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ISO 16750-4

Fourth edition
2023-07

Road vehicles — Environmental conditions and testing for electrical and electronic equipment —

Part 4: Climatic loads

Véhicules routiers — Spécifications d'environnement et essais de l'équipement électrique et électronique —

Partie 4: Contraintes climatiques

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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 document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

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

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

This fourth edition cancels and replaces the third edition (ISO 16750-4:2010), which has been technically revised.

The main changes are as follows:

— integration and harmonization of contents from ISO 19453-4:2018 (e.g. addition of 5.8 and 5.12);

— subdivision of test methods in temperature cycle test for application to DUTs of "small and lightweight" or "large and heavy" size (5.3);

— addition of test methods for large and heavy DUTs in cold water shock test (5.4);

— addition of three salt spray corrosion tests (5.5.4, 5.5.5 and 5.5.6);

— addition of concrete test method and requirements in solar radiation test (5.10);

— addition of optional test method in dust test for DUT installed in passenger compartment or luggage/load compartment (5.11);

— addition of new tests and the selection of applied cycles in rapid change of temperature with specified transition duration (Clause 6, Table 10);

— subdivision of mounting location defining the corresponding severities (Annex A);

— error correction (Annex B, Figure B.1, B.2 and Table B.1 taken over from ISO 19453-4:2018);

— clarification of technical background to determine number of cycles and severities according to the mounting location (Annex B, Clause B.4);

— subdivision of electric isolation test methods for voltage class A and voltage class B (Annex C).

A list of all parts in the ISO 16750 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.

Road vehicles — Environmental conditions and testing for electrical and electronic equipment —

Part 4: Climatic loads

1 Scope

This document applies to electric and electronic systems and components for vehicles including electric propulsion systems and components with maximum working voltages according to voltage class B. It describes the potential environmental stresses and specifies tests and requirements recommended for the specific mounting location on/in the vehicle.

This document describes climatic loads.

This document is not intended to apply to environmental requirements or testing for systems and components of motorcycles and mopeds.

Systems and their components released for production, or systems and their components already under development prior to the publication date of this document, can be exempted from fulfilling the changes in this edition compared to the previous one.

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 4892-2, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 4892-3, *Plastics — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

ISO 4892-4, *Plastics — Methods of exposure to laboratory light sources — Part 4: Open-flame carbon-arc lamps*

ISO 9227:2022, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 11997-3, *Paints and varnishes — Determination of resistance to cyclic corrosion conditions — Part 3: Testing of coating systems on materials and components in automotive construction*

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

ISO 16750-2, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

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

ISO 21498-1, *Electrically propelled road vehicles — Electrical specifications and tests for voltage class B systems and components — Part 1: Voltage sub-classes and characteristics*

ISO 21780, *Road vehicles — Supply voltage of 48 V — Electrical requirements and tests*

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

IEC 60068-2-1:2007, *Environmental testing — Part 2-1: Tests — Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing — Part 2-2: Tests — Test B: Dry heat*

IEC 60068-2-11:2021, *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 60068-2-30:2005, *Environmental testing — Part 2-30: Tests — Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-38, *Environmental testing — Part 2-38: Tests — Test Z/AD: Composite temperature/humidity cyclic test*

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

IEC 60068-2-60:2015, *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 60664-1:2020, *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 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/

4 Operating temperature ranges

Choose the applicable temperature range from Table 1 to be presented in the specifications of the 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 5.3.1.

The paint repair temperature (T_{maxPR}) as defined in ISO 16750-1 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

Table 1 *(continued)*

Code	Minimum operating temperature T_{min} [°C]	Maximum operating temperature T_{max} [°C]
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} [°C]
a	15
b	30
c	50
z	As agreed

NOTE For DUTs with hot soak, the code letter is defined as a combination of Tables 1 and 2, e.g. Hb (T_{max} = 90 °C and ΔT_{HS} = 30 °C).

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 systems/components to low temperatures without electrical operation, e.g. during shipment of the systems/components. The 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 60068-2-1:2007, 5.2, Test Ab, at a temperature of −40 °C for a duration of 24 h unless otherwise indicated in the DUT specification. The operating mode is 1.1 as defined in ISO 16750-1.

5.1.1.1.3 Requirement

The functional status shall be class C as defined in ISO 16750-1.

5.1.1.2 Operation test

5.1.1.2.1 Purpose

This test simulates the exposure of the systems/components to low temperatures with electrical operation, e.g. the use of the systems/components at very low ambient temperature. The failure mode is an electrical malfunction caused by low temperature, e.g. the freezing of capacitors with liquid electrolyte.

5.1.1.2.2 Test method

Perform the test in accordance with IEC 60068-2-1:2007, 5.2, Test Ab or 5.3, Test Ad, at a temperature of T_{min} for a duration of 24 h. Test Ab is applied for non-heat-dissipating DUTs and Test Ad is applied for heat-dissipating DUTs. The operating mode is 3.3 or 4.3 as defined in ISO 16750-1.

5.1.1.2.3 Requirement

The functional status shall be class A as defined in ISO 16750-1.

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 systems/components to high temperatures without electrical operation, e.g. during the shipment of the systems/components. 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 60068-2-2:2007, 5.2, Test Bb, 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 16750-1.

5.1.2.1.3 Requirement

The functional status shall be class C as defined in ISO 16750-1.

5.1.2.2 Operation test

5.1.2.2.1 Purpose

This test simulates the exposure of the systems/components to high temperatures with electrical operation, e.g. the use of the systems/components at 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 60068-2-2:2007, 5.2 Test Bb or 5.3 Test Bd, at a temperature of T_{max} for a duration of 96 h. Test Bb is applied for non-heat-dissipating DUTs and Test Bd is applied for heat-dissipating DUTs. The operating mode is 3.4 or 4.4 as defined in ISO 16750-1.

5.1.2.2.3 Requirement

The functional status shall be class A as defined in ISO 16750-1.

5.2 Temperature step test

5.2.1 Purpose

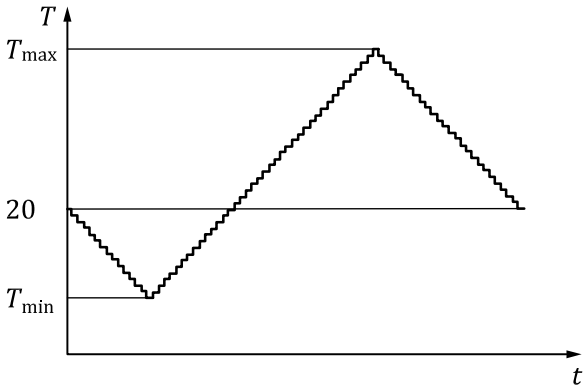
This test checks the mechanical and electrical device for malfunctions (including failure to change properly between different operating modes) which may occur within a small section of the operating temperature range.

This test mainly applies to small and lightweight components, but can also be used for large and heavy components if agreed between the customer and the supplier. See a mass classification example in ISO 16750-1:2023, Annex C.

5.2.2 Test method

Install the DUT in a temperature chamber. According to Figure 1, decrease the temperature in steps of 5 °C from 20 °C to T_{min}, then increase the temperature in steps of 5 °C from T_{min} to T_{max} and then decrease the temperature in steps of 5 °C from T_{max} to 20 °C (see Figure 1). Wait at each step until the DUT has obtained thermal equilibrium. Perform functional tests with operating mode 3.2 in accordance with ISO 16750-1 at minimum supply voltage, U_{Smin}, and at maximum supply voltage, U_{Smax}, in accordance with the specified ISO 16750-2 code letter, at each temperature step. In addition, for each temperature step transitions of the DUT between different operating modes shall also be verified (e.g. change between operating modes 3.2 and 2.1). Switch the DUT off (operating mode 2.1) during transition to the next temperature. If the DUT has a nominal supply voltage other than 12/24 V, this test shall be performed by the voltage range corresponding to functional status class A as defined in ISO 16750-1 according to agreement between the customer and the supplier. In case of 48 V, the test shall be performed at the upper and lower voltage of nominal voltage range in accordance with ISO 21780. In case of voltage class B, the test shall be performed at the upper and lower voltage of unlimited operating capability in accordance with ISO 21498-1. For DUTs with multiple voltage supply

levels, e.g. 12 V supply and voltage class B supply, the combination of test voltages for each temperature step shall be agreed between the customer and the supplier.



Key

T temperature, in °C

t time, in min

T_{min} minimum operating temperature (see Table 1)

T_{max} maximum operating temperature (see Table 1)

Figure 1 — Temperature step test

5.2.3 Requirement

For each temperature step between T_{min} and T_{max}, the DUT shall have functional status class A as defined in ISO 16750-1 for active operating modes.

5.3 Temperature cycling tests

5.3.1 Temperature cycle with specified change rate

5.3.1.1 Purpose

This test simulates varying temperatures with electrical operation of the systems/components, 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.

The mass of the DUT is the main influence factor that determines the design of the temperature cycle. This test shall be selected from 5.3.1.2 or 5.3.1.3 in accordance with mass classification example in ISO 16750-1:2023, Annex C.

NOTE 1 This test is not intended to be a life test.

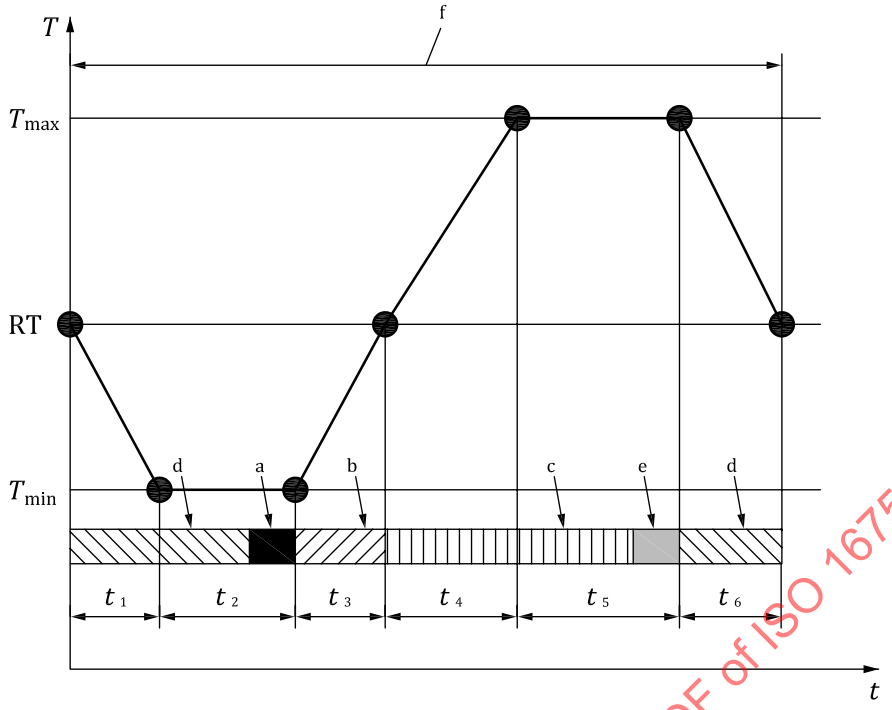
NOTE 2 For applying this test, it is important to calculate and check the temperature change rate against available test chamber capabilities. If the specified change rate is not technically feasible, the temperature profile can be changed by agreement between the customer and the supplier.

5.3.1.2 Test method for small and lightweight DUT

For a small and lightweight DUT, perform the temperature cycling in accordance with IEC 60068-2-14, Test Nb, not using its specified temperature changing rates, but using the variant given in Figure 2 and Table 3. For the test including hot-soak temperature (T_{maxHS}), also use the variant given in Figure 3 and Table 4. The test shall be performed with 30 cycles.

Perform temperature cycling with the following as one cycle. Decrease ambient temperature from room temperature (RT) to T_{min}, expose the DUT at T_{min}, increase ambient temperature from T_{min} to T_{max}, expose the DUT at T_{max} with/without including T_{maxHS} and then decrease ambient temperature from T_{max} to RT (see Figure 2 and Figure 3).

Perform a functional test at the end of T_{min} as short as possible with operating mode 3.3 or 4.3 as defined in ISO 16750-1 (see key a in Figure 2 or Figure 3). In addition, operate with operating mode 3.3 or 4.3 as defined in ISO 16750-1 (see key b in Figure 2 or Figure 3) during the section from T_{min} to RT. Change operating mode to 3.4 or 4.4 (see key c in Figure 2 or Figure 3) during the section from RT to the end of T_{max}. Perform a functional test at the end of T_{max} as short as possible with operating mode 3.4 or 4.4 as defined in ISO 16750-1 (see key e in Figure 2 or Figure 3). During the other sections, operate with operating mode 2.1 (see key d" in Figure 2 or Figure 3). For tests including T_{maxHS}, the DUT shall not be operated at the time which is over T_{max} (see key t_6, t_7, t_8 in Figure 3). If operating mode 4.3/4.4 is not technically feasible, operating mode 3.3/3.4 may be used if agreed between the customer and the supplier.



