INTERNATIONAL STANDARD

ISO 19453-4

First edition
2018-03

Road vehicles — Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles —

Part 4: Climatic loads

Véhicules routiers — Spécifications d'environnement et essais de l'équipement électrique et électronique pour les véhicules à propulsion électrique —

Partie 4: Contraintes climatiques

Reference number
ISO 19453-4:2018(E)

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Published in Switzerland

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Foreword

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

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

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

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

A list of all parts in the ISO 19453 series can be found on the ISO website.

Road vehicles — Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles —

Part 4: Climatic loads

1 Scope

This document specifies requirements for the electric propulsion systems and components with maximum working voltages according to voltage class B. It does not apply to high voltage battery packs (e.g. for traction) and systems and components inside. It describes the potential environmental stresses and specifies tests and requirements recommended for different stress levels on/in the vehicle.

This document describes climatic loads.

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 16750-1, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 1: General*

ISO 19453-1, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles — Part 1: General*

ISO 20653, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water and access*

IEC 60068-1:2013, *Environmental testing — Part 1: General and guidance*

IEC 60068-2-1, *Environmental testing — Part 2-1: Tests — Test A: Cold*

IEC 60068-2-2, *Environmental testing — Part 2-2: Tests — Test B: Dry heat*

IEC 60068-2-11, *Basic environmental testing procedures — Part 2-11: Tests — Test Ka: Salt mist*

IEC 60068-2-14, *Environmental testing — Part 2-14: Tests — Test N: Change of temperature*

IEC 60068-2-30, *Environmental testing — Part 2-30: Tests — Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-52:2017, *Environmental testing — Part 2-52: Tests — Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-60, *Environmental testing — Part 2-60: Tests — Test Ke: Flowing mixed gas corrosion test*

IEC 60068-2-78, *Environmental testing — Part 2-78: Tests — Test Cab: Damp heat, steady state*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems — Part 1: Principles, requirements and tests*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16750-1 and ISO 19453-1 apply.

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

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

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

4 Operating temperature ranges

Choose the applicable temperature range from Table 1 to be presented in the specifications of the device under test (DUT).

In the case of hot soak, choose from Table 2 the relative temperature increase ΔT_{HS} and add it to the maximum temperature T_{max} to have the absolute hot soak temperature (T_{maxHS}).

$$T_{max} + \Delta T_{HS} = T_{maxHS}$$

For further details, refer to 5.2.1.

The paint repair temperature (T_{maxPR}) can be set to a higher value than the operating temperature. Specify this temperature in the specifications of the DUT.

Table 1 — Operating temperature ranges

Code	Minimum operating temperature T_{min} °C	Maximum operating temperature T_{max} °C
A	−20	65
B	−30	65
C	−40	65
D		70
E		75
F		80
G		85
H		90
I		95
J		100
K		105
L		110
M		115
N		120
O		125
P		130
Q		140
R		150
S		155
T		160
U		165
V		170
W		175
X		180
Z	As agreed	

Table 2 — Relative temperature increase in hot soak

Code	ΔT_{HS} K
a	15
b	30
c	50
z	As agreed

NOTE The code letter is defined as a combination of Tables 1 and 2, e.g. Hb (T_{max} = 90 °C and ΔT_{HS} = 30 K).

5 Tests and requirements

5.1 Tests at constant temperature

5.1.1 Low-temperature tests

5.1.1.1 Storage test

5.1.1.1.1 Purpose

This test simulates the exposure of the DUT to low temperatures without electrical operation, e.g. during shipment of the system/component. Failure mode is a malfunction due to insufficient frost resistance, e.g. the freezing of a coolant.

5.1.1.1.2 Test method

Perform the test in accordance with IEC 60068-2-1 at a temperature of −40 °C for a duration of 24 h unless otherwise indicated in the DUT specification. The operating mode of the DUT is 1.1, as defined in ISO 19453-1.

5.1.1.1.3 Requirement

The functional status shall be class C as defined in ISO 19453-1.

5.1.1.2 Operation test

5.1.1.2.1 Purpose

The purpose of the test is to make sure that the device under test maintains the function even after storage at low temperature.

5.1.1.2.2 Test method

Perform the test in accordance with IEC 60068-2-1 at a temperature of T_{min} for a duration of 24 h. The operating mode is 3.2 and/or 4.2 as defined in ISO 19453-1.

5.1.1.2.3 Requirement

The functional status shall be class A as defined in ISO 19453-1.

5.1.2 High-temperature tests

5.1.2.1 Storage test

5.1.2.1.1 Purpose

This test simulates the exposure of the DUT to high temperatures without electrical operation, e.g. during the shipment of the system/component. The failure mode is insufficient heat resistance, e.g. warping of plastic housings.

5.1.2.1.2 Test method

Perform the test in accordance with IEC 60068-2-2 at a temperature of 85 °C for a duration of 48 h unless otherwise indicated in the DUT specification. The operating mode is 1.1 as defined in ISO 19453-1.

5.1.2.1.3 Requirement

The functional status shall be class C as defined in ISO 19453-1.

5.1.2.2 Operation test

5.1.2.2.1 Purpose

This test simulates the exposure of the DUT to high temperatures with electrical operation, e.g. the use of the system/component at a very high ambient temperature. The failure mode is an electrical malfunction caused by high temperature, e.g. thermal degradation of components.

5.1.2.2.2 Test method

Perform the test in accordance with IEC 60068-2-2 at a temperature of T_{max} for a duration of 96 h. Use operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.

5.1.2.2.3 Requirement

The functional status shall be class A as defined in ISO 19453-1.

5.2 Temperature cycling tests

5.2.1 Temperature cycle with specified change rate

5.2.1.1 Purpose

This test simulates varying temperatures with electrical operation of the DUT, e.g. during the use of the system/component at changing ambient temperature. If a system/component is exposed to hot-soak temperatures (e.g. engine-mounted systems/components), an additional short temperature peak is added during the high temperature stage of the profile to ensure proper function during short temperature peaks. The electrical operation is switched off during stages of decreasing temperature to avoid electrical heat dissipation of the system/component which would inhibit reaching T_{min} inside the system/component. The failure mode is an electrical malfunction during temperature change.

NOTE This test is not intended to be a life test.

5.2.1.2 Test method

Perform the temperature cycling in accordance with IEC 60068-2-14.

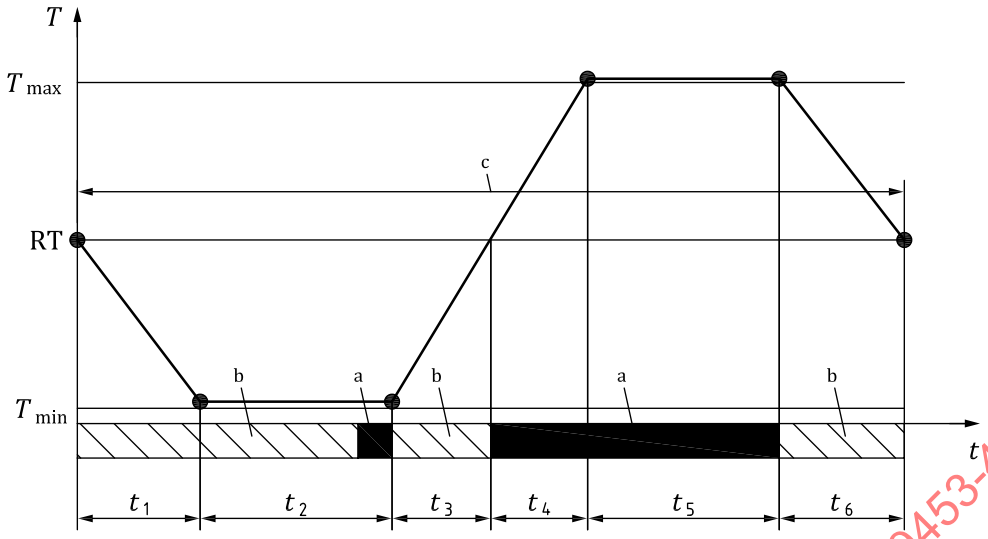
Operate the DUT electrically (functional test) after the whole device has reached T_{min} for the shortest possible duration to check the correct functioning of the device. In addition, an operation check should be done at stable high temperature (see Figure 1). Use operating mode 3.2 and/or 4.2 as defined in ISO 19453-1 for the stages with electrical operation.

The changes in temperature shall correspond to the specifications given in Table 3. For tests including hot-soak temperature (T_{maxHS}), see Table 4 and Figure 2. The supplier and the customer shall agree on a complete profile of temperature cycle.

A long period of electrical operation is started at room temperature (RT) as defined in ISO 19453-1 in order to allow possible condensation of humidity on the DUT. A permanent operation starting at T_{min} would prevent this due to the electrical power dissipation.

Additional drying of the test chamber air is not permitted.

Perform 30 test cycles as specified.



