Mercedes-Benz
Company Standard

MBN LV 124-2

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Person in charge: Dr. Ralf Getto
Plant: 059; Dept.: RD/EDF
Phone: +49 7031 4389 413

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Electric and Electronic Components in Motor Vehicles up to 3,5t – General Requirements, Test Conditions and Tests Part 2: Environmental Requirements

Foreword

This edition of this Standard is based on the document LV 124 which has been established by representatives of the automotive manufacturers AUDI AG, BMW AG, Daimler AG, Porsche AG and Volkswagen Aktiengesellschaft within Working Group 4.9 "Process Validation Hardware Quality of Electronic Components by Suppliers".
Deviations from LV 124 are listed in the cover sheet of this Standard.
If in individual cases modifications to individual test sections are required, such modifications shall be agreed separately between the departments responsible of the automotive manufacturer and the supplier.

The contents of LV 124, Version 2.2, Edition 2013-02-28, have been adopted unchanged, but divided into two parts in the set of standards of Mercedes-Benz with the exception of the test parameters in test E-05 in accordance with the following Table:

MBN standard number	LV number	Content	Pages of LV 124
MBN LV 124-1	LV 124	Part 1 – Electrical Requirements and Tests – 12 V On-Board Electrical System	2-3; 6-54; 160
MBN LV 124-2	LV 124	Part 2 – Environmental Requirements	2-5; 55-160

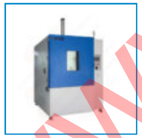
General requirements:
For safety requirements, homologation (in particular, exhaust emissions) and quality, the existing statutory requirements and laws shall be complied with. In addition, the relevant requirements of the Daimler Group apply.
All materials, procedures, processes, components, and systems shall conform to the current regulatory (governmental) requirements regarding regulated substances and recyclability.

Deviations from LV 124:
With regard to this edition of Standard MBN LV 124-2 of Daimler AG, for test "Damp heat, steady state", severity 2 according to Section 14.14.2 shall be applied; the application of test "Damp heat, steady state", severity 1 according to Section 14.14.1 is not permissible.

Changes

In comparison with edition MBN LV 124-2: 2009-11, the following changes have been made:
- Cover sheet updated
- For other changes, refer to Section "Change history" of LV 124

NOTE: This translation is for information purposes only.
The German version shall prevail above all others.



ISO16750-4, VW80000 Ice Water Shock Test Chamber | Ice Water Splash/Immersion Impact Test Machine

Product No: JL-IWJ-010

Description Download

JL-IWJ-010 Ice Water shock Splash test chamber is a composite test box for ice water splash test and ice water immersion test, can be splashed alone or immersion test. It is simulating winter when ice water splashes onto heating systems or components while driving on wet

Water Shock Test
• VOLKSWAGEN | VW 80000 Electric and Electronic Components in Motor Vehicles up to 3.5 t General Requirements, Test Conditions, and Tests | 11.12 K-12 Thermal Shock with Splash Water | 11.13 K-13 Thermal Shock Immersion
• MBN LV 124-2 Electric and Electronic Components in Motor Vehicles up to 3,5t – General Requirements, Test Conditions and Tests | Part 2: Environmental Requirements → 14.12 K-12 Thermal Shock With Splash Water | 14.13 K-13 Thermal Shock Immersion
• GB/T 28046.4 Road Vehicles – Environmental Conditions and Testing for Electrical and Electronic Equipment – Part 4: Climatic Loads (ISO 16750-4:2006, MOD)

Specifications:
• Applicable to the product of the ice -resistant water splash test and the ice water immersion test
• The inner box is made of SUS316#stainless steel plate to ensure that it is not rust for a long time
• The high -temperature system uses a long -axis fan motor, which is resistant to high and low temperature 316 stainless steel multi -wing leaf wheels to achieve the intensity -to -blooming circulation, so that the temperature in the laboratory is uniform and keeps stable
• The testhole (100mm diameter) is installed on the left side of the device.
• The control system uses a 7 -inch touch screen+Panasonic PLC control to control the temperature in the chamber, the temperature of the water tank, the flow and the pump and the test time in the chamber.
• The refrigeration system adopts a fully closed French Taikang compressor.
• Ice water splash test: spraying the peak is fixed on the right side of the test chamber; adjust the water spray distance through the sample movement.
• Flow Sensor: Use the flow sensor to control the flow of the ice water splash test. The signal of the flow sensor will be fed back to the PLC, and the automatic constant current controls it through the PID.
• Set the automatic high and low water level of the water tank. The high water level is used to do ice water immersion test. The bottom water level is used to do ice water splash test to reduce the amount of dust use
• The ice water splash test and the water tank flushing circulation test uses custom cycle pumps to ensure the stable flow and water temperature.
• The ice water temperature control device adopts water circulation cooling method to ensure the uniformity of water temperature and mixed water

Inner Dimensions	1000*1000*1000 (mm) (W*D*H)

Immersed water tank size	600*600*600(W*D*H)
Nozzle quantity	1 slot nozzle
Spraying position	On the right side of the inner box
Spirit and sample distance	325±25mm（Can be adjusted manually)
Basket load	50KG
Immersion water tank	About 200L (stirring in circulating water, the bottom slope, easy to clean and drain)
High temperature chamber temperature range	RT+10℃～150℃（PLC settings)
Heating rate	RT+10℃～150℃≤45min
Water temperature control range	(0～+4) ℃ (Control by PLC)
Cooling rate	25℃～2℃≤60min

Spray time per cycle (30 minutes)	3s, interval time: interval time: [illegible] (PLC setting)
Number of Cycles	100(PLC setting)
Transfer duration	≤20S（PLC Setting）
Immersion Time	1～99 min（PLC Setting）
Number of Immersion time	1～99 （PLC Setting）
The temperature uniformity of the ice water in the chamber	±0.5℃
Automatic cleaning function	After the test is completed, automatically clean the pipeline and the inner chamber (need to be used to hold the spray gun)
Water temperature cooling method	Pipe circulation water flow cooling
Dust mixed method	Pipe circulation water flow mixing
Spray nozzle	Folding and removing crack nozzle (spray can be disassembled and cleaned)

Sample carrier table	Lifting
Power Supply	380V/15KW/50Hz， Three -phase and five -line system
Safety protection function	Leakage protection, water deficiency protection, short circuit protection, phase sequence protection, heat overload protection

Tags: JL-IWJ-010

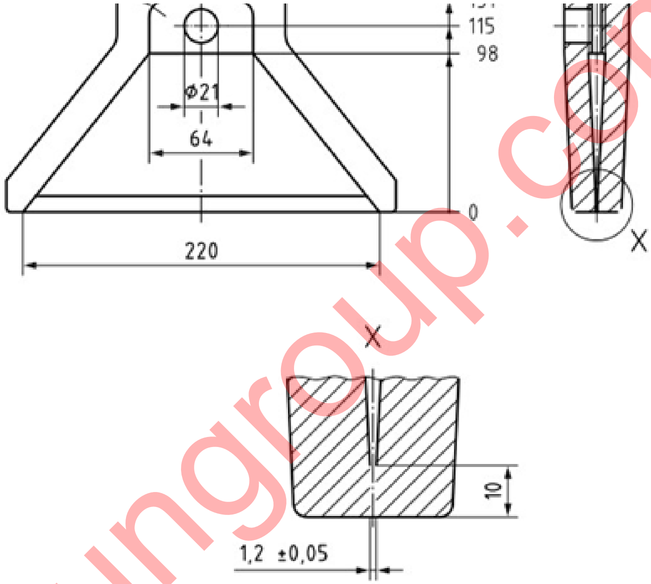
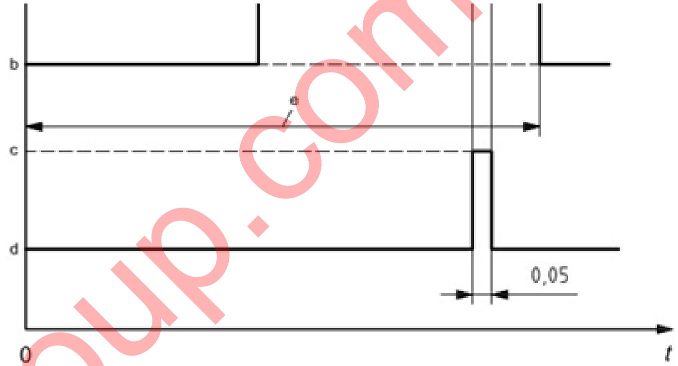


Figure 4 Jet



Key

t time, in min

t_h holding time, in min

a Operating mode 3.2 in accordance with ISO 16750-1.

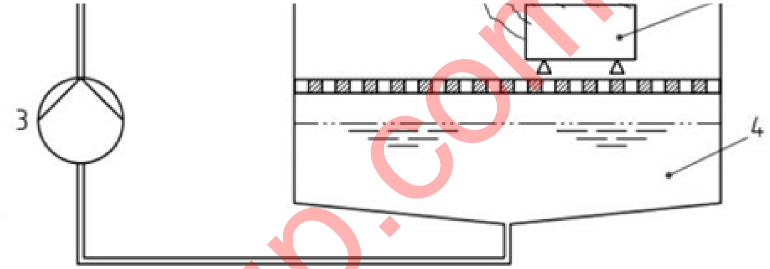
b Operating mode 1.2 in accordance with ISO 16750-1.

c Splash on.

d Splash off.

e One cycle.

Figure 5 Test Cycle for Splash water test



Key

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

Figure 6 Test set for Splash water test

Change history

Edition	
2013-02	Editorial changes integrated. **Part I: Electrical Requirements and Tests 12 V On-Board Electrical System:** Complete revision - each test adjusted to latest requirements. **Part II – Environmental Requirements and Tests:** Extension to components which are described in several operating modes, components connected to coolant circuits, and revision of life tests.

Contents

Pages 6 to 54 of LV 124 contain Part I of LV 124 which has been adopted into the Mercedes-Benz set of standards as MBN LV 124-1 (also refer to cover sheet of MBN LV 124-2)

Part II – Environmental Requirements and Tests

7 Scope

This document specifies requirements, test conditions and tests for electric, electronic and mechatronic components and systems for use in motor vehicles up to 3,5 t.

Any additional or deviating requirements, test conditions and tests shall be defined in the respective Component Requirement Specifications.

Note: The represented tests are not intended for component qualification or a qualification of the manufacturing process.

8 Normative references

Table 38: Normative references

DIN 75220	Ageing of Automotive Components in Solar Simulation Units
DIN EN 13018	Non-Destructive Testing – Visual Testing – General Principles
DIN EN 60068-2-1	Environmental Testing - Part 2-1: Tests – Test A: Cold
DIN EN 60068-2-2	Environmental Testing - Part 2-2: Tests – Test B: Dry Heat
DIN EN 60068-2-6	Environmental Testing – Part 2-6: Tests – Test Fc: Vibration (Sinusoidal)
DIN EN 60068-2-11	Environmental Testing - Part 2: Tests – Test Ka: Salt Mist
DIN EN 60068-2-14	Environmental Testing - Part 2: Tests – Test N: Change of Temperature
DIN EN 60068-2-27	Environmental Testing – Part 2-27: Tests – Test Ea and Guidance: Shock
DIN EN 60068-2-29	Environmental Testing - Part 2: Tests – Test Eb and Guidance: Bump
DIN EN 60068-2-30	Environmental Testing - Part 2-30: Tests – Test Db: Damp Heat, Cyclic (12 + 12 Hours)
DIN EN 60068-2-38	Environmental Testing – Part 2: Tests — Test Z/AD: Composite Temperature/Humidity Cyclic Test
DIN EN 60068-2-60	Environmental Testing – Part 2: Tests — Test Ke: Flowing Mixed Gas Corrosion Test
DIN EN 60068-2-64	Environmental Testing – Part 2: Tests — Test Fh: Vibration, Broadband Random (Digital Control) and Guidance
DIN EN 60068-2-78	Environmental Testing – Part 2-78: Tests — Test Cab: Damp Heat, Steady State
DIN EN ISO 11124 - 2	Preparation of Steel Substrates before Application of Paints and Related Products - Specifications for Metallic Blast-Cleaning Abrasives - Part 2: Chilled-Iron Grit
DIN EN ISO 20567-1	Paints and Varnishes – Determination of Stone-Chip Resistance of Coatings – Part 1: Multi-Impact Testing
DIN EN ISO 6270-2	Paints and Varnishes – Determination of Resistance to Humidity – Part 2: Procedure for Exposing Test Specimens in Condensation-Water Atmospheres

ISO 12103-1	Road Vehicles — Test Dust for Filter Evaluation — Part 1: Arizona Test Dust
ISO 16750-3	Road Vehicles – Environmental Conditions and Testing for Electrical and Electronic Equipment – Part 3: Mechanical Loads
ISO 16750 - 5	Road Vehicles – Environmental Conditions and Testing for Electrical and Electronic Equipment – Part 5: Chemical Loads
ISO 20653	Road Vehicles — Degrees of Protection (IP-Code) — Protection of Electrical Equipment against Foreign Objects, Water and Access.

9 Terms and definitions

9.1 Terms and abbreviations

Table 39: Abbreviations environmental requirements and tests

Electronic assembly	Circuit board (without housing) with mounted electronic devices
Modules/devices	Electric, electronic or mechatronic device (e.g. resistor, capacitor, transistor, IC, relay)
DUT	Device Under Test – the system or component to be tested
Functions	Comprises system-specific functions and diagnostic functions
Hardware freeze	The point during development at which a modification of the hardware is not possible any more.
ICT	In Circuit Test
Climatic chamber with condensation option	A specially controlled water bath in the climatic chamber which converts the required water quantity into water vapor. The intensity of the condensation film on the PCB depends on the thermal mass, the relative humidity and the temperature gradient of the water bath. The climate control of the climatic chamber is switched off during the condensation phase. The test room temperature is controlled by means of the temperature-controlled water bath.
Component	Complete unit, control unit or mechatronic system (with housing)
Test piece	The system or component to be tested (device under test).
PTB	Physikalisch-Technische Bundesanstalt (German national metrology institute providing scientific and technical services)
PSD	Power Spectral Density
Circuit board	Unmounted interconnect device (PCB, ceramic, leadframe, flexband etc. without mounted parts)
System	Functionally linked components, e.g. brake control system (control unit, hydraulic, sensors)

9.2 Voltages

Table 40: Abbreviations for voltage definitions

U_{Bmin}	Lower operating voltage limit
U_B	Operating voltage
U_{Bmax}	Upper operating voltage limit

9.2.1 Voltages for components with extended requirements

$U_{Bmin,HV}$	Lower operating voltage limit HV – lower DC operating voltage
$U_{B,HV}$	Operating voltage HV – DC operating voltage
$U_{Bmax,HV}$	Upper operating voltage limit HV - upper DC operating voltage

9.3 Temperatures

Table 41: Temperature definitions

T_{min}	Minimum operating temperature
T_{RT}	Room temperature
T_{max}	Maximum operating temperature
$T_{op,min}$	Minimum operating temperature for components with overload protection/low-temperature protection
$T_{op, max}$	Maximum operating temperature for components with overload protection/over-temperature protection
T_{Test}	Test temperature

9.3.1 Temperatures for components connected to coolant circuits

$T_{cool,nom}$	Nominal cooling temperature coolant circuit
$T_{cool,min}$	Minimum cooling temperature coolant circuit
$T_{cool, max}$	Maximum cooling temperature coolant circuit

9.4 Times/durations

Table 42: Time definitions

t_{test}	Test duration
t_{op}	Operating hours over service life

9.5 Standard tolerances

Unless otherwise indicated, the tolerances according to Table 43 apply.
The tolerances refer to the required measured value.

Table 43: Standard tolerances

Frequencies	± 1 %
Temperatures	± 2 °C
Humidity	± 5 %
Times/durations	+ 5 %; 0 %
Voltages	± 2 %
Currents	± 2 %
Vibrations	± 3 dB
Vibration PSD	± 5 %

9.6 Standard values

Unless otherwise indicated, the standard values according to Table 44 apply.

Table 44: Standard values

Room temperature	T_{RT} = 23 °C ± 5 °C
Humidity	F_{rel} = 25 % to 75 % relative humidity
Test temperature	T_{test} = T_{RT}
Operating voltage (for test)	U_B = 14 V

10 General

10.1 Working conditions

For vehicles with pure combustion-engined drive the operating status of the vehicle during its service life can normally be divided in the following two working conditions:

- Driving
- Parking

For vehicles with alternative drives additional working conditions shall be considered if necessary (see Table 45).

For components with several relevant working conditions (see Figure 22), the operating modes (see Section 10.2) shall be specified for every working condition if necessary.

Table 45: Description General Working conditions

Working condition	Vehicle parked	Charging cable plugged in	Charging drive battery	Powerline communication active (if existing)
Driving	no	no	yes/no	no
Charging	yes	yes	yes	yes
Preconditioning	yes	yes/no	yes/no	yes/no
ON-grid parking	yes	yes	no	yes
OFF-grid parking or parking	yes	no	no	no

All relevant working conditions for the component according to (Figure 22) shall be considered to derive the testing requirements.

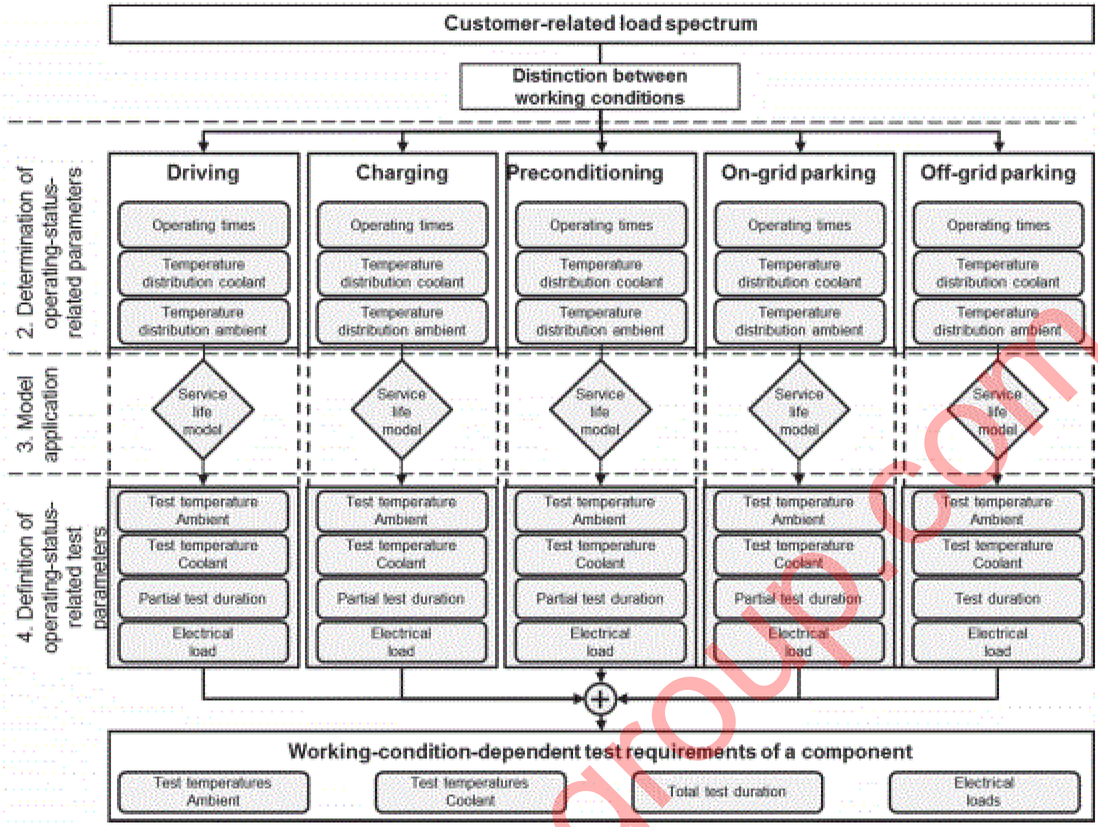


Figure 22: Classification of load spectrum according to working conditions

10.2 Operating modes

10.2.1 General

The electric, electronic and mechatronic components and systems will be operated in different operating modes during their service life, which shall be simulated correspondingly during the tests. Details concerning the operating modes, operating loads (e.g. actuation, bus activity, bus messages, original sensors, original actuators or replacement circuitry) and the necessary boundary conditions shall be coordinated between the buyer and supplier and documented.