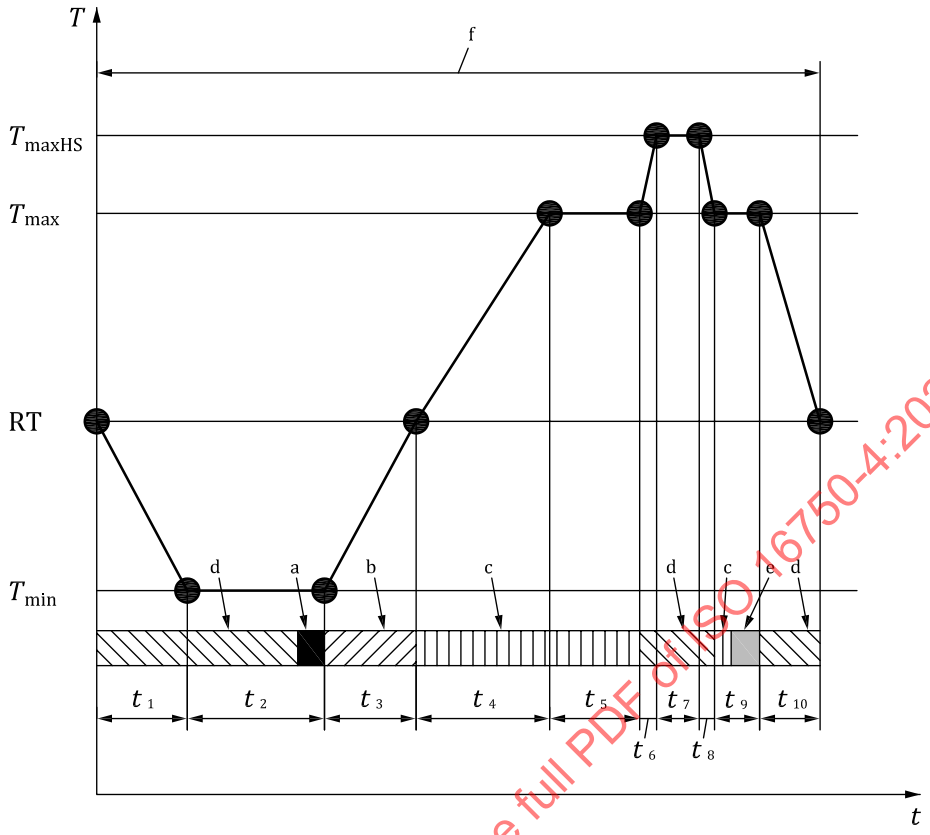
Key

T	temperature, in °C
t	time, in min
T_{min}	minimum operating temperature (see Table 1)
T_{max}	maximum operating temperature (see Table 1)
RT	room temperature (see ISO 16750-1)
t_1, t_2, t_3, t_4, t_5, t_6	time parameter as defined in Table 3
a	Functional test with operating mode 3.3 or 4.3 as defined in ISO 16750-1.
b	Operating mode 3.3 or 4.3 as defined in ISO 16750-1.
c	Operating mode 3.4 or 4.4 as defined in ISO 16750-1.
d	Operating mode 2.1 as defined in ISO 16750-1.
e	Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.
f	One cycle.

Figure 2 — Temperature cycle with specified change rate for small and lightweight DUT

Table 3 — Temperatures and time duration for temperature cycling for small and lightweight DUT

Parameter	Duration [min]	Temperature [°C]
t_1	60	From RT to T_{min}
t_2	90	Exposure time at T_{min}
t_3	60	From T_{min} to RT
t_4	90	From RT to T_{max}
t_5	110	Exposure time at T_{max}
t_6	70	From T_{max} to RT



Key

T	temperature, in °C
t	time, in min
T_{min}	minimum operating temperature (see Table 1)
T_{max}	maximum operating temperature (see Table 1)
T_{maxHS}	hot soak temperature (see Table 2)
RT	room temperature (see ISO 16750-1)
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	Functional test with operating mode 3.3 or 4.3 as defined in ISO 16750-1.
b	Operating mode 3.3 or 4.3 as defined in ISO 16750-1.
c	Operating mode 3.4 or 4.4 as defined in ISO 16750-1.
d	Operating mode 2.1 as defined in ISO 16750-1.
e	Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.
f	One cycle.

Figure 3 — Temperature cycle with specified change rate and hot-soak stage for small and lightweight DUT

Table 4 — Temperatures and time duration for temperature cycling with hot-soak stage for small and lightweight DUT

Parameter	Duration [min]	Temperature [°C]
t_1	60	From RT to T_{min}
t_2	90	Exposure time at T_{min}
t_3	60	From T_{min} to RT

Table 4 *(continued)*

Parameter	Duration [min]	Temperature [°C]
t_4	90	From RT to T_{max}
t_5	60	Exposure time at T_{max}
t_6	10	From T_{max} to T_{maxHS}
t_7	30	Exposure time at T_{maxHS}
t_8	10	From T_{maxHS} to T_{max}
t_9	30	Exposure time at T_{max}
t_{10}	70	From T_{max} to RT

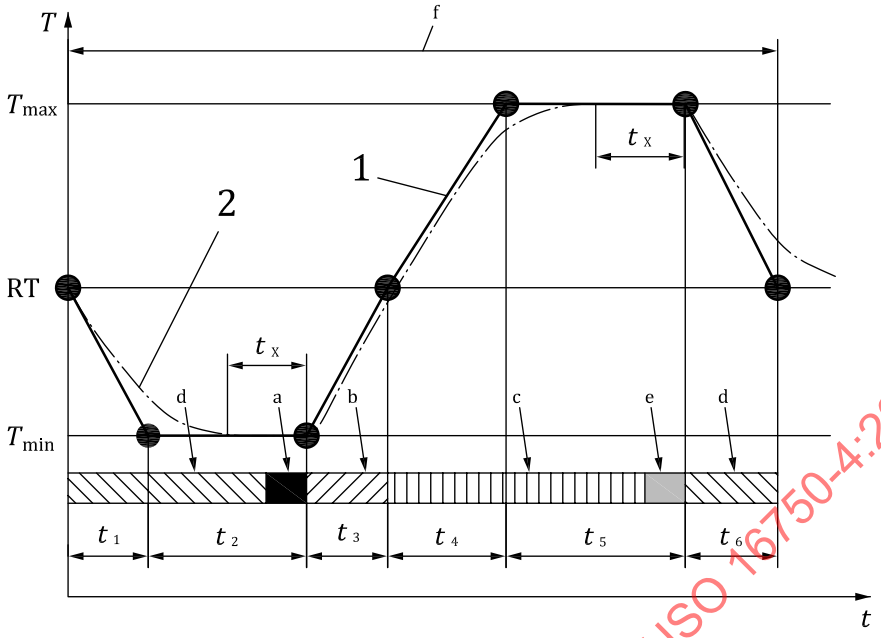
5.3.1.3 Test method for large and heavy DUT

For large and heavy DUT, perform the temperature cycling in accordance with IEC 60068-2-14, Test Nb, not using its specified temperature changing rates, but using the variant given in Figure 4 and Table 5. For the test including hot-soak temperature (T_{maxHS}), also use the variant given in Figure 5 and Table 6. The test shall be performed with 30 cycles.

Perform temperature cycling with the following as one cycle. Decrease ambient temperature from RT to T_{min}, expose the DUT at T_{min}, increase ambient temperature from T_{min} to T_{max}, expose the DUT at T_{max} with/without including T_{maxHS} and then decrease ambient temperature from T_{max} to RT (see Figure 4 and Figure 5).

Before performing this test, a separate temperature measurement (with DUT in operating mode 2.1 as defined in ISO 16750-1) shall be performed to determine what exposure time at T_{max}, T_{min} or T_{maxHS} (see Figure 4 or Figure 5) is necessary to obtain thermal equilibrium of the DUT. If operating mode 2.1 is not technically feasible for the separate temperature measurement, operating mode 1.2 as defined in ISO 16750-1 can be used as agreed between the customer and the supplier. The measuring point of DUT shall be agreed between the customer and the supplier, considering a target device (e.g. microprocessor, motor coil) which is temperature-influenced in functionality or performance. The dwell time t_x of DUT at T_{min}, T_{max} and T_{maxHS} shall be more than 30 min each per temperature cycle; therefore, exposure time shall be adjusted accordingly depending on the size and other characteristics of the DUT. The customer and the supplier shall agree on a complete profile of temperature cycle, including dwell time and stabilisation time, depending on the size and other properties of the DUT.

Perform a functional test at the end of T_{min} as short as possible with operating mode 3.3 or 4.3 as defined in ISO 16750-1 (see key a in Figure 4 or Figure 5). In addition, operate with operating mode 3.3 or 4.3 as defined in ISO 16750-1 (see key b in Figure 4 or Figure 5) during the section from T_{min} to RT. Change operating mode to 3.4 or 4.4 (see key c in Figure 4 or Figure 5) during the section from RT to the end of T_{max}. Perform a functional test at the end of T_{max} as short as possible with operating mode 3.4 or 4.4 as defined in ISO 16750-1 (see key e in Figure 4 or Figure 5). During the other sections, operate with operating mode 2.1 (see key d in Figure 4 or Figure 5). For tests including T_{maxHS}, the DUT shall not be operated at the time which is over T_{max} (see key t_6, t_7, t_8 in Figure 5). If operating mode 4.3/4.4 is not technically feasible, operating mode 3.3/3.4 may be used if agreed between the customer and the supplier.



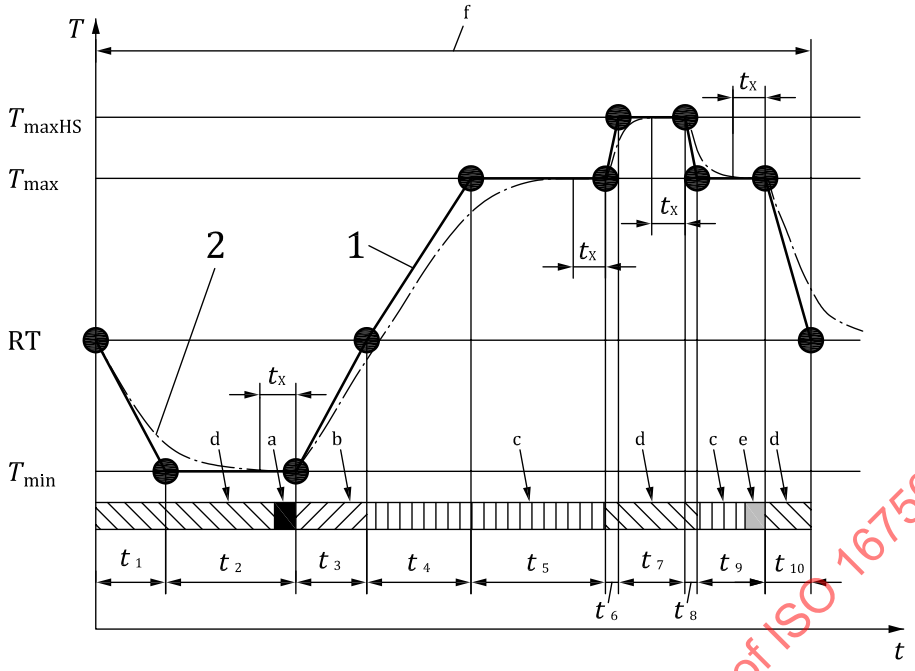
Key

T	temperature, in °C
t	time, in min
1	ambient temperature
2	DUT temperature, exemplary for non-heat-dissipating DUTs
T_{min}	minimum operating temperature (see Table 1)
T_{max}	maximum operating temperature (see Table 1)
RT	room temperature (see ISO 16750-1)
t_1, t_2, t_3, t_4, t_5, t_6	time parameter as defined in Table 5
t_x	dwell time at T_{min} and T_{max}
a	Functional test with operating mode 3.3 or 4.3 as defined in ISO 16750-1.
b	Operating mode 3.3 or 4.3 as defined in ISO 16750-1.
c	Operating mode 3.4 or 4.4 as defined in ISO 16750-1.
d	Operating mode 2.1 as defined in ISO 16750-1.
e	Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.
f	One cycle.

