct shall be sealed by compressing the filter gasket in accordance with the filter manufacturer's 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 min 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 design air flow rate shall be set, as specified in 6.2.3.

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. Pressure drop values shall be recorded at 1 min intervals or less.

9.4.2 Measurement of the salt removal efficiency

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

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

where

$C_{\text{downstream}}$ 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.

The test sequence for the measurement of salt removal efficiency is as follows:

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 concentrations 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 weighing the total water collected downstream the test object. In the event that the volume of the water found downstream of the filter is very small and does not reach the drain, weigh a piece of paper or similar before and after drying out the test duct with said paper.

The water removal efficiency is calculated as follows:

$$E_{\mathrm{w}} = \left(1 - \frac{W_{\mathrm{downstream}}}{W_{\mathrm{upstream}}}\right)100$$

where

$W_{\mathrm{downstrean}}$	is the mass of water collected downstream of the filter in g;
W_{upstream}	is the mass of water injected upstream of the filter in g.

$\mathrm{W}_{\mathrm{upstream}}$ is calculated as follows:

$$W_{upstream} = c_{\mathrm{wm}} \times Q \times t_d$$

where

c_{wm}	is the water fog mass concentration in g/m^3;
Q	is the test air flow rate in m^3/h;
t_{d}	is the time for the water deluge challenge in h.

The collected water mass downstream shall be determined by a scale with the measurement accuracy of ±0,5 g.

9.4.4 Cumulative salt loading

The cumulative salt loading is calculated as follows:

$$c_{\mathrm{sl}} = \left(\frac{Q \times t \times C_{\mathrm{upstream}}}{100}\right)$$

where

c_{sl}	is the cumulative salt loading in g;
Q	is the air flow rate in m^3/h;
t	is the time in h;
C_{upstream}	is the salt concentration upstream.

9.4.5 Cumulative salt penetration

The cumulative salt penetration is calculated as follows:

$$c_{sp} = \left(\frac{Q \times t \times C_{upstream} \times (100 - E_{salt})}{100} \right)$$

where

c_{sp}	is the cumulative salt penetration in g;
Q	is the air flow rate in m^3/h;
t	is the time in h;
$C_{upstream}$	is the salt concentration upstream used to calculate salt removal efficiency;
E_{salt}	is the salt removal efficiency.

10 Test procedure

10.1 Preparation of test rig (no test object installed)

The procedure is as follows:

a) With an empty test rig (no test object), turn on the air flow.

b) Allow the air flow to stabilize (variation of ± 100 m^3/h) at the desired test air flow rate.

c) Turn on the SFP and salt generator, and allow the SFP to warm up according to the manufacturer's specification. Measure background concentration and zero the SFP.

d) Measure the salt concentration with the SFP, salt concentration shall be 4 mg per m^3 of air.

e) When the salt concentration has been verified, turn off the SFP and the salt generator.

f) Turn on the water challenge, water mass flow rate shall be 1,7 g per m^3 of air.

g) Visually check the dispersion plumes to make sure no nozzles are clogged.

h) When the water challenge dispersion plumes have been verified, increase the water mass flow rate to 3,4 g per m^3 of air.

i) Visually check the dispersion plumes to make sure no nozzles are clogged.

j) When the water challenge dispersion plumes have been verified, turn off the water challenge and air flow.

10.2 Cleaning of test rig

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

Prior to installation into the test rig, the test object shall be weighed in a new and dry condition. The test object shall be stored in an air environment of 25 °C ± 5 °C and 40 % RH +0/-10 % for at least 12 h prior to weighing. 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 the design air flow rate in order to condition the test object. This conditioning shall be done for minimum of 1 h.

10.4 Installation of the test object

The procedure is as follows:

a) To accommodate cleaning of the test rig as per 10.2 above, remove any obstructing test rig components i.e. removable panels, viewing windows etc. to accommodate the installation of the test object.

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

c) 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

The procedure is as follows:

a) Turn on the air flow.

b) Allow the air flow to stabilize the desired test air flow rate (±100 m^3/h), the air temperature shall be 25 °C ± 5 °C and 40 % RH +0/-10 %.

c) Turn on the water challenge with a water mass flow rate that corresponds to a water content of 3,4 g per m^3 of air and run for a period of 1 h. It is expected that the RH will increase during the deluge phase, it is not required to be controlled at 40 % RH during this phase.

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

e) Allow the test object to dry at an air temperature of 25 °C ± 5 °C and 40 % RH +0/-10 % for a period of 1 h and return to the initial pressure drop.

10.6 Salt loading

The procedure is as follows:

a) Turn on the salt generator for the remaining entirety of the test.

b) 1 h of salt loading.

c) Measure the salt removal efficiency using the SFP.