10.2.2 Operating mode I - DUT not electrically connected

10.2.2.1 Operating mode I.a

The DUT is without power; connector and harness are not connected.
Any existing coolant circuit is unfilled, and the connections are sealed.

10.2.2.2 Operating mode I.b

The DUT is without power; but the connector and harness are connected.
Any existing coolant circuit is filled, and the coolant hoses are connected.

10.2.3 Operating mode II – DUT electrically connected

10.2.3.1 Operating mode II.a

The DUT shall be operated without operating load.
Any existing coolant circuit shall be filled, and the coolant hoses shall be connected. If required, the flow rate and temperature of the coolant shall be adjusted - as specified in the Component Requirement Specifications.

10.2.3.2 Operating mode II.b

The DUT shall be operated with minimal operating load.
The DUT shall be operated such that minimal self-heating occurs (e.g. by means of a reduction of continuous output power or through infrequent activation of external loads).
Any existing coolant circuit shall be filled, and the coolant hoses shall be connected. If required, the flow rate and temperature of the coolant shall be adjusted - as specified in the Component Requirement Specifications.

10.2.3.3 Operating mode II.c

The DUT shall be operated with maximum operating load (power user, but no misuse).
The DUT shall be operated such that maximum self-heating occurs (for example by means of a realistic maximization of a continuous output power or frequent activation of external loads).
Any existing coolant circuit shall be filled, and the coolant hoses shall be connected. If required, the flow rate and temperature of the coolant shall be adjusted - as specified in the Component Requirement Specifications.

10.2.3.4 Examples of operating modes

Table 46: Examples of operating modes

Example of component	Operating mode II.a	Operating mode II.b	Operating mode II.c
Car radio with navigation	Component as in parked vehicle (sleep). Follow-on current stopped Terminal 30 "ON"	Component in running vehicle. Component switched off by driver, BUS/µC's active, Terminal 15 "ON"	Component in running vehicle. Component switched on (CD, navigation system, output stage), BUS/navigation computer active
Anti-theft alarm system	No operation when vehicle is running	Vehicle interior is monitored while vehicle is parked	
Brake control system	Component as in parked vehicle. Follow-on current stopped	Driving without brake actuation	Driving with frequent brake cycles (no misuse, such as uninterrupted brake control operation)
On-board charger	Off-grid parking or driving	On-grid parking (power line communication only, no charging) Vehicle conditioning	Charging
HV battery (battery management system)	Off-grid parking	On-grid parking with power line communication	Driving, charging

10.3 Attainment of complete thermal equilibrium

A component that is kept at a constant ambient temperature under defined operating conditions is deemed to have attained complete thermal equilibrium at that point in time at which the temperature will not change by more than ±3 °C at any point of the component over the further course of time.

The time until complete thermal equilibrium is achieved shall be determined by the supplier through experiments and indicated in the test documentation.

For temperature cycle tests, the DUTs, after having attained complete thermal equilibrium, shall additionally be kept at the specified temperature basic values for a defined time, so that stress in the component can turn into strain. This additional holding time shall be indicated for the respective tests.

10.4 Parameter test

A set of sensitive parameters, so-called key parameters, e.g. closed-circuit current consumption, operating currents, output voltages, contact resistances, input impedances, signal rates (rise/fall times) and bus specifications, shall be defined in the Component Requirement Specifications. These parameters shall be checked for their compliance with the specifications before the start and after the end of each test.
For components connected to the coolant circuit parameter tests shall be carried out at T_{RT} with $T_{cool,nom}$, at T_{max} with $T_{cool,max}$ and at T_{min} with $T_{cool,min}$.
If not specified otherwise in the Component Requirement Specifications, for components with HV supply the parameter tests shall be carried out at U_{Bmin} with $U_{Bmin,HV}$, at U_B with $U_{B,HV}$ and at U_{Bmax} with $U_{Bmax,HV}$.

10.4.1 Parameter test (small)

The key parameters shall be measured and the functional behavior of the components checked at T_{RT} and U_B. For components with fault memory, the fault memory shall be read out. The components shall be checked for external damage/changes such as cracks, chipping/peeling, discoloration, deformation etc. by visual testing according to DIN EN 13018, without opening the DUT.
Changes in the values of the key parameters, the functional behavior or the fault memory entries as well as irregularities found during the visual test shall be evaluated against the new condition with regard to the previous test exposures.

All results shall be documented in the test report.

10.4.2 Parameter test (large)

The key parameters shall be measured and the functional behavior of the components measured at temperatures T_{max}, T_{RT} and T_{min} at each of the voltages U_{Bmin}, U_B and U_{Bmax}.
For components with fault memory, the content of the fault memory shall be read out. The components shall be checked for external damage/changes such as cracks, chipping/peeling, discoloration, deformation etc. by visual testing according to DIN EN 13018.

Changes in the values of the key parameters, the functional behavior or the fault memory entries as well as irregularities found during the visual test shall be evaluated against the new condition with regard to the previous test exposures.

All results shall be documented in the test report.

10.4.3 Parameter test (function test)

The key parameters shall be measured at one specified temperature and at each of the voltage levels U_{Bmin}, U_B and U_{Bmax}.
The basic functionalities of the components shall be measured.
For components with fault memory, the content of the fault memory shall be read out.

Changes in the values of the key parameters, the basic functionality of the component or the fault memory entries shall be evaluated with regard to the previous test loads.
The results shall be documented in the test report.

10.4.4 Physical analysis

For the physical analysis, the DUT shall be opened, and a visual test shall be performed according to DIN EN 13018.
Additional analyses shall be agreed between the buyer and the supplier.
Examples of examinations are given in Annex G.
Changes of the component compared to the new condition shall be evaluated.
If a DUT demonstrates irregularities, the additional analysis shall be agreed with the buyer, if appropriate by adding additional DUTs or using additional analytical methods.
The results shall be documented and evaluated in the test report.

10.5 Continuous parameter monitoring with drift analysis

The key parameters to be monitored shall be recorded throughout the test.

For components with fault memory, the fault memory shall be monitored continuously and the entries shall be documented.

The data resulting from the continuous parameter monitoring shall be examined for trends and drifting to detect abnormalities, aging or malfunctions of the component.

10.6 Leakage test

For components through which coolant flows, evidence of the leakage shall be provided by means of appropriate tests; the specific construction of the component and the specification of the coolant circuit shall be taken into account in this process. Unless specified otherwise in the Component Requirement Specifications, at least the following tests shall be carried out to provide evidence of leakage:

- Pressure pulsation test with 100 000 pressure changes between minimum and maximum specified pressure of the coolant circuit at T_{max} and $T_{cool,max}$ and with 50 000 pressure changes between minimum and maximum specified pressure of the coolant circuit at T_{min} and $T_{cool,min}$.
- Static leakage test at minimal, maximal and nominal specified pressure of the coolant circuit each at T_{RT} with $T_{cool,nom}$, at T_{max} with $T_{cool,max}$ and at T_{min} with $T_{cool,min}$.
- Vacuum pressure test with test pressure less than 20 mbar at T_{RT}, if the component is filled using a vacuum process. Unless specified otherwise in the Component Requirement Specifications, each pressure change from ambient pressure to test pressure and back shall occur in <5s. The holding time at test pressure shall be at least 30s.
- Test of the coolant flow rate at minimum, maximum and nominal specified pressure of the coolant circuit each at T_{RT} with $T_{cool,nom}$, at T_{max} with $T_{cool,max}$ and at T_{min} with $T_{cool,min}$.

Unless specified in the Component Requirement Specifications, details of the leakage test shall be agreed between the buyer and the supplier.

The leakage test shall be carried out after the first and the last "parameter test (large)" during the sequential tests (A.2), tests outside the sequence (parallel tests) (A.3) and life tests (A.4).

10.7 Sampling rates and measured value resolutions

The sampling rate and bandwidth of the measuring system shall be adapted to the respective test.

It shall be ensured that functionally relevant peaks (temporary positive/negative deviation) are detected and recorded.

The resolution of the measured values shall be adapted to the respective test.

11 Mission profile

11.1 Service life specification

Table 47 shows the typical parameters for the service life specification:

Table 47: Service life specification

Service life	15 years
Operating hours driving	8 000 h
Mileage	300 000 km

For vehicles with alternative drives additional working conditions shall be considered if necessary (see Table 45).

The operating hours for the additional working conditions (see Table 45)

- operating hours charging,
- operating hours preconditioning,
- operating hours ON-Grid parking

shall be specified specific to each component in the Component Requirement Specifications.

11.2 Temperature distribution profiles

In order to describe the thermal stress comprehensively to which a component is exposed at its installation location in the vehicle, in addition to the specification of the minimum operating temperature T_{min} and the maximum operating temperature T_{max}, the distribution is required, which indicates for how long a component is exposed to the different temperatures between T_{min} and T_{max}.

For vehicles with alternative drives, a distinction shall be drawn between the working conditions “driving”, “charging”, “preconditioning” and “ON-Grid parking” and the respective temperature distribution profiles shall be specified for both the ambient temperature and the coolant circuit temperature (see Figure 22).

In principle, this temperature distribution is a continuous distribution, as the ambient temperature of the component may adopt any value between T_{min} and T_{max}.
For the design of the component and for a simple calculation of the test times by means of the accelerated life-stress model by Arrhenius (see Annex C), this continuous distribution can be described sufficiently by means of several discrete temperature nodes $T_{field, i}$. For each temperature node, the percentage p_i of the operating time shall be indicated for which the component is exposed to the node temperature.
The respective temperature distribution profile therefore has the following general form:

Table 48: Temperature distribution profile

Temperature in °C	Distribution
$T_{field.1} = T_{min}$	p_1
$T_{field.2}$	p_2
...	...
$T_{field.n} = T_{max}$	p_n

It is based mainly on field measurements and technical experiences.

Typical temperature distribution profiles in driving mode for different installation locations are indicated in Annex B.
The usability of these typical temperature distribution profiles for a specific component shall be verified e.g. by means of vehicle measurement, simulation or experience. In the case of deviations, the temperature distribution profile shall be adapted to the relevant component.
For special installation locations and mounting situations (e.g. a location near a heat source), a component-specific temperature distribution profile shall always be defined.
The valid temperature distribution profile shall be documented in the Component Requirement Specifications.
In addition to the typical temperature distribution profiles, Annex B indicates typical values for an average temperature delta, which a component within a vehicle in driving mode may experience.
For temperature distribution profiles defined or adopted on a component-specific basis, this value shall also be documented on a component-specific basis and in the Component Requirement Specification.

12 Test selection

12.1 Test selection table

Table 49: Test selection table

Test	Applicable to	Required specifications
M-01 Free fall	All components. For components that will obviously be damaged in this test (e.g. glass bodies, highly sensitive sensors), this test may be omitted following discussions with the buyer. This shall be documented.	None
M-02 Stone chip test	Components mounted in areas that may be affected by stone impact.	None
M-03 Dust test	All components	None
Degree of protection IP6KX	For components for which the ingress of dust is not allowed	
Degree of protection IP5KX	For components for which the ingress of dust is allowed as long as functionality and safety are not impaired	
M-04 Vibration test	All components	None
- as per vibration profile A	For components mounted on the engine	
- as per vibration profile B	For gear box mounted components	
- as per vibration profile C	For components mounted on flexible plenum chamber but not rigidly attached	
- as per vibration profile D	For components mounted on sprung masses (vehicle body)	
- as per vibration profile E	For components mounted on unsprung masses (wheel, wheel suspension)	
M-05 Mechanical shock	All components	None
M-06 Mechanical shock endurance	Components mounted in or on doors and hoods	Number of shocks
K-01 High/low temperature storage	All components	None
K-02 Temperature step test	All components	None
K-03 Low temperature operation	All components	None
K-04 Repainting temperature	Components mounted on the vehicle exterior, which could be exposed to increased temperatures during repainting.	None
K-05 Thermal shock (component)	All components -	Test method (Na or Nc), if Nc: test medium
as per DIN EN 60068-2-14 Na (air-air)	For components that are not permanently operated in a fluid	
as per DIN EN 60068-2-14 Nc (medium-medium)	For components that are permanently operated in a fluid (IP X8)	
K-06 Salt spray test, operating, exterior	Components mounted on the vehicle exterior, underbody or in the engine compartment	None

Test	Applicable to	Required specifications
K-07 Salt spray test, operating, interior	Components mounted in exposed positions in the interior (e.g. side pockets in the trunk, door wet space, spare wheel well)	None
K-08 Damp heat, cyclic	All components	None
K-09 Damp heat, cyclic (with frost)	All components	None
K-10 Water protection – IPX0 to IPX6K	All components	None
- Degree of protection IPX0	For components that do not require water protection	
- Degree of protection IPX1	For components on which vertically falling drips must not cause any damage	
- Degree of protection IPX2	For components with an inclination of up to 15° in installation position on which vertically falling drips must not cause any damage	
- Degree of protection IPX3	For components on which spray water must not cause any damage	
- Degree of protection IPX4K	For components on which splash water with increased pressure must not cause any damage	
- Degree of protection IPX5	For components on which water jets must not cause any damage	
- Degree of protection IPX6K	For components on which strong water jets with increased pressure must not cause any damage	
K-11 High-pressure/steam-jet cleaning	Components that may be directly exposed to high-pressure/steam-jet cleaning or underbody cleaning	None
K-12 Thermal shock with splash water	Components mounted on the vehicle exterior or in the engine compartment which are expected to be exposed to splash water (e.g. when driving through puddles)	None
K-13 Thermal shock immersion	Components mounted below the fording line for which the temporary immersion into (salt) water is to be expected (e.g. when driving through waters) (IPX7)	None
K-14 Damp heat, steady state	All components	Severity
K-15 Condensation and climate test	The necessity of this test shall be evaluated specifically for each component. If required, the test shall be specified in the Requirement Specifications. If the test is listed in the Requirement Specifications, the test for components with waterproof housings may alternatively be carried out as test K-15 a Condensation test with electronic assemblies or as test K-15 b Climate test for components with waterproof housings; for components without waterproof housings the test shall be carried out as test K-15 a Condensation test with electronic assemblies.	None
K-16 Thermal shock (without housing)	Electronic assemblies of all components.	None

Test	Applicable to	Required specifications
K-17 Solar radiation	Components exposed to direct solar radiation in installation location.	None
K-18 Corrosion test with flow of mixed gas	Components with switching contacts that are not gas tight	None
C Chemical requirements and tests	All components	Chemicals Operating mode
L-01 Life test: mechanical/hydraulic endurance test	Components with mechanical/hydraulic actuation/operating cycles, e.g. brake actuation, seat adjustment cycles, switch/pushbutton actuations	Number of actuation/operating cycles
L-02 Life test: high-temperature endurance test	All components	Test duration
L-03 Life test: temperature cycle endurance test	All components	Number of test cycles

12.2 Test sequence

A component-specific test sequence plan shall be defined in the Component Requirement Specification.

A test sequence plan is contained in Annex A as basis for discussions relating to cooperation projects between several OEMs (e.g. Industrial Assembly (IBK)).

13 Mechanical requirements and tests

13.1 M-01 Free fall

13.1.1 Purpose

This test simulates the free fall of a component to the floor, as it may occur during the complete process chain until the intended mounting of the component.
The test is intended to verify that a part that does not show any visible damage as a result of a fall and therefore is mounted in the vehicle, does not have any hidden damage or pre-damage, e.g. internal part displacement or cracks.

13.1.2 Test

Table 50: Test parameters M-01 Free fall

Operating mode of the DUT	Operating mode I.a
Drop height	1 m
Impact surface	Concrete ground
Test cycle	For each of the 3 DUTs one drop in both directions of each dimensional axis (1st DUT: ±X, 2nd DUT: ±Y, 3rd DUT: ±Z)
Number of DUTs	3

13.1.3 Requirement

The DUTs shall be visually inspected with the naked eye and shaken to check for loose or rattling parts.

- If the DUT is visibly damaged, all incidents of damage shall be documented in the test report.

- If the DUT is not visibly damaged, it shall be fully functional after the test, and all the parameters shall meet the specifications. Verification is done by means of a parameter test (large) as per Section 10.4. Hidden damage is not permitted.

13.2 M-02 Stone chip test

13.2.1 Purpose

This test simulates the mechanical exposure of the component to grit impact. The test is intended to verify the resistance of the component to faults such as deformation and cracks.

13.2.2 Test

The test shall be applied in analogy with DIN EN ISO 20567-1, test method B, with the following parameters:

Table 51: Test parameters M-02 Stone chip test

Operating mode of the DUT	Operating mode I.b
Mass of grit	500 g
Test pressure	2 bar
Blasting material	Chilled-iron grit in accordance with DIN EN ISO 11124-2, particle size 4 to 5 mm
Test surface on DUT	All surfaces that are freely accessible on the vehicle
Impact angle	54° to blasting direction
Apparatus	Multi-impact tester in accordance with DIN EN ISO 20567-1
Number of cycles	2
Number of DUTs	6

13.2.3 Requirement

The DUT shall be fully functional before and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (small) as per Section 10.4.

In addition, the DUT shall be evaluated visually with the naked eye and shaken to check for loose or rattling parts.
Changes/damage shall be documented in the test report and evaluated with the buyer.