Figure 4 — Temperature cycle with specified change rate for large and heavy DUT

Table 5 — Temperatures and time duration for temperature cycling for large and heavy DUT

Parameter	Duration [min]	Temperature [°C]
t_1	60	From RT to T_{min}
t_2	As agreed	Exposure time at T_{min}
t_3	60	From T_{min} to RT
t_4	90	From RT to T_{max}
t_5	As agreed	Exposure time at T_{max}
t_6	70	From T_{max} to RT
t_x	> 30	Dwell time at T_{min} and T_{max}



Key

T	temperature, in °C
t	time, in min
1	ambient temperature
2	DUT temperature, exemplary for non-heat-dissipating DUTs
T_{min}	minimum operating temperature (see Table 1)
T_{max}	maximum operating temperature (see Table 1)
T_{maxHS}	hot soak temperature (see Table 2)
RT	room temperature (see ISO 16750-1)
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 6
t_x	dwell time at T_{min}, T_{max} and T_{maxHS}
a	Functional test with operating mode 3.3 or 4.3 as defined in ISO 16750-1.
b	Operating mode 3.3 or 4.3 as defined in ISO 16750-1.
c	Operating mode 3.4 or 4.4 as defined in ISO 16750-1.
d	Operating mode 2.1 as defined in ISO 16750-1.
e	Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.
f	One cycle.

Figure 5 — Temperature cycle with specified change rate and hot-soak stage for large and heavy DUT

Table 6 — Temperatures and time duration for temperature cycling with hot-soak stage for large and heavy DUT

Parameter	Duration [min]	Temperature [°C]
t_1	60	From RT to T_{min}
t_2	As agreed	Exposure time at T_{min}
t_3	60	From T_{min} to RT
t_4	90	From RT to T_{max}

Table 6 *(continued)*

Parameter	Duration [min]	Temperature [°C]
t_5	As agreed	Exposure time at T_{max}
t_6	10	From T_{max} to T_{maxHS}
t_7	As agreed	Exposure time at T_{maxHS}
t_8	10	From T_{maxHS} to T_{max}
t_9	As agreed	Exposure time at T_{max}
t_{10}	70	From T_{max} to RT
t_x	> 30	Dwell time at T_{min}, T_{max} and T_{maxHS}

5.3.1.4 Requirement

The functional status shall be class A as defined in ISO 16750-1 during active operating modes.

5.3.2 Rapid change of temperature with specified transition duration

5.3.2.1 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 mode is an electrical malfunction and/or mechanical failure due to cracking of materials or seal failures caused by ageing and different temperature expansion coefficients.

NOTE If the failure mechanism is known, it is possible to perform the test only with a subcomponent by agreement between the customer and the supplier. Mechanical constraints and interfaces such as for instance casing or fixation points are examples of things that can contribute to the failure mechanisms during this test, and can be taken into consideration if running the test on subcomponent level.

5.3.2.2 Test method

Perform the temperature cycling in accordance with IEC 60068-2-14, Test Na, not using its conditions, but using the variant such as the combination of the two temperatures, the transfer time, the exposure time and the number of cycles. The DUT shall be exposed to T_{min} and to T_{max} alternately. Transfer time is within 30 s or less. Use operating mode 1.2 as defined in ISO 16750-1. The number of cycles refers to Table 10 which relates the mounting location shown in Table A.1.

The transfer time between T_{min} and T_{max} can be extended to 3 min by agreement between the customer and the supplier due to the size of the DUT or test setup feasibility. If the transfer time exceeds 3 min, this test can be skipped by agreement between the customer and the supplier. In case of doubt, a separate measurement can be performed to determine how long the transfer time shall be.

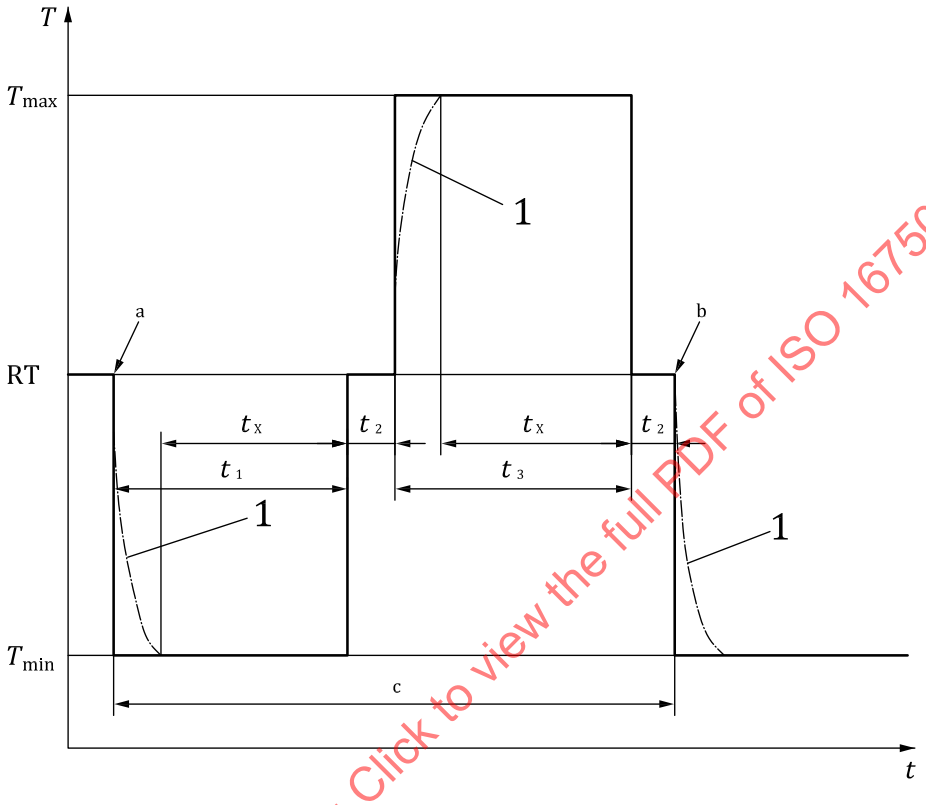
NOTE 1 As a background of possible extension to 3 min of the transfer time, in case of large DUT (e.g. commercial vehicle e-motor), it is possible that the transfer time is longer than 30 s for applying this test.

NOTE 2 It can be difficult for large and heavy components (e.g. e-motor over 100 kg), to fulfil Test Na with a transfer time of 3 min. In such cases an alternative testing approach can be agreed between the customer and the supplier (e.g. IEC 60068-2-14, Test Nb).

Keep the DUT at T_{min} or T_{max} for a given dwell time t_x after thermal equilibrium of the DUT is obtained. The customer and the supplier shall agree on a complete profile of temperature cycle, including dwell time and stabilisation time, depending on the size and other properties of the DUT. In case of doubt, a separate measurement (with DUT in operating mode 2.1 as defined in ISO 16750-1) can be performed to determine how long the exposure time shall be at T_{max} or T_{min}. If operating mode 2.1 is not technically feasible for the separate temperature measurement, operating mode 1.2 as defined in ISO 16750-1

can be used as agreed between the customer and the supplier. The measuring point of DUT shall be agreed between the customer and the supplier, considering a target device and its heat capacity (e.g. microprocessor, motor coil). Ambient temperature needs to be kept at the required temperature until thermal equilibrium is obtained. The dwell time of DUT at T_{min} and T_{max} shall be more than 10 min each per temperature cycle (see key t_x in Figure 6).

Upon agreement between the customer and the supplier, this test may be performed during the development of the DUT with opened housing or without housing.



Key

T	temperature, in °C
t	time, in min
1	DUT temperature
T_{max}	maximum operating temperature (see Table 1)
T_{min}	minimum operating temperature (see Table 1)
t_1, t_3	exposure time at T_{min} or T_{max}
t_2	transfer time
t_x	dwell time at T_{min} or T_{max} (≥ 10 min)
a	Start of first cycle.
b	End of first cycle and start of second cycle.
c	One cycle.

Figure 6 — Temperature cycle changes with specified transition duration

5.3.2.3 Requirement

The functional status shall be class C as defined in ISO 16750-1.

5.4 Cold water shock tests

5.4.1 Purpose

The purpose of the test is to simulate the thermal shock induced by cold water splashing over a hot system/component. This happens when driving on wet roads in winter and applies to products in the splash areas of the vehicle. The failure modes are a mechanical cracking of materials or seal failures caused by different temperature expansion coefficients. Additional failure modes not addressed in 5.3.2.1 are loss of tightness and/or intrusion of water into the system/component.

There are two possible methods to perform this test (see 5.4.2 and 5.4.3). For all components mounted over the fording depth, the submersion test can be skipped.

NOTE This is not a corrosion test.

5.4.2 Splash water test

5.4.2.1 Test method

The DUT shall be tested with the following procedure as one cycle. The procedure of c) and g) and transfer time (t_{t1} and t_{t2} in Figure 8) may be skipped in case of using one single chamber with both heating and splashing.

a) Place the DUT with operating mode 1.2 as defined in ISO 16750-1 (see key b in Figure 8) in a chamber at T_{max} for the specified holding time, t_{h1}.

b) During the last 15 min of holding time, operating mode is switched to 3.2 or 4.2 as defined in ISO 16750-1 (see key c in Figure 8) to induce self-heating of the DUT.

c) The operating mode is switched to 1.1 or 1.2 (see key a in Figure 8) and the DUT is moved into splash area within t_{t1}.

d) The operating mode is switched to 3.2 or 4.2 again when the DUT has been set in test equipment for splash test.

e) Splash the DUT with cold water for 3 s (see key t_s in Figure 8) within "$t_p - t_{t1} \leq 1$ min".

f) After splash, the operating mode is continuously kept as 3.2 or 4.2 for 2 min or more (see key t_{h2} in Figure 8).

g) The operating mode is switched to 1.1 or 1.2, and the DUT is moved back into a chamber.

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 DUT is splashed from various directions in the vehicle, then these directions shall be taken into account. In this case, use an additional 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 a DUT of considerable size is splashed and proven too big for one jet, arrange several jets in a row to produce a line of splash impact on the DUT, see Figures 7 to 9.

NOTE 1 Difference between a high-pressure load during holding time and a low-pressure load during splash time can be caused by the initial humidity inside the DUT. It is important to store the DUT for a sufficient time in the initial state defined as the general test condition (see ISO 16750-1).

Test parameters include the following.

— Number of cycles: 100.

— Holding time, t_{h1}, at T_{max}: 1 h or until thermal equilibrium of the DUT is obtained. The longest of the two durations shall be selected.

— First transfer time, t_{t1}: < 20 s (for manual transfer of the DUT between temperature storage and splashing). The transfer time can be extended to 3 min by agreement between the customer and the supplier due to the size of the DUT or test setup feasibility.

— Second transfer time, t_{t2}: t_{t2} can be set in consideration of the effect of once again reaching temperature equilibrium in t_{h1}.

— Preparation time for splash, t_p: $t_p - t_{t1} \leq 1$ min. The preparation time for splash shall be as short as possible to minimise the temperature drop of the DUT.

— Test fluid: water.

— Water temperature: 0 °C to +4 °C.

— Water flow: between 3 l and 4 l per 3 s (splash time, t_s).

— Holding time after splash, t_{h2}: ample time to allow cold water to affect sealings, crevices, etc. on the DUT, but at least $t_{h2} \geq 2$ min.

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

— Test cycle: see Figure 8.

— Orientation of the DUT: as in the vehicle.

NOTE 2 As a background of possible extension to 3 min of the transfer time, in case of large DUT (e.g. commercial vehicle e-motor) the transfer time can be longer than 20 s for applying this test.

NOTE 3 The holding time at next cycle can be minimised by shortening of the second transfer time of t_{t2}.

NOTE 4 Substances such as colours, dust, salt or soap can be added to the water in order to improve detectability. When using soap, a small amount of soap is sufficient for reduction of surface tension. If additional substances are added, these can cause corrosive effects in subsequent tests.