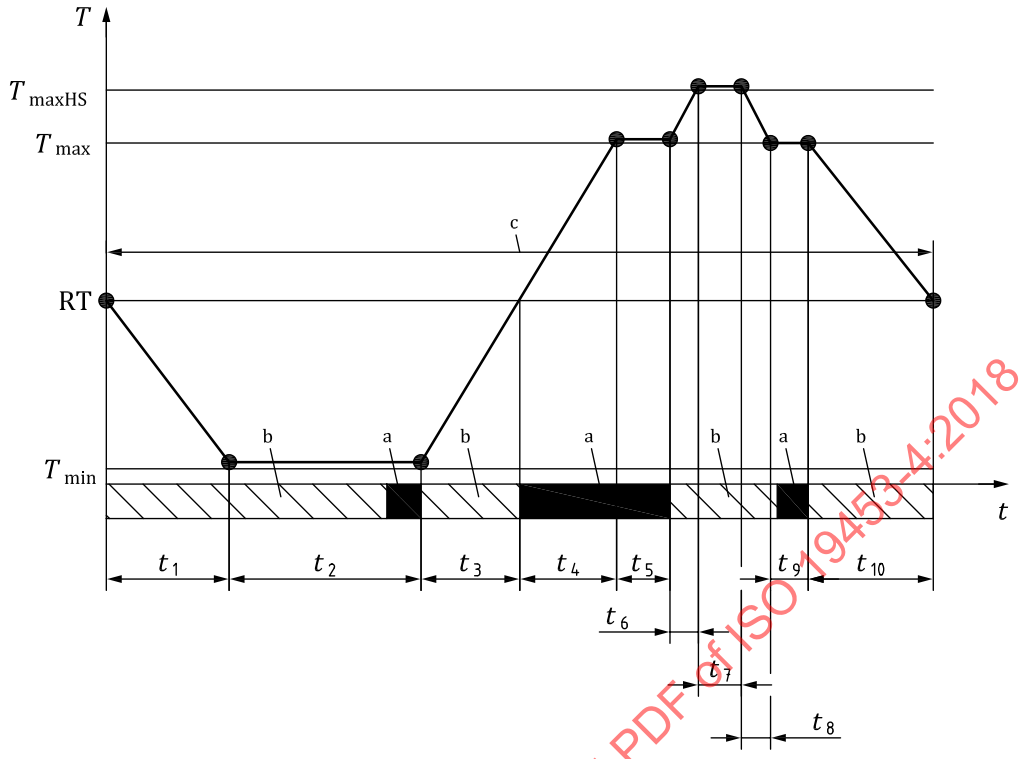
Key

T	temperature, in °C
t	time, in min
t_1, t_2, t_3, t_4, t_5, t_6	time parameter as defined in Table 3
a	Operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.
b	Operating mode 2.1 as defined in ISO 19453-1.
c	One cycle.

Figure 1 — Temperature cycles with specified change rate

Table 3 — Temperature and time duration for temperature cycling (see Figure 1)

Parameter	Duration min	Temperature °C
t_1	As agreed	From RT to T_{min}
t_2	> 30	Stabilized time at T_{min}
t_3	As agreed	From T_{min} to RT
t_4	As agreed	From RT to T_{max}
t_5	> 30	Stabilized time at T_{max}
t_6	As agreed	From T_{max} to RT



Key

T	temperature, in °C
t	time, in min
t_1, t_2, t_3, t_4, t_5, t_6, t_7, t_8, t_9, t_{10}	time parameter as defined in Table 4
a	Operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.
b	Operating mode 2.1 as defined in ISO 19453-1.
c	One cycle.

Figure 2 — Example of a temperature cycle with hot-soak stage

Table 4 — Temperature and time duration for temperature cycling with hot-soak stage (see Figure 2)

Parameter	Duration min	Temperature °C
t_1	As agreed	From RT to T_{min}
t_2	>30	Stabilized time at T_{min}
t_3	As agreed	From T_{min} to RT
t_4	As agreed	From RT to T_{max}
t_5	>30	Stabilized time at T_{max}
t_6	As agreed	From T_{max} to T_{maxHS}
t_7	> 30	Stabilized time at T_{maxHS}
t_8	As agreed	From T_{maxHS} to T_{max}
t_9	> 30	Stabilized time at T_{max}
t_{10}	As agreed	From T_{max} to RT

Instead of operating mode 3.2 and/or 4.2 in Figures 1 and 2, operating mode 2.1 may be used if agreed between the customer and the supplier.

5.2.1.3 Requirement

The functional status shall be class A as defined in ISO 19453-1.

5.2.2 Rapid change of temperature with specified transition duration

5.2.2.1 Purpose

This is an accelerated test which simulates a very high number of slow temperature cycles in the vehicle. The acceleration is possible due to a much higher temperature change rate and a bigger temperature change in one cycle in comparison with real vehicle stress. The failure modes are a cracking of materials or seal failures caused by ageing and different temperature expansion coefficients. Because this test creates mechanical defects (cracks), electrical operation is not required during the test.

5.2.2.2 Test method

Perform the temperature cycling in accordance with IEC 60068-2-14.

Raise the temperature from T_{min} to T_{max} within 30 s or less. Keep the DUT at T_{min} or T_{max} for a given soak time after thermal stability is obtained. The soak time can be agreed between the customer and the supplier, or the exposure time can be chosen among the values 20 min, 40 min, 60 min or 90 min, depending on the size and other properties of the DUT. Use operating mode 1.2 as defined in ISO 19453-1. See Table 9 for the number of cycles.

Upon agreement, this test may be performed during the development of a DUT with opened housing or without housing.

5.2.2.3 Requirement

The functional status shall be class C as defined in ISO 19453-1.

5.3 Cold water shock tests

5.3.1 Purpose

This test simulates a thermal shock induced by cold water and applies to products in the splash areas of the vehicle. The purpose of the test is to simulate ice water splashing over a hot system/component. This happens when driving on wet roads in winter. The failure modes are a mechanical cracking of materials or seal failures caused by different temperature expansion coefficients. An additional failure mode not addressed in 5.2.2.1 is a loss of tightness and the intrusion of water into the system/component.

There are two possible methods to perform this test (see 5.3.2 and 5.3.3).

NOTE This is not a corrosion test.

5.3.2 Splash water test

5.3.2.1 Test method

Heat the DUT in a hot air oven at T_{max} for the specified holding time, t_h. Then splash the DUT with cold water for 3 s.

If the DUT is splashed in the vehicle from only one direction, splash it from this direction only while it is in an as-installed position. If the equipment is splashed from various directions in the vehicle, then these directions shall be taken into account. In this case, use a new DUT for each splash direction. The width of the splash directed at the DUT shall always be greater than the width of the DUT. If DUTs of considerable size are splashed and prove too big for one jet, arrange several jets in a row to produce a line of splash impact on the DUTs, see Figures 3 to 5.

Test parameters include:

— Number of cycles: 100.

— Holding time, t_h, at T_{max}: 1 h or until DUT temperature stabilization is reached.

— Transition duration: < 20 s (for manual transition of DUT between temperature storage and splashing).

— Test fluid: de-ionized water.

— Water temperature: 0 °C to +4 °C.

— Water flow: between 3 l and 4 l per 3 s (splash duration).

— Distance between jet and DUT surface: (325 ± 25) mm (water shall be applied over the complete width of the DUT).

— Operating mode: see Figure 4.

— Orientation of the DUT: as in the vehicle.

NOTE Substances such as colours or salt can be added to the water in order to improve detectability.

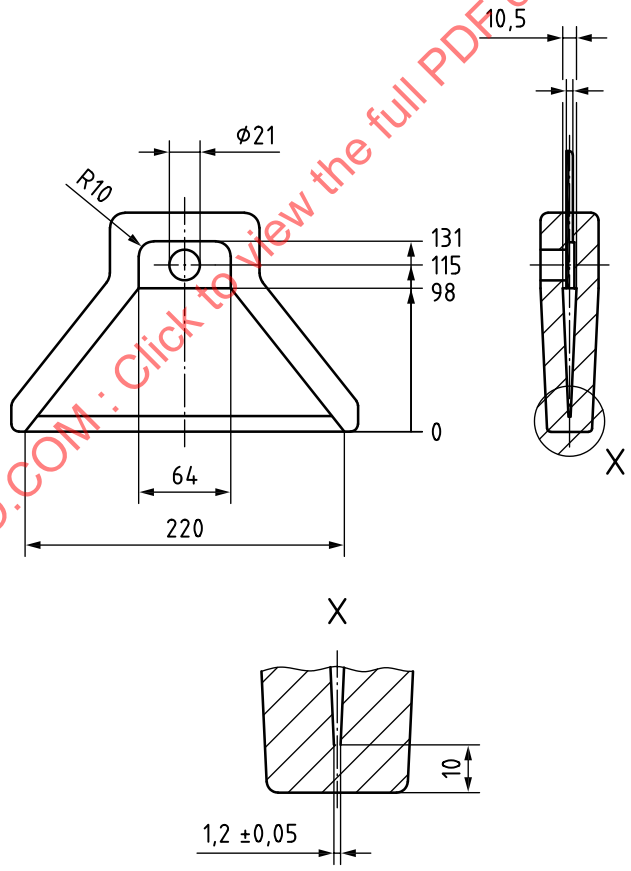
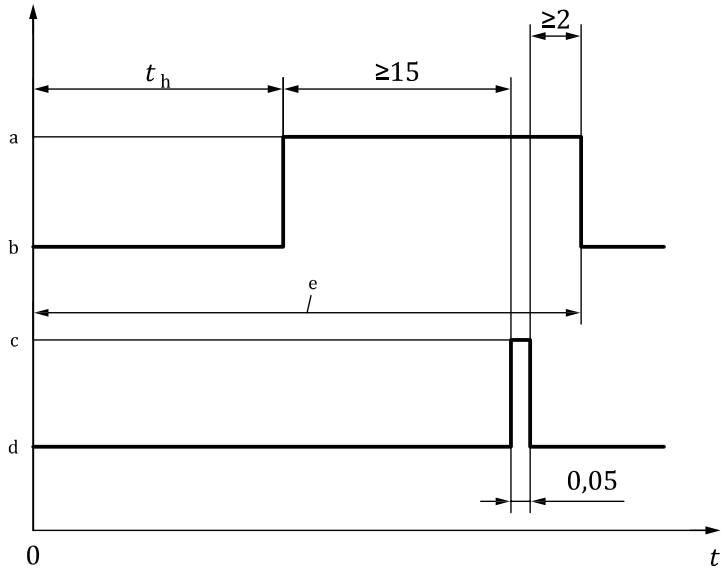