An evaluation according to the ratings given in DIN EN ISO 20567-1 is not required.

13.3 M-03 Dust test

13.3.1 Purpose

This test simulates the dust load of the component during vehicle operation.
The test is intended to verify the resistance of the component to electrical and mechanical faults.

13.3.2 Test

This test shall be carried out in accordance with ISO-20653 with the following parameters:

Table 52: Test parameters M-03 Dust test

Operating mode of the DUT	For electric/electronic components: Operating mode II.a For mechatronic components (e.g. for components with fan): Intermitting between operating mode II.c and operating mode II.a as per Figure 23. If several working conditions are relevant for the component in operating mode II.c (see Section 10) during the times in which operating mode II.c is required in this test, the component shall be operated in each relevant working condition in equal lengths of time.
Test set-up	Vertical flow according to ISO-20653:2006 Figure 1
Degree of protection to be achieved	As specified in the Component Requirement Specification
Test duration	20 cycles of 20 minutes each
Number of DUTs	6

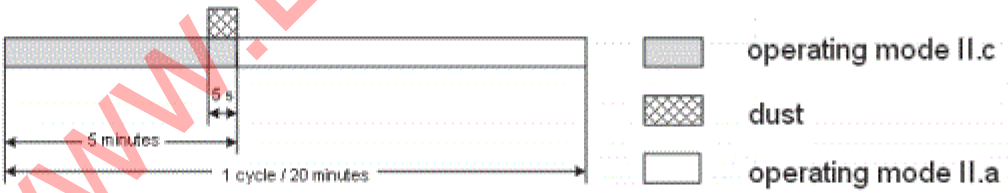


Figure 23: Test sequence M-03 Dust test

When performing the test, the installation position of the component in the vehicle shall be simulated. The test setup (installation position, covers, trim, situation during operation) shall be recommended by the supplier, coordinated with the buyer, and documented.

13.3.3 Requirement

The degree of protection specified in the Component Requirement Specification in accordance with ISO 20653 shall be achieved.

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (small) as per Section 10.4.

In addition, the DUT shall be evaluated visually with the naked eye and shaken to check for loose or rattling parts.
Changes/damage shall be documented in the test report and evaluated with the buyer.

13.4 M-04 Vibration test

13.4.1 Purpose

These tests simulate the exposure of the component to vibrations during driving operation.
The test is intended to verify the resistance of the component to faults such as component displacement or material fatigue.

13.4.2 Test

This test shall be carried out in accordance with ISO 16750 Part 3.
Execution of the test in accordance with DIN EN 60068-2-6 for sinusoidal excitation, and DIN EN 60068-2-64 for broadband excitation with the following parameters:

Table 53: Test parameters for general vibration

Operating mode of the DUT	If the component is not operated with operating load in driving mode: II.a during the entire test If the component is operated with operating load in driving mode: Intermitting II.a and II.c during working condition driving (see Figure 24)
Superimposed temperature profile	Repeating profile as per Figure 24: Temperature profile - vibration and Table 54: Temperature profile - vibration
Frequency sweep time for sinusoidal excitation	1 octave/min, logarithmic
Vibration profile A (Equipment mounted directly on the engine)	Sinusoidal excitation as per Figure 25 and Table 55 Broadband excitation as per Figure 26 and Table 56
Vibration profile B (Gear box mounted equipment)	Sinusoidal excitation as per Figure 27 and Table 57 Broadband excitation as per Figure 28 and Table 58
Vibration profile C (Equipment mounted on flexible plenum chamber but not rigidly attached)	Sinusoidal excitation as per Figure 29 and Table 59
Vibration profile D (Equipment mounted on sprung masses (vehicle body))	Broadband excitation as per Figure 30 and Table 60
Vibration profile E Equipment mounted on unsprung masses (wheel, wheel suspension)	Broadband excitation as per Figure 31 and Table 61
Number of DUTs	6

Components which are mounted on an e-machine shall be tested according to vibration profile D at least. However, this test profile does not include special vibration loads generated by an e-machine. In practice, however, these special vibration loads may occur and stress the component. Therefore the special vibration loads originating from an e-machine shall be included in the test. Measurements on the respective e-machine are necessary for that purpose.

The test shall be carried out without brackets or attached parts. The mounting of connected lines (e.g. electrical wires, coolant hoses, hydraulic lines, ...) in the test setup shall be defined in the Component Requirement Specifications.

For components that are mounted on the bracket or vehicle through vibration isolators, the Component Requirement Specifications shall specify whether

- all DUTs with vibration isolators,
- all DUTs without vibration isolators,
- three DUTs with vibration isolators and three DUTs without vibration isolators

are required to be tested.

The sampling rate shall be selected such that open circuits and short circuits will be detected with absolute certainty.

Any additional tests for protection of the strength of the complete system that includes an assembly of component, brackets and attached parts shall be coordinated with the buyer.

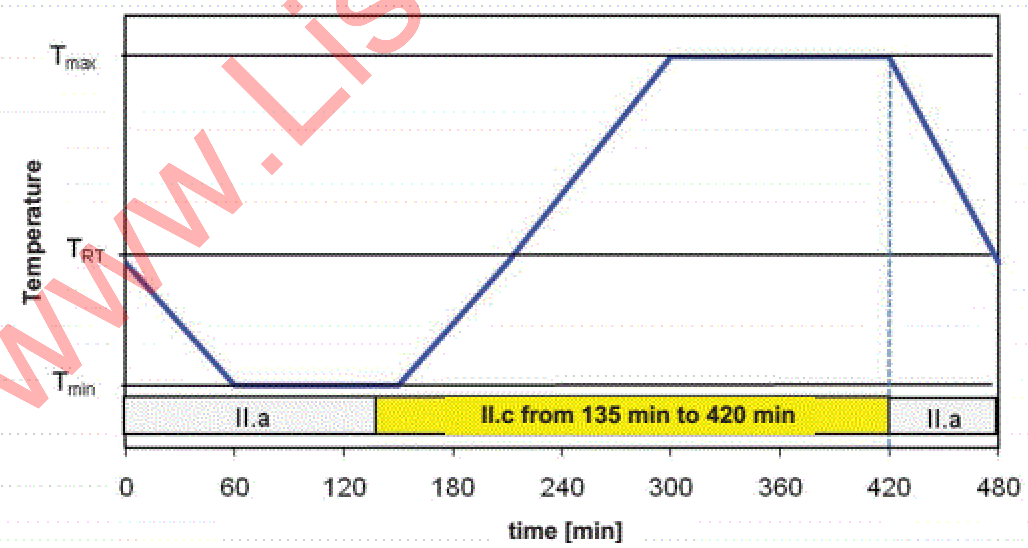


Figure 24: Temperature profile - vibration

Table 54: Temperature profile - vibration

Time in min	Temperature in °C
0	T_{RT}
60	T_{min}
150	T_{min}
300	T_{max}
410	T_{max}
480	T_{RT}

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature between $T_{cool,min}$ and $T_{cool,max}$. Outside the coolant temperature limits, only the ambient temperature shall be varied.

13.4.2.1 Vibration profile A (for equipment mounted directly on the engine)

Table 55: Test parameters vibration, sinusoidal for equipment mounted directly on the engine

Excitation	Sinusoidal	
Test duration for each dimensional axis	22 h	
Vibration profile	Curve 1 for DUTs intended for mounting on engines with 5 cylinders or fewer Curve 2 for DUTs intended for mounting on engines with 6 or more cylinders Combine the curves for components that can be used in both cases.	
Curve 1 in Figure 25	Frequency in Hz	Amplitude of acceleration in m/s²
	100	100
	200	200
	240	200
	270	100
	440	100
Curve 2 in Figure 25	Frequency in Hz	Amplitude of acceleration in m/s²
	100	100
	150	150
	440	150
Combination	Frequency in Hz	Amplitude of acceleration in m/s²
	100	100
	150	150
	200	200
	240	200
	255	150
	440	150

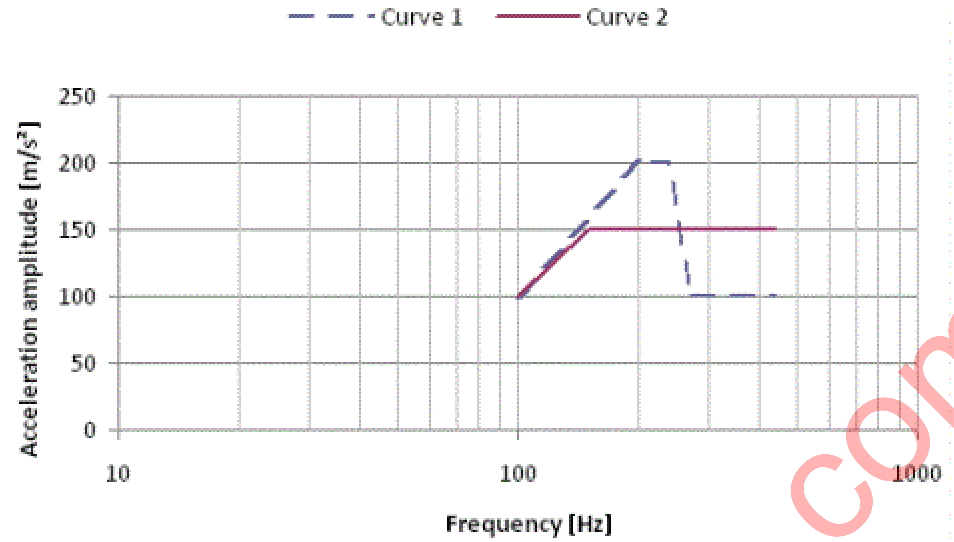


Figure 25: Vibration profile, sinusoidal for equipment mounted directly on the engine

Table 56: Test parameters vibration, broadband random vibration for equipment mounted directly on the engine

Excitation	Broadband random vibration	
Test duration for each dimensional axis	22 h	
Acceleration rms value	181 m/s²	
Vibration profile Figure 26	Frequency in Hz	Power spectral density in (m/s²)²/Hz
	10	10
	100	10
	300	0,51
	500	20
	2 000	20

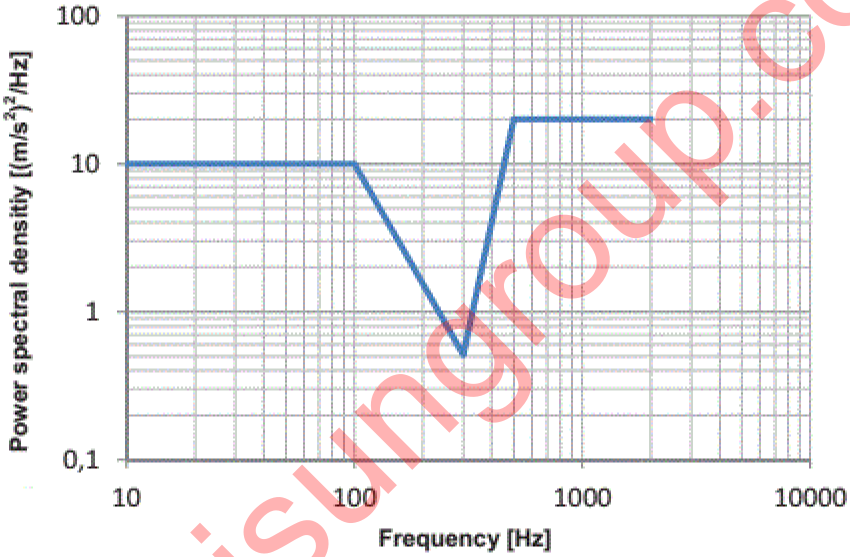


Figure 26: Vibration profile, broadband random vibration for equipment mounted on the engine

13.4.2.2 Vibration profile B (for gear box mounted equipment)

Table 57: Test parameters vibration, sinusoidal for gear box mounted equipment

Excitation	Sinusoidal	
Test duration for each dimensional axis	22 h	
Vibration profile Figure 27	Frequency in Hz	Amplitude of acceleration in m/s²
	100	30
	200	60
	440	60

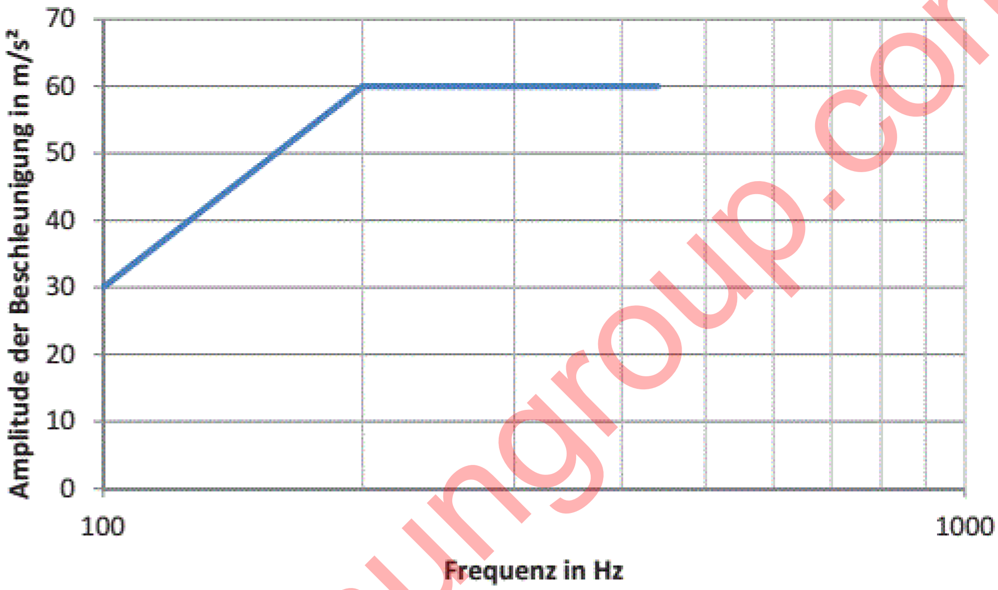


Figure 27: Vibration profile, sinusoidal for gear box mounted equipment

Table 58: Test parameters vibration, broadband random vibration for gear box mounted equipment

Excitation	Broadband random vibration	
Test duration for each dimensional axis	22 h	
Acceleration rms value	96,6 m/s²	
Vibration profile Figure 28	Frequency in Hz	Power spectral density in (m/s²)²/Hz
	10	10
	100	10
	300	0,51
	500	5
	2 000	5

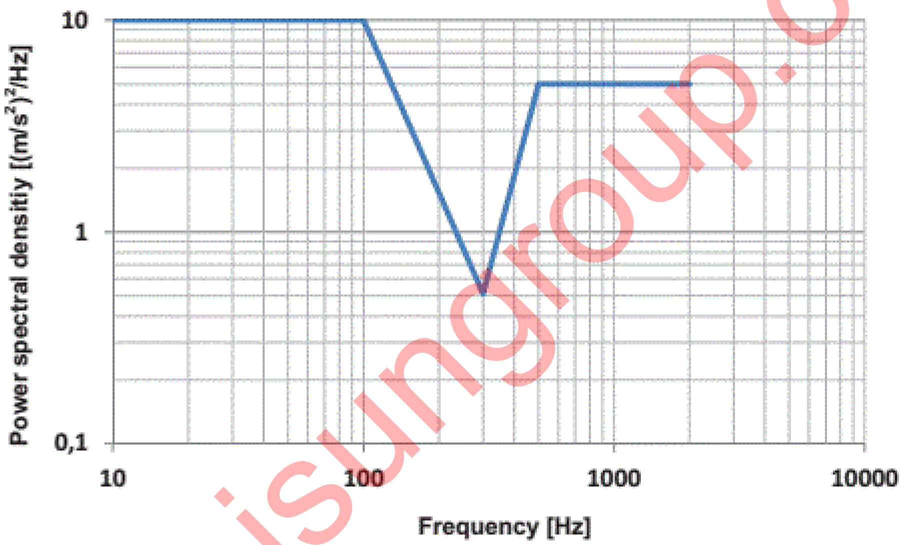


Figure 28: Vibration profile, broadband random vibration for gear box mounted equipment

13.4.2.3 Vibration profile C (for equipment mounted on flexible plenum chamber but not rigidly attached)

Table 59: Test parameters vibration, sinusoidal for equipment mounted on flexible plenum chamber but not rigidly attached

Excitation	Sinusoidal	
Test duration for each dimensional axis	22 h	
Vibration profile Figure 29	Frequency in Hz	Amplitude of acceleration in m/s²
	100	90
	200	180
	325	180
	500	80
	1 500	80

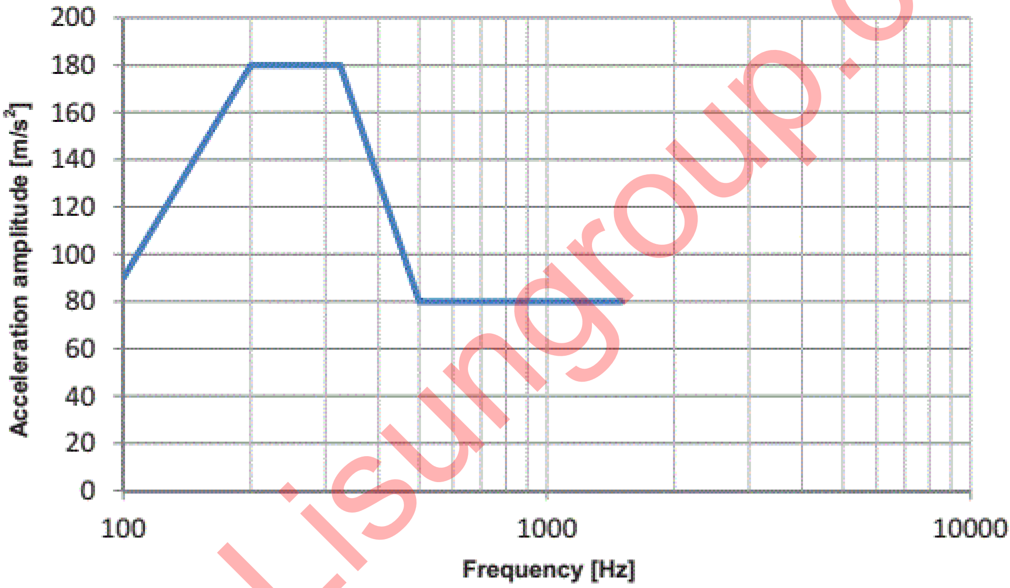


Figure 29: Vibration profile, sinusoidal for equipment mounted on flexible plenum chamber but not rigidly attached

13.4.2.4 Vibration profile D (for equipment mounted on sprung masses (vehicle body))

Table 60: Test parameters, broadband random vibration for equipment mounted on sprung masses (vehicle body)