Dimensions in millimetres

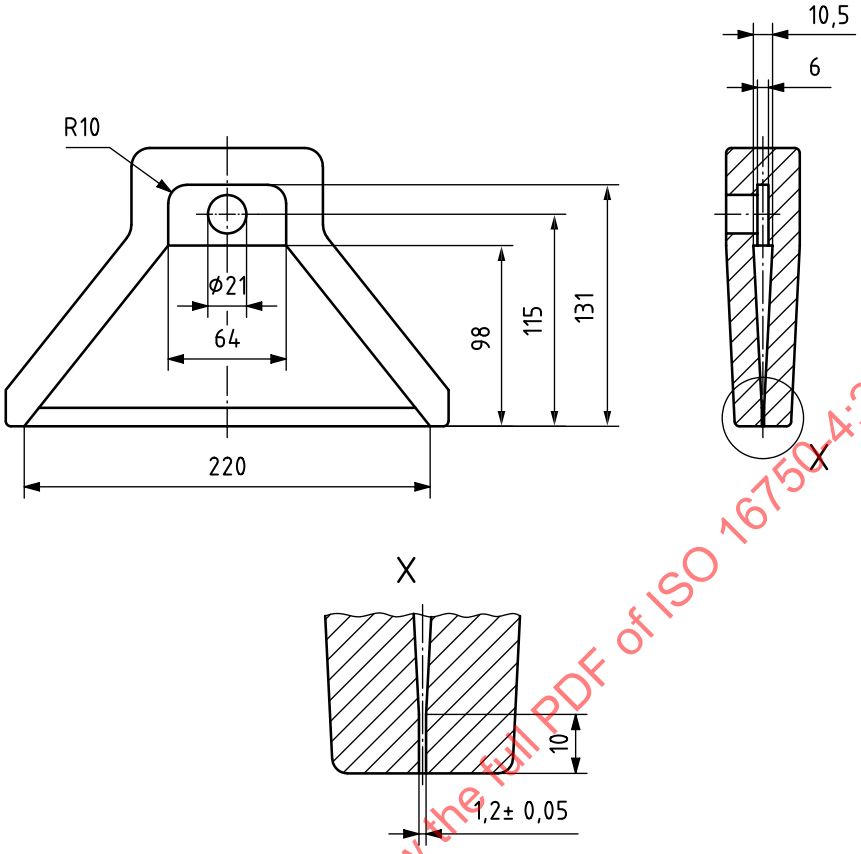
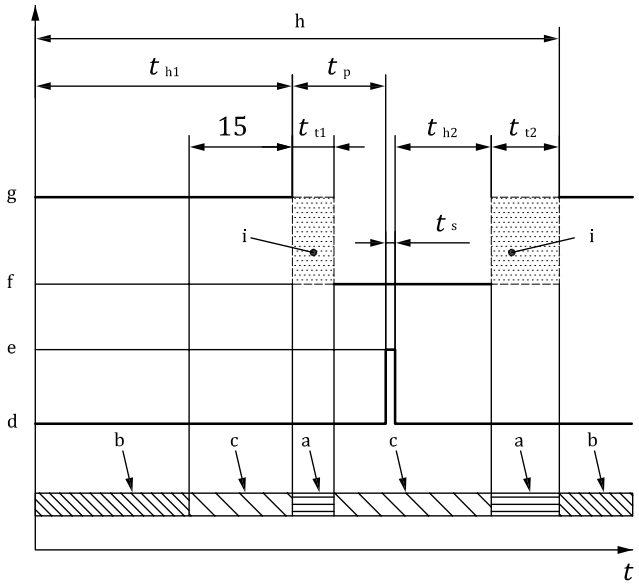


Figure 7 — Jet

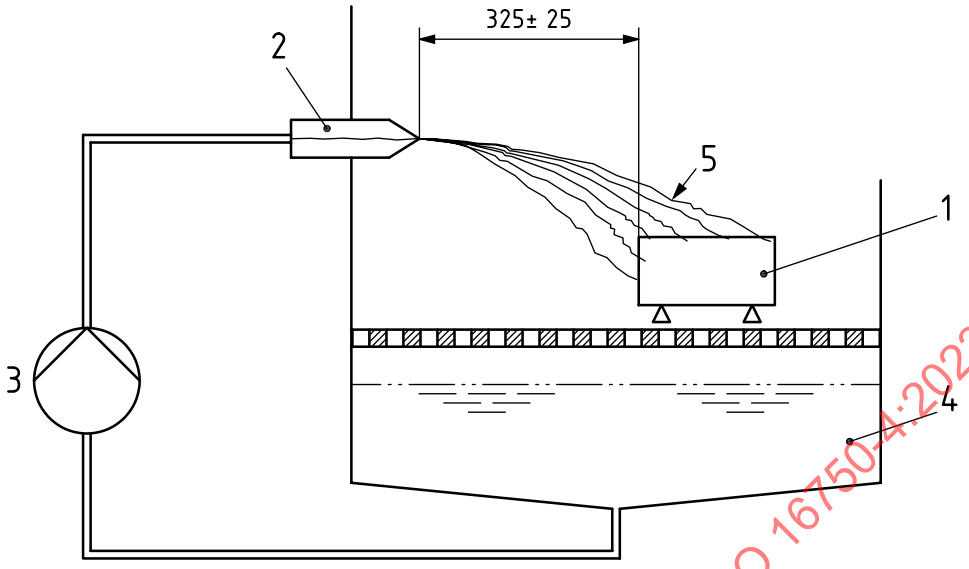


Key

t	time, in min	t_{h1}	holding time at T_{max} (T_{max} is defined in Table 1)
t_p	preparation time for splash	t_{t1}	first transfer time
t_s	splash time	t_{h2}	holding time after splash
t_{t2}	second transfer time		
a	Operating mode 1.1 or 1.2 as defined in ISO 16750-1.	b	Operating mode 1.2 as defined in ISO 16750-1.
c	Operating mode 3.2 or 4.2 as defined in ISO 16750-1.	d	Splash off.
e	Splash on.	f	DUT is in splash area.
g	DUT is in chamber.	h	One cycle.
i	Transfer the DUT.		

Figure 8 — Test cycle for splash water test

Dimensions in millimetres



Key

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

Figure 9 — Test set up for splash water test

5.4.2.2 Requirement

The functional status shall be class A as defined in ISO 16750-1 during active operating modes.

5.4.3 Submersion test

5.4.3.1 Test method

Connect the DUT to the test equipment. Operate the DUT in a chamber at T_{max} as defined in Table 1 for the specified holding time, t_h. With the device still operating, submerge it for 5 min in a cold-water tank, in a depth equal to or greater than 10 mm (see Figure 10). Although operation of the DUT should be kept during the submersion, it is allowed to change its operating modes from 3.2 or 4.2 to 1.2 only during the submersion if agreed between the customer and the supplier due to safety in test.

Test parameters include:

— Number of cycles: 10.

— Holding time t_h at T_{max}: 1 h or until thermal equilibrium of DUT is obtained. The longest of the two durations shall be selected.

— Transfer time, t_t: < 20 s. The transfer time can be extended to 3 min by agreement between the customer and the supplier due to the size of DUT or test setup feasibility.

— Test fluid: water.

— Water temperature: 0 °C to +4 °C.

— Immersion time: 5 min.

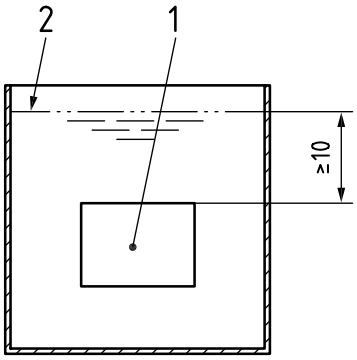
— Operating mode: 3.2 or 4.2 as defined in ISO 16750-1.

— Orientation of the DUT: as in the vehicle.

NOTE 1 As a background of possible extension to 3 min of the transfer time, in case of large DUT (e.g. commercial vehicle e-motor) the transfer time can be longer than 20 s for applying this test.

NOTE 2 Substances such as colours, dust, salt or soap can be added to the water in order to improve detectability. When using soap, a small amount of soap is sufficient for reduction of surface tension. Before adding additional substances, it is noted that these can cause corrosive effects in subsequent tests.

Dimensions in millimetres



Key

1 DUT

2 water surface

Figure 10 — DUT in a cold-water tank

5.4.3.2 Requirement

The functional status shall be class A as defined in ISO 16750-1 during active operating modes.

5.5 Salt spray tests

5.5.1 General

Salt spray tests consist of four types of tests, each one described below.

Corrosion test is applied to check the resistance of materials and surface coatings of a system/component (see 5.5.2).

Leakage and function type of test is applied to check the functional influence by the ingress of salt water. For DUTs except rotating machines with open housing (e.g. alternator, integrated starter generator), use test described in 5.5.3. For rotating machines with open housing, use test described in 5.5.4, which is more effective than 5.5.3 to detect the corrosion on energized parts.

Salt spray combined cycle test can be an accelerated corrosion test based on the tests defined in 5.5.2 and 5.5.3. For sealed systems/components, salt spray combined cycle test may be used to substitute 5.5.2 and 5.5.3. For unsealed systems/components which have an electrical failure mechanism by the ingress of salt water, this test may be used to substitute only the salt spray test of 5.5.2 (see 5.5.5).

Another cyclic corrosion test (5.5.6) can be used aiming to reproduce field-correlating results (e.g. cosmetic corrosion, crevice corrosion and galvanic corrosion). The cyclic corrosion test may be used by agreement between the customer and the supplier. For sealed system/component, cyclic corrosion test may be used to substitute 5.5.2 and 5.5.3. For unsealed system/component which has an electrical failure mechanism by the ingress of salt water, this test may be used to substitute only the test in 5.5.2.

The applied tests shall be decided by agreement between the customer and the supplier.

5.5.2 Corrosion test

5.5.2.1 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.

5.5.2.2 Pre-conditioning

Whether to apply cleaning procedure on the DUT before the test shall be prescribed. In case of applying the cleaning procedure, it shall be stated whether temporary protective coatings are removed or not.

The cleaning method used should not interfere with the effect of the salt mist on the test specimen, nor introduce any secondary corrosion.

Touching of the test surface by hand is recommended to avoid as far as possible before the test.

5.5.2.3 Test condition

Check test condition in accordance with ISO 9227:2022, 9.2, 9.4 and Clause 10.

5.5.2.4 Test method

Perform the test in accordance with IEC 60068-2-52:2017, test method 4 or 5. Depending on the mounting location, the climatic requirement code is selected (see Table A.1). Test method is selected from Table 10 according to this climatic requirement code. A neutral salt solution in accordance with IEC 60068-2-11:2021, Clause 5 shall be used. Use operating mode 1.2 as defined in ISO 16750-1. In the case of rotating components with open housings, operation mode 3.3 or 4.3, respectively, can be applied in a short time at standard atmosphere to avoid moving parts being blocked by corrosion. The number of activations as well as the duration of the activation shall be agreed between the customer and the supplier, but should be kept to a minimum.

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. Also dismantle the DUT to do an internal inspection. If needed, a microscopy can be used as a complement to visual inspection with naked eye.

5.5.2.5 Requirements

There shall be no changes that could impair performance, e.g. sealing function, marking and labelling shall remain visible and legible. Specific criteria for appearance of the DUT after test shall be agreed between the customer and the supplier before the test.

The minimum functional status shall be class C as defined in ISO 16750-1.

5.5.3 Leakage and function test

5.5.3.1 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.

NOTE It is possible that the electrical malfunction does not occur immediately in response to the wetness ingress, but can be a result of prolonged exposure to moisture and corrosion effects, therefore even signs of wetness ingress without immediate electrical malfunction are considered.

5.5.3.2 Pre-conditioning

Perform pre-conditioning in accordance with 5.5.2.2.

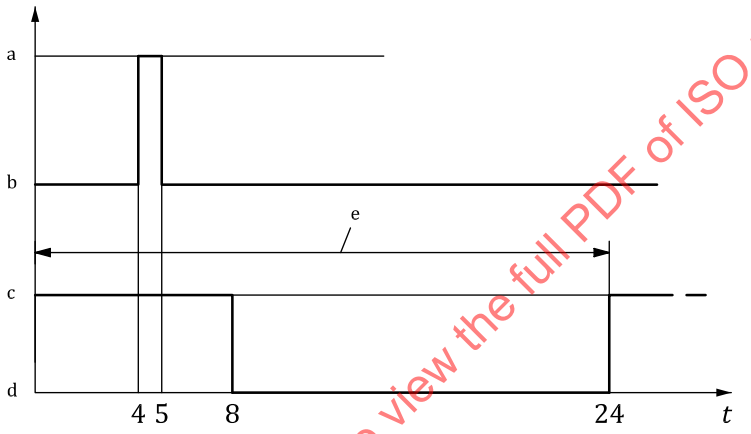
5.5.3.3 Test condition

Check test condition in accordance with ISO 9227:2022, 9.2, 9.4 and Clause 10.

5.5.3.4 Test method

Perform the test cycle shown in Figure 11, in accordance with IEC 60068-2-11:2021, Clauses 6 and 11. The duration of one cycle is 24 h. Spray on the DUT for 8 h, then stop spraying for a rest period of 16 h. Operate the DUT with operating mode 3.2 or 4.2 as defined in ISO 16750-1 between the fourth and fifth hour of each cycle.

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



Key

t time, in h
a Operating mode 3.2 or 4.2 as defined in ISO 16750-1.
b Operating mode 1.2 as defined in ISO 16750-1.
c Salt spray on.
d Salt spray off.
e One cycle.

Figure 11 — Test cycle for salt spray test

5.5.3.5 Requirements

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

The functional status shall be class A as defined in ISO 16750-1 during active operating modes.

5.5.4 Salt spray active test for rotating machines with open housing

5.5.4.1 Purpose

This test checks the resistance of a system/component to salt mist and salt water on winter streets. The test is used for rotating machines with open housings (e.g. alternators, integrated starter generators). It simulates the corrosion load during operating of the component. The failure mode is corrosion, especially on energized parts.

5.5.4.2 Pre-conditioning

Perform pre-conditioning in accordance with 5.5.2.2.

5.5.4.3 Test condition

Check test condition in accordance with ISO 9227:2022, 9.2, 9.4 and Clause 10.