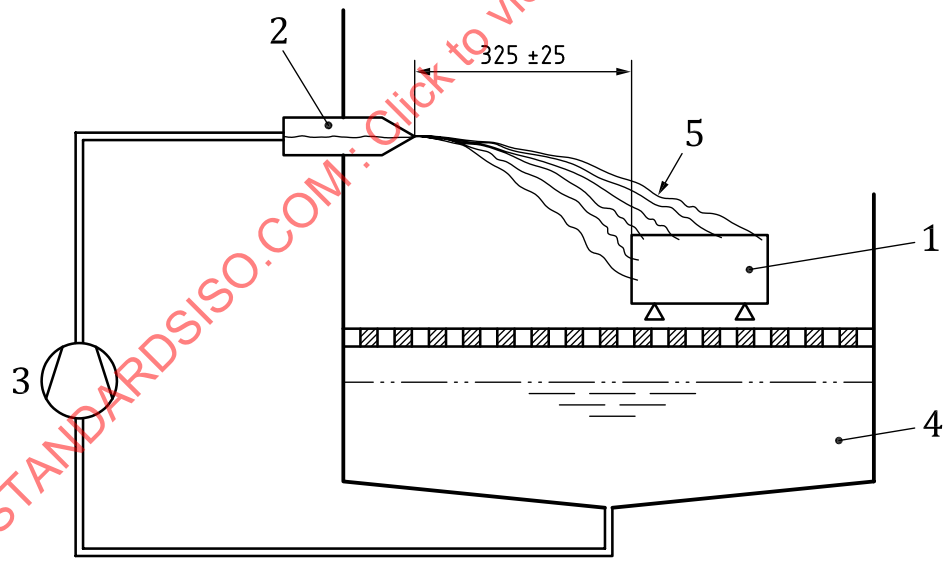
Figure 3 — Jet



Key

t	time, in min	t_h	holding time, in min
a	Operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.	d	Splash off.
b	Operating mode 1.2 as defined in ISO 19453-1.	e	One cycle.
c	Splash on.		

Figure 4 — Test cycle for splash water test



Key

1	DUT	4	splash water
2	slot jet	5	splash
3	pump		

Figure 5 — Test set-up for splash water test

5.3.2.2 Requirement

The functional status shall be class A during the operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.

5.3.3 Submersion test

5.3.3.1 Test method

Connect the DUT to the test equipment. Operate the DUT in a hot air oven at T_{max} for the specified holding time, t_h. With the device still operating, submerge it for 5 min in an ice water tank, in a depth equal to or greater than 10 mm (see Figure 6).

Test parameters include:

— Number of cycles: 10.

— Holding time t_h at T_{max}: 1 h or until DUT temperature stabilization is reached.

— Transition duration: < 20 s.

— Test fluid: de-ionized water.

— Water temperature: 0 °C to +4 °C.

— Immersion time: 5 min.

— Operating mode: 3.2 and/or 4.2 as defined in ISO 19453-1.

— Orientation of the DUT: as in the vehicle.

NOTE Substances such as colours or salt can be added to the water in order to improve detectability.

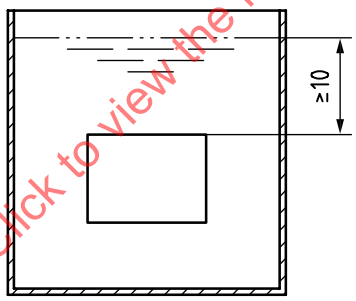


Figure 6 — DUT in a cold water tank

5.3.3.2 Requirement

The functional status shall be class A, as defined in ISO 19453-1.

5.4 Salt spray tests

5.4.1 Corrosion test

5.4.1.1 Purpose

This test checks the resistance of materials and surface coatings of a system/component to de-icing agents. This test generates corrosion similar to reality. The failure mode is corrosion.

Visual examination as detailed below shall allow identification, appearance, workmanship and finish of the item to be checked against the relevant specification.

5.4.1.2 Test method

Perform the test in accordance with IEC 60068-2-52. Select a severity from Table 9. See also Annex A. Use operating mode 1.2, as defined in ISO 19453-1.

Carry out a visual examination with the naked eye, normal strength of vision and normal colour perception, at the most favourable distance and with suitable illumination.

5.4.1.3 Requirements

There shall be no changes that could impair normal performance, e.g. sealing function, marking and labelling shall remain visible.

The minimum functional status shall be class C, as defined in ISO 19453-1.

5.4.2 Leakage and function test

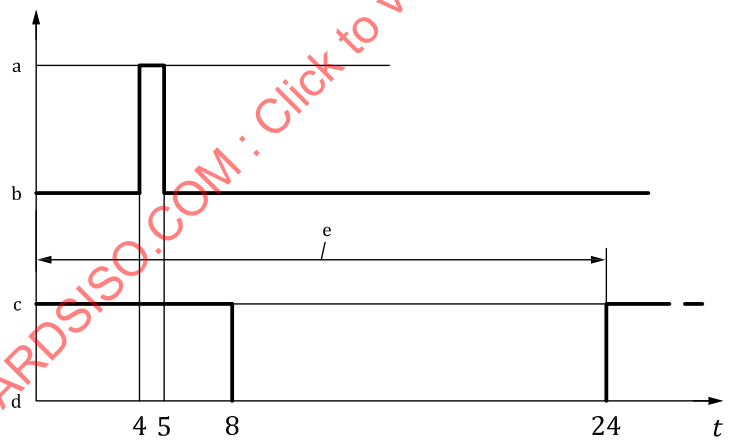
5.4.2.1 Purpose

This test checks the resistance of a system/component to salt mist and salt water on winter streets. The failure mode is an electrical malfunction due to leakage currents caused by the ingress of salt water.

5.4.2.2 Test method

Perform the test cycle shown in Figure 7, in accordance with IEC 60068-2-11. The duration of one cycle is 24 h. Spray the DUT for 8 h, then stop spraying for a rest period of 16 h. Operate the DUT with operating mode 3.2 and/or 4.2 as defined in ISO 19453-1 between the fourth and fifth hours of each cycle.

Test duration: 6 cycles correspond to 6 days as a minimum.



Key

t time, in h

a Operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.

b Operating mode 1.2 as defined in ISO 19453-1.

c Salt spray on.

d Salt spray off.

e One cycle.

Figure 7 — Test cycle for salt spray test

5.4.2.3 Requirements

The intrusion of salt water into the housing is not permitted.

Functional status class A is required in stages with electrical operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.

5.4.3 Salt spray combined cycle test

5.4.3.1 Purpose

This test is an accelerated corrosion test based on the tests defined in 5.4.1 and 5.4.2. This test may be used to substitute other salt spray tests (5.4.1 and 5.4.2).

This test checks the resistance of materials and surface coatings of a system/component to salt mist and salt water on streets in winter. This test generates corrosion similar to reality. The failure mode is corrosion.

5.4.3.2 Test method

5.4.3.2.1 Salt solution

The salt solution shall be in accordance with IEC 60068-2-52:2017, Clause 6.

5.4.3.2.2 Number of cycles

Select a number of cycles from Table 5 and Table 6. The number of cycles depends on the severity and the kind of materials. Background information to determine the number of cycles of the salt spray combined test to be carried out is given in Annex B.

Table 5 — Number of cycles for the corrosion test

Severity	Number of cycles	
	Steel	Aluminium
1	3	8
2	9	23
3	12	30
4	24	60

Table 6 — Number of cycles for the leakage and function test

Severity	Number of cycles	
	Steel	Aluminium
1	1	1
2	2	3
3	3	4
4	5	8

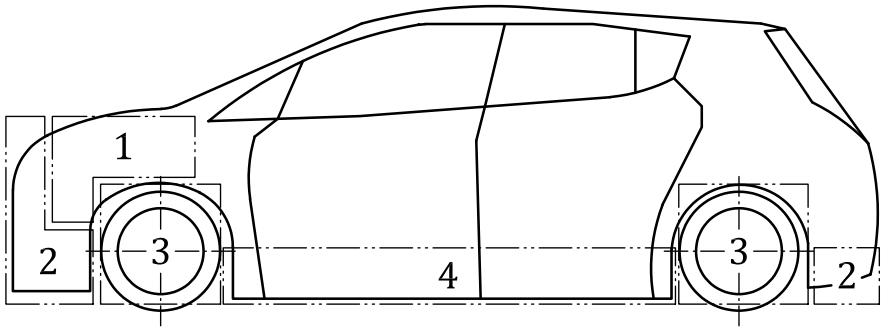


Figure 8 — Severity considered in vehicle corrosion evaluation

5.4.3.2.3 Initial measurement

The DUT shall be visually inspected and, if necessary, electrically and mechanically checked as required by the relevant specification.