Excitation	Broadband random vibration	
Test duration for each dimensional axis	8 h	
Acceleration rms value	30,8 m/s²	
Vibration profile Figure 30	Frequency in Hz	Power spectral density in (m/s²)²/Hz
	5	0,884
	10	20
	55	6,5
	180	0,25
	300	0,25
	360	0,14
	1 000	0,14
	2 000	0,14

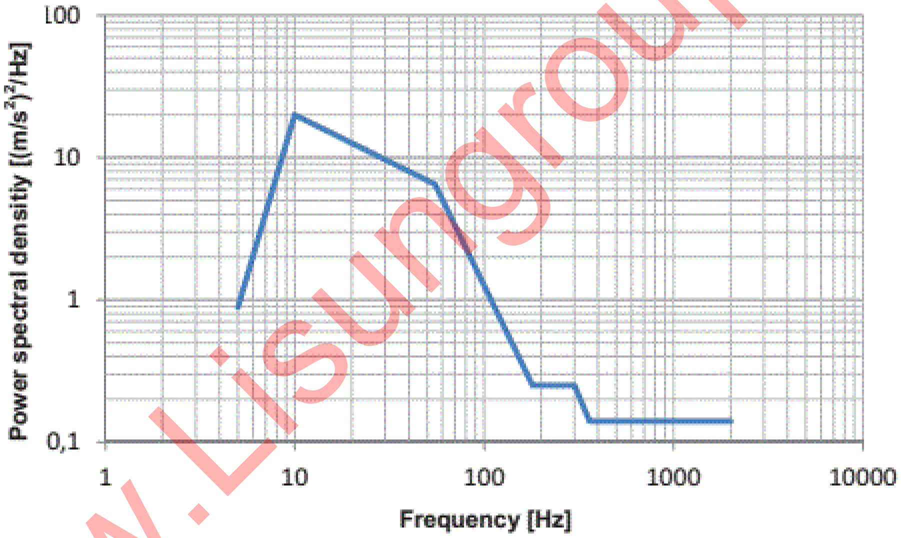


Figure 30: Vibration profile, broadband random vibration for equipment mounted on sprung masses (vehicle body)

13.4.2.5 Vibration profile E (for equipment mounted on unsprung masses (wheel, wheel suspension))

Table 61: Test parameters, broadband random vibration for equipment mounted on unsprung masses (wheel, wheel suspension)

Excitation	Broadband random vibration	
Test duration for each dimensional axis	8 h	
Acceleration rms value	107,3 m/s²	
Vibration profile Figure 31	Frequency in Hz	Power spectral density in (m/s²)²/Hz
	20	200
	40	200
	300	0,5
	800	0,5
	1 000	3
	2 000	3

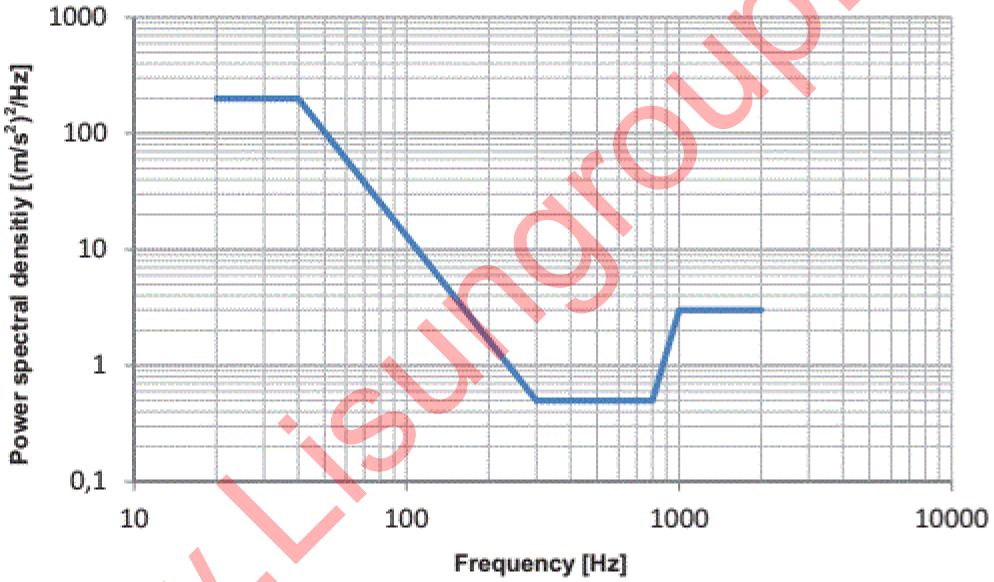


Figure 31: Vibration profile, broadband random vibration for equipment mounted on unsprung masses (wheel, wheel suspension)

13.4.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (large) as per Section 10.4.

13.5 M-05 Mechanical shock

13.5.1 Purpose

This test simulates the mechanical exposure of components, e.g. when driving over curbs or in accidents.
The test is intended to verify the resistance of the component to faults such as cracks or component displacements.

13.5.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-27 with the following parameters:

Table 62: Test parameters M-05 Mechanical shock

Operating mode of the DUT	If the component is operated with operating load in driving mode: II.c during working condition driving If the component is not operated with operating load in driving mode: II.a
Peak acceleration	500 m/s^2
Duration of pulse	6 ms
Pulse shape	Half-sine
Number of shocks per direction (±X, ±Y, ±Z)	10
Number of DUTs	6

13.5.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (small) as per Section 10.4.

13.6 M-06 Mechanical shock endurance

13.6.1 Purpose

This test simulates the acceleration forces of components that are mounted in doors or flaps and are subjected to high accelerations during opening and closing.
The test is intended to verify the resistance of the component to faults such as component displacement or material fatigue.

13.6.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-29 with the following parameters:

Table 63: Test parameters M-06 Mechanical shock endurance

<table>
<tr><td>Operating mode of the DUT</td><td>Operating mode II.c

If several working conditions are relevant for the component in operating mode II.c (see Section 10), during the times in which operating mode II.c is required in this test, the mechanical shocks shall be carried out in each relevant working condition in equal numbers of shocks.</td></tr>
<tr><td>Peak acceleration</td><td>300 m/s²</td></tr>
<tr><td>Duration of pulse</td><td>6 ms</td></tr>
<tr><td>Pulse shape</td><td>Half-sine</td></tr>
<tr><td>Number of shocks</td><td><table>
<tr><th>Installation area</th><th>Number of shocks</th></tr>
<tr><td>Driver's door</td><td>100 000</td></tr>
<tr><td>Front passenger and rear doors</td><td>50 000</td></tr>
<tr><td>Trunk lid/tailgate</td><td>30 000</td></tr>
<tr><td>Engine hood</td><td>3 000</td></tr>
</table>If the component is mounted in several installation areas, the highest number of shocks shall be applied.</td></tr>
<tr><td>Installation position</td><td>The DUT shall be fixed on the test fixture in the appropriate installation position in the vehicle.</td></tr>
<tr><td>Number of DUTs</td><td>6</td></tr>
</table>

13.6.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (small) as per Section 10.4.

14 Climatic requirements and tests

14.1 K-01 High/low temperature storage

14.1.1 Purpose

This test simulates the thermal exposure of the component during storage and transport.
The test is intended to verify the resistance to storage at high or low temperatures, e.g. during the transport of the component (plane, ship container).
If the test is carried out at the beginning of a test sequence, it is also intended to adjust all components to the same initial conditions.

14.1.2 Test

Table 64: Test parameters K-01 High/low temperature storage

Operating mode of the DUT	Operating mode I.a
Test duration and test temperature	2 cycles of 24 h (consisting of 12 h storage at T_{min} and 12 h storage at T_{max})
Number of DUTs	As specified in the test sequence plan in the Component Requirement Specification.

14.1.3 Requirement

The DUT shall be fully functional before and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (large) as per Section 10.4.

14.2 K-02 Temperature step test

14.2.1 Purpose

This test simulates the operation of the component at different ambient temperatures. The test is intended to verify the resistance of the component to malfunctions that may occur within a small interval of the operating temperature range.

14.2.2 Test

Table 65: Test parameters K-02 Temperature step test

Operating mode of the DUT	During the parameter test (function test) operating mode II.c, otherwise operating mode II.a
Test temperature	The DUTs shall be subjected to the temperature profile shown in Figure 32. Temperature change of 5 °C for each step.
Test sequence	The DUT shall be maintained at each temperature step until the specified temperature is attained throughout (see Section 10.4). This shall be followed by a parameter test (function test) as per Section "Parameter test" (see Section 10.4).
Number of DUTs	6

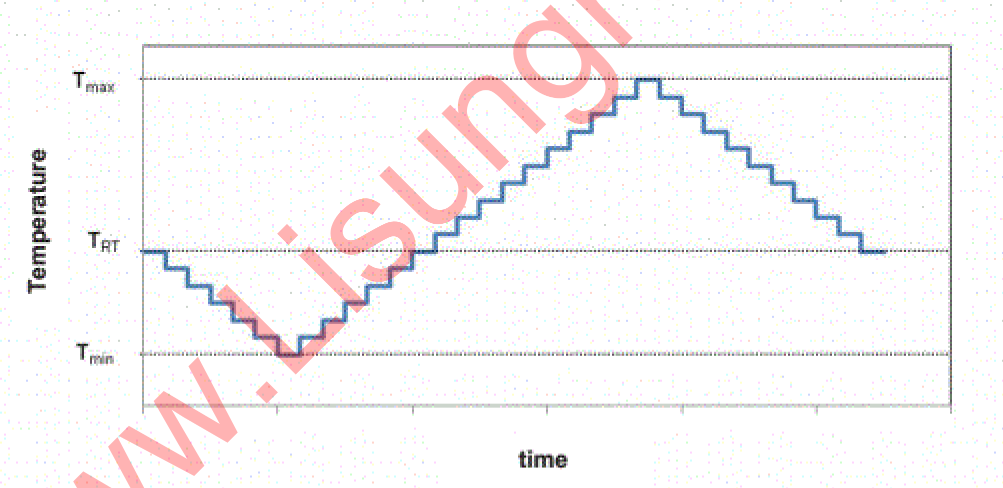


Figure 32: Temperature profile for temperature step test

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature between $T_{cool,min}$ and $T_{cool,max}$. Outside the coolant temperature limits, only the ambient temperature shall be varied.

14.2.3 Requirement

All parameters of the DUT shall lie within the specification during each parameter test (function test).

14.3 K-03 Low temperature operation

14.3.1 Purpose

This test simulates the exposure of the component to low temperatures.
The test is intended to verify the function of the component after a long parking time or operation time at extremely low temperatures.

14.3.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-1, test Ab, with the following parameters:

Table 66: Test parameters K-03 Low temperature operation

Operating mode of DUT	12 h operating mode II.a 12 h operating mode II.c at U_{Bmin} 12 h operating mode II.a 12 h operating mode II.c at U_B If several working conditions are relevant for the component in operating mode II.c (see Section 10) during the times in which operating mode II.c is required in this test, the component shall be operated in each relevant working condition in equal lengths of time.
Test duration	48 h
Test temperature	T_{min}
Number of DUTs	6

For components dissipating heat, the test shall also be carried out in accordance with DIN EN 60068-2-1, test Ab.
For components attached to a coolant circuit the minimum coolant temperature $T_{cool,min}$ shall be adjusted.

For components with high power dissipation a rise of the test chamber temperature by means of self-heating above T_{min} is allowed for this test in operating mode II.c, in agreement between supplier and buyer.

14.3.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (small) as per Section 10.4.

14.4 K-04 Repainting temperature

14.4.1 Purpose

This test simulates the exposure of the component during repainting.
The test is intended to verify the resistance of the component to faults that occur due to thermal exposure, e.g. cracking in soldered joints, adhesive joints and welded joints, in bond connections as well as in seals and housings.

14.4.2 Test

Table 67: Test parameters K-04 Repainting temperature

Operating mode of DUT	Operating mode II.a
Test duration and test temperature	15 min at 130 °C and 1 h at 110 °C
Number of DUTs	6

For components attached to a coolant circuit, the temperature of the stationary coolant shall be set to T_{RT}.

14.4.3 Requirement

The DUT shall be fully functional before and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (small) as per Section 10.4.

14.5 K-05 Thermal shock (component)

14.5.1 Purpose

This test simulates the thermal exposure of a component to rapid temperature changes during vehicle operation.
The test is intended to verify the resistance of the component to faults that occur due to thermal exposure, e.g. cracking in soldered joints, adhesive joints and welded joints, in bond connections as well as in seals and housings.

14.5.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-14 with the following parameters:

Table 68: Test parameters K-05 Thermal shock (component)

Operating mode of DUT	Operating mode I.b
Lower temperature / temperature of cold test bath	T_{min}
Upper temperature / temperature of the warm test bath	T_{max}
Holding time at upper/lower temperature	15 min following attainment of complete thermal equilibrium (see Section 0)
Transition time (air - air, medium - medium)	≤ 30 s
Test fluid for Nc test	Fluid in which the component is operated in the vehicle
Test	In accordance with DIN EN 60068-2-14 Na for components that are **not** permanently operated in a fluid. In accordance with DIN EN 60068-2-14 Nc for components that are permanently operated in a fluid (IP X8). The DUT shall be immersed such that all sides of the DUT are surrounded by at least 25 mm of test fluid.
Number of cycles	100
Number of DUTs	6

14.5.3 Requirement

The DUT shall be fully functional before and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (large) as per Section 10.4.

For medium - medium test additionally:
There shall be no ingress of fluid. The DUT shall not be opened until after completion of the entire test sequence as given in the test sequence plan (Section 12.2).

14.6 K-06 Salt spray test, operating, exterior

14.6.1 Purpose

This test simulates the exposure of the component to air and water containing salt, a situation that may occur in certain areas of the world and in wintry road conditions. The test is intended to verify the resistance of the component to malfunction when exposed to salt, e.g. due to short circuits and leakage currents caused by the ingress of salt into the component.

14.6.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-11 with the following parameters:

Table 69: Test parameters K-06 Salt spray test, operating, exterior

Operating mode of DUT	During spray phase: Intermitting between 1 h operating mode II.a and 1 h operating mode II.c. During rest phase: Operating mode II.a
Test temperature	35 °C
Test cycle	Each test cycle consists of an 8 h spray phase and a 4 h rest phase as per Figure 33
Number of test cycles	For components in the underbody/engine compartment: 12 cycles For other components: 8 cycles
Number of DUTs	6

When performing the test, the installation position of the component in the vehicle shall be simulated.

For components connected to a coolant circuit the coolant temperature shall be adjusted to the test temperature.

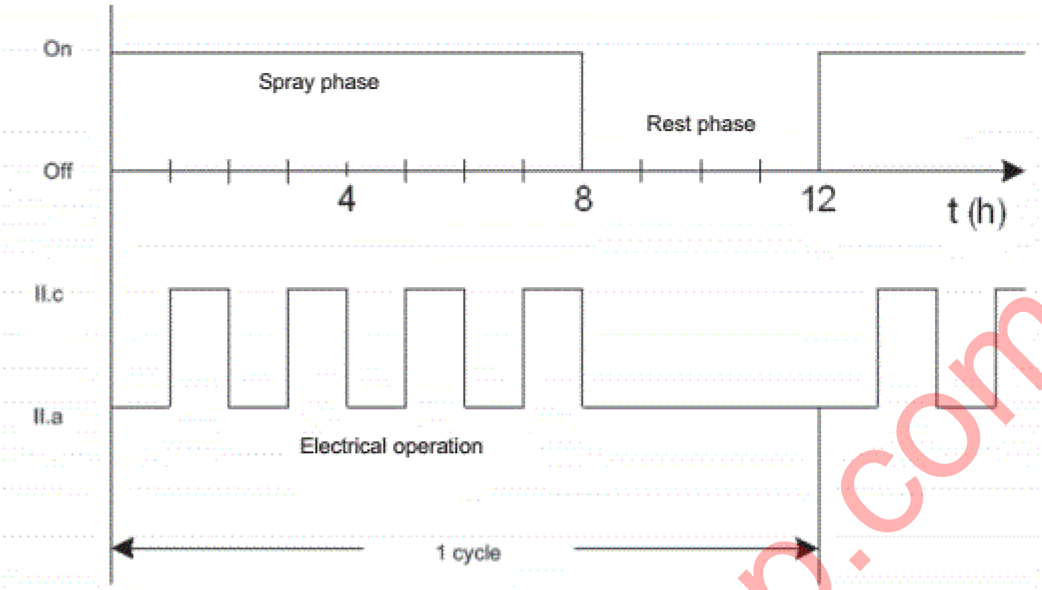


Figure 33: Salt spray test, operating, exterior - spray phases

14.6.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (small) as per Section 10.4.

K-07 Salt spray test, operating, interior

14.6.4 Purpose

This test simulates the exposure of the component to air containing salt, as it may occur in certain areas of the world.
The test is intended to verify the resistance of the component to malfunction when exposed to salt, e.g. due to short circuits and leakage currents caused by the ingress of salt into the components.

14.6.5 Test

This test shall be carried out in accordance with DIN EN 60068-2-11 Ka with the following parameters:

Table 70: Test parameters K-07 Salt spray test, operating, interior

Operating mode of DUT	During spray phase: intermitting between 55 min operating mode II.a and 5 min. operating mode II.c If several working conditions are relevant for the component in operating mode II.c (see Section 10) during the times in which operating mode II.c is required in this test, the component shall be operated in each relevant working condition in equal lengths of time. During rest phase: Operating mode II.a
Test temperature	35 °C
Test cycle	Each test cycle consists of an 8 h spray phase and a 4 h rest phase as per Figure 34
Number of test cycles	2
Number of DUTs	6

When performing the test, the installation position of the component in the vehicle shall be simulated. The test setup (installation position, covers, trim, situation during operation) shall be recommended by the supplier, coordinated with the buyer, and documented.
For components connected to a coolant circuit the coolant temperature shall be adjusted to the test temperature.

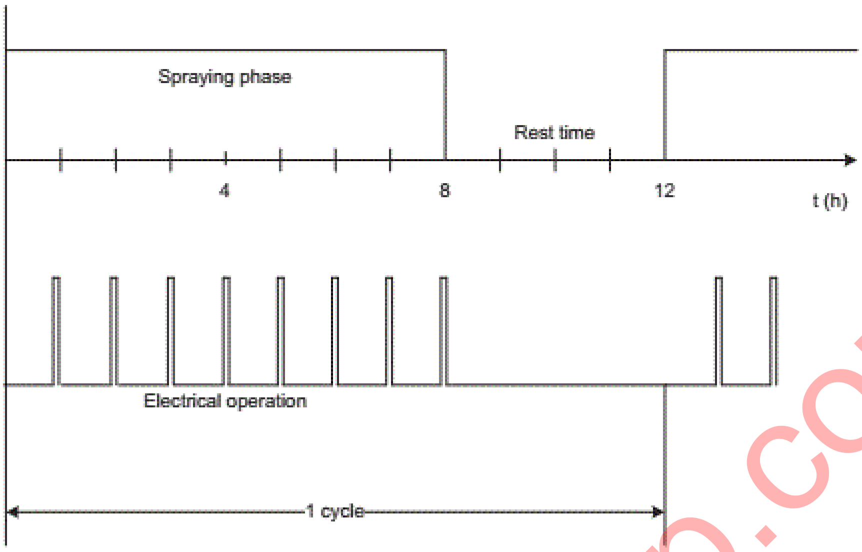


Figure 34: Salt spray test, operating, interior - spray phases

14.6.6 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (large) as per Section 10.4.