10.7 Water deluge challenge

The procedure is as follows:

a) 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 % shall be 15 min. Any deviation from the target ramp up duration shall be added or subtracted to the time of the next step in the test procedure.

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

c) At the end of the 60 min period, turn off the water deluge challenge. Measure the water collected in each basin.

d) 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 % shall be 30 min.

e) Run for a period of 90 min at RH 40 % +0/-10 %.

10.8 Relative humidity cycles

The procedure is as follows:

a) Measure the salt removal efficiency using the SFP.

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

c) Run for a period of 60 min at RH > 95 %.

d) 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 % shall be 30 min.

e) Run for a period of 90 min at RH 40 % +0/-10 %.

f) 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 % shall be 15 min.

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

h) At the end of the 60 min period, turn off the water deluge challenge. Measure the water collected in each basin and make a visual inspection of duct and test object regarding water penetration.

i) 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 % shall be 30 min.

j) Run for a period of 90 min at RH 40 % +0/-10 %.

Repeat 10.8 a) to j) until one of the stop-test criteria is met, see Figure 4.

10.9 End of test

The procedure is as follows:

a) Measure the final salt removal efficiency using the SFP.

b) Stop the salt generator.

c) Run the filter for an additional 60 min at RH 40 % +0/-10 %.

10.10 Secondary weighing of the test object

The procedure is as follows:

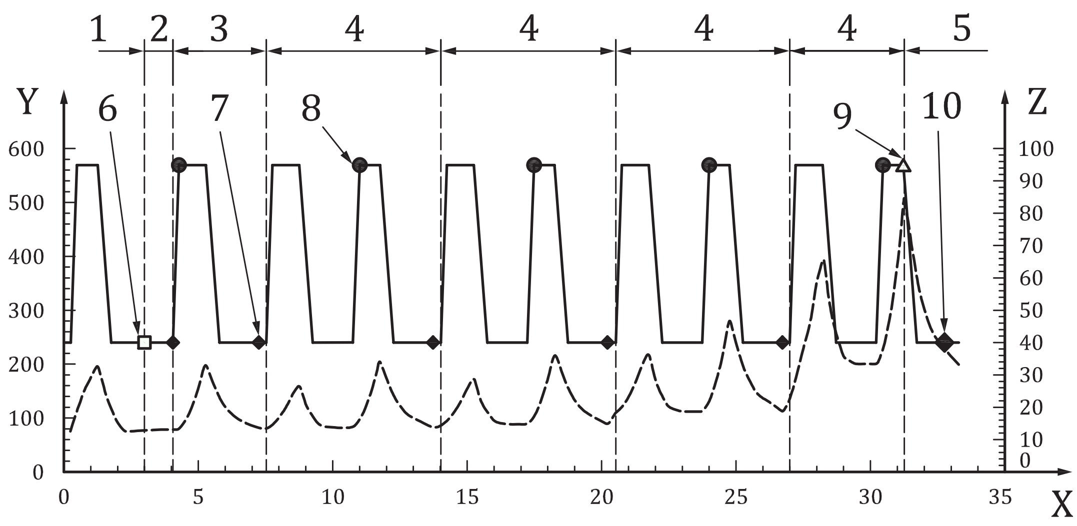
a) Extract the test object from the test rig and drain any free water from the filter by tipping it forwards and backwards.

NOTE Water can be present when removing the test object.

b) Dry the filter in ambient air for 24 h. During the drying, the temperature shall be 25 °C ± 5 °C and 50 % ± 10 % RH.

c) The extracted test object shall be weighed in a loaded condition (ambient air temperature 25 °C ± 5 °C and 50 % ± 10 % RH).

d) Record the final weight.



Key

X time (h)

Y pressure drop (Pa)

Z relative humidity (%)

1 primary deluge challenge (10.5)

2 salt loading (10.6)

3 water deluge challenge (10.7)

4 relative humidity cycles (10.8)

5 end of test (10.9)

- - - - pressure drop

——— relative humidity

6 start SFP

7 measure salt removal efficiency

8 water deluge challenge

9 leakage detected

10 final salt removal efficiency measurement

Figure 4 — Test procedure

11 Reporting results

11.1 General

The report (see Figure 5 and Figure 6) shall describe all deviations from the test setup specified in this document and shall include:

a) reference to this document (ISO 29461-4: 202X);

b) date of test;

c) description of test object;

d) results from the test procedure (including observations);

e) any deviations from the procedure;

f) any unusual features observed.