5.4.3.2.4 Pre-conditioning

The relevant specification shall prescribe the cleaning procedure to be applied immediately before the test; it shall also state whether temporary protective coating shall be removed.

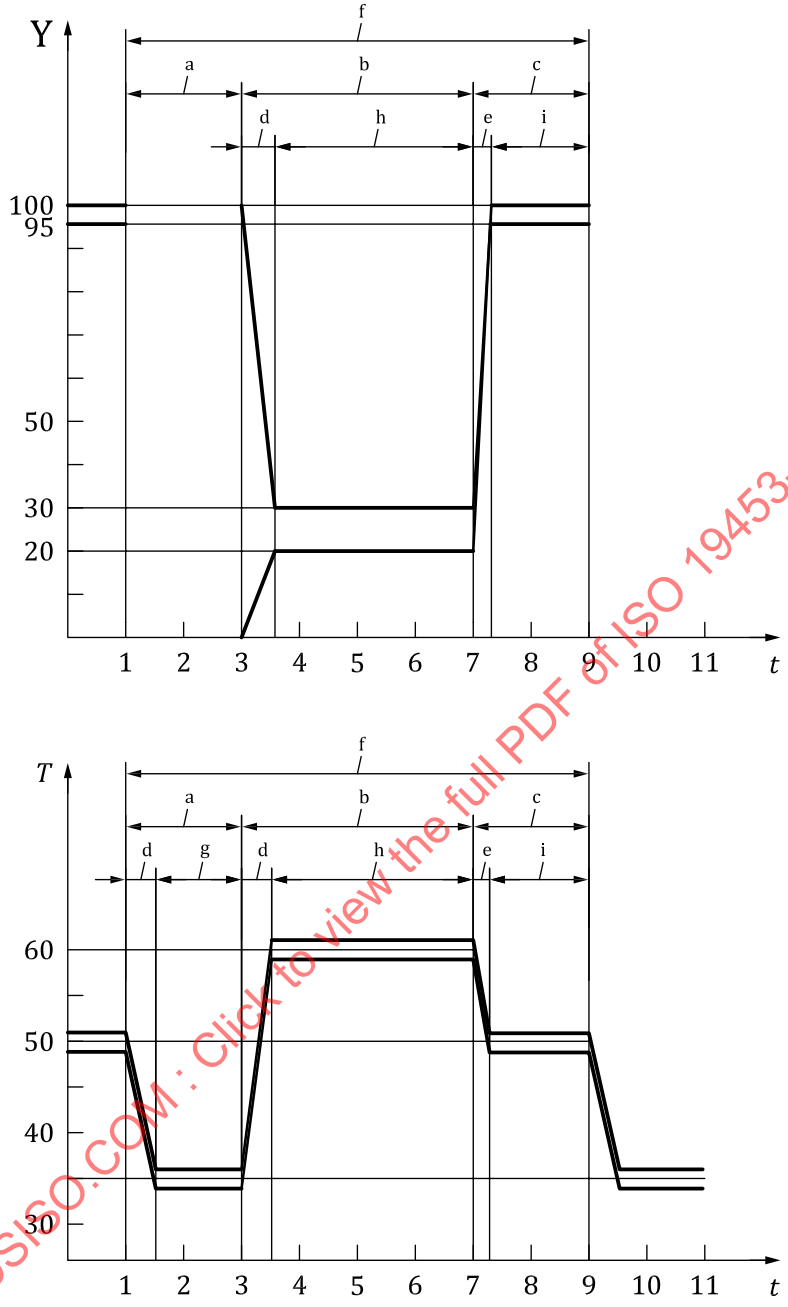
The cleaning method before the test usually has an impact on the effect of the salt mist on the surface. Therefore a suitable choice of the cleaning agents depending on the surface material and contamination shall be made.

Touching of the test surface by hand should be avoided as far as possible before the test.

5.4.3.2.5 Testing

Perform the test cycle shown in Figure 9. The duration of one cycle is 8 h; spray the DUT for 2 h, then stop spraying for a dry period of 4 h and continue with a humidity period of 2 h.

Use operating mode 1.2 as defined in ISO 19453-1 during the complete test sequence.



Key

t time, in h

Y relative humidity, in %

T temperature, in °C

a Salt spray (with uncontrolled humidity).

b Dry.

c Humid.

d Less than 0,5 h.

e Less than 0,25 h.

f One cycle,

g Holding time (1,5 h).

h Holding time (3,5 h).

i Holding time (1,75 h).

NOTE If necessary, d and e can be extended depending on the size and mass of the DUTs.

Figure 9 — Test cycle for the salt spray combined cycle test

The DUT shall be placed in the salt mist chamber and sprayed with the salt solution for a period of 2 h at a temperature of 35 °C ± 1 °C.

The salt mist conditions shall be maintained in all parts of the exposure zone, such that a clean collecting receptacle with a horizontal collecting area of 80 cm^2, placed at any point in the exposure zone, shall collect between 1,0 ml and 2,0 ml of solution per hour, averaged over the collecting period. A minimum of two receptacles shall be used. The receptacles shall be placed such that they are not shielded by the DUT and so that no condensate from any source shall be collected.

When calibrating the spray rate of the chamber, a minimum spray period of 8 h should be used for accurate measurement.

At the end of the spray period, the DUT shall be transferred to the dry chamber and stored 4 h at a temperature of 60 °C ± 1 °C and with a relative humidity between 20 % and 30 %.

At the end of dried period, the DUT shall be transferred to the "humidity chamber" and stored at a temperature of 50 °C ± 1 °C and with a relative humidity of more than 95 % for a period of 2 h.

The required number of test cycles is defined in Table 5 and Table 6. If the DUT consists of more than one item, the items shall not be in contact with each other or with other metal parts and shall be arranged so as to exclude any influence of one part on another.

5.4.3.2.6 Recovery

The relevant specification shall state whether or not the DUT shall be washed. In case of washing, the DUT shall be washed in running tap water for 5 min, rinsed in distilled or demineralized water, shaken by hand or subjected to air blast to remove droplets of water and then dried for one to four hours at 55 °C ± 2 °C (relative humidity < 20 %).The dry time depends on the size and mass of the DUT. The DUT may cool under controlled recovery conditions for not less than 1 h and not more than 2 h.

The relevant specification shall indicate, if needed, other methods to be used for washing and drying the DUT. The DUT shall be stored under controlled recovery condition in accordance with IEC 60068-1:2013, 4.4.2 for not less than 1 h and not more than 2 h. The temperature of the water used for washing shall not exceed 35 °C.

5.4.3.2.7 Final measurement

The DUT shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification, which shall provide the criteria to be used for the acceptance or rejection of the DUT.

5.4.3.3 Requirements

There shall be no changes that could impair normal performance, e.g. sealing function, marking and labelling shall remain visible.

The minimum functional status shall be class C, as defined in ISO 19453-1.

After the test, sealing function shall follow the IP class agreed between the supplier and the customer.

5.5 Humid heat, cyclic test — Dewing test

5.5.1 Purpose

This test simulates the use of the system/component under cyclic high ambient humidity. The failure mode is electrical malfunction caused by moisture, e.g. leakage current caused by a printed circuit board which is soaked with moisture. An additional failure mode is a breathing effect which transports moisture inside the housing when the air inside the system/component cools down and ambient air with high humidity is drawn into the system/component.