5.5.4.4 Test method

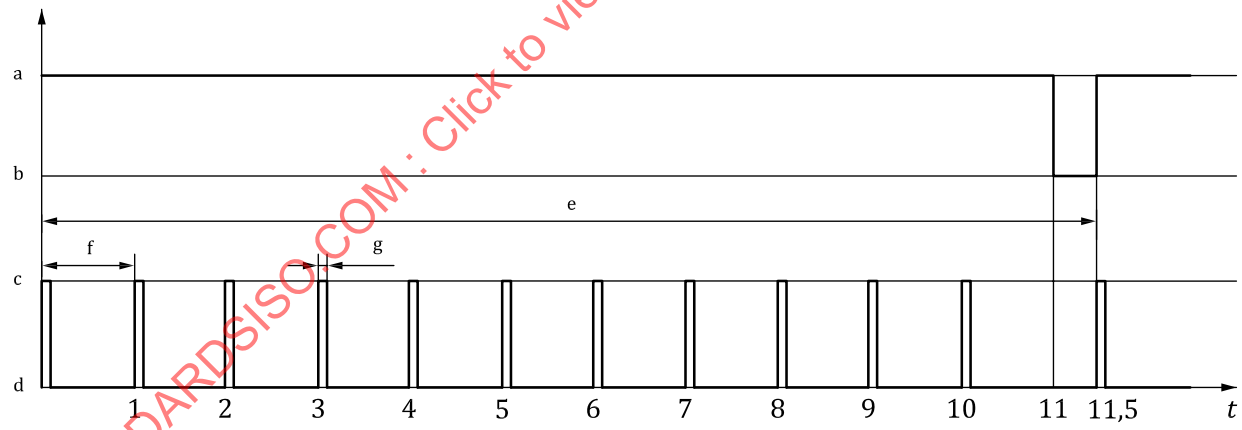
A neutral salt solution in accordance with IEC 60068-2-11:2021, Clause 5 shall be used, but with a significantly reduced sodium chloride content. Concentration of the sprayed solution collected shall be (5 ± 0,5) g/l.

Install the DUT in the chamber, with the mounting orientation as in the vehicle.

Perform the test cycle shown in Figure 12. The duration of one sub cycle is 1 h. Spray for 6 min (see key g in Figure 12), then stop spraying for a rest period of 54 min. The DUT is run at typical idle speed with operating mode 3.3 or 4.3 as defined in ISO 16750-1. After 11 sub cycles, stop spraying for a rest period of 30 min with operating mode 2.1. With these as one cycle, the number of cycles is 8 cycles for the DUT in the protected mounting position (e.g. protected by surrounding parts like underbody panel). For components in the unprotected mounting position, the number of cycles is 16 cycles. Whether the DUT is in protected mounting position shall be agreed between the customer and the supplier.

Ambient temperature outside of the chamber shall be (23 ± 5) °C. The temperature inside the chamber is not controlled. The temperature may increase due to waste heat of the DUT.

The continuous monitoring (e.g. output voltage, output current) during the test can be performed by agreement between the customer and the supplier.



Key

t time, in h

a Operating mode 3.3 or 4.3 as defined in ISO 16750-1 at typical idle speed.

b Operating mode 2.1 as defined in ISO 16750-1.

c Salt spray on.

d Salt spray off.

e One cycle.

f One sub cycle.

g Spraying time.

Figure 12 — Test cycle for salt spray active test

5.5.4.5 Requirements

There shall be no changes that could impair performance, e.g. electrical function. Specific criteria for appearance of the DUT after test shall be agreed between the customer and the supplier before the test.

The functional status shall be class A as defined in ISO 16750-1 during active operating modes.

5.5.5 Salt spray combined cycle test

5.5.5.1 Purpose

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

5.5.5.2 Pre-conditioning

Perform pre-conditioning in accordance with 5.5.2.2.

5.5.5.3 Test condition

Check test condition in accordance with ISO 9227:2022, 9.2, 9.4 and Clause 10.

5.5.5.4 Test method

Perform the test in accordance with IEC 60068-2-52:2017, test method 7. A neutral salt solution in accordance with IEC 60068-2-11:2021, Clause 5 shall be used.

Select the severity which corresponds to the mounting location in Table A.1. An example of severity levels in a passenger vehicle is given in Figure A.1. The number of cycles for substitution of 5.5.2 corrosion test shall be determined from Table 7 by using the selected severity. The number of cycles for substitution of 5.5.3 leakage and function test is 8 cycles. Background information to determine the number of cycles of the salt spray combined cycle test to be carried out is given in Annex B. If the severity of each mounting location is not specified, it should be agreed between the customer and the supplier.

Table 7 — Number of cycles for the corrosion test

Severity	Number of cycles
1	8
2	15
3	30
4	60

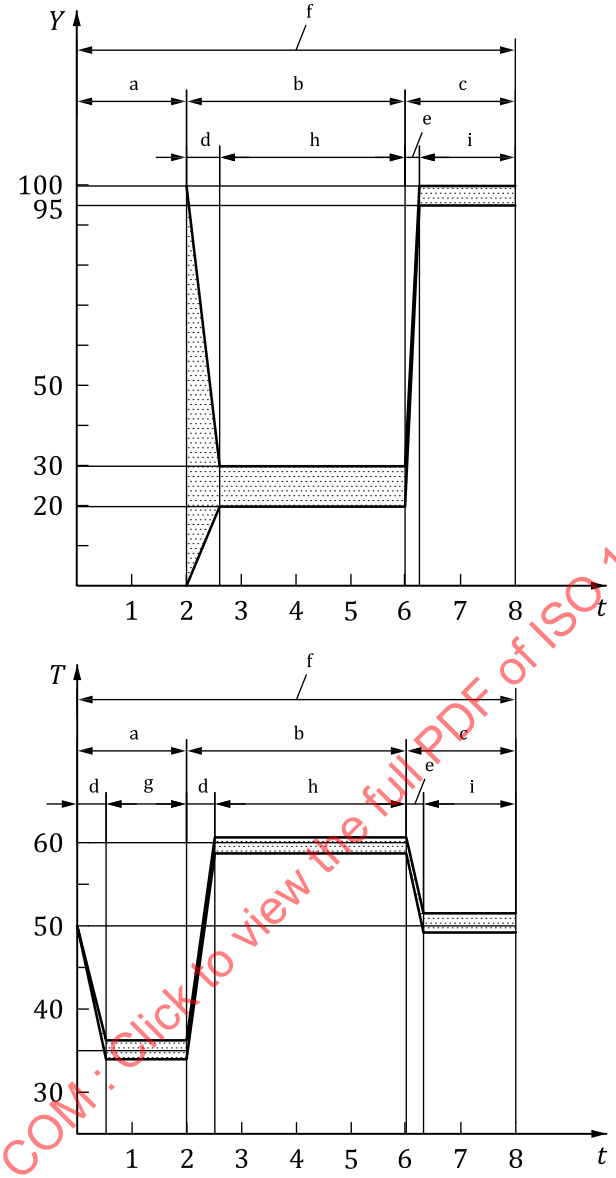
Perform the test cycle shown in Figure 13. The duration of one cycle is 8 h; spray the DUT for 2 h, then stop spraying for a dry period of 4 h and continue with a humidity period of 2 h.

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 ± 1) °C.

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

At the end of dry period, the DUT shall be subjected to the humid condition and stored at a temperature of (50 ± 1) °C and with a relative humidity of more than 95 % for a period of 2 h.

Use operating mode 1.2 as defined in ISO 16750-1 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 Exposure time (1,5 h).

h Exposure time (3,5 h).

i Exposure time (1,75 h).

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

Figure 13 — Test cycle for the salt spray combined cycle test

5.5.5.5 Recovery

The temperature of the water used for washing shall not exceed 35 °C. 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, air blasted at a distance of approximately 300 mm with an overpressure not exceeding 200 kPa to remove droplets of water and then dried for 1 h to 4 h at (55 ± 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.

5.5.5.6 Requirements

There shall be no changes that could impair performance, e.g. sealing function, marking and labelling shall remain visible and legible. Specific criteria for appearance of DUT after test shall be agreed between the customer and the supplier before the test.

The minimum functional status shall be class C as defined in ISO 16750-1.

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

5.5.6 Cyclic corrosion test

5.5.6.1 Purpose

This test checks the resistance of materials and surface coatings of a system/component to salt mist and salt water on streets in winter in diverse humidity conditions. This test generates corrosion simulating actual use in the market with precise control of temperature and humidity. The failure mode is corrosion (e.g. cosmetic corrosion, crevice corrosion and galvanic corrosion).

NOTE The typical testing time of six weeks is proposed as a stress representing three years in a severe corrosive market/vehicle location.

5.5.6.2 Pre-conditioning

Perform pre-conditioning in accordance with 5.5.2.2.

5.5.6.3 Test condition

Check test condition in accordance with ISO 9227:2022, 9.2, 9.4 and Clause 10.

5.5.6.4 Test method

Perform the test in accordance with ISO 11997-3.

The typical testing time is six weeks. It is recommended to adjust the testing time by agreement between the customer and the supplier. It can be reduced to three weeks for parts exposed to a lower corrosive load or the testing time can be increased to nine weeks for parts exposed to a higher corrosive load, considering the stress during the actual use of products.

Install the DUT with mounting orientation as in vehicle in the chamber. Use operating mode 1.2 as defined in ISO 16750-1 during the complete test sequence. By means of agreement between the customer and the supplier, the operating mode can be changed to 2.1 or 3.1 to allow for possible corrosion driven by applied voltage (e.g. electro-migration).

5.5.6.5 Recovery

Perform recovery in accordance with 5.5.5.5.

5.5.6.6 Requirements

There shall be no changes that could impair performance, e.g. sealing function, marking and labelling shall remain visible and legible. Specific criteria for appearance of the DUT after test shall be agreed between the customer and the supplier before the test.

The minimum functional status after the test shall be class C as defined in ISO 16750-1.

5.6 Humid heat, cyclic tests

5.6.1 Purpose

These tests simulate the use of the systems/components under cyclic high ambient humidity. The failure mode is an electrical malfunction caused by leakage current and corrosion. Leakage current and corrosion occurs on a printed circuit board (PCB) or between terminals of external interface connectors due to moisture. Also, they can occur due to condensation with ambient temperature change. Long-time exposure of moisture accumulation by humid air breathing effect produces such internal corrosion (e.g. electrochemical migration on surface of a PCB or discrete PCB mounted components). Also surface condensation with ambient temperature change can make such terminal leakage occur.

5.6.2 Test method

5.6.2.1 General

Perform the following tests given in the code for climatic loads in Table 10 depending on the mounting location shown in Table A.1. The continuous monitoring (e.g. quiescent current, operating current) during these tests (5.6.2.2, 5.6.2.3 and 5.6.2.4) can be performed by agreement between the customer and the supplier.

NOTE Measurement of quiescent current/operating current consumption during the test can show that any of the failure modes indicated in 5.6.1, or any changes that could lead to the mentioned failure modes, does not occur during or after the test. Measurement accuracy in time and magnitude as well as pass/fail criteria for the measurements is set by agreement between the customer and the supplier.

5.6.2.2 Test 1: Damp heat cyclic test

Perform the test in accordance with IEC 60068-2-30:2005, Test Db, Variant 1:

— upper temperature: (55 ± 2) °C;

— number of cycles: 6.

Perform a functional test with operating mode 3.3 as defined in ISO 16750-1 for the shortest possible duration when the maximum temperature is reached. Use operating mode 2.1 as defined in ISO 16750-1 except while performing a functional test.

5.6.2.3 Test 2: Composite temperature/humidity cyclic test

Perform the test in accordance with IEC 60068-2-38, Test Z/AD.

Perform a functional test with operating mode 3.3 as defined in ISO 16750-1 for the shortest possible duration when the maximum temperature is reached. Use operating mode 2.1 as defined in ISO 16750-1 except while performing a functional test.