14.7 K-08 Damp heat, cyclic

14.7.1 Purpose

This test simulates the thermal exposure of a component to cyclic temperature changes at high humidity during vehicle operation.
The test is intended to verify the function of the component when exposed to damp heat.

14.7.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-30 with the following parameters:

Table 71: Test parameters K-08 Damp heat, cyclic

Operating mode of DUT	Operating mode II.a
Total test duration	144 h
Test variant	Variant 1
Upper test temperature	55 °C
Number of cycles	6
Number of DUTs	6

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature between $T_{cool,min}$ and $T_{cool,max}$. Outside the coolant temperature limits, only the ambient temperature shall be varied.

14.7.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (large) as per Section 10.4.

In addition, a parameter test (function test) shall be performed each time the upper test temperature is reached and each time the lower test temperature is reached.

14.8 K-09 Damp heat, cyclic (with frost)

14.8.1 Purpose

This test simulates the thermal exposure of a component to cyclic temperature changes (including frost) at high humidity during vehicle operation.
The test is intended to verify the function of the component when exposed to damp heat.

14.8.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-38 with the following parameters:

Table 72: Test parameters K-09 Damp heat, cyclic (with frost)

Operating mode of DUT	Intermitting between 40 min operating mode II.a and 10 min operating mode II.c If several working conditions are relevant for the component in operating mode II.c (see Section 10) during the times in which operating mode II.c is required in this test, the component shall be operated in each relevant working condition in equal lengths of time.
Total test duration	240 h
Number of cycles	10
Test cycle sequence	The first five cycles shall include a cold subcycle and the remaining cycles shall be carried out without a cold subcycle.
Number of DUTs	6

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature between $T_{cool,min}$ and $T_{cool,max}$. Above the coolant temperature limits, only the ambient temperature shall be varied.

14.8.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (large) as per Section 10.4.

14.9 K-10 Protection against water – IPX0 to IPX6K

14.9.1 Purpose

This test simulates the exposure of the component to water.
The test is intended to verify the function of the component, e.g. when exposed to condensation water, rain or spray water.

14.9.2 Test

This test shall be carried out in accordance with ISO 20653 with the following parameters:

Table 73: Test parameters K-10 Protection against water – IPX0 to IPX6K

Operating mode of DUT	Intermitting between 1 min operating mode II.a and 1 min operating mode II.c If several working conditions are relevant for the component in operating mode II.c (see Section 10) during the times in which operating mode II.c is required in this test, the component shall be operated in each relevant working condition in equal lengths of time.
Required degree of protection	As specified in the Component Requirement Specifications
Number of DUTs	6

14.9.3 Requirement

The degree of protection specified in the Component Requirement Specifications in accordance with ISO 20653 shall be achieved.

There shall be no water ingress. The DUT shall not be opened until completion of the entire test sequence.

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (small) as per Section 10.4.

14.10 K-11 High-pressure/steam-jet cleaning

14.10.1 Purpose

This test simulates the exposure of the component to water during vehicle cleaning. The test is intended to verify the function of the component when exposed to high-pressure/steam-jet cleaning.

14.10.2 Test

This test shall be carried out in accordance with ISO 20653 with the following parameters:

Table 74: Test parameters

Operating mode of DUT	Operating mode II.a
Required degree of protection	IP X9K
Water pressure	The steam jet shall have a minimum pressure of 10 000 kPa (100 bar) as measured directly at the nozzle.
Water temperature	80 °C
Test procedure	The DUT shall be subjected to the water jet from every freely accessible direction around the vehicle.
Number of DUTs	6

14.10.3 Requirement

The degree of protection IP X9K in accordance with ISO 20653 shall be achieved.

There shall be no water ingress. The DUT shall not be opened until completion of the entire test sequence (Section 12.2).

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (small) as per Section 10.4.

14.11 K-12 Thermal shock with splash water

14.11.1 Purpose

This test simulates the exposure of the component to splash water as it occurs when driving through puddles.
The test is intended to verify the function of the component when exposed to abrupt cooling by means of water.

14.11.2 Test

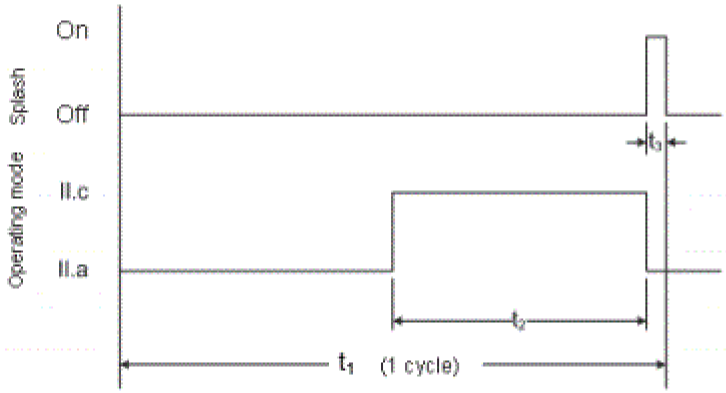
Table 75: Test parameters K-12 Thermal shock with splash water

Operating mode of DUT	If the component is not operated with operating load in driving mode: II.a during the entire test If the component is operated with operating load in driving mode: Intermitting II.a and II.c during working condition driving (see Figure 35)
Test procedure	Heating of DUT to test temperature. This is followed by the cyclic splashing of the DUT as per Figure 35. The DUT shall be splashed over its entire width.
Cycle duration	30 min
Test temperature	T_{max}
Test medium for splashing	Tap water containing 3 % Arizona dust by weight, fine, in accordance with ISO 12103-1. Permanent mixing shall be ensured.
Splash water temperature	0 to +4 °C
Splash nozzle	See Figure 36
Splash duration	3 s
Water flow	3 to 4 liters per splash/nozzle
Distance of nozzle to DUT	300 to 350 mm
Number of cycles	100
Number of DUTs	6

When performing the test, the installation position of the component in the vehicle shall be simulated.
The test setup (installation position, covers, trim, situation during operation) shall be recommended by the supplier, coordinated with the buyer, and documented.

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature up to the limit $T_{cool,max}$. Above the coolant temperature limits, only the ambient temperature shall be varied.

Test setup as per Figure 37.

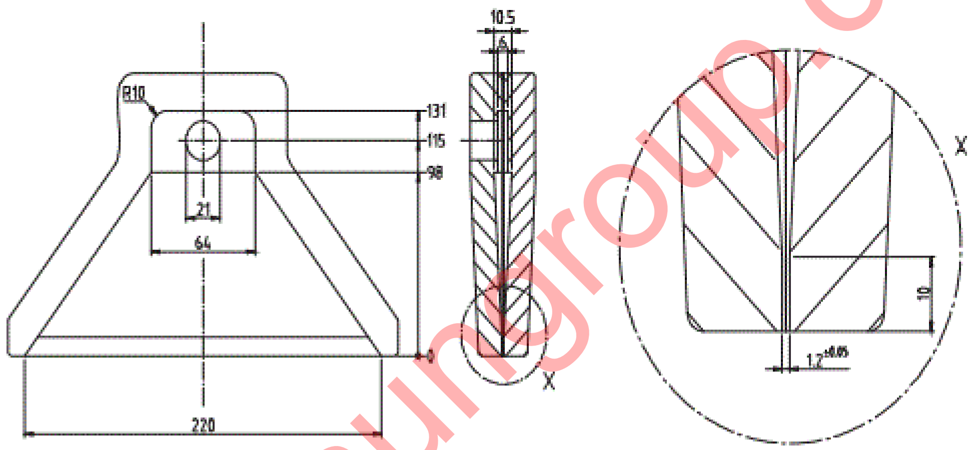


t_1 = 30 minutes

t_2 = 14:57 minutes

t_3 = 3 seconds

Figure 35: Splash water test, splashing times



Dimensions in mm

Figure 36: Splash water test - splash nozzle

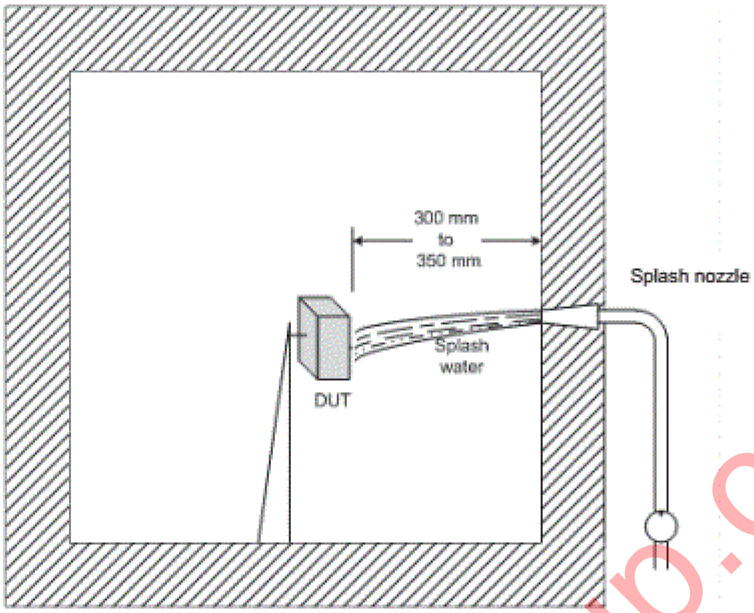


Figure 37: Splash water test setup

14.11.3 Requirement

There shall be no water ingress. The DUT shall not be opened until completion of the entire test sequence.

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (small) as per Section 10.4.

14.12 K-13 Thermal shock immersion

14.12.1 Purpose

This test simulates the exposure of the component when immersed in water. The test is intended to verify the function of the component when subjected to immediate cooling by means of immersion of the heated component.

14.12.2 Test

This test shall be carried out in accordance with ISO 20653 with the following parameters:

Table 76: Test parameters K-13 Thermal shock immersion

Operating mode of DUT	If the component is operated with operating load in driving mode: II.c during working condition driving If the component is not operated with operating load in driving mode: II.a
Required degree of protection	IP X7
Test procedure	Heating of DUT to $T_{op,max}$ Hold at $T_{op,max}$ until complete thermal equilibrium is reached (see Section 10.3) and then for 15 min more. Fully immerse the DUT within five seconds into the test fluid such that all sides of the DUT are surrounded by at least 25 mm of the test fluid.
Test medium	0 °C cold, 5 % salt water solution
Immersion time	5 min
Number of cycles	20
Number of DUTs	6

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature up to the limit $T_{cool,max}$. Above the coolant temperature limits, only the ambient temperature shall be varied.

14.12.3 Requirement

There shall be no water ingress. The DUT shall not be opened until completion of the entire test sequence (Section 12.2).

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (small) as per Section 10.4.

14.13 K-14 Damp heat, steady state

14.13.1 Damp heat, steady state – severity 1(#)

14.13.1.1 Purpose

This test simulates the exposure of the component to damp heat.
The test is intended to verify the resistance of the component to faults caused by damp heat, e.g. corrosion, migration/dendritic growth, swelling and degradation of plastics, sealing and grouting compounds.

14.13.1.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-78 with the following parameters:

Table 77: Test parameters K-14 Damp heat, steady state – severity 1

Operating mode of DUT	Operating mode II.a
Test temperature	40 °C
Humidity	93 % relative humidity
Test duration	21 days
Number of DUTs	6

14.13.1.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (large) as per Section 10.4.

In addition, a parameter test (function test) shall be carried out every seven days.

(#) With regard to MBN LV124-2 of Daimler AG, the application of this test with severity 1 is not permissible.

14.13.2 Damp heat, steady state – severity 2

14.13.2.1 Purpose

This accelerated test simulates the exposure of the component to damp heat during vehicle service life.
The test is intended to verify the quality and reliability of the component with respect to faults caused by damp heat, e.g. corrosion, migration/dendritic growth, swelling and degradation of plastics, sealing and grouting compounds.

14.13.2.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-78 with the following parameters:

Table 78: Test parameters K-14 Damp heat, steady state – severity 2

Operating mode of DUT	Intermitting operation between 47 h operating mode II.a and 1 h operating mode II.c repeating until end of test duration If several working conditions are relevant for the component in operating mode II.c (see Section 10) during the times in which operating mode II.c is required in this test, the component shall be operated in each relevant working condition in equal lengths of time.
Test duration	As specified in the Component Requirement Specification as per Section E.1 (Lawson model)
Test temperature	65 °C
Test humidity	93 % relative humidity
Number of DUTs	6

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature up to the limit $T_{cool,max}$. Above the coolant temperature limits, only the ambient temperature shall be varied.

Prior to the execution of this service life test, a check shall be conducted to ascertain whether the high test acceleration using the test parameters 65 °C and 93 % r.h. exceeds the physical limits of the materials used in the components (e.g. hydrolysis of plastics). Where applicable, the supplier and buyer shall agree to changes in the test temperature and test humidity (e.g. to 55 °C and 93 % relative humidity) while increasing the test duration as per the Lawson model such that the physical limits of the materials used are not exceeded during the test. The overall severity of the testing shall, however, remain unchanged. The test humidity shall not exceed the level of 93 % relative humidity.

Care shall be taken to ensure that no condensation occurs on the DUT during the test (including local condensation).

14.13.2.3 Deviating test sequence for components with reduced performance at high temperatures

For components with reduced performance (e.g. reduction of backlight of LCDs) at high temperatures starting at $T_{op,max}$ ($T_{op, max}$ < 65 °C), the test shall not - deviating from Table 78 - be carried out at a constant test temperature of 65 °C, but with the following parameters (see Table 79).

Table 79: Test parameters K-14 Damp heat, steady state for components with reduced performance at high temperatures

Operating mode of DUT	Intermitting operation as per Figure 38
Test duration	As specified in the Component Requirement Specification as per Section E.1 (Lawson model). The ramp times between 65 °C and $T_{op, max}$ shall not be included in the test duration.
Test temperature	As per Figure 38 The temperature gradient shall be selected such that no condensation occurs at the DUT.
Test humidity	93 % relative humidity
Interval time t_1	47 h
Interval time t_2	1 h
Number of DUTs	6

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature up to the limit $T_{cool,max}$. Above the coolant temperature limits, only the ambient temperature shall be varied.

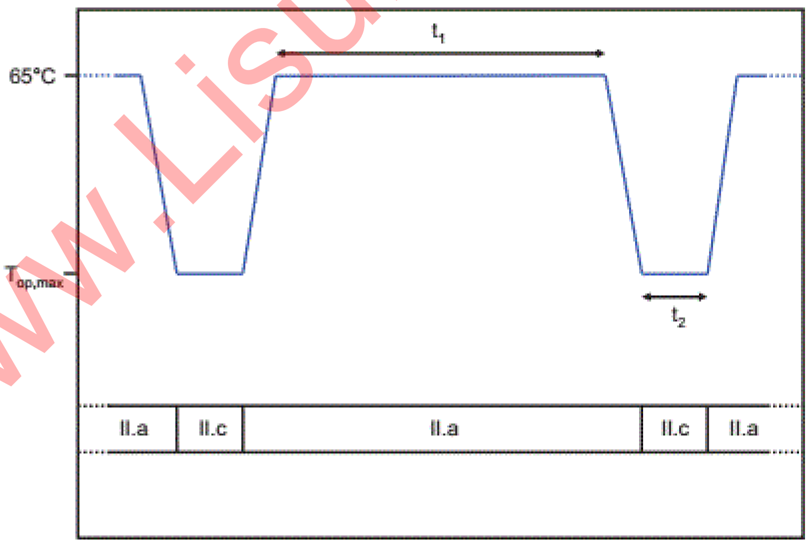


Figure 38: Temperature profile for testing components with reduced performance at high temperatures above $T_{op,max}$

14.13.2.4 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (large) as per Section 10.4.

14.14 K-15 Condensation and climate test

14.14.1 K-15 a Condensation test with electronic assemblies

14.14.1.1 Purpose

This test simulates the condensation on electronic assemblies in motor vehicles.
It serves to evaluate the robustness of the electronic assembly with respect to condensation.