11.2 Observations

Observations made during test shall include:

a) media bulging;

b) filter breaking;

c) pleat deformations;

d) water penetration and location;

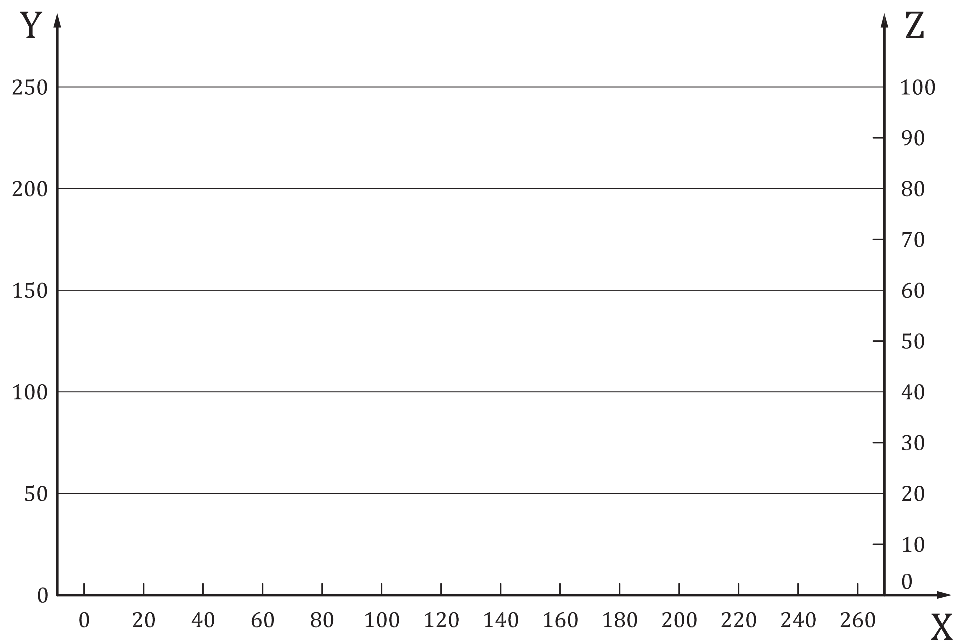
e) penetration of salt through filter;

f) any unusual observations.

11.3 Report template

Test report according to ISO 29461-4: 202X			
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			
Air flow rate		Ambient temperature	
Ambient relative humidity		Water concentration	
Salt concentration		Total water mass fed	
Results			
Initial pressure drop		Number of cycles	
Max pressure drop		Total testing time	
Initial filter weight		Final filter weight (dry)	
Reason for ending test			
Observations			
Deviations from test setup			

Salt and water mass fed vs. time



Key

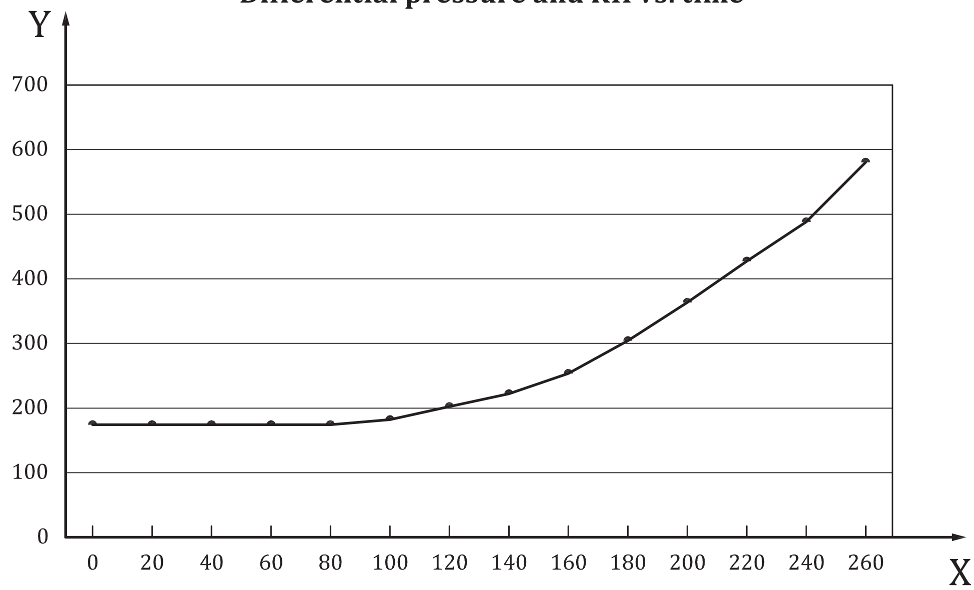
X time (min)

Y water mass fed (kg)

Z salt mass fed (g)

Figure 5 — Report template page 1

Differential pressure and RH vs. time



Test according to ISO 29461-4: 202X							
Air filter				Test number			
Water concentration				Salt concentration			
Air flow rate							
Table of results							
Cycle number	**T(min)**	***dP* (Pa)**	**Cumulative water mass (g)**	**Cumulative water penetration mass (g)**	**Cumulative salt mass (g)**	**Cumulative salt penetration mass (g)**	**Salt removal efficiency (%)**

Key

X time (min)