5.5.2 Test method

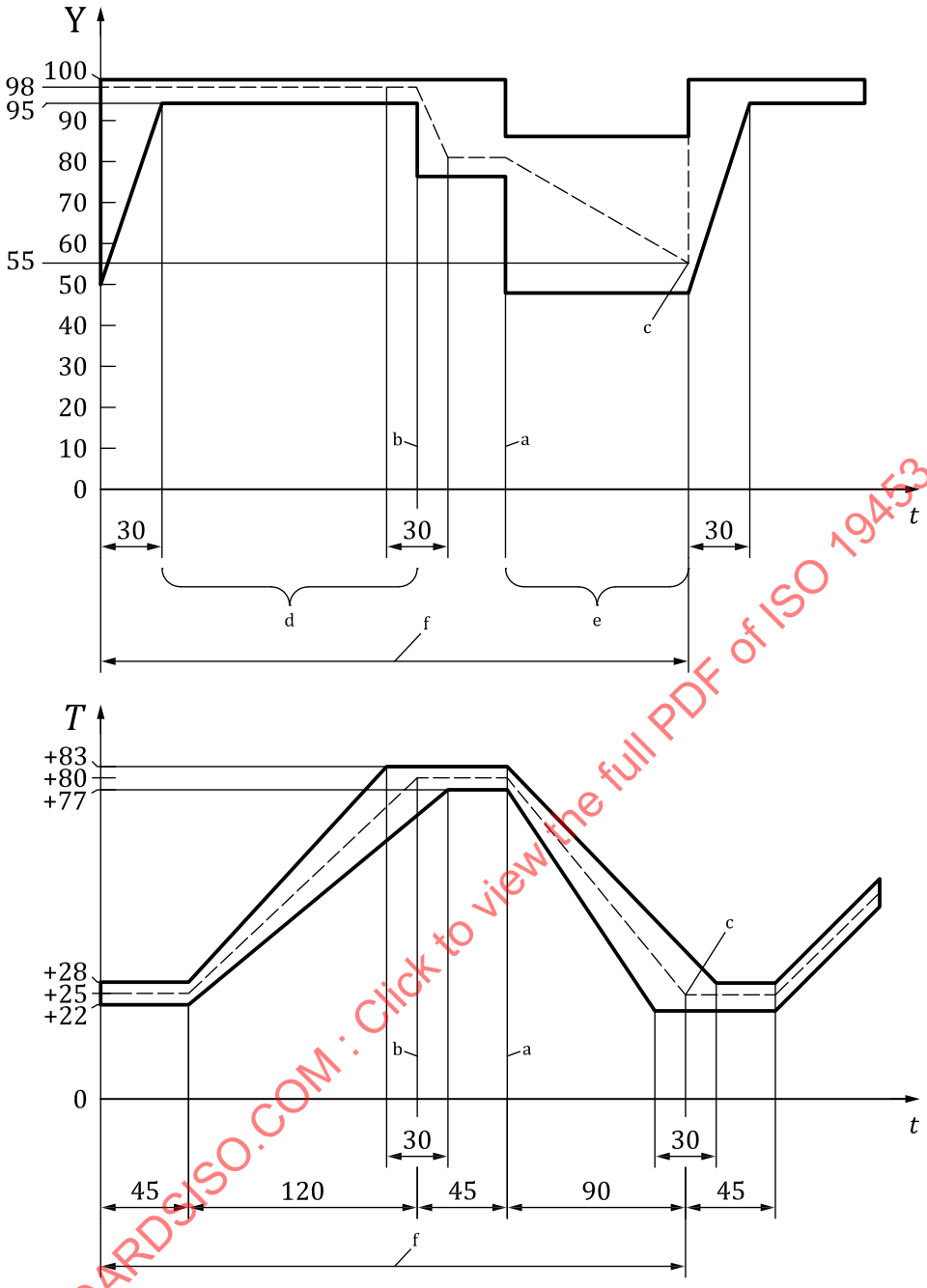
Perform the test in accordance with IEC 60068-2-30, using the variant illustrated in Figure 10:

— upper temperature: (80 ± 3) °C;

— number of cycles: 5.

Use operating mode 2.1 as defined in ISO 19453-1 during the complete test sequence.

The temperature and humidity profile has been defined to generate a dewing effect similar to that in the vehicle environment.



Key

t	time, in min
Y	relative humidity, in %
T	temperature, in °C
a	Start of temperature fall.
b	End of temperature rise.
c	Recommended set value for humidity/temperature.
d	Condensation.
e	Drying.
f	One cycle.

Figure 10 — Dewing test cycle

5.5.3 Requirements

The minimum functional status shall be class B, as defined in ISO 19453-1.

The insulation resistance test and withstand voltage test can be carried out to confirm the insulation function. Refer to Annex C for the insulation resistance test method and the withstand voltage test method.

5.6 Damp heat, steady state test

5.6.1 Purpose

This test simulates the use of the system/component under steady high ambient humidity. The failure mode is an electrical malfunction caused by moisture, e.g. leakage current caused by a printed circuit board which is soaked with moisture.

5.6.2 Test method

Perform the test in accordance with IEC 60068-2-78:

— Test duration: 21 days.

— Severity: (40 ± 2) °C and (93 ± 3) % humidity.

— Operating mode:

  — Operating mode 2.1 as defined in ISO 19453-1 for a duration of 20 days and 23 h.

  — Operating mode 3.2 as defined in ISO 19453-1 for the last hour of the test.

5.6.3 Requirements

For systems which are powered while the engine is shut off, functional status shall be class A, as defined in ISO 19453-1, for the entire test duration. Other systems shall meet minimum functional status class C up to the last hour and class A for the last hour.

5.7 Condensation test

5.7.1 Purpose

This test simulates condensation by rapid change of temperature and humidity, e.g. condensation occurring while the DUT moves from a cold environment to a warm one. The failure mode is electrical malfunction caused by moisture.

5.7.2 Test method

Select a code stated in Table 9. See also Annex A.

Check that there is no condensation on the DUT before starting the first cycle.

Perform the test based on Table 7 (refer to Figure 12 or Figure 13 as test profiles as well).

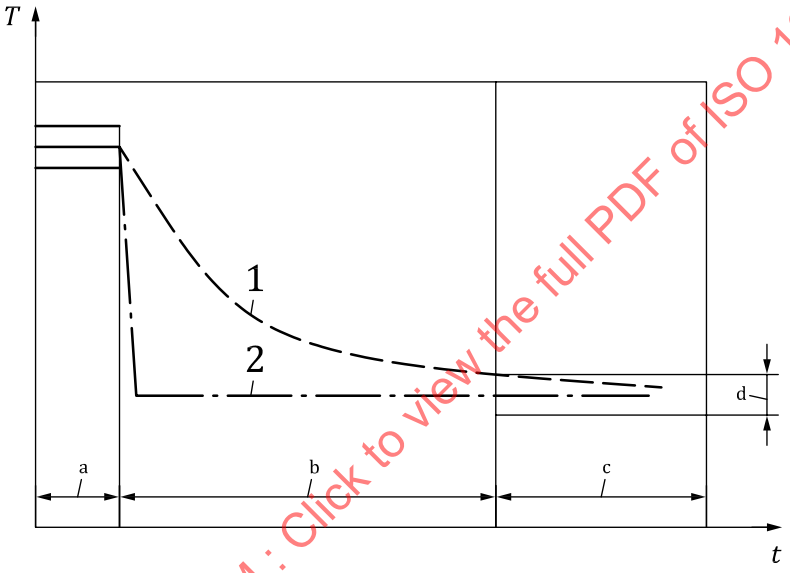
Ensure that the DUT temperature reaches the specified temperature before the low temperature stage of each cycle (see Figure 11 regarding the stabilizing period).

Perform a functional test (operating mode 3.2 and/or 4.2 as defined in ISO 19453-1) for the shortest possible duration in order to minimize self-heating effects as soon as the ambient humidity reaches a high humidity level, as condensation is then present (refer to Figure 12 and Figure 13 for function test and operation mode).

For reproducible test results, wind speed around the DUT is preferred to be 1 m/s ± 0,5 m/s during the high temperature and high humidity stage.

Table 7 — Temperature, humidity and duration of each stage of the condensation test

Code	Low temperature stage		High temperature and high humidity stage		De-humidification stage		Number of cycles
	Temperature	Duration	Temperature/ humidity	Duration	Temperature/ humidity	Duration	
A	(10 ± 3) °C	2 h	(50 ± 3) °C (70 ± 5) %	3 h	—	—	3
B	(–30 ± 3) °C	1 h	(25 ± 3) °C (90 ± 5) %	1 h	(25 ± 3) °C Less than 50 %	1,5 h	5
Z	As agreed						



Key

t time, in h

T temperature, in °C

1 DUT temperature

2 ambient temperature

a RT for the first cycle.
High temperature stage for the second and following cycles (code A).
De-humidification stage for the second and following cycles (code B).