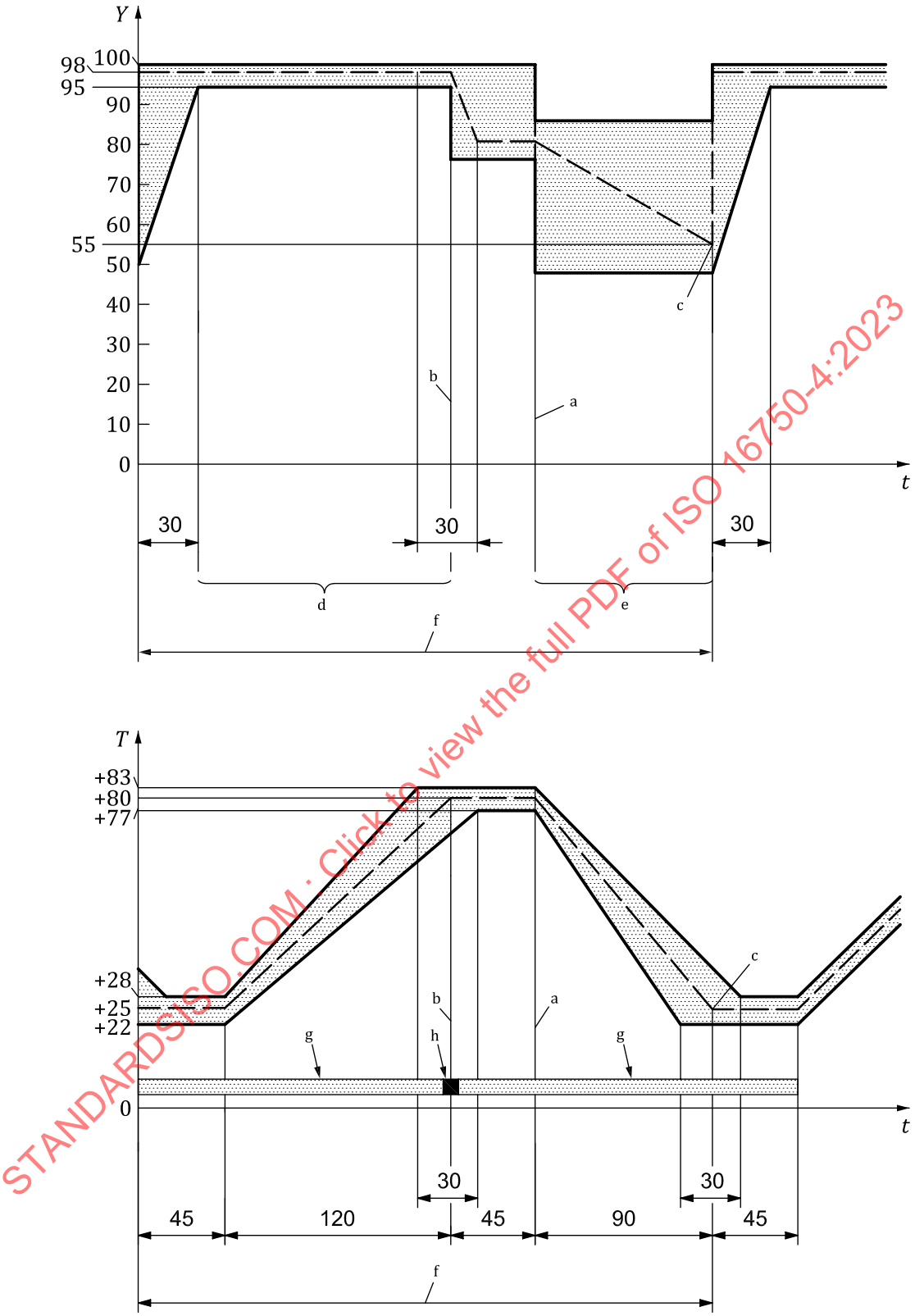
5.6.2.4 Test 3: Dewing test

Perform the test in accordance with IEC 60068-2-30, using the variant illustrated in Figure 14:

— upper temperature: (80 ± 3) °C;

— number of cycles: 5.

Perform a functional test with operating mode 3.3 as defined in ISO 16750-1 for the shortest possible duration when the maximum temperature and humidity are reached. Use operating mode 2.1 as defined in ISO 16750-1 except while performing a functional test.



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.

g Operating mode 2.1 as defined in ISO 16750-1.

h Functional test with operating mode 3.3 as defined in ISO 16750-1.

Figure 14 — Dewing test cycle

5.6.3 Requirements

The functional status shall be class A as defined in ISO 16750-1 during active operating modes for all three tests.

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.

5.7 Damp heat, steady state test

5.7.1 Purpose

This test simulates the use of the systems/components under steady high ambient humidity. The failure mode is an electrical malfunction caused by leakage current and corrosion. Leakage current and corrosion occurs on a PCB or between terminals of external interface connectors due to moisture by diffusion gradients (e.g. electrochemical migration on surface of PCB or discrete PCB mounted components, or conductive anodic filament within the PCB).

5.7.2 Test method

Perform the test in accordance with IEC 60068-2-78, Test Cab, with the following test conditions:

— test duration: 21 days;

— severity: (40 ± 2) °C and (93 ± 3) % humidity;

— operating mode:

  — operating mode 2.1 as defined in ISO 16750-1 for a duration of 20 days and 23 h;

  — operating mode 3.3 as defined in ISO 16750-1 for the last one hour of the test.

The continuous monitoring (e.g. quiescent current, operating current) during this test can be performed by agreement between the customer and the supplier.

NOTE Measurement of quiescent current/operating current consumption during the test can show that any of the failure modes indicated in 5.7.1, or any changes that could lead to the mentioned failure modes, does not occur during or after the test. Measurement accuracy in time and magnitude as well as pass/fail criteria for the measurements is set by agreement between the customer and the supplier.

5.7.3 Requirements

For systems which are powered while the engine is shut off, functional status shall be class A as defined in ISO 16750-1, for the entire test duration. Functional status of other systems shall be minimum class C up to the last hour and class A for the last one hour.

5.8 Condensation test

5.8.1 Purpose

This test simulates condensation by rapid change of temperature and humidity. Such condensation can occur when the vehicle moves in a warm garage from a cold outside or when opening vehicle windows hot and humid air flows into the cabin cooled and dried by air conditioner. The failure mode is an electrical malfunction caused by leakage current and corrosion. Leakage current and corrosion occurs on a PCB or between terminals of external interface connectors due to moisture. Also, they can occur due to condensation with ambient temperature change. Long-time exposure of moisture accumulation by humid air breathing effect produces such internal corrosion (e.g. electrochemical migration on surface of PCB or discrete PCB mounted components).

5.8.2 Test method

Select a type in Table 8 referring to 5.8 in Table 10 which relates the mounting location shown in Table A.1 to the applied type.

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

Perform the test based on Table 8 (refer to Figure 16 or Figure 17 as test profiles as well).

In order to achieve sufficient dew condensation on the DUT in high temperature and high humidity stage, temperature on the DUT should be monitored and compared with the dew point calculated from the setting temperature and humidity. The duration in high temperature and high humidity stage may be extended if the temperature on the DUT does not reach the calculated dew point within the set duration. The duration in high temperature and high humidity stage (for type A) or in de-humidification stage (for type B) shall be extended if the DUT does not dry before the start of next stabilizing stage.

Ensure that the DUT temperature reaches the specified temperature before the low temperature stage of each cycle (see Figure 15 regarding the stabilizing stage).

Functional test (operating mode 3.3 as defined in ISO 16750-1) shall be performed two times per cycle as described below as first and second functional tests. The first functional test shall be performed as soon as the ambient temperature reaches the maximum temperature level or the ambient humidity reaches the maximum humidity level, as condensation is then present (refer to the figures for functional test and operation mode). The first functional test shall be completed in the shortest possible duration in order to minimize the effect of self-heating on the condensation. The first functional test is selected from one of the timings showed by b_1 or b_2 in Figure 16 and Figure 17, depending on mass classification of the DUT. The timing b_1 applies to small and lightweight DUTs. The timing b_2 applies to a large and heavy DUTs.

Second functional test shall be performed at the end of stage with maximum temperature and humidity shown by b_3 in the figures for checking the DUT condition.

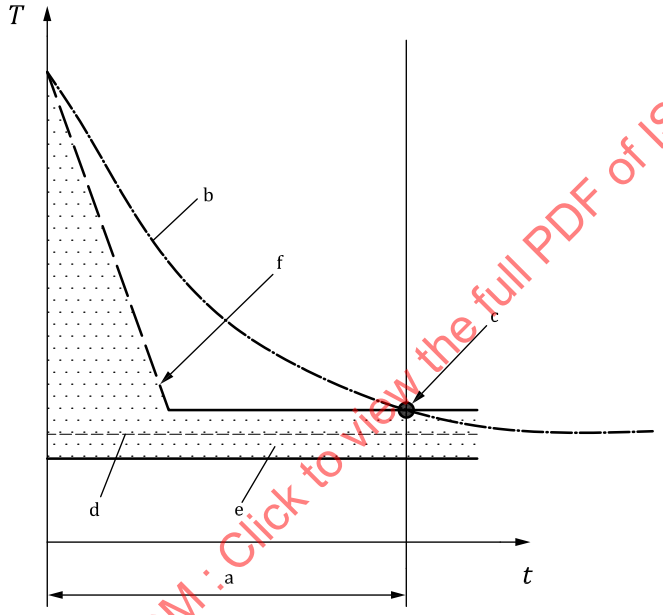
The continuous monitoring (e.g. quiescent current, operating current) during this test can be performed by agreement between the customer and the supplier.

NOTE Measurement of quiescent current/operating current consumption during the test can show that any of the failure modes indicated in 5.8.1, or any changes that could lead to the mentioned failure modes, does not occur during or after the test. Measurement accuracy in time and magnitude as well as pass/fail criteria for the measurements is set by agreement between the customer and the supplier.

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

Table 8 — Temperature, humidity and duration of each stage of the condensation test

Type	Stabilizing stage		Low temperature stage		High temperature and high humidity stage		De-humidification stage		Number of cycles
	Temperature	Duration	Temperature	Duration	Temperature/ humidity	Duration	Temperature/ humidity	Duration	
A	(10 ± 3) °C	See NOTE	(10 ± 3) °C	2 h	(50 ± 3) °C (70 ± 5) %	3 h	—	—	3
B	(−30 ± 3) °C		(−30 ± 3) °C	1 h	(25 ± 3) °C (90 ± 5) %	1 h	(25 ± 3) °C Less than 50 %	1,5 h	5
NOTE The duration of stabilizing stage is determined by a separate measurement or automatic control to detect when the DUT temperature has reached the temperature tolerance of low temperature stage, and also obtained thermal equilibrium.									



Key

t time, in h

T temperature, in °C

a Stabilizing stage.

b DUT temperature.

c Point at which DUT temperature reaches the upper tolerance limit of low temperature stage.

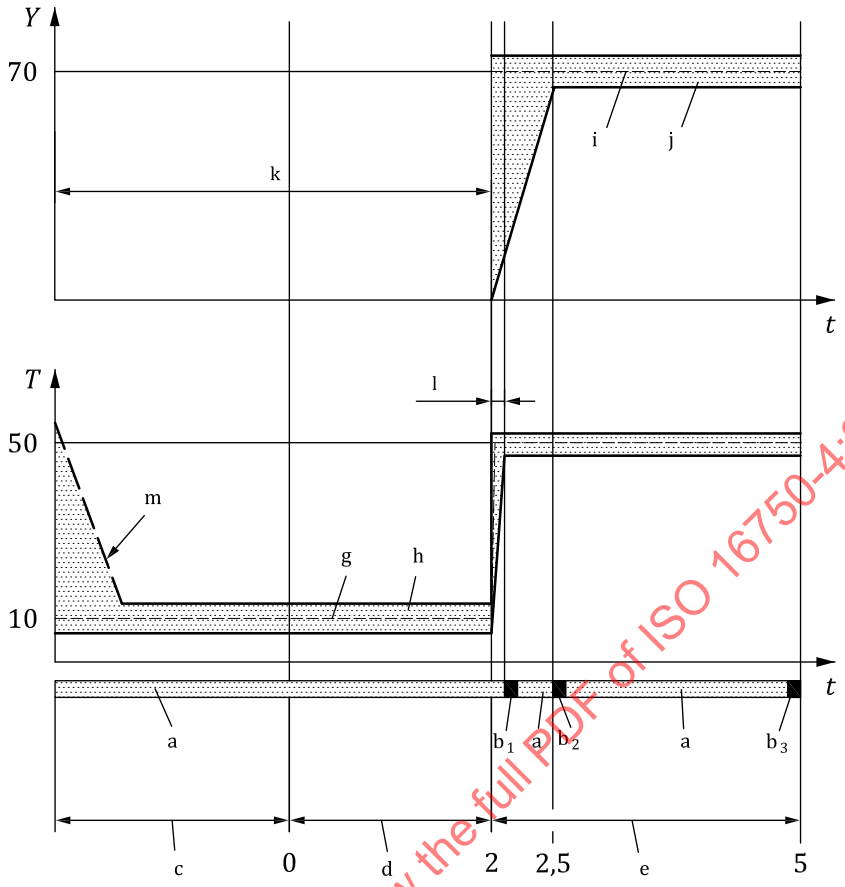
d Control target value of chamber temperature.

e Tolerance of chamber temperature.

f No specific rate of cooling is required.