14.14.1.2 Test

Performance of the test with electronic assemblies without housing with the following parameters:

Table 80: Test parameters K-15 a Condensation test with electronic assemblies

Operating mode of DUT	Operating mode II.a In addition, parameter tests (function tests) as described in row "Test procedure" shall be carried out.
Apparatus	Climatic chamber with condensation option (specially controlled water bath which converts the required quantity of water to water vapor). The climate control is switched off during the condensation phase. The test chamber temperature is controlled by means of the temperature-controlled water bath.
Test procedure	1. The climatic chamber remains at the initial temperature for 60 min to ensure that the DUT has attained complete thermal equilibrium. Then the condensation phase begins. 2. In the period between 30 min after the start until 30 min before the end of the condensation phase (as per Figure 41), a parameter test (function test), shall be performed at each 10 K increase in the water bath temperature, however only at voltage $U_{B,}$. The parameter test (function test) shall be performed with a minimum of power loss for max. 2 min since otherwise the DUT will heat up too much and condensation will no longer take place.
Test temperature	See Figure 41
Relative test chamber humidity	See Figure 41 During the condensation phase the relative test chamber humidity shall be 100 % r.h. (0 %, -5 %).
Test duration	32,5 h (5 cycles of 6,5 h)
Test medium	Distilled water with a maximum conductivity of 5 µS/cm

Position of DUT	Installation position as in vehicle. Plastic brackets shall be used to ensure that the electronic assembly remains in its installation position in the test chamber. If the assembly is used in different installation positions, the DUTs shall also be positioned in these different installation positions in the test chamber.
Test set-up	See Figure 39 During the test a plastic hood as per Figure 40 shall be used to eliminate any undesired effects caused by variations in air speed. The hood shall be aligned such that the bevel points to the test chamber door. The dimensions of the plastic hood shall be adapted to the size of the test chamber. The distance between the plastic hood and the test chamber wall shall be 10 % of the test chamber width/depth, however, at least 8 cm. In accordance with DIN EN ISO 6270-2 an alpha angle of ≥ 12° shall be used for the top slope of the plastic hood.
Condition for testing	The condensation test shall be performed initially prior to the final definition of the circuit layout (hardware freeze), but shall be done on assemblies manufactured under near-production-level conditions so that any sensitivities to condensation found during the test can be remedied, e.g. through changes to the layout and the circuit. If changes to the assembly manufacturing process are introduced (e.g. circuit board, soldering agent, flux, soldering process, layout, relocation or electronic devices), the test shall be repeated.
Number of cycles	5
Number of DUTs	6 electronic assemblies

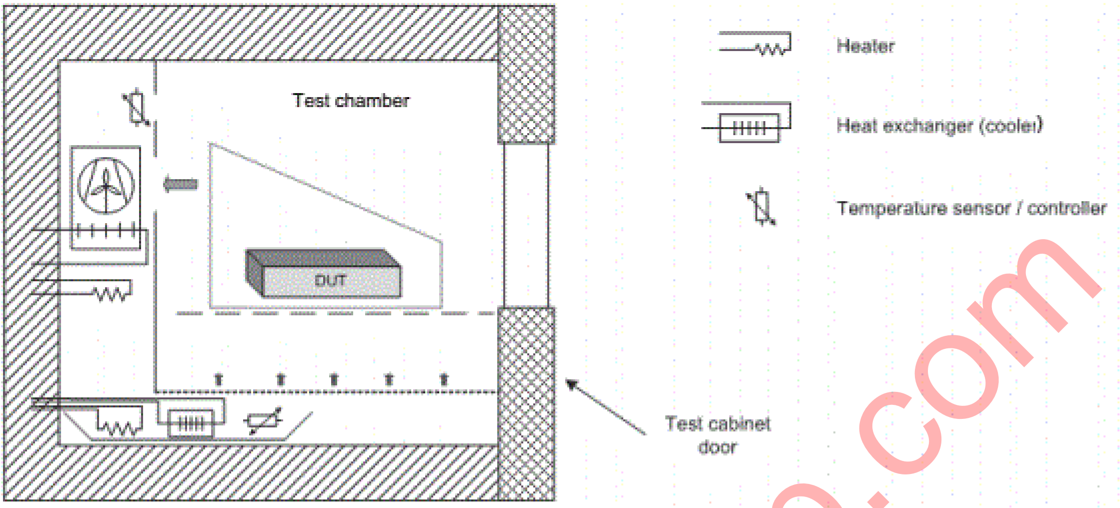


Figure 39: Test setup K-15 a Condensation test with electronic assemblies

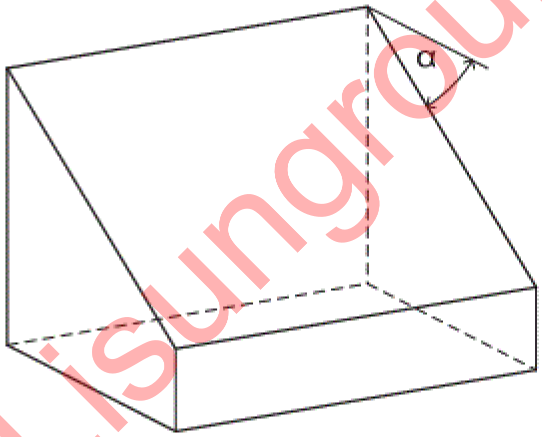


Figure 40: Plastic hood

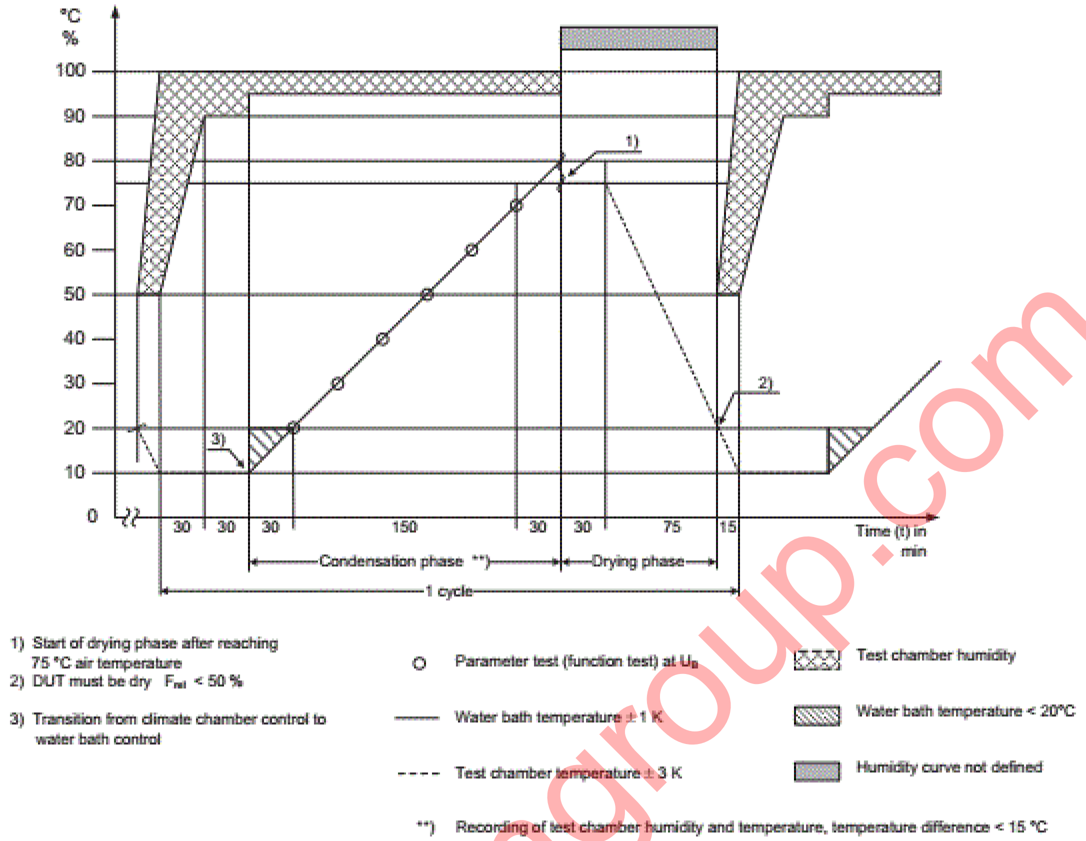


Figure 41: Test sequence K-15 a Condensation test with electronic assemblies

14.14.1.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (large) as per Section 10.4.

In addition, the assembly shall be examined with respect to electrochemical migration (e.g. signs of silver and tin migration) and dendritic growth.

Any occurrence of electrochemical migration/dendritic growth is not permissible.

Other changes to the assembly (e.g. corrosion, contamination) shall be documented in the test report and evaluated with the buyer.

The following documentation shall be included with the test report:

1. Programming of the test chamber
2. Parameters (specified/actual) of one cycle
3. Parameters (specified/actual) of all five cycles

For examples, see Annex F.

14.14.2 K-15 b Climate test for components with waterproof housings

14.14.2.1 Purpose

This accelerated test simulates the thermal exposure of the component to damp heat taking into account the protective effect of waterproof housings during the vehicle service life.
The test is intended to verify the quality and reliability of the component with respect to faults caused by damp heat, e.g. corrosion, migration/dendritic growth, swelling and degradation of plastics, sealing and grouting compounds.

14.14.2.2 Test

The test shall be carried out with complete components (device, control unit, mechatronics, … with housings).

The test shall be carried out as a sequence of five test blocks according to Figure 42:

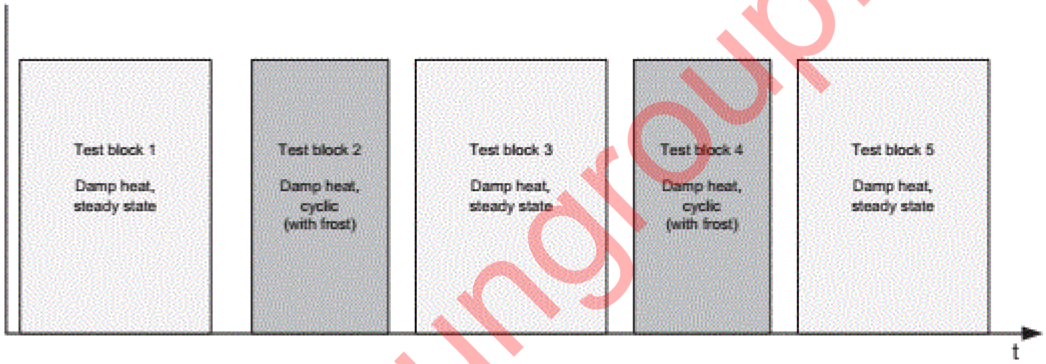


Figure 42: Test sequence K-15 b Climate test for components with waterproof housings

Test blocks 1, 3 and 5:
This test shall be carried out in accordance with DIN EN 60068-2-78 with the following parameters:

Table 81: Test parameters K-15 b Climate test for components with waterproof housings test blocks 1, 3 and 5

Operating mode of DUT	Operating mode II.a 12 hours after beginning of the test block and afterwards every 24 hours a parameter test (function test) shall be carried out.

Test duration per test block	As specified in the Component Requirement Specifications Note: The total test duration of test K-15 b (test blocks 1 to 5) complies with the test duration of test K-14 Damp heat, steady state – severity 2. This total test duration consists of two times 240 hours test duration for each of the test blocks 2 and 4. The remaining test duration is divided into one third for each of the test blocks 1, 3 and 5: Test $duration_{Test\ block\ 1}$ = Test $duration_{Test\ block\ 3}$ = Test $duration_{Test\ block\ 5}$ = 1/3 (total test duration - 2*240 hours).
Test temperature	65 °C
Test humidity	93 % relative humidity
Number of DUTs	6

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature up to the limit $T_{cool,max}$. Above the coolant temperature limits, only the ambient temperature shall be varied.

Test blocks 2 and 4:
This test shall be carried out in accordance with DIN EN 60068-2-38 with the following parameters:

Table 82: Test parameters K-15 b Climate test for components with waterproof housings test blocks 2 and 4

Operating mode of DUT	Operating mode II.a 12 hours after beginning of the test block and afterwards every 24 hours a parameter test for environmental tests (function test) shall be carried out.
Test duration per test block	240 h
Number of cycles	10
Test cycle sequence	The first five cycles shall include a cold subcycle and the remaining cycles shall be carried out without a cold subcycle.
Number of DUTs	6

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature between $T_{cool,min}$ and $T_{cool,max}$. Outside the coolant temperature limits, only the ambient temperature shall be varied.

14.14.2.3 Requirement

The DUT shall be fully functional before, during and after the test and all parameters shall meet the specifications. Verification is done by means of continuous parameter monitoring and a parameter test (large) as per Section 10.4.2.

14.15 K-16 Thermal shock (without housing)

14.15.1 Purpose

This technology test does not simulate any real exposure.
Instead, it is intended to detect weak points in the mechanical properties of interconnect technologies on electronic assemblies, such as soldering points.

The test shall be performed exclusively with the electronic assembly of the component without housing and mechanical parts.

14.15.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-14 with the following parameters:

Table 83: Test parameters K-16 Thermal shock (without housing)

Operating mode of DUT	Operating mode I.a
Lower temperature	T_{min}
Upper temperature	T_{max}
Holding time at upper/lower temperature	15 min following attainment of complete thermal equilibrium (see Section 0)
Transition time	≤ 10 s
Number of cycles	300
Number of DUTs	6 electronic assemblies

14.15.3 Requirement

The DUT shall be fully functional before and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (large) as per Section 10.4.

14.16 K-17 Solar radiation

14.16.1 Purpose

This test simulates the influence of solar radiation and UV light on the component.
The test is intended to verify the resistance of the component to damage caused by material fatigue, such as cracks or discolorations.

14.16.2 Test

This test shall be carried out in accordance with DIN 75220 with the following parameters:

Table 84: Test parameters K-17 Solar radiation

Operating mode of DUT	Operating mode I.a
Applied test profiles	The test profiles according to DIN 75220 shall be applied depending on the installation space for the component.
Components in the exterior	Use of the Z-OUT profile as per Table 2 and Table 5 of DIN 75220
Components in the interior	Use of the Z-IN1 profile as per DIN 75220
Test duration	25 days (15 days dry, 10 days humid)
Number of cycles	1
Number of DUTs	6

14.16.3 Requirement

The DUT shall be fully functional before and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (large) as per Section 10.4.

In addition, the DUT shall be visually inspected with the naked eye.
Changes or damage shall be documented in the test report and evaluated with the buyer.

14.17 K-18 Corrosion test with flow of mixed gas

14.17.1 Purpose

This test simulates the influence of corrosive gases on the component, particularly its plug contacts and switches.
The test is intended to verify the resistance of the component to faults such as corrosion and component damages.

14.17.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-60 Method 4 with the following parameters:

Table 85: Test parameters K-18 Corrosion test with flow of mixed gas

Operating mode of DUT	Operating mode I.b	
Temperature	T_{RT}	
Humidity	75 % relative humidity	
Corrosive gas concentration	SO_2	0,2 ppm
	H_2S	0,01 ppm
	NO_2	0,2 ppm
	Cl_2	0,01 ppm
Test duration	21 days	
Number of DUTs	6	

14.17.3 Requirement

The DUT shall be fully functional before and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (large) as per Section 10.4.

In addition, the contact resistance of switches and contacts shall be measured. The measured values shall meet the specifications.

15 Chemical requirements and tests

15.1 C-01 Chemical tests

15.1.1 Purpose

This test simulates the exposure of the component to different chemicals.
The test is intended to verify the resistance of the component to chemical changes on the housing and impairment of functioning due to chemical reactions.

15.1.2 Test

Table 86: Test parameters - chemical tests

Operating mode of DUT	As specified in the Component Requirement Specifications
Chemicals	As specified in the Component Requirement Specifications Typical chemicals for different installation locations are indicated in Table 87.
Conditioning	Unless otherwise specified, the DUT and the chemical shall be stored in standard atmosphere.
Test procedure	The test shall be carried out in analogy with ISO 16750 Part 5: 1. The chemical shall be applied to the DUT at T_{RT}. Unless otherwise specified in the Component Requirement Specifications, an appropriate application method shall be selected for each chemical as per Table 88. The selected application method shall be documented in the test report. Care shall be taken to ensure that the DUT is covered with a sufficient amount of the chemical. 2. The DUT shall then be stored at the temperature indicated in Table 87 for the specified exposure time.
Number of DUTs	1 DUT per chemical. A DUT may be used multiple times for multiple chemicals subject to an agreement with the buyer.

Safety instructions and warnings for the chemicals shall be observed.

15.1.2.1 Chemicals

Table 87: Overview of chemicals (see also ISO 16750- 5)

ID	Chemical agent	Temperature of DUT	Exposure time	Description / reference
1	Diesel fuel	T_{max}	22 h	EN 590
2	Biodiesel	T_{max}	22 h	EN 14214
3	Petrol/gasoline, unleaded	T_{RT}	10 min	EN 228
4	Kerosene	T_{RT}	10 min	ASTM 1655
5	Methanol	T_{RT}	10 min	CAS 67-56-1
6	Engine oil	T_{max}	22 h	Multigrade oil SAE 0W40, API SL/CF
7	Differential oil	T_{max}	22 h	Hypoid gear oil SAE 75W140, API GL-5
8	Transmission fluid	T_{max}	22 h	ATF Dexron III
9	Hydraulic fluid	T_{max}	22 h	DIN 51 524-3 (HVLP ISO VG 46)
10	Grease	T_{max}	22 h	DIN 51 502 (KP2K-30)
11	Silicone oil	T_{max}	22 h	CAS 63148-58-3 (AP 100)
12	Battery fluid	T_{RT}	22 h	37 % H_2SO_4
13	Brake fluid	T_{max}	22 h	ISO 4926
14	Antifreeze fluid	T_{max}	22 h	Ethylene glycol ($C_2H_6O_2$) – water (mixture ratio 1:1)
15	Urea	T_{max}	22 h	ISO 22241-1
16	Cavity protection	T_{RT}	22 h	e.g. underbody protection, by Teroson [1]
17	Preservative	T_{RT}	22 h	e.g. W550 (by Pfinder) [1]
18	Preservative remover	T_{max}	22 h	e.g. Friapol 750 (by Pfinder) [1]
19	Windscreen washer fluid	T_{RT}	2 h	5 % anionic tensides, distilled water
20	Vehicle washing chemicals	T_{RT}	2 h	CAS 25155-30-0 CAS 9004-82-4
21	Interior cleaner / cockpit spray	T_{RT}	2 h	e.g. Cockpit spray (by Motip) [1]
22	Glass cleaner	T_{RT}	2 h	CAS 111-76-2
23	Wheel cleaner	T_{RT}	2 h	e.g. Xtreme (Sonax) [1]
24	Cold-cleaning agent	T_{RT}	22 h	e.g. P3-Solvclean AK (by Henkel) [1]
25	Acetone	T_{RT}	10 min	CAS 67-64-1
26	Cleaning solvent	T_{RT}	10 min	DIN 51 635
27	Ammonia cleaner	T_{RT}	22 h	e.g. Ajax (by Henkel) [1]
28	Denatured alcohol	T_{RT}	10 min	CAS 64-17-5 (ethanol)
29	Contact spray	T_{max}	22 h	e.g. WD 40 [1]
30	Sweat	T_{RT}	22 h	DIN 53 160
31	Cosmetic products, e.g. creams	T_{RT}	22 h	e.g. Nivea, Kenzo [1]
32	Beverages containing caffeine and sugar	T_{RT}	22 h	Cola
33	Runway de-icer	T_{RT}	2 h	SAE AMS 1435A
34	E85 fuel	T_{RT}	10 min	DIN 51625
	Other chemicals			
	[1]) Manufacturer intended as example, exact chemicals shall be agreed with the responsible department			

Table 88: Types of application

Code number	Application method
I	Spraying
II	Brushing
III	Wiping (e.g. with cotton cloth)
IV	Pouring
V	Dipping
VI	Immersing

15.1.3 Requirement

The DUT shall be fully functional before and after the test and all parameters shall meet the specifications. Verification is done by means of a parameter test (large) as per Section 10.4.

Changes to labels and markings shall be documented in the test report and coordinated with the buyer.

16 Life tests

16.1 L-01 Life test: mechanical/hydraulic endurance test

16.1.1 Purpose

This test simulates the actuation/operating cycles of the component during the vehicle service life.
The test is intended to verify the quality and reliability of the component with respect to operating/actuation cycles, e.g. brake actuation, seat adjustment cycles, switch/pushbutton actuation.

16.1.2 Test

Test details shall be defined in the Component Requirement Specifications in line with the operating/actuation cycle.