Y *dP* (Pa)

Z RH (%)

Figure 6 — Report template page 2

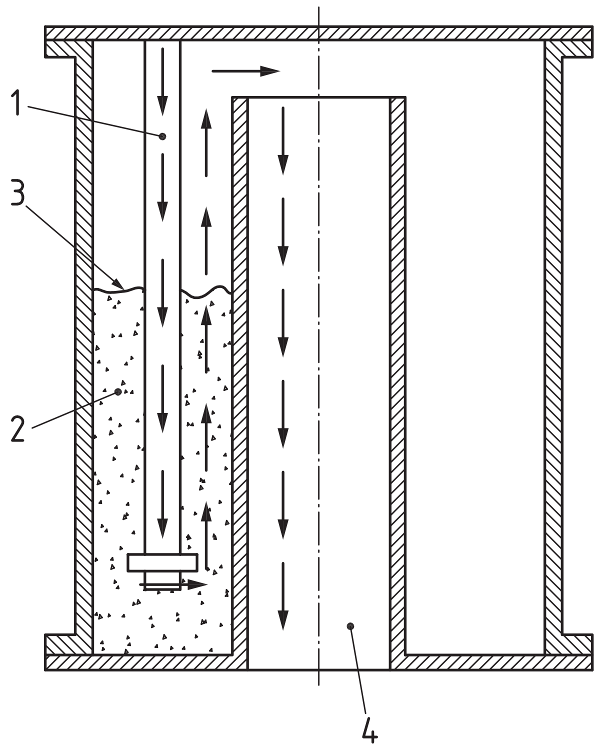
Annex A
(informative)

Ultrafine dry solid salt generator

A.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 solid salt particles with sizes ≥ 0,01 µm. To replicate this phenomenon and generate small salt particles, the salt generator (see Figure A.1) 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.

Figure A.2 illustrates a 3D model of a salt generator.