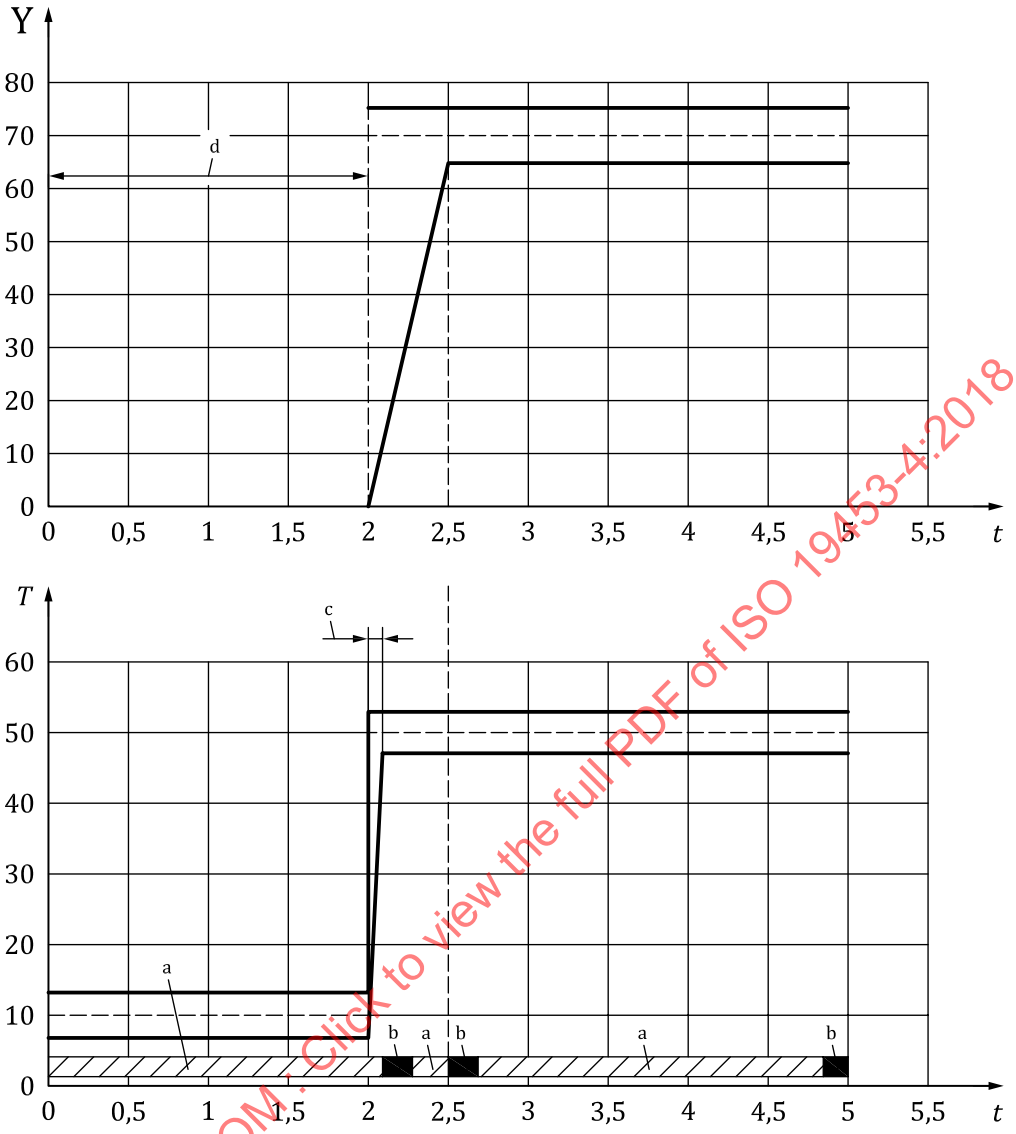
b Stabilizing stage.

c Low temperature stage.

d Tolerance of temperature for low temperature stage.

NOTE The decreasing rate of temperature in the stabilizing stage is not specified.

Figure 11 — Stabilizing period



Key

t time, in h

Y relative humidity, in %

T ambient temperature, in °C

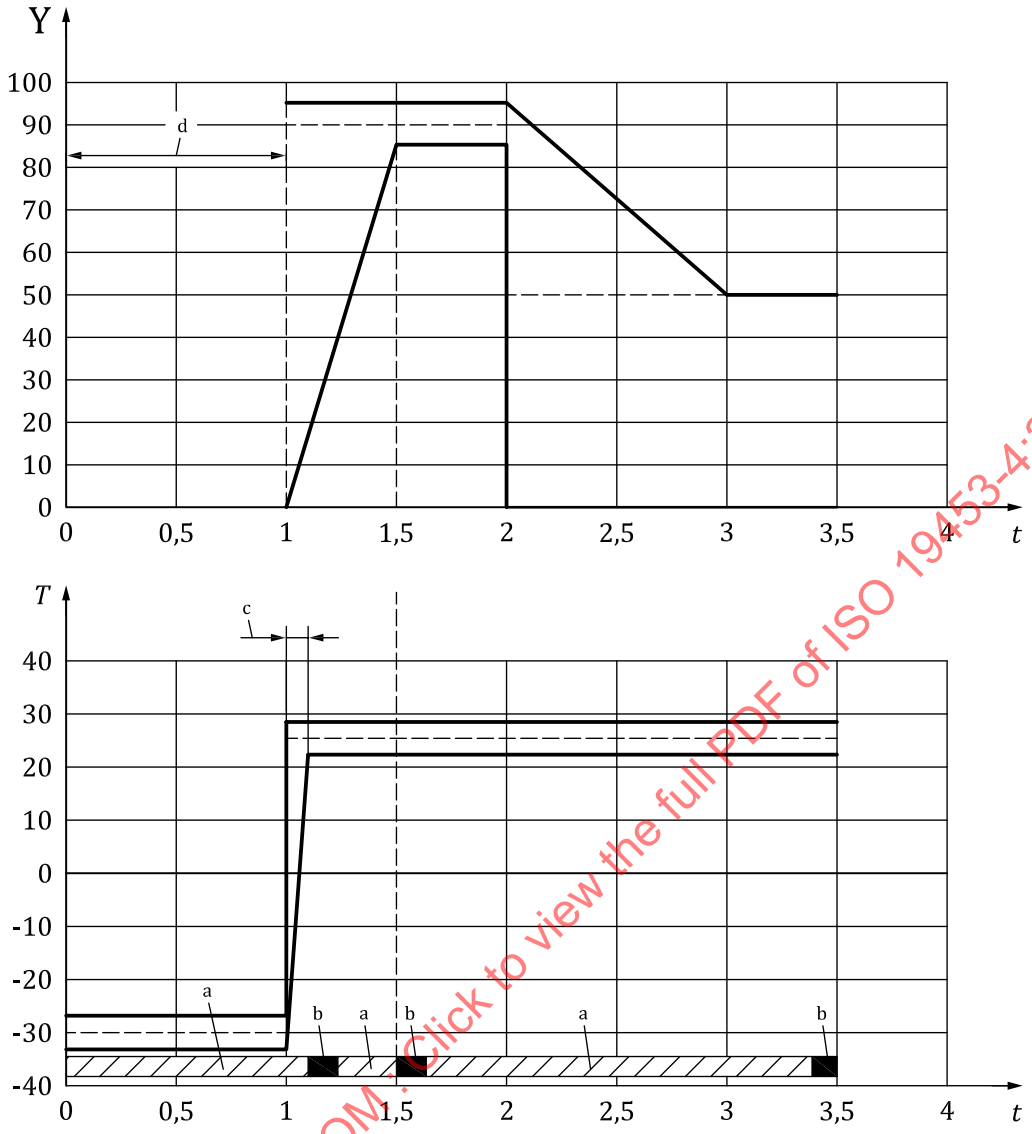
a Operating mode 1.2 as defined in ISO 19453-1.

b Operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.

c Less than 5 min.

d Uncontrolled humidity.

Figure 12 — Condensation test (code A)



Key

t time, in h
Y relative humidity, in %
T ambient temperature, in °C
a Operating mode 1.2 as defined in ISO 19453-1.
b Operating mode 3.2 and/or 4.2 as defined in ISO 19453-1.
c Less than 5 min.
d Uncontrolled humidity.

Figure 13 — Condensation test (code B)

5.7.3 Requirement

The functional status shall be class B, as defined in ISO 19453-1, during operating mode 3.2 and/or 4.2.

5.8 Corrosion test with flow of mixed gas

5.8.1 Purpose

This test simulates the use of the system/component in the presence of corrosive gases, e.g. in highly polluted atmospheres. The failure mode is an electrical malfunction caused by insulating corrosion products on the surface of electrical contacts. This test is relevant for plug contacts and open switching contacts. Another failure mode is the penetration of protective (paint) coatings with subsequent corrosion of the structures below.

The application of this test shall be stated in the specification of the DUT.

5.8.2 Test method

Perform the test as specified in IEC 60068-2-60, method 4. The operating mode of the DUT shall be 1.2 in accordance with ISO 19453-1. The test duration is:

— 10 days for components intended for mounting in the passenger compartment or luggage/load compartment; and

— 21 days for all other mounting locations.

5.8.3 Requirement

The functional status shall be class C as defined in ISO 19453-1.

5.9 Solar radiation test

If required, resistance to solar radiation shall be ensured by the choice of a suitable material.

5.10 Dust test

5.10.1 Purpose

This test simulates a dust pumping effect caused by temperature changes inside the housing of the DUT, due to intermittent electrical operation. The failure mode is an electrical or mechanical malfunction caused by dust, e.g. on the surface of electrical contacts.

The application of this test shall be stated in the specification of the DUT.

5.10.2 Test method

Perform the test as specified in ISO 20653, using the variant described below.

Upon agreement between the supplier and the customer, the following test dust mixture may be used as an alternative to the Arizona A2 test dust that is specified in the ISO 20653 test method:

— 50 % by weight of limestone (with clay and sand), i.e. “unbaked Portland cement”; and

— 50 % fly ash with the following grain size distribution (in accordance with IEC 60068-2-68):

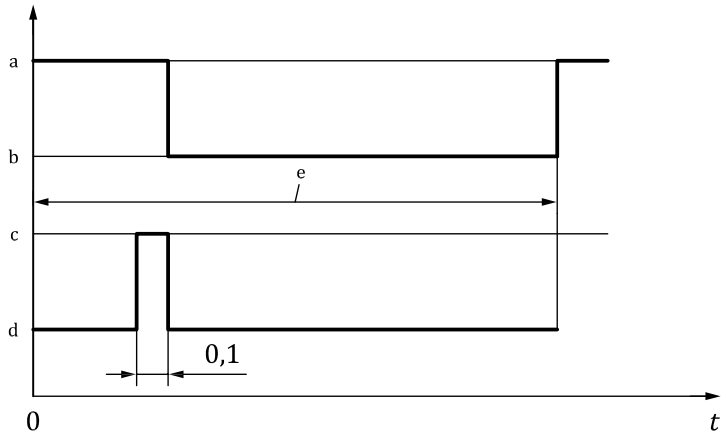
  — 33 % by weight ≤ 32 µm; and

  — 67 % by weight > 32 µm, but ≤ 250 µm.