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

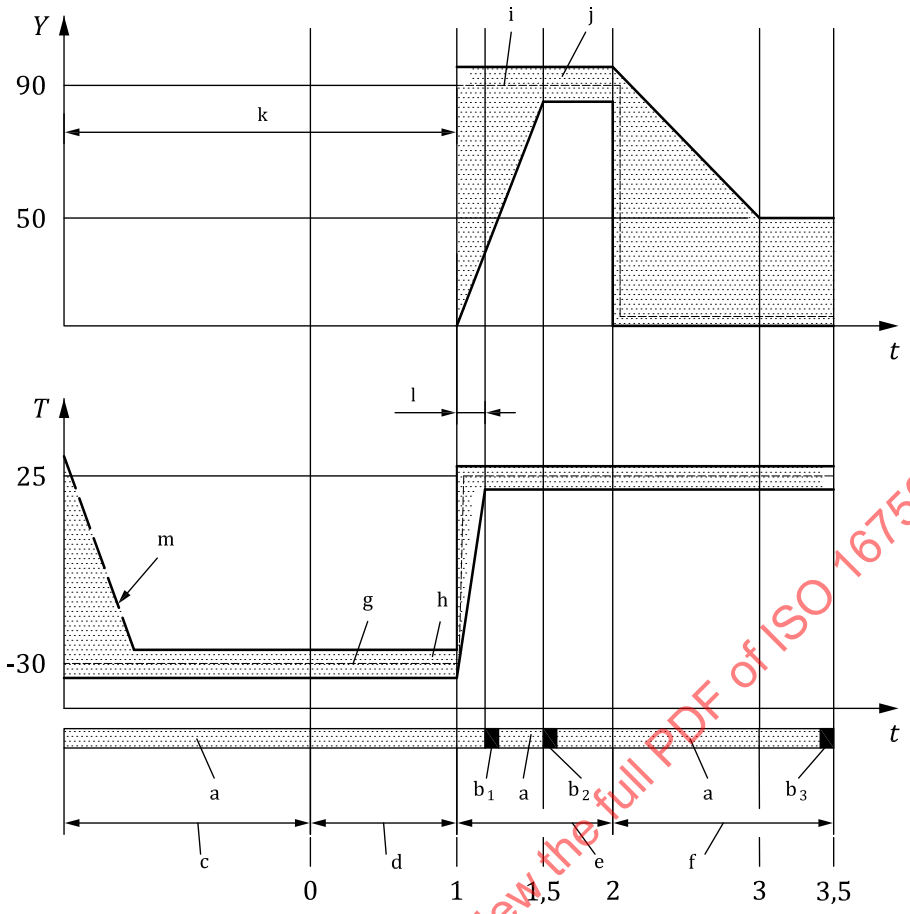
Figure 15 — Stabilizing stage



Key

t	time, in h
Y	relative humidity, in %
T	ambient temperature, in °C
a	Operating mode 1.2 as defined in ISO 16750-1.
b_1	First functional test for small and lightweight DUTs with operating mode 3.3 as defined in ISO 16750-1.
b_2	First functional test for large and heavy DUTs with operating mode 3.3 as defined in ISO 16750-1.
b_3	Second functional test with operating mode 3.3 as defined in ISO 16750-1.
c	Stabilizing stage.
d	Low temperature stage.
e	High temperature and high humidity stage.
g	Control target value of chamber temperature.
h	Tolerance of chamber temperature.
i	Control target value of chamber humidity.
j	Tolerance of chamber humidity.
k	Uncontrolled humidity.
l	Less than 5 min.
m	No specific rate of cooling is required.

Figure 16 — Condensation test (type A)



Key

t	time, in h
Y	relative humidity, in %
T	ambient temperature, in °C
a	Operating mode 1.2 as defined in ISO 16750-1.
b_1	First functional test for small and lightweight DUTs with operating mode 3.3 as defined in ISO 16750-1.
b_2	First functional test for large and heavy DUTs with operating mode 3.3 as defined in ISO 16750-1.
b_3	Second functional test with operating mode 3.3 as defined in ISO 16750-1.
c	Stabilizing stage.
d	Low temperature stage.
e	High temperature and high humidity stage.
f	De-humidification stage.
g	Control target value of chamber temperature.
h	Tolerance of chamber temperature.
i	Control target value of chamber humidity.
j	Tolerance of chamber humidity.
k	Uncontrolled humidity.
l	Less than 5 min.
m	No specific rate of cooling is required.

Figure 17 — Condensation test (type B)

5.8.3 Requirement

The functional status shall be class A as defined in ISO 16750–1 during operating mode 3.3.

5.9 Corrosion test with flow of mixed gas

5.9.1 Purpose

This test simulates the use of the systems/components in the presence of corrosive gases, e.g. in polluted atmospheres. The failure mode is an electrical malfunction caused by conductive corrosion or corrosive product on the surface of electrical/electronic components. 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 systems/components.

NOTE The various gases used in this test can affect both the casing/surface of a DUT as well as the electrical/electronic components inside the DUT (e.g. corrosion/breakdown of for instance silver content in electronic components and PCB). It is important to look for signs of detriment (e.g. corrosion products, spot wise discoloration, tarnishing of terminals), even though these corrosion effects might not be visible on function level during the testing.

5.9.2 Test method

Perform the test in accordance with IEC 60068-2-60:2015, method 4. The operating mode is 1.2 as defined in ISO 16750-1. 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.

Also dismantle the DUT to do internal inspection. If needed, microscopy can be used as a complement to visual inspection with naked eye.

NOTE Operating mode 1.1 with protection seals (e.g. sealed mating connector) can be applicable.

5.9.3 Requirement

The functional status shall be class C as defined in ISO 16750-1.

5.10 Solar radiation test

5.10.1 Purpose

This test simulates the use of the systems/components in an environment with long term exposure to solar radiation. This test is applied to surface treatment (e.g. protective coating), paint marking and labelling pasted on the surface of systems/components mounted in places affected by solar radiation (see Table 10 and Annex A). This test can be skipped when agreed between the customer and the supplier.

5.10.2 Test method

Compliance shall be shown by material test reports, data sheets, or similar. If in need of physical validation, a test shall be performed according to either ISO 4892-2, ISO 4892-3 or ISO 4892-4, chosen by agreement between the customer and the supplier.

5.10.3 Requirements

Allowable surface deterioration (e.g. fading, discoloration, peeling or cracking etc.) shall be agreed between the customer and the supplier.

The marking and labelling shall remain visible and legible (e.g. high voltage caution labels).

5.11 Dust test

5.11.1 Purpose

This test simulates a dust pumping effect caused by temperature changes inside the housing of the systems/components, 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 systems/components.

NOTE Dust intrusion into components can worsen their internal pollution degree and cause malfunctions in combination with other environmental stresses, e.g. moisture.

5.11.2 Test method

Perform the test in accordance with ISO 20653.

The DUT shall be tested with the following procedure as one cycle (see Figure 18).

a) Connect the DUT to the test equipment.

b) Operate the DUT in a chamber with operating mode 3.2 as defined in ISO 16750-1.

c) At the end of operating time, perform dust circulation.

d) After dust circulation, operating mode is changed to 1.2 as defined in ISO 16750-1.

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.

NOTE 1 If the DUT is only partly exposed in vehicle, i.e. if some parts of the DUT are covered by panels, interior, dashboard, etc. in the vehicle installation (e.g. console audio devices), the DUT areas covered in the vehicle can be covered in test setup if agreed between the customer and the supplier.

Test parameters include:

— test dust:

  1) 50 % by weight of limestone (with clay and sand), i.e. “unbaked Portland cement”;

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

    i) 33 % by weight ≤ 32 µm; and

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

Upon agreement between the customer and the supplier, Arizona A2 test dust that is specified in ISO 12103-1 may be used as an alternative to above test dust.

— number of cycles: 20;

— one cycle, e: 20 min;

— operating time, t_o: 5 min; and

— dust circulation time, t_c: 6 s.

NOTE 2 The customer and the supplier can agree on a different cycle time and number of cycles.

For a DUT installed in a passenger compartment or luggage/load compartment, for example, switch and actuator, instead of the test method of ISO 20653 stated above, this test may be performed as defined in SAE J575/JIS D 0207 by agreement between the customer and the supplier.

Test parameters include:

— test dust: Portland Cement (type I) as defined in ASTM C150-07;

— concentration of dust: more than 100 mg/m^3 and less than 3 000 mg/m^3;

— number of cycles: 24;

— one cycle, e: 20 min;

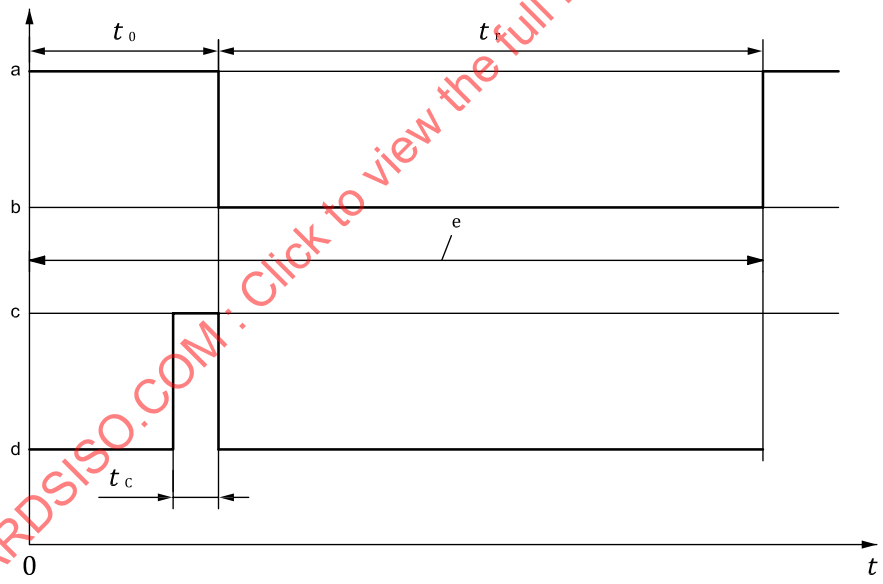
— operating time, t_o: 5 min; and

— dust circulation time, t_c: 6 s.

NOTE 3 The value of concentration of dust is referred from JIS D 0207 for passenger compartment or luggage/load compartment.

NOTE 4 Cycle time can be changed to 15 min by agreement between the customer and the supplier.

NOTE 5 For measurement of concentration of dust, information can be found in JIS Z 8813.



Key

t time, in min
t_o operating time
t_r resting time
t_c dust circulation time
a Operating mode 3.2 as defined in ISO 16750-1.
b Operating mode 1.2 as defined in ISO 16750-1.
c Dust circulation on.
d Dust circulation off.
e One cycle.

Figure 18 — Dust test (one time cycle)

5.11.3 Requirements

The functional status shall be class A during operating mode 3.2 as defined in ISO 16750-1.

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

5.12 Atmospheric pressure test

5.12.1 Purpose

This test simulates an electric phenomenon known as "electric discharge", particular to high voltage use under low atmospheric pressure. This test applies to only voltage class B components.

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 component, 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.

If the electric discharge is not expected to occur due to systems/components composition or their operation, this test can be skipped when agreed between the customer and the supplier.

5.12.2 Test method

Set the DUT in a decompression chamber. Use operating mode 1.2 as defined in ISO 16750-1.

The pressure is decompressed to the value as defined in Table 9.

After reaching the desired pressure value and the pressure in the chamber has stabilised, perform partial discharge test in accordance with IEC 60664-1:2020, 6.4.6. A test voltage U_t is applied as shown in Figure 19.

The test voltage shall be applied between parts of the equipment which are galvanically separated from each other:

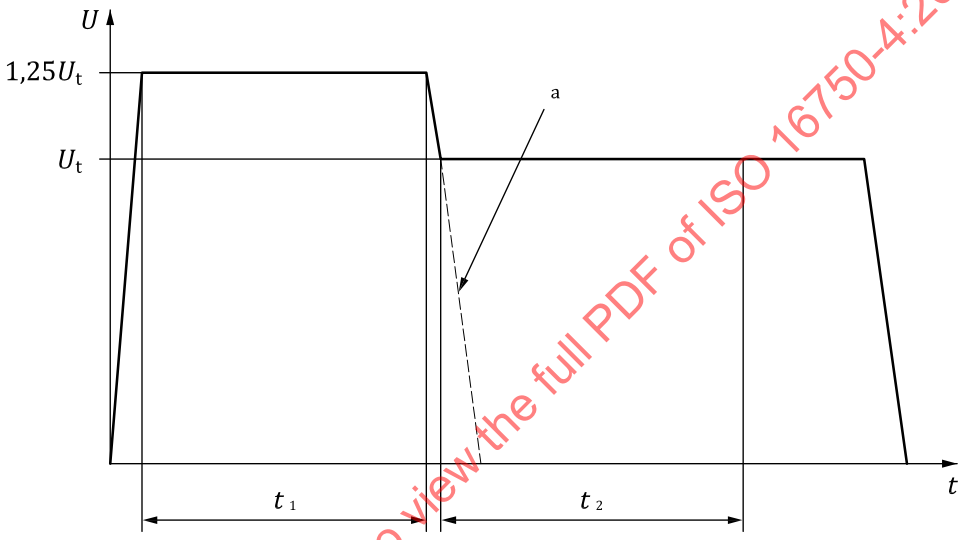
— live parts;

— separate circuits; and

— earthed circuits.