Key

1 compressed air through Laskin nozzle

2 salt water

3 bubbles bursting creating droplets

4 exit pipe to air dryer

Figure A.1 — Working principle of salt generator

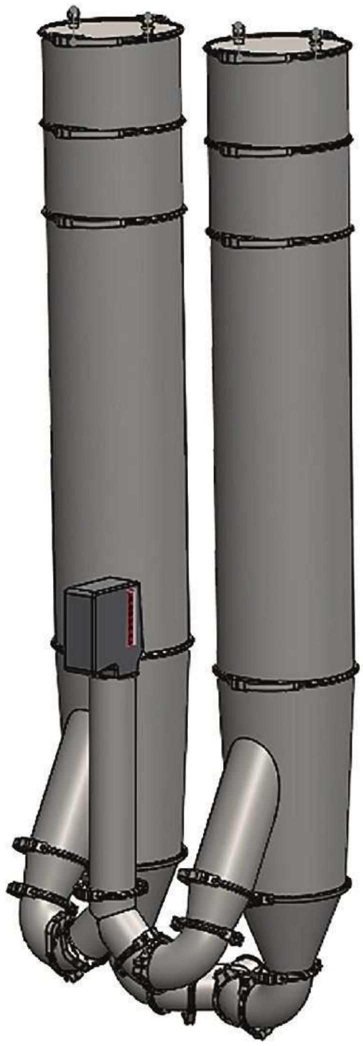


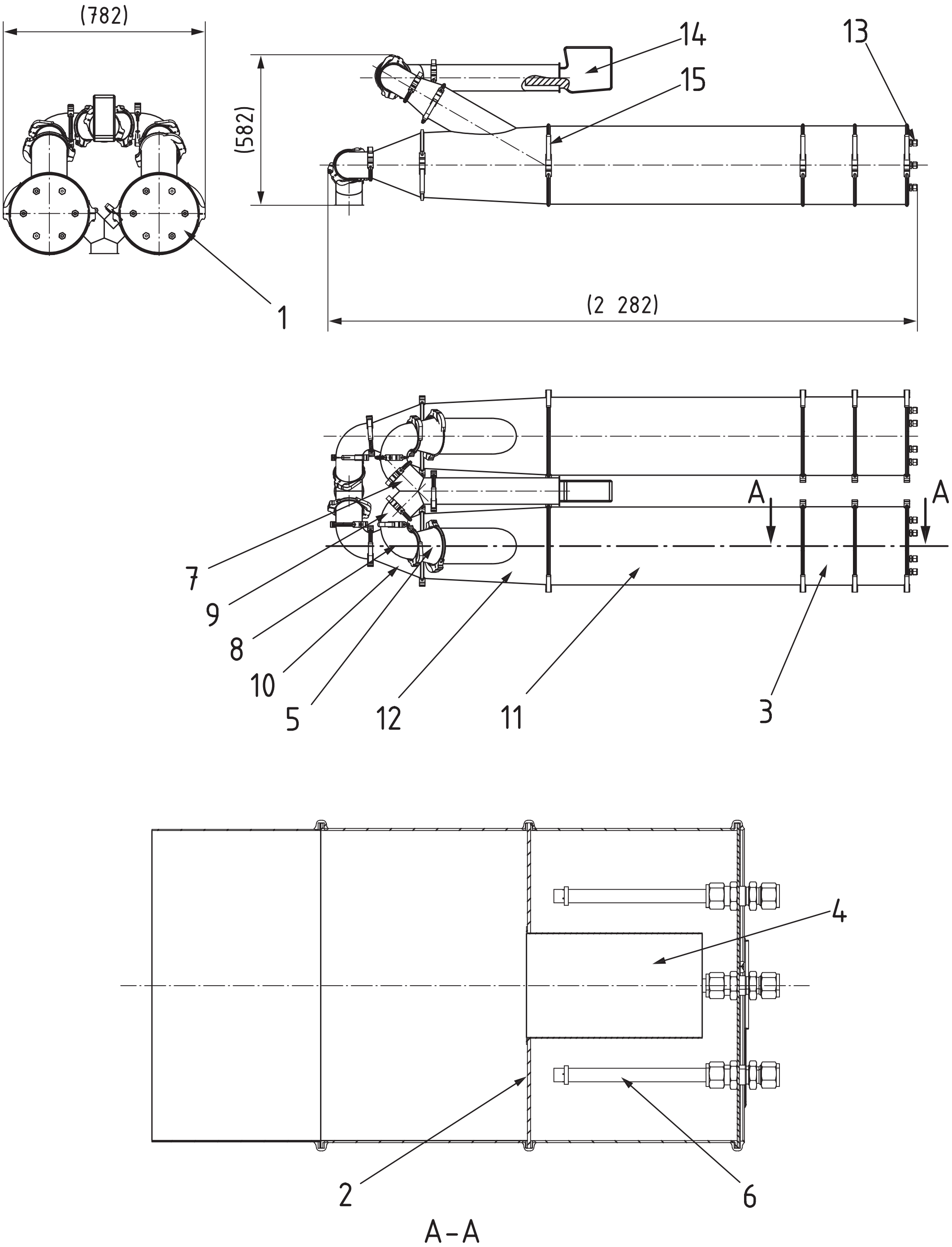
Figure A.2 — 3D model of salt generator

A.2 Solid salt generator assembly

A.2.1 Design

The solid salt generator consists of several parts such as salt generator (the part containing saline solution and Laskin nozzles), heater, drying pipes and transition pieces. The salt generator assembly is illustrated in Figure A.3. The salt generator is located on top, see Figure A.3. The generator is connected to a drying pipe, see Figure A.6. Transition pipes (see Figure A.4, Figure A.5, and Figure A.6) connect the outflow of aerosol with the drying air from the heater. All parts except the heater shall be manufactured from stainless steel.

Dimensions in millimetres



Key

1 salt generator - top lid
2 liquid container - bottom
3 salt generator
4 aerosol exit pipe
5 cone
6 laskin nozzle
7 Y-fork
8 bend
9 bend
10 cone
11 drying pipe
12 conical fork
13 compressed air fittings
14 heater
15 clamps