The test shall be carried out in the orientation as mounted in the vehicle as long as the direction of the dust in the test is as in the vehicle.

The test will consist of 20 cycles, each one as defined in Figure 14.

The customer and the supplier shall agree on the cycle time and time of operating mode 3.2. The recommended cycle time is 20 min. The recommended time of operating mode 3.2 is 5 min.



Key

t time, in min
a Operating mode 3.2 as defined in ISO 19453-1.
b Operating mode 1.2 as defined in ISO 19453-1.
c Dust circulation on.
d Dust circulation off.
e One cycle.

Figure 14 — Dust test (one time cycle)

5.10.3 Requirement

The functional status shall be class A during operating mode 3.2, as defined in ISO 19453-1.

5.11 Atmospheric pressure test

5.11.1 Purpose

When there is a tiny void inside the insulator or at a boundary between the insulator and the conductor (e.g. winding of electric motors) with high voltage in use for the electric propulsion system and components, an electric field concentrates in the void and a weak electric discharge occurs. This phenomenon called "partial discharge" deteriorates the insulator and possibly causes breakdown after a long-time use. The partial discharge inception voltage is affected by atmospheric pressure.

Besides the electric discharge in a void of the insulation, another effect is taken into account by this test. Due to the pressure difference between the ambient pressure and the pressure in the voids, cracks can possibly be initiated in the insulation around the voids. Thus, the thickness of the insulation is reduced and the likelihood of electrical discharge is increased.

The purpose of this test, which consists in measuring an extremely small amount of discharge, is to detect potential defectiveness likely to shorten the durable life, and which is hardly detectable by measuring withstand voltage or insulation resistance.

The necessity of such a test is explained in Annex D.

5.11.2 Test method

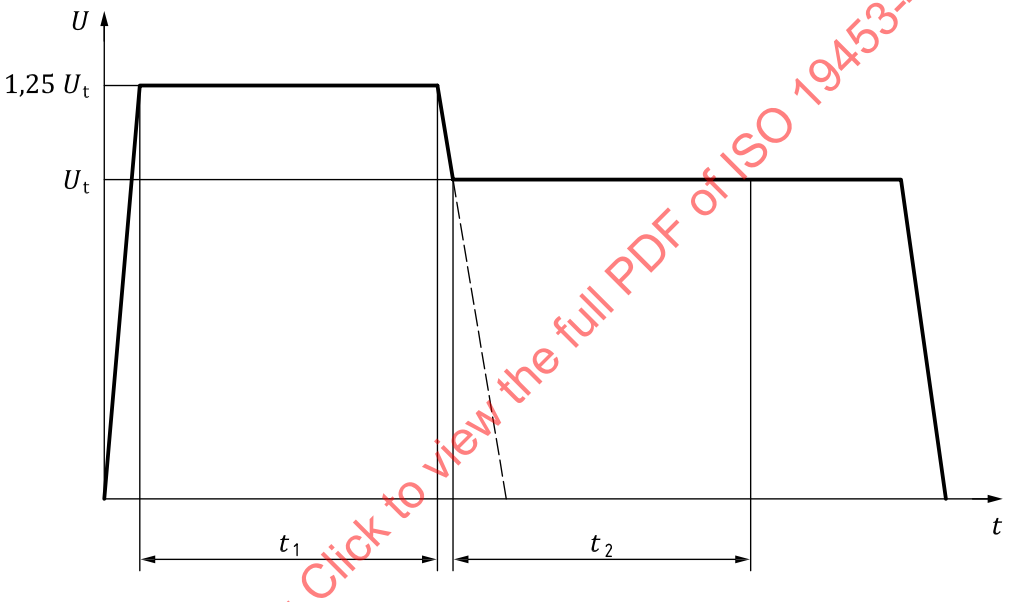
Set the DUT in a decompression chamber. Use operating mode 1.2 as defined in ISO 19453-1.

The pressure is decompressed to the value specified in Table 8.

After reaching the pressure value in the chamber was stabilized, perform this test in accordance with IEC 60664-1:2007, 6.1.3.5. A test voltage U_t is applied as shown in Figure 15.

Table 8 — Pressure for atmospheric pressure test

Code	Pressure kPa	Altitude m
A	54,0	5 000
B	62,0	4 000
C	80,0	2 000 and lower
Z	As agreed	



Key

U voltage, in V

t time, in min

U_t 1,2 × U_X as defined in ISO 19453-1

t_1 less than 5 s

t_2 until the partial discharge magnitude is measured

Figure 15 — Test voltage

The test voltage shall be applied between parts of the equipment which are electrically separated from each other. Examples of such parts include:

— live parts;

— separate circuits; and

— earthed circuits.

5.11.3 Requirements

Insulation breakdown shall not occur.

Partial discharges shall not occur; however, they may occur only if the magnitude of discharge measured in the period of t_2 at the voltage of U_t does not exceed the specified value.

Criteria for the partial discharge magnitude shall not exceed 10 pC (see IEC 60664-1:2007, 6.1.3.5.4.1). It may be changed up to 50 pC by agreement between the supplier and the customer, when it is difficult to keep measurement accuracy.

6 Code for climatic loads

See Table 9.

Table 9 — Codes, tests, and requirements

Tests and requirements in accordance with		Code									
Subclause	Parameter	A	B	C	D	E	F	G	H	I	Z
5.1.1	Low temperature	yes	yes	yes	yes	yes	yes	yes	yes	yes	As agreed
5.1.2	High temperature	yes	yes	yes	yes	yes	yes	yes	yes	yes	
5.2.1	Temperature cycle with specified change rate	yes	yes	yes	yes	yes	yes	yes	yes	yes	
5.2.2	Rapid change of temperature (number of cycles)	300	300	100	100	100	100	100	100	100	
5.3	Cold water shock	yes	no	no	yes	yes	no	no	yes	yes	
5.4.1	Salt spray, corrosion (severity)	4	—	—	4	5	—	—	4	5	
5.4.2	Salt spray, leakage and function (number of cycles)	6	—	—	6	6	—	—	6	6	
5.4.3	Salt spray combined cycle test (Severity: see Table 5 and Table 6)	1,2,3	—	—	1,2,3	3,4	—	—	1,2,3	1,2,3	
5.5	Humid heat, cyclic — Dewing test	yes	yes	yes	yes	yes	yes	yes	yes	yes	
5.6	Damp heat	yes	yes	yes	yes	yes	yes	yes	yes	yes	
5.7	Condensation (code)	B	A	A	B	B	A	A	B	B	
5.9	Solar radiation	no	no	no	no	no	no	yes	yes	yes	
5.10	Dust test	yes	yes	yes	yes	yes	yes	yes	yes	yes	
5.11	Atmospheric pressure	yes	yes	yes	yes	yes	yes	yes	yes	yes	

NOTE 1 The corrosion test with flow of mixed gas in 5.8 is not part of the basic coded specification.

NOTE 2 The salt spray combined cycle test (5.4.3) can substitute other salt spray tests (5.4.1 and 5.4.2).

7 Protection against dust and water

Check the DUT in accordance with ISO 20653. Recommended IP classes are given in Annex A.

8 Documentation

For documentation, the designations outlined in ISO 19453-1 shall be used.

Annex A
(informative)

Usual tests and requirements for equipment depending on the mounting location

Table A.1 outlines the usual tests and requirements for equipment depending on the mounting location.

Table A.1 — Usual tests and requirements for equipment depending on the mounting location

Mounting location			Recommended operating temperature range[a]	Recommended climatic requirements[b]	Recommended protection against dust and water[c]
Powertrain	to the body		G,J,O	A, D	IP6K9K
	to the frame		G,J,O	A, D	IP6K9K
	on the flexible plenum chamber, not rigidly attached		G,J,O	A	IP6K9K
	in the flexible plenum chamber, not rigidly attached		G,J,O	B	not specified
	on the engine/motor		O,Q	A, D	IP6K9K
	in the engine/motor		O,Q	B	not specified
	on the transmission/retarder		O,Q	A, D	IP6K9K
	in the transmission/retarder		O,Q	B	not specified
Passenger compartment	without special requirements		D	C	IP5K0
	exposed to direct solar radiation		H	G	IP5K0
	exposed to radiated heat		J	C	IP5K0
Luggage compartment/load compartment			E	C	IP5K0
Mounting on the exterior/ in cavities	to the body		E	D, H	IP5K4K, IP6K9K
	to the frame		E	D	IP5K4K, IP6K9K
	to underbody/ wheel housing	sprung masses	H	E	IP5K4K, IP6K9K
		unsprung masses	H	E	IP6K9K
	in/on the passenger compartment door		E	D, H	IP5K3
	to the engine compartment cover		N	D, H	IP5K4K
	to the luggage compartment lid/door		D, E	D, H	IP5K
	to trunk lid/door		D, E	D, H	IP5K3

[a] See Table 1.