Table 9 — Pressure for atmospheric pressure test

Code	Pressure [kPa]	Altitude [m]
A	54,0	5 000
B	62,0	4 000
C	70,0	3 000
D	80,0	2 000 and lower
Z	As agreed	



Key

U voltage, in V

t time, in min

U_t test voltage, 1,2 × U_X as defined in ISO 16750-1

t_1 time to check for partial discharge, less than 5 s

t_2 time until the partial discharge magnitude is measured

[a] If partial discharge does not occur, the test voltage is reduced to zero after t_1.

Figure 19 — Test voltage

5.12.3 Requirements

Insulation breakdown shall not occur.

Partial discharges may occur, but 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 60664-1:2020, 6.4.6.4.1). It may be changed up to 50 pC by agreement between the customer and the supplier, when it is difficult to keep measurement accuracy.

6 Code for climatic loads

For code letters for climatic loads, see Table 10. Recommended climatic requirements for DUT depending on the mounting location are given in Annex A (Table A.1).

Table 10 — Codes, tests, and requirements

Tests and requirements in accordance with		Code									
Subclause	**Test name** (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	Temperature step[a]	yes	yes	yes	yes	yes	yes	yes	yes	yes	
5.3.1	Temperature cycle with specified change rate	yes	yes	yes	yes	yes	yes	yes	yes	yes	
5.3.2	Rapid change of temperature with specified transition duration (number of cycles)[d]	100, 300	300	100	100, 300	100, 300	100	100	100	100	
5.4	Cold water shock	no	no	no	yes	yes	yes	no	yes	yes	
5.5.2	Salt spray, corrosion (test method)	4	—	—	4	5	—	—	4	5	
5.5.3	Salt spray, leakage and function	yes	no	no	yes	yes	no	no	yes	yes	
5.5.4	Salt spray active test for rotating machines with open housing	yes	no	no	yes	yes	no	no	yes	yes	
5.5.5	Salt spray combined cycle	yes	no	no	yes	yes	no	no	yes	yes	
5.5.6	Cyclic corrosion	yes	no	no	yes	yes	no	no	yes	yes	
5.6	Humid heat, cyclic (test numbers)	2, 3	2, 3	1, 3	2, 3	2, 3	1, 3	1, 3	2, 3	2, 3	
5.7	Damp heat, steady state	yes	yes	yes	yes	yes	yes	yes	yes	yes	
5.8	Condensation (type)	B	B	A	B	B	A	A	B	B	
5.10	Solar radiation	no	no	no	no	no	no	yes	yes	yes	
5.11	Dust	yes	yes	yes[b]	yes	yes	yes[b]	yes[b]	yes	yes	
5.12	Atmospheric pressure[c]	yes	yes	yes	yes	yes	yes	yes	yes	yes	

NOTE 1 The corrosion test with flow of mixed gas in 5.9 is not part of the basic coded specification, but is regarded as a generic test that is applicable regardless of mounting location.

NOTE 2 The salt spray combined cycle (5.5.5) can substitute salt spray, corrosion (5.5.2) and salt spray, leakage and function (5.5.3) according to 5.5.1.

NOTE 3 The cyclic corrosion (5.5.6) can be used by agreement between the customer and the supplier. It can substitute salt spray, corrosion (5.5.2) and salt spray, leakage and function (5.5.3) according to 5.5.1.

[a] Mainly for small and lightweight components, but can also be used for large and heavy components if agreed between the customer and the supplier.

[b] The test method in accordance with SAE J575/JIS D 0207 can be applied by agreement between the customer and the supplier (see 5.11).

[c] Only voltage class B components.

[d] For components not influenced by heating from powertrain, number of cycles is 100. For components influenced by heating from powertrain (e.g. close to exhaust pipe, etc.), number of cycles is 300.

7 Protection against water and foreign objects

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

NOTE For dust test, refer to 5.11.

8 Documentation

For documentation, the designations outlined in ISO 16750-1 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]	For passenger vehicle		For commercial vehicle		Recommended protection against dust and water[c]
			Recommended climatic requirements[b]	Estimated corrosive severity in product[de]	Recommended climatic requirements[b]	Estimated corrosive severity in product[de]	
Engine/motor compartment							
to the body							
	front end, upper	G,J,O	D	Severity 2	D	Severity 2, 3	IP6K6K /IP6K9K
	front end, lower		D	Severity 2, 3	D, E[j]	Severity 3, 4	
	higher than side member		A ,D[i]	Severity 1, 2	D	Severity 2, 3	
	lower than side member		D	Severity 2, 3	D, E[j]	Severity 3, 4	
to the frame							
	front end, upper	G,J,O	D	Severity 2	D	Severity 2, 3	IP6K6K /IP6K9K
	front end, lower		D	Severity 2, 3	D, E[j]	Severity 3, 4	
	Higher than members		A ,D[i]	Severity 1, 2	D	Severity 2, 3	
	lower than members		D	Severity 2, 3	D, E[j]	Severity 3, 4	
below the compartment cover (hood, cab floor)		G, J, O	A	Severity 1	D	Severity 2, 3	IP6K4 /IP6K9K
on the flexible plenum chamber, not rigidly attached		G,J,O	A, D[i]	Severity 1, 2	D	Severity 2, 3	IP6K4 / IP6K9K
in the flexible plenum chamber, not rigidly attached		G,J,O	B	N/A	B	N/A	not specified
on the engine/motor							
	top and middle part	O,Q	A	Severity 1	D	Severity 2, 3	IP6K6K /IP6K9K
	bottom part		D	Severity 2, 3	D, E[j]	Severity 3, 4	
in the engine/motor		O,Q	B	N/A	B	N/A	not specified
on the transmission/ gearbox /retarder		O,Q	D	Severity 2, 3	D, E[j]	Severity 3, 4	IP6K6K /IP6K9K

Table A.1 *(continued)*

Mounting location	Recommended operating temperature range[a]	For passenger vehicle		For commercial vehicle		Recommended protection against dust and water[c]
		Recommended climatic requirements[b]	Estimated corrosive severity in product[de]	Recommended climatic requirements[b]	Estimated corrosive severity in product[de]	
in the transmission/ gearbox /retarder	O,Q	B	N/A	B	N/A	not specified
Passenger compartment						
without special requirements	D	C	N/A	C	N/A	IP5KX[g]
exposed to direct solar radiation	H	G	N/A	G	N/A	IP5KX[g]
exposed to radiated heat	J	C	N/A	C	N/A	IP5KX[g]
Luggage compartment/ load compartment	E	C	N/A	C	C	IP5KX[g]
Mounting on the exterior/ in cavities						
to the body (except under body)						
top part	G	H	Severity 2	H	Severity 2	IP6K4K /IP6K9K
side part	E	H	Severity 3	H	Severity 3	IP6K4K /IP6K9K
bottom part		I	Severity 4	I	Severity 4	IP6K6K /IP6K9K
to the frame for commercial vehicle						
space between frame members	E,H	N/A[f]	N/A[f]	D, E[j]	Severity 3, 4	IP6K4K / IP6K9K
outside space of frame members		N/A[f]	N/A[f]	I	Severity 4	IP6K6K /IP6K9K
to underbody/wheel housing						
unsprung masses	H	D, E[j]	Severity 3, 4	E	Severity 4	IP6K6K /(IP6K7) /IP6K9K
sprung masses						
in the wheelbase	E	E	Severity 4	E	Severity 4	IP6K6K /(IP6K7) /IP6K9K
floor tunnel	H	D	Severity 2, 3	D, E[j]	Severity 3, 4	
rear overhang	E,H	D, E[j]	Severity 2, 3, 4	D, E[j]	Severity 3, 4	

Table A.1 *(continued)*

Mounting location		Recommended operating temperature range[a]	For passenger vehicle		For commercial vehicle		Recommended protection against dust and water[c]
			Recommended climatic requirements[b]	Estimated corrosive severity in product[de]	Recommended climatic requirements[b]	Estimated corrosive severity in product[de]	
to the passenger compartment door							
	outside	E	H	Severity 2, 3	H	Severity 2, 3	IP6K4K /IP6K9K
	inside		A	Severity 1	A	Severity 1	IP5K3
to the engine/motor compartment cover (hood)							
	(outside)	G, J, O	H	Severity 2, 3	H	Severity 2, 3	IP6K4K/ IP6K9K
in/on the luggage compartment lid/door							
	outside	E, G	H, I[k]	Severity 2, 3, 4	H, I[k]	Severity 2, 3, 4	IP6K4K /IP6K9K
	inside		A	Severity 1	A	Severity 1	IP5K3
in cavity[h]							
	open towards interior	D	C	N/A	C	N/A	IP5KX
	open towards exterior	D	D, H	Severity 2, 3	D, H	Severity 2, 3	IP6K4K /IP6K9K

Table A.1 *(continued)*

Mounting location	Recommended operating temperature range[a]	For passenger vehicle		For commercial vehicle		Recommended protection against dust and water[c]
		Recommended climatic requirements[b]	Estimated corrosive severity in product[de]	Recommended climatic requirements[b]	Estimated corrosive severity in product[de]	
in special compartments	Z	Z	Z	Z	Z	not specified

For degrees of protection against water 7, 8 and 9K, lower degrees of protection are not covered. In such cases where a lower degree of protection is required at the same time, it shall be indicated separately (e.g. IPX6K/IPX8, IPX8/IPX9K.).

NOTE 1 The submersion test is performed by agreement between the customer and the supplier according to the wading depth definition.

NOTE 2 The severity of salt spray combined cycle test is selected considering the imposed environment load (e.g. temperature or splash water) and the mounting location. For more guidance on the different severity zones, see Figure A.1.

[a] See Table 1.

[b] See Table 10.

[c] IP code (see ISO 20653).

[d] The applied number of cycles according to the severities is shown in 5.5.5.4.

[e] In case of protecting with panel or splash board, it is recommended to reduce the severity by agreement between the customer and the supplier.

[f] In case of passenger car, this mounting location is corresponding to sprung masses.

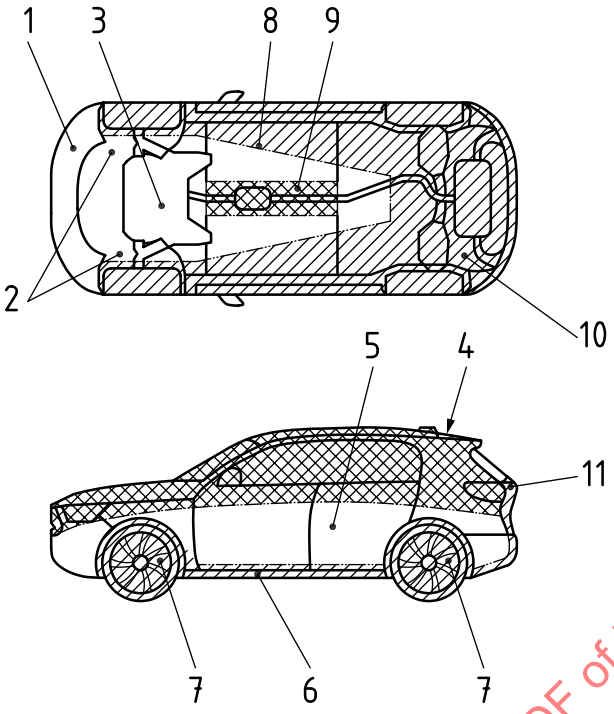
[g] The meaning of X is “no statement on the degree of protection against ingress of water for the cover of this part”, and protection code is selected by agreement between the customer and the supplier.

[h] Hollow structure part of vehicle body (e.g. inside the pillar). If the hollow part is located in engine/motor compartment, passenger compartment, luggage compartment or other suitable locations (e.g. under body), such a special mounting location is recommended to apply.

[i] For regions not expecting water splash, code A can be considered, and for regions expecting water splash, code D can be considered.

[j] Code D or E is selected according to the test method of salt spray, corrosion (5.5.2).

[k] For components exposed to solar radiation, code H or I is selected according to the test method of salt spray, corrosion (5.5.2).



Key

1	engine/motor compartment (front end, lower)	7	wheel housing (unsprung masses)
2	engine/motor compartment (lower than side member)	8	underbody (in the wheelbase)
3	engine/motor compartment (engine/motor, bottom part)	9	underbody (floor tunnel)
4	exterior (top part)	10	underbody (rear overhang)
5	exterior (side part)	11	luggage compartment lid/door (outside)
6	exterior (bottom part)		
▨	severity 2		
□	severity 3		
▨	severity 4		

NOTE The severity in some mounting locations has more than one level due to the differences in environment load (e.g. due to temperature or splash water) and vehicle structure. There are no sharp borderlines between severity zones.

Figure A.1 — An example of severities in passenger vehicle