Figure A.3 — Salt generator assembly

Dimensions in millimetres

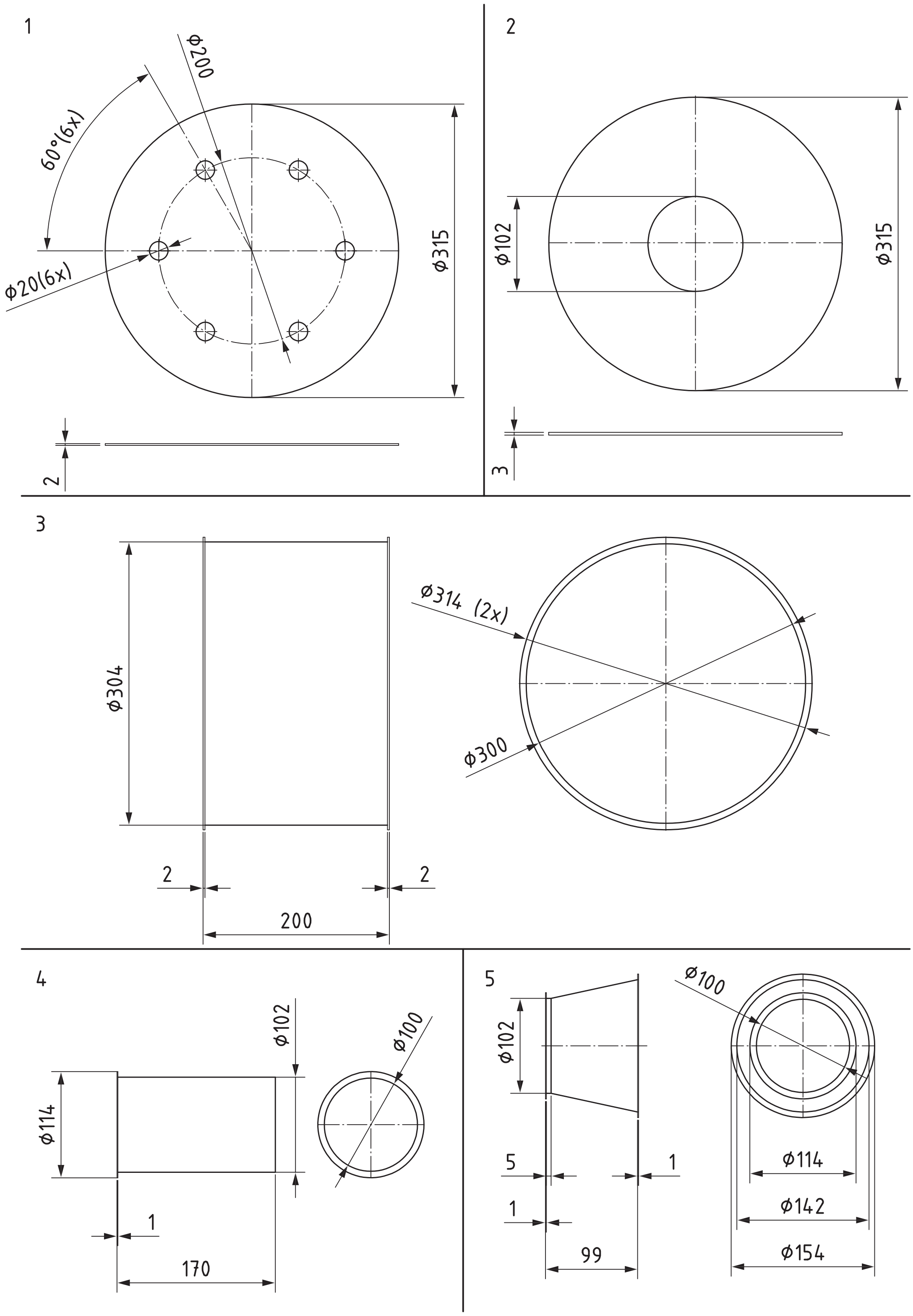


Figure A.4 — Parts 1 to 5

Dimensions in millimetres

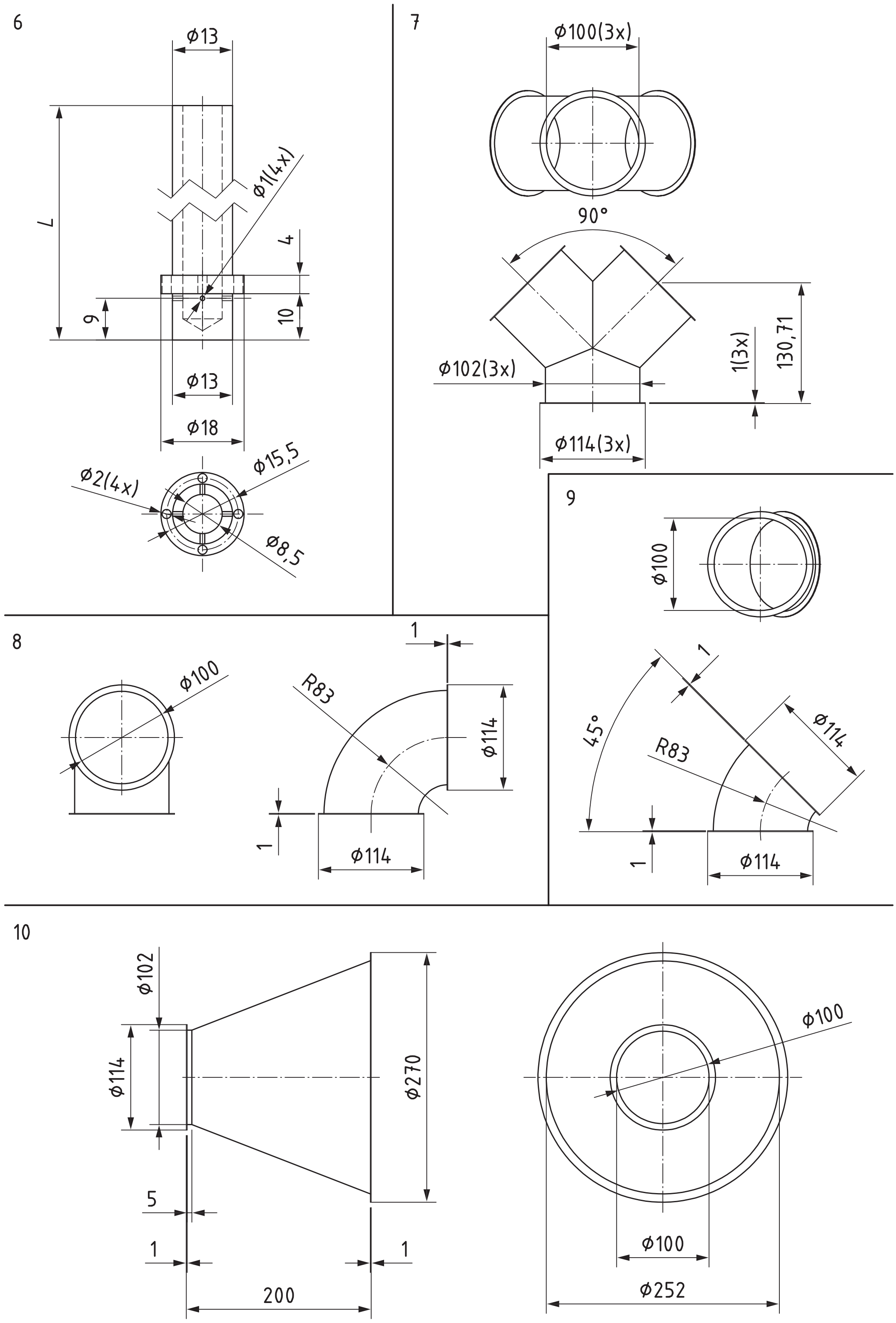


Figure A.5 — Parts 6 to 10

Dimensions in millimetres

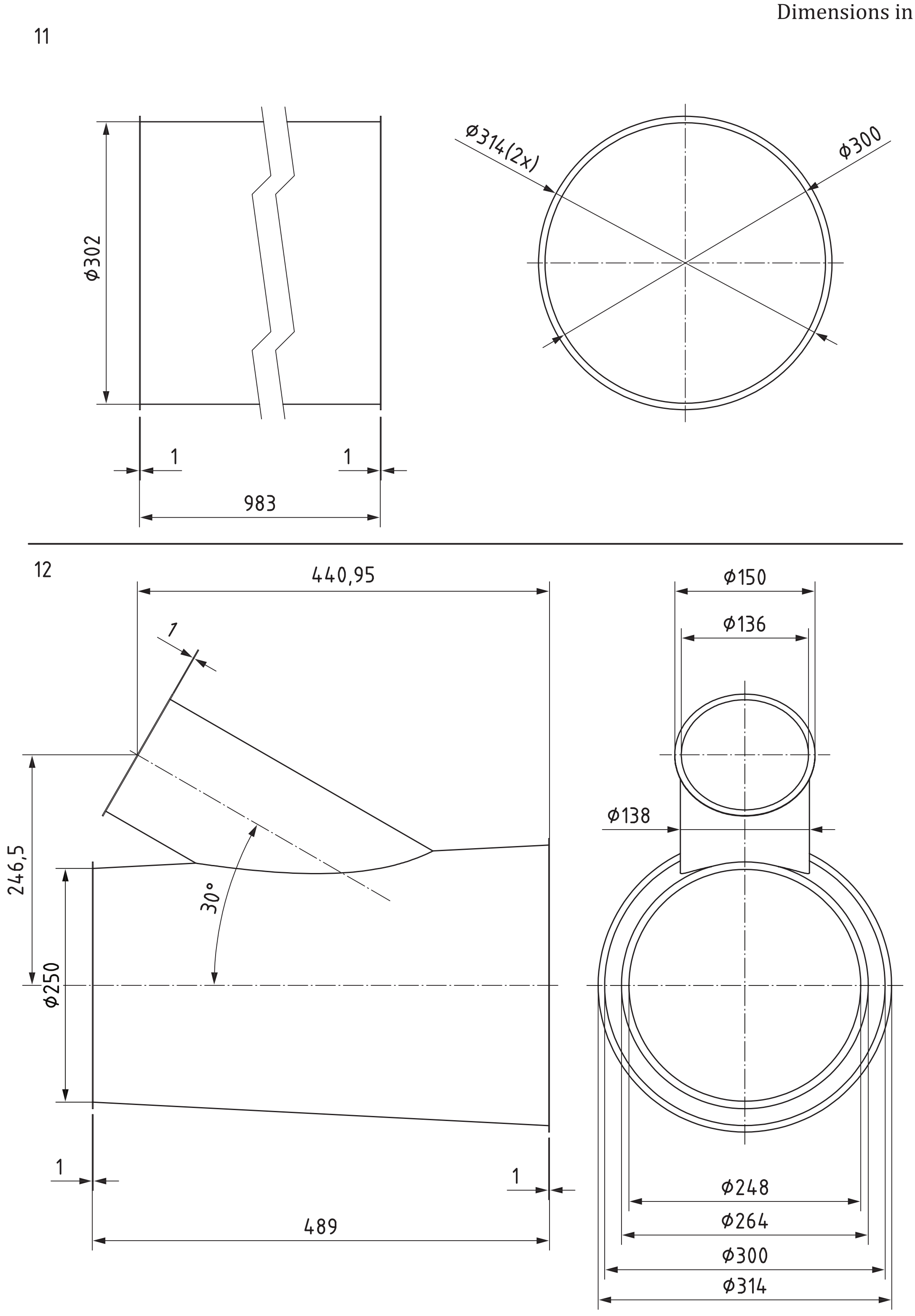
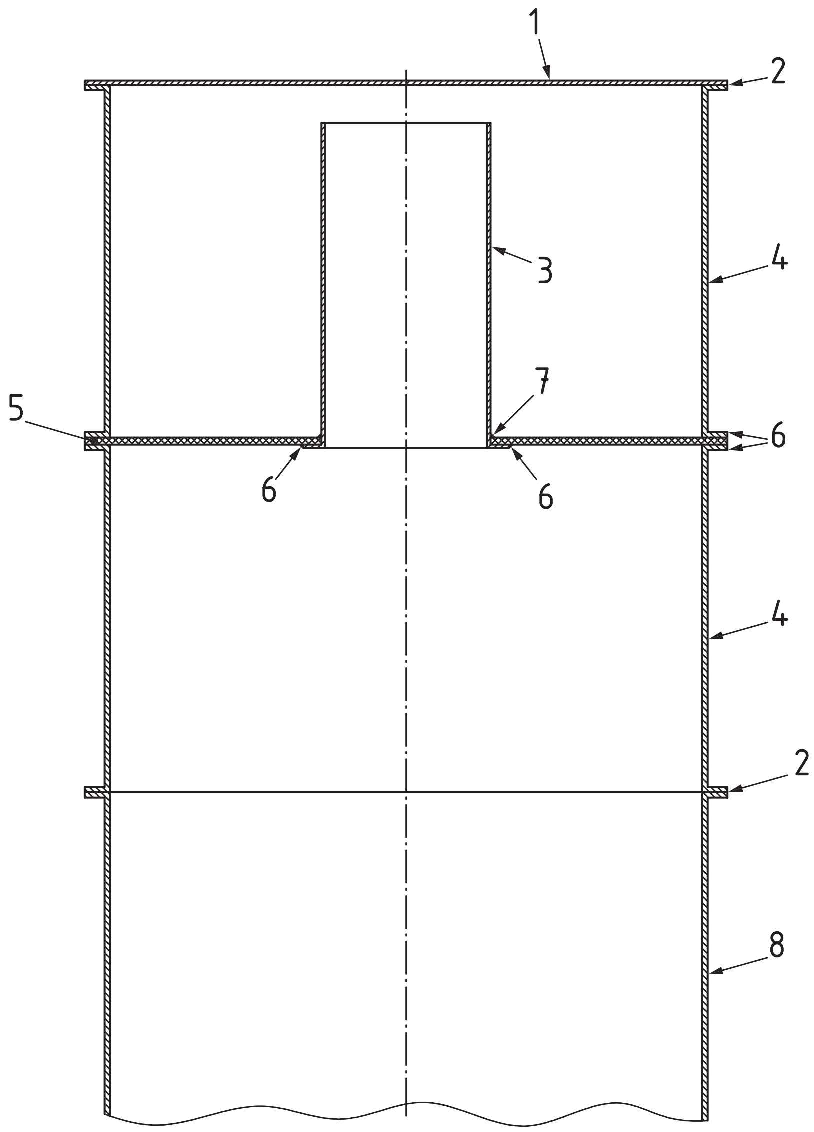


Figure A.6 — Parts 11 to 12

A.2.2 Solid salt generator — Description

The generator (see Figure A.2) consists of two pipes with a disc of stainless steel welded between them in order to make the interconnections watertight. The upper pipe holds the saltwater and the lower pipe is connected to the rest of the drying tower with a quick connect clamp to allow cleaning of the generator. In the centre of the disc, a hole shall be cut and the exit pipe to the dryer shall be welded, see Figure A.7.



Key

1 lid
2 quick connect clamp
3 pipe
4 stainless steel pipes
5 disc of stainless steel
6 weld
7 alternative weld
8 drying pipe

Figure A.7 — Section view of salt generator

A.2.3 Laskin nozzles

Laskin nozzles shall be stainless steel and be dimensioned according to Figure A.5, part 6. The nozzle can be cut short and internally threaded, or left long and externally threaded.

Bibliography

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

ICS 29.160.99

Price based on 28 pages

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