[b] See Table 9.

[c] IP code (see ISO 20653).

Table A.1 *(continued)*

Mounting location			Recommended operating temperature range[a]	Recommended climatic requirements[b]	Recommended protection against dust and water[c]
	in cavity	open towards interior	D	C	IP5K0
		open towards exterior	D	E, I	IP5K4K
	in special compartments		Z	Z	not specified

[a] See Table 1.

[b] See Table 9.

[c] IP code (see ISO 20653).

Annex B
(informative)

Background information to determine the number of cycles of the salt spray combined test

B.1 General

This annex gives background information to determine the number of cycles of the salt spray combined test (5.4.3).

As mentioned in 5.4.3, the salt spray combined test is set as an accelerated version of 5.4.1 (corrosion test) and 5.4.2 (leakage and function test). The number of cycles of the salt spray combined test is decided based on correlation measurements performed by using test pieces of metal plate, in comparison between the tests of 5.4.1, 5.4.2 and 5.4.3. The severity according to the mounting location on a vehicle is defined for the salt spray combined test.

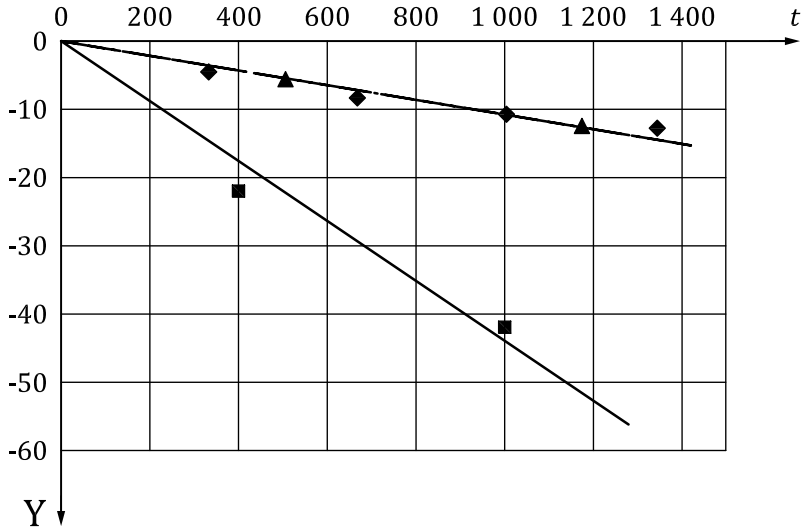
B.2 Comparison analysis among the salt spray tests

To decide on the number of cycles of 5.4.3 (salt spray combined test), correlation tests between 5.4.3, 5.4.1 (corrosion test) and 5.4.2 (leakage and function test) have been performed by using test pieces of metal plate.

The mass loss in each salt spray test is different according to the kind of materials. See ISO 14993:2001, Annex B, for the essential information needed.

In the case of steel (SAE 1010), the level of the salt spray combined test is four times more severe than the levels of the corrosion test and the leakage and function test (see Figure B.1).

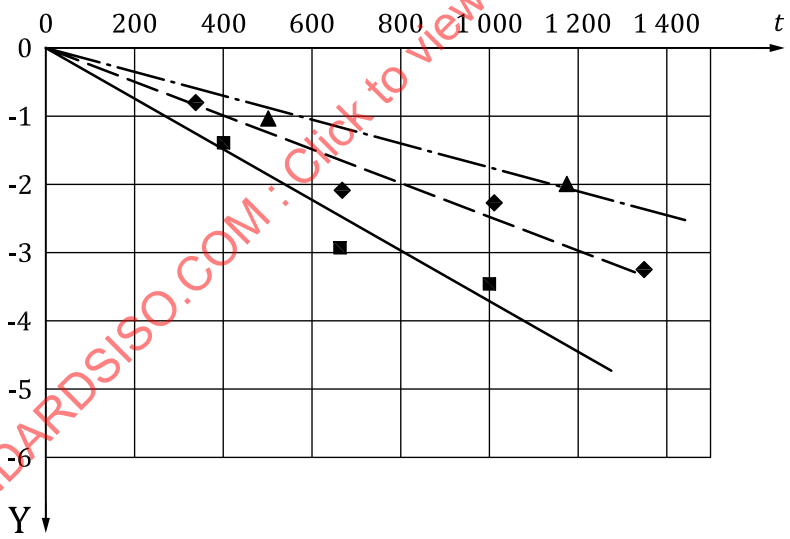
In the case of aluminium (ADC 12), the level of the salt spray combined test is 1,5 times more severe than the level of the corrosion test and 2,2 times more severe than the level of the leakage and function test (see Figure B.2).



Key

Y	mass loss, in %
t	test duration, in h
—·▲·—	5.4.1 corrosion test result
— ◆ —	5.4.2 leakage and function test result
—■—	5.4.3 salt spray combined cycle test result

Figure B.1 — Mass loss for salt spray test (steel)



Key

Y	mass loss, in %
t	test duration, in h
—·▲·—	5.4.1 corrosion test result
— ◆ —	5.4.2 leakage and function test result
—■—	5.4.3 salt spray combined cycle test result

Figure B.2 — Mass loss for salt spray test (aluminium)

Metal coupons used:

— Steel: SAE 1010;

— Aluminium: ADC 12.

During these experiments, the mass losses in 5.4.3 have been 150 g/m^2 for steel and 7 g/m^2 for aluminium coupons at 48 h (6 cycles) of test time.

B.3 Background information for the number of cycles of the salt spray combined test

The duration of the corrosion test (5.4.1) is 168 h per cycle and the test condition is given in two severities. One is 672 h (4 cycles) and the other is 840 h (5 cycles). The duration of the salt spray combined test (5.4.3) is 8 h per cycle.

As shown in Figure B.1 and Figure B.2, the mass loss in each salt spray test is different according to the kind of materials. The mass loss of the salt spray combined test is 4 times more severe than the corrosion test in the case of steel and 1,5 times more severe in the case of aluminium.

The duration and number of cycles of the salt spray combined test are calculated based on the duration of the corrosion test and the mass loss shown in B.2.

The calculation formula is defined as follows:

$$\text{mass loss ratio} = \frac{\text{mass loss in 5.4.3}}{\text{mass loss in 5.4.1}}$$

$$\text{number of cycles} = \frac{\text{test duration of 5.4.1, in h}}{\text{mass loss ratio}} \times \frac{1}{\text{1 cycle duration of 5.4.3, in h}}$$

In the salt spray combined test, 60 cycles and 24 cycles are determined as the most severe numbers for aluminium and steel, respectively, as a mean value between the 2 levels of test duration shown in Table B.1. These values match the results of the test performed as the simulation test of the market environmental condition.

Table B.1 — Numbers of cycles for the corrosion test

Test name	Corrosion test (5.4.1)	Salt spray combined test (5.4.3)	
Material	Not defined	Steel	Aluminium
Test duration (test cycles)	672 h (4 cycles)	168 h (21 cycles)	448 h (56 cycles)
	840 h (5 cycles)	210 h (26 cycles)	560 h (70 cycles)

The duration of the leakage and function test (5.4.2) is 24 h per cycle and the number of cycles is 6 cycles.

As shown in Figure B.1 and Figure B.2, the mass loss in each salt spray test is different according to the kind of materials. The mass loss of the salt spray combined test is 4 times more severe than the leakage and function test in the case of steel and 2,2 times more severe in the case of aluminium.

The duration and number of cycles of the salt spray combined test are defined based on the duration of the leakage and function test and the mass loss shown in B.2. The numbers of cycles for the leakage and function test and the corresponding durations are shown in Table B.2.

The calculation formula is defined as follows:

$$\text{mass loss ratio} = \frac{\text{mass loss in 5.4.3}}{\text{mass loss in 5.4.2}}$$

$$\text{number of cycles} = \frac{\text{test duration of 5.4.2, in h}}{\text{mass loss ratio}} \times \frac{1}{\text{1 cycle duration of 5.4.3, in h}}$$

Table B.2 — Numbers of cycles for the leakage and function test

Test name	Leakage and function test (5.4.2)	Salt spray combined test (5.4.3)	
Material	Not defined	Steel	Aluminium
Test duration (test cycles)	144 h (6 cycles)	36 h (5 cycles)	65 h (8 cycles)

B.4 Severity according to the mounting location (frequency and amount of water exposure)

The corrosion ratio differs according to the mounting location in a vehicle because of the difference in frequency and amount of exposure to water.

This severity corresponds to the mounting location in a vehicle classified in 4 areas (see Figure 8). When the lightest stress is defined as severity 1, the ratio of severity is shown as follows.

Severity 1:severity 2:severity 3:severity 4 = 1:3:4:8.

The concrete number of cycles is shown in Table 5 and Table 6. For example, in the case of severity 2 of aluminium for the corrosion test, the value is calculated as 60 cycles × 3/8 = 23 cycles.