Table 89: Test parameters L-01 Life test: mechanical/hydraulic endurance test

Operating mode of DUT	Operating mode II.c corresponding to operating/actuation cycle
Test temperature	The operating/actuation cycles shall be performed at the temperatures specified in the temperature distribution profile, the number of cycles at each temperature corresponding to the percentage share associated with that temperature.
Number of actuation/operating cycles	As specified in the Component Requirement Specifications
Number of DUTs	6

For components attached to a coolant circuit the coolant temperature shall follow the relevant test temperature between $T_{cool,min}$ and $T_{cool,max}$. Outside the coolant temperature limits, only the ambient temperature shall be varied.

16.1.3 Requirement

The DUT shall be fully functional before, during and after the test and all key parameters shall meet the specifications. Verification shall be done using continuous parameter monitoring. Intermediate measurements at 25 %, 50 % and 75 % of the test duration and parameter tests as per the test sequence plan shall only be carried out if the functions of the component cannot be sufficiently monitored during the test.

The intermediate measurements shall be carried out as a parameter test (large).

The data acquired from continuous parameter monitoring shall be assessed for drifts, trends and conspicuous behavior or anomalies.

For components connected to a coolant circuit:
For components with coated copper parts in the coolant path these copper parts shall be investigated after the test by means of a stereomicroscope using 20x magnification. Identifiable defects and copper corrosion are not permitted.

16.2 L-02 Life test: high-temperature endurance test

16.2.1 Purpose

This accelerated test simulates the thermal exposure of the component during vehicle service life.
The test is intended to verify the quality and reliability of the component with respect to faults that occur due to thermal exposure such as diffusion, migration and oxidation.

16.2.2 Test

16.2.2.1 Test for components not connected to a coolant circuit and without reduced performance at high temperatures

This test shall be carried out in accordance with DIN EN 60068 -2-2 with the following parameters:

Table 90: Test parameters L-02 Life test: high-temperature endurance test - Test for components not connected to a coolant circuit and without reduced performance at high temperatures

Operating mode of DUT	Intermitting between 47 h operating mode II.c and 1 h operating mode II.a
Test duration	For each relevant working condition according to Section 10.1, the respective part test duration shall be calculated according to Annex C.1 (Arrhenius model); the working conditions parking / off-grid parking shall not normally be considered in this process. The total test duration is the sum of all part test durations and specified in the Component Requirement Specifications.
Test temperature	T_{max}
Number of DUTs	6

16.2.2.2 Test for components not connected to a coolant circuit and with reduced performance at high temperatures

For components with reduced performance (e.g. reduction of backlight of LCDs) at high temperatures starting at $T_{op,max}$, the test according to Table 91 shall not be carried out at a constant test temperature of T_{max}, but with a temperature profile with the following parameters:

This test shall be carried out in accordance with DIN EN 60068 -2-2 with the following parameters:

Table 91: Test parameters L-02 Life test: high-temperature endurance test - Test for components not connected to a coolant circuit and with reduced performance at high temperatures

Operating mode of DUT	As per Figure 43
Test duration	For each relevant working condition according to Section 10.1, the respective part test duration shall be calculated according to Annex C.3 (Arrhenius model for use with components with reduced performance at high temperatures); the working conditions parking / off-grid parking shall not normally be considered in this process. The total test duration is the sum of all part test durations and specified in the Component Requirement Specifications. The ramp times between T_{max} and $T_{op, max}$ shall not be included in the test duration.
Test temperature	As per Figure 43
Interval time t_1	To be calculated in accordance with Annex C.3 and to be specified in the Component Requirement Specifications.
Interval time t_2	To be calculated in accordance with Annex C.3 and to be specified in the Component Requirement Specifications.
Number of DUTs	6

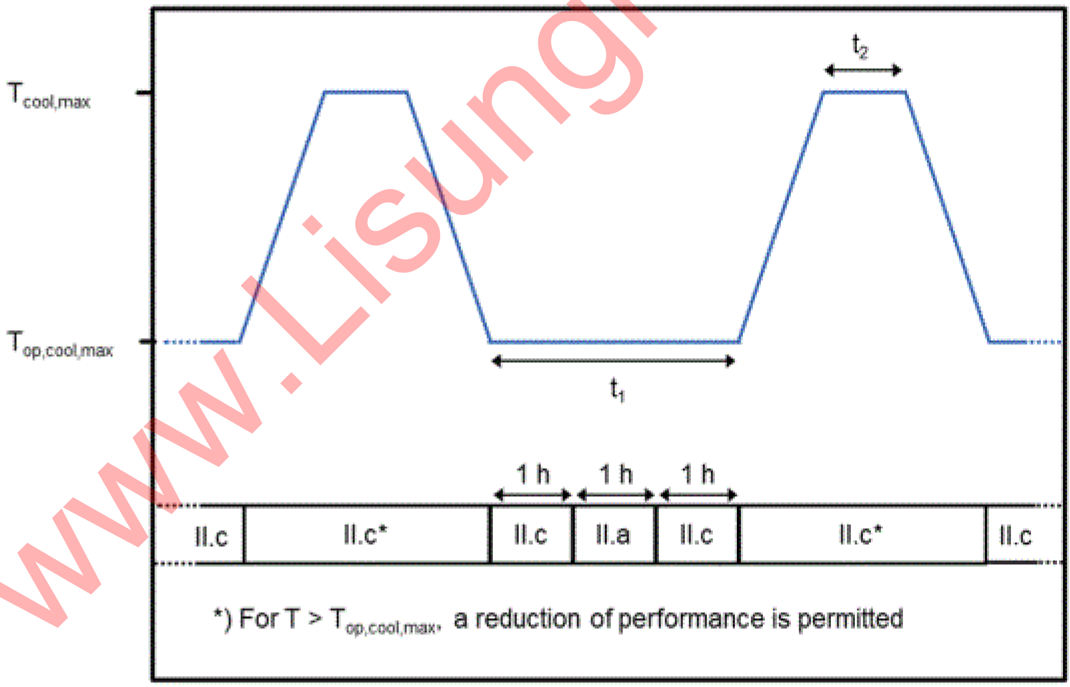


Figure 43: Temperature profile for testing components with reduced performance at high temperatures.

16.2.2.3 Test for components connected to a coolant circuit

This test shall be carried out in accordance with DIN EN 60068 -2-2 with the following parameters:

Table 92: Test parameters L-02 Life test: high-temperature endurance test - Test for components connected to a coolant circuit

Operating mode of DUT	Intermitting between 47 h operating mode II.c and 1 h operating mode II.a
Test duration	For each relevant working condition according to Section 10.1, the respective part test duration shall be calculated according to Annex C.5 (Arrhenius model for use with components connected to coolant circuits); the working conditions parking / off-grid parking shall not normally be considered in this process. The total test duration is the sum of all part test durations and specified in the Component Requirement Specifications.
Ambient test temperature	According to Annex C.5 (Arrhenius model for use with components connected to coolant circuits)
Test temperature coolant	According to Annex C.5 (Arrhenius model for use with components connected to coolant circuits)
Number of DUTs	6

16.2.3 Requirement

The DUT shall be fully functional before, during and after the test and all key parameters shall meet the specifications. Verification shall be done using continuous parameter monitoring. Intermediate measurements at 25 %, 50 % and 75 % of the test duration and parameter tests as per the test sequence plan shall only be carried out if the functions of the component cannot be sufficiently monitored during the test.

The intermediate measurements shall be carried out as a parameter test (large).

The data acquired from continuous parameter monitoring shall be assessed for drifts, trends and conspicuous behavior or anomalies.

For components connected to a coolant circuit:
For components with coated copper parts in the coolant path these copper parts shall be investigated after the test by means of a stereomicroscope using 20x magnification. Identifiable defects and copper corrosion are not permitted.

16.3 L-03 Life test: temperature cycle endurance test

16.3.1 Purpose

This accelerated test simulates the thermomechanical exposure of the component as a result of temperature changes that occur during vehicle service life.
The test is intended to verify the quality and reliability of the component with respect to faults that occur due to thermomechanical exposure such as aging and cracking in soldered joints, adhesive joints and welded joints, in bond connections as well as in seals or housings.

16.3.2 Test

This test shall be carried out in accordance with DIN EN 60068-2-14 with the following parameters:

16.3.2.1 Test for components not connected to a coolant circuit and without reduced performance at low or high temperatures

Table 93: Test parameters L-03 Life test: temperature cycle endurance test - Test for components not connected to a coolant circuit and without reduced performance at low or high temperatures

Operating mode of DUT	Intermitting between operating mode II.a and operating mode II.c as per Figure 44.
Temperature profile	As per Figure 44.
Minimum test temperature	T_{min}
Maximum test temperature	T_{max}
Temperature gradient	4 °C/min If the temperature gradient cannot be realized in the test equipment, it may be reduced to a minimum of 2 °C/min following discussions with the buyer.
Holding times at T_{min} and T_{max}	15 min following attainment of complete thermal equilibrium (see Section 0)
Number of cycles	The total number of test cycles shall be calculated considering all relevant working conditions (Section 10.1) according to Annex D.1 (Coffin-Manson model) and specified in the Component Requirement Specifications.
Number of DUTs	6

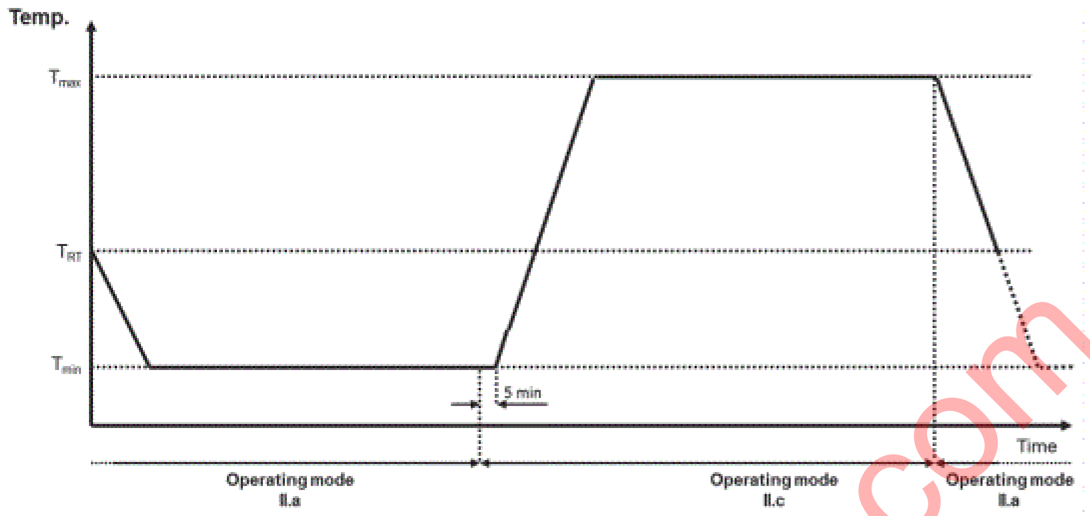


Figure 44: Temperature profile L-03 Life test: temperature cycle endurance test for components not connected to a coolant circuit and without reduced performance at low or high temperatures

16.3.2.2 Test for components not connected to a coolant circuit and with reduced performance at low or high temperatures

For components with reduced performance (e.g. reduction of backlight of LCDs) at low or high temperatures below $T_{op,min}$ and above $T_{op,max}$, the test shall be performed with the following parameters:

Table 94: Test parameters L-03 Life test: temperature cycle endurance test – Test for components not connected to a coolant circuit and with reduced performance at low or high temperatures

Operating mode of DUT	Operating mode II.a and operating mode II.c as per Figure 45
Temperature profile	As per Figure 45
Minimum test temperature	T_{min}
Maximum test temperature	T_{max}
Temperature gradient	4 °C/min
Holding times at T_{min}, T_{max}, $T_{op,min}$ and $T_{op,max}$	15 min following attainment of complete thermal equilibrium (see Section 0)
Number of cycles	The total number of test cycles shall be calculated considering all relevant working conditions (Section 10.1) according to Annex D.1 (Coffin-Manson model) and specified in the Component Requirement Specifications.
Number of DUTs	6

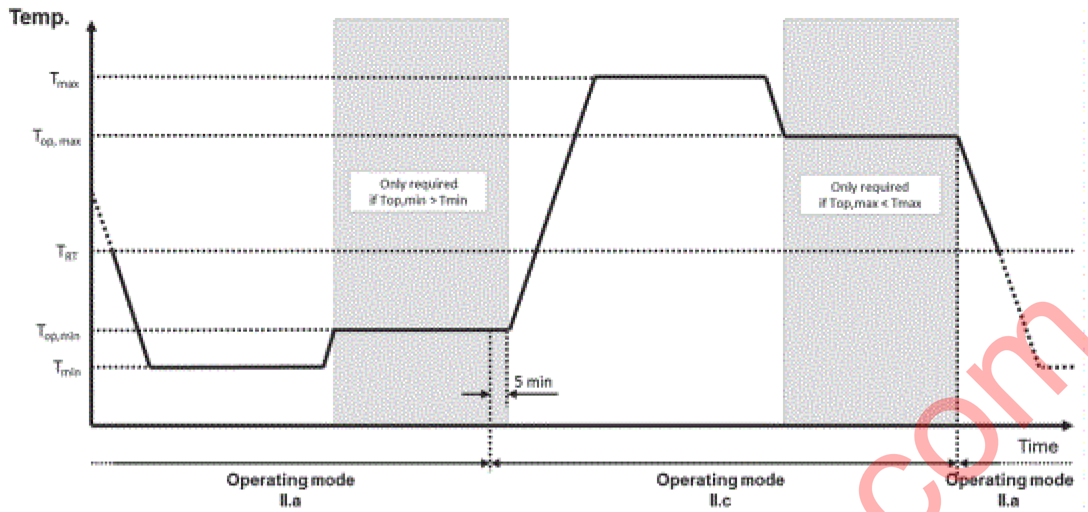


Figure 45: Temperature profile – Test for components with reduced performance at low or high temperatures

16.3.2.3 Test for components connected to a coolant circuit

The test for components connected to coolant circuits shall be carried out with the following parameters:

Table 95: Test parameters L-03 Life test: temperature cycle endurance test – Test for components connected to a coolant circuit

Operating mode of DUT	Operating mode II.a and operating mode II.c as per Figure 44 / Figure 45
Temperature profile	As per Figure 44 / Figure 45
Minimum test temperature	T_{min} and $T_{cool, min}$
Maximum test temperature	T_{max} and $T_{cool, max}$
Temperature gradient	4 °C/min
Holding times at T_{min}, T_{max}, $T_{op,min}$ and $T_{op,max}$	15 min following attainment of complete thermal equilibrium (see Section 0)
Number of cycles	The total number of test cycles shall be calculated considering all relevant working conditions (Section 10.1) according to Annex D.3 (Coffin-Manson model for use for components connected to coolant circuits) and specified in the Component Requirement Specifications.
Number of DUTs	6

16.3.3 Requirement

The DUT shall be fully functional before, during and after the test and all key parameters shall meet the specifications. Verification shall be done using continuous parameter monitoring. Intermediate measurements at 25 %, 50 % and 75 % of the test duration and parameter tests as per the test sequence plan shall only be carried out if the functions of the component cannot be sufficiently monitored during the test.

The intermediate measurements shall be carried out as a parameter test (large).

The data acquired from continuous parameter monitoring shall be assessed for drifts, trends and conspicuous behavior or anomalies.

For components connected to a coolant circuit:
For components with coated copper parts in the coolant path these copper parts shall be investigated after the test by means of a stereomicroscope using 20x magnification. Identifiable defects and copper corrosion are not permitted.

Annex A (normative)

Test sequence

A.1 Test sequence plan

A component-specific test sequence plan shall be defined in the Component Requirement Specifications.

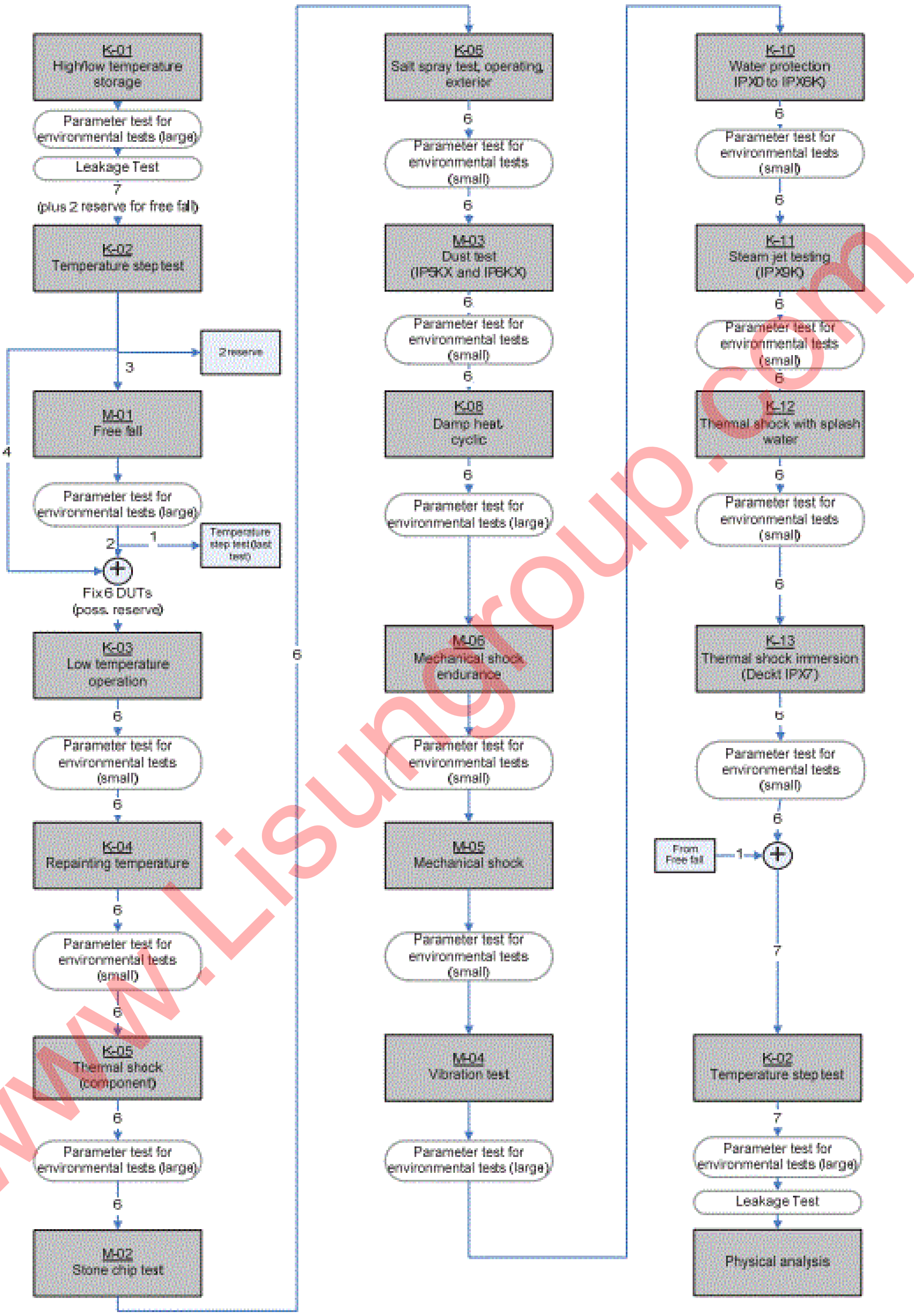
Tests that are not required for a component according to the test selection table shall be deleted from the test sequence plan.

If a component-specific adaptation of the test sequence is required, the test sequence plan may be adapted.

If, during sequential testing, the test Damp heat, cyclic (with frost) is performed in place of the test Damp heat, cyclic, the test Damp heat, cyclic (with frost) may, in consultation with the buyer, be omitted from the parallel tests.

All components shall be tested with original connector or adapter starting with the test M-01 Free fall.

A.2 Sequential tests



Numerical data on the arrows denote the number of DUTs to be used.

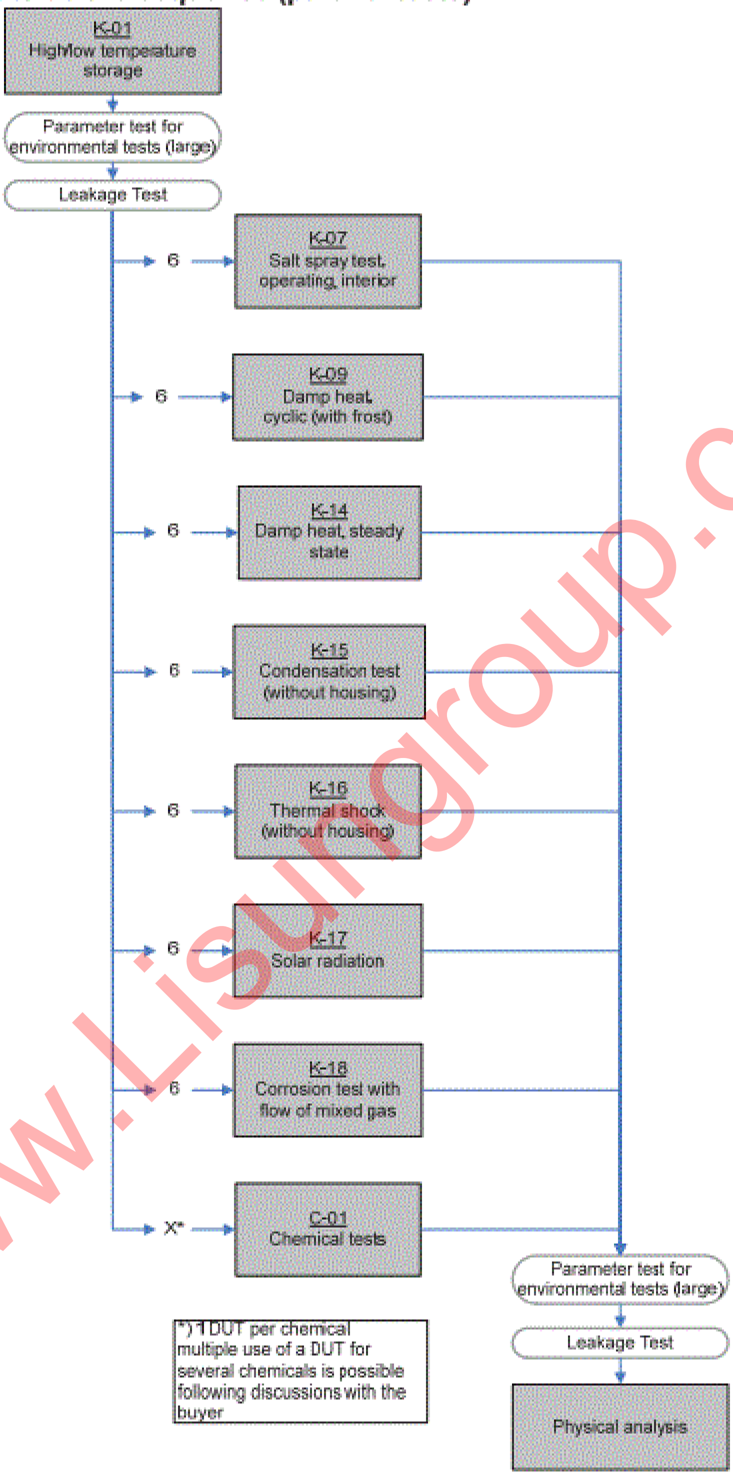
Figure 46: Test sequence plan – sequential tests

If the DUTs have not been damaged in the test M-01 Free fall, two DUTs shall be used for the further sequence test. Otherwise, the spare DUTs shall be used.

If, during sequential testing, the test Damp heat, cyclic (with frost) is performed in place of the test Damp heat, cyclic, the test Damp heat, cyclic (with frost) may, in consultation with the buyer, be omitted from the parallel tests.

All components shall be tested with original connector or adapter starting with the test M-01 Free fall.

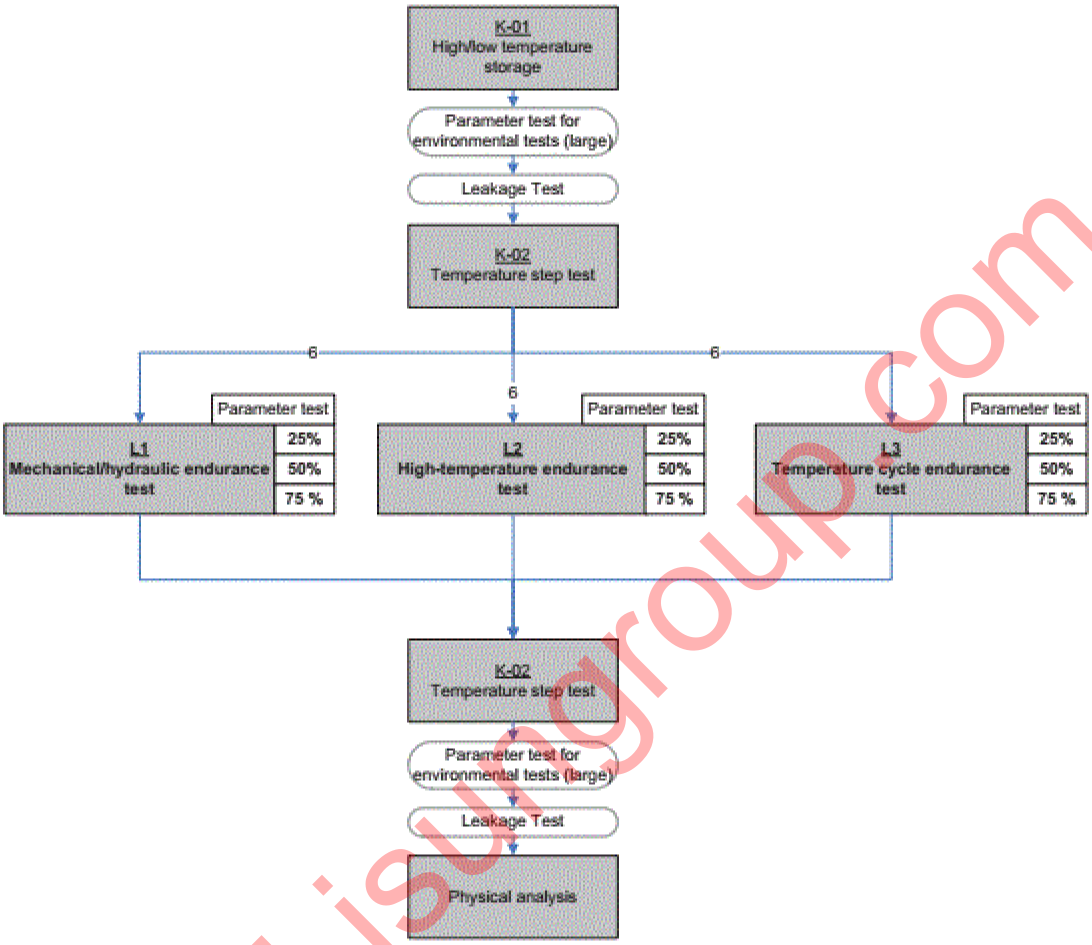
A.3 Tests outside the sequence (parallel tests)



Numerical data on the arrows denote the number of DUTs to be used.

Figure 47: Test sequence plan - parallel tests

A.4 Life tests



Numerical data on the arrows denote the number of DUTs to be used.

Figure 48: Test sequence plan - service life

Annex B (normative)

Typical temperature distribution profiles for different installation areas

Table 96: Overview of installation locations, typical distribution profiles and temperature deltas

Installation location of the component	Profile no.	Temperature delta in K
Interior, without special requirement	1	36
Body-mounted part, without special requirements	1	36
Interior exposed to solar radiation	2	46
Body-mounted part, roof	2	46
Engine compartment, but not on the engine	3	60
On the radiator	3	60
Engine-mounted parts	4	75
Gearbox-mounted parts	4	75

B.1 Temperature distribution profile 1

Table 97: Temperature distribution profile 1

Temperature in °C	Distribution in %
-40 °C	6 %
23 °C	20 %
40 °C	65 %
75 °C	8 %
80 °C	1 %

B.2 Temperature distribution profile 2

Table 98: Temperature distribution profile 2

Temperature in °C	Distribution in %
-40 °C	6 %
23 °C	20 %
50 °C	65 %
100 °C	8 %
105 °C	1 %

B.3 Temperature distribution profile 3

Table 99: Temperature distribution profile 3

Temperature in °C	Distribution in %
-40 °C	6 %
23 °C	20 %
65 °C	65 %
115 °C	8 %
120 °C	1 %

B.4 Temperature distribution profile 4

Table 100: Temperature distribution profile 4

Temperature in °C	Distribution in %
-40 °C	6 %
23 °C	20 %
85 °C	65 %
135 °C	8 %
140 °C	1 %

Annex C (normative)

Calculation models for the life test 'High-temperature endurance test'

C.1 Arrhenius model

The calculation of the test duration of the high-temperature endurance test life test is based on the temperature distribution profile according to the mission profile in the Component Requirement Specifications.

Table 101: Temperature distribution profile

Temperature in °C	Distribution in %
$T_{field.1}$	p_1
$T_{field.2}$	p_2
…	…
$T_{field.n}$	p_n

and the operating hours t_{op} of the vehicle in the field.

For each temperature $T_{field,1}$ … $T_{field,n}$ an acceleration factor $A_{T,1}$ … $A_{T,n}$ is calculated on the basis of the following equation:

$$A_{T,i} = e^{\left[-\left(\frac{E_A}{k}\right)\left(\frac{1}{T_{test}+273,15}-\frac{1}{T_{field,i}+273,15}\right)\right]} \quad (1)$$

where:

- $A_{T,i}$ Acceleration factor of the Arrhenius model
- E_A Activation energy E_A = 0,45 eV
- k Boltzmann constant (k = 8,617 x 10^{-5} eV/K)
- T_{test} Test temperature in [°C], normally T_{max}
- $T_{field,i}$ Field temperature in [°C] according to temperature distribution profile based on mission profile
- -273,15 °C Absolute zero of the temperature

The total test duration for the high-temperature endurance test results from the acceleration factor according to

$$t_{test} = t_{op} \cdot \sum_i \frac{p_i}{A_{T,i}} \quad (2)$$

where:

- t_{test} Test duration (hours) of the high-temperature endurance test life test
- t_{op} Operating time (hours) in the field
- p_i Percentage of the operating time for which the component is operated at the temperature $T_{field,i}$ in the field.
- $A_{T,i}$ Acceleration factor for temperature $T_{field,i}$

C.2 Example Arrhenius model:

For a control unit with the temperature distribution profile indicated in the following table

Table 102: Sample temperature distribution profile

Temperature in °C	Distribution in %
-40	6
23	20
60	65
100	8
105	1

and an operating time of 8 000 h, the test duration for the life test high-temperature endurance test is calculated as follows:

Using equation (1) and $T_{Test} = T_{max} = 105$ °C, the acceleration factors $A_{T,i}$ for all five temperatures (see Table 102) of the temperature distribution profile indicated above are calculated:

$$A_{T,1} = 5369$$
$$A_{T,2} = 45{,}8$$
$$A_{T,3} = 6{,}46$$
$$A_{T,4} = 1{,}20$$
$$A_{T,5} = 1{,}00$$

The operating time of the component is $t_{op} = 8\,000$ h.

The total test duration of the life test high-temperature endurance test results from equation (2) as:

$$t_{test} = 8000 \text{ hours} \cdot \left(\frac{0{,}06}{5369} + \frac{0{,}20}{45{,}8} + \frac{0{,}65}{6{,}46} + \frac{0{,}08}{1{,}20} + \frac{0{,}01}{1{,}00} \right) = 1452 \text{ hours}.$$

C.3 Arrhenius model for use with components with reduced performance at high temperatures

To calculate the test duration for the life test high-temperature endurance for components with reduced performance at high temperatures starting with $T_{op,max}$, the temperature distribution profile according to the mission profile in the Component Requirement Specification is divided into the two temperature ranges $T \leq T_{op,max}$ and $T > T_{op,max}$:

Table 103: Temperature distribution profile for $T \leq T_{op,max}$ with test temperature $T_{op,max}$

Temperature in °C	Distribution in %
$T_{field.1}$	p_1
$T_{field.2}$	p_2
…	…
$T_{field.m}$ ($\leq T_{op,max}$)	p_m

m < n

Table 104: Temperature distribution profile for $T_{op,max} < T \leq T_{max}$ with test temperature T_{max}

Temperature in °C	Distribution in %
$T_{field.m+1}$($> T_{op,max}$)	p_{m+1}
$T_{field.m+2}$	p_{m+2}
…	…
$T_{field.n}$	p_n

m < n

For each temperature $T_{field,1}$ … $T_{field,m}$ … $T_{field,n}$, an acceleration factor $A_{T,1}$ … $A_{T,m}$ … $A_{T,n}$ is calculated by means of equation (1), where for temperature range $T \leq T_{op,max}$ a test temperature of $T_{Test}=T_{op, max}$ and for temperature range $T>T_{op,max}$ a test temperature of $T_{Test}=T_{max}$ is assumed.

The required test duration $t_{op, max}$ at test temperature $T_{op, max}$ results from equation (2) with i=1 …m.

The required test duration t_{max} at test temperature T_{max} results from equation (2) with i=m+1 …n.

The total test duration t_{tot} is the sum of $t_{op, max}$ and t_{max}.

To ensure a test close to reality, the test is carried out intermittently at the test temperatures $T_{op, max}$ and T_{max} (see Figure 43).
The typical interval of 48 h is divided using the ratio of the part test durations $t_{op, max}$ and t_{max}.

C.4 Example Arrhenius model for use with components with reduced performance at high temperatures:

The temperature distribution profile according to Table 105 and Table 106 applies to the control unit. The test duration for the life test high-temperature endurance test for components with reduced performance starting with a temperature of $T_{op, max}$ = 90 °C for an operating time of 8 000 h is calculated as follows:
The percentage temperature distribution profile according to the mission profile is divided into the two ranges $T \leq T_{op,max}$ and $T>T_{op,max}$:

Table 105: Sample temperature distribution profile for T ≤ 90 °C

Temperature in °C	Distribution in %
-40	6
23	20
60	65

Table 106: Sample temperature distribution profile for T > 90 °C

Temperature in °C	Distribution in %
100	8
105	1

By means of equation (1) and T_{Test} = 90 °C, the acceleration factors $A_{T,i}$ for all temperatures T ≤ 90 °C (see Table 105) of the first part of the temperature distribution profile are calculated:

$$A_{T,1} = 3060{,}78$$
$$A_{T,2} = 25{,}95$$
$$A_{T,3} = 3{,}65$$

This results in a test duration $t_{op, max}$ at a test temperature of $T_{op,max}$ = 90 °C of

$$t_{op,max}(T_{test} = 90°C) = 8000\,\text{hours} \cdot \left(\frac{0{,}06}{3060{,}78} + \frac{0{,}2}{25{,}95} + \frac{0{,}65}{3{,}65}\right) = 1485\,\text{hours}$$

By means of equation (1) and T_{Test} = 105 °C, the acceleration factors $A_{T,i}$ for all temperatures T >90 °C (see Table 106) of the second part of the temperature distribution profile are calculated:

$$A_{T,4} = 1{,}20$$
$$A_{T,5} = 1{,}00$$

This results in a test duration t_{max} at a test temperature of T_{max} = 105 °C of

$$t_{max}(T_{test} = 105°C) = 8000\,\text{hours} \cdot \left(\frac{0{,}08}{1{,}20} + \frac{0{,}01}{1{,}00}\right) = 612\,\text{hours}$$

The total test duration for the life test high-temperature endurance test is the sum of the two test durations

$$t_{tot} = t_{op,max} + t_{max} = 1485 \text{ hours } + 612 \text{ hours } = 2097 \text{ hours}$$

The test shall be carried out as per Figure 43 intermittently at the test temperatures $T_{op,\,max}$ / T_{max} with the intervals

t_1 = 48 h * $t_{op,max}$ / t_{tot} = 48 h * 1485/2097 = 34 h
t_2 = 48 h * t_{max} / t_{tot} = 48 h * 612/2097 = 14 h.

C.5 Arrhenius model for use with components connected to coolant circuits

For components connected to the coolant circuit all relevant working conditions i (see Figure 22; i corresponds to the consecutive number of the working conditions) with their corresponding temperature distributions for ambient temperature and coolant circuit shall be considered.
As described below, for the life test high-temperature endurance the test durations and test temperatures for the ambient temperature and the coolant circuit shall be calculated for each relevant working condition i; the total test duration is the sum of all part test durations for each relevant working condition i.

To calculate the test duration for each relevant working condition i, the test duration for the ambient temperature and the coolant circuit shall initially be calculated separately according to the Arrhenius model as per Annex C.1 / C.3.
Given that the resulting test durations $t_{test,ambient}$ and $t_{test, CC}$, normally differ, an equalization of the test durations between ambient temperature and coolant circuit is necessary, because the component can only be tested at a consistent test duration for the each working condition i.

In doing so the shorter of the two test durations $t_{test, ambient}$ and $t_{test, CC}$ shall be adapted to the longer test duration by separating the test into at least two partial tests and by decreasing the test temperatures in all partial tests except for one, according to the following iteration method.

Case A: $t_{test, ambient} < t_{test, CC}$

<u>Test duration:</u>
For $t_{test, ambient} < t_{test, CC}$, the test duration for working condition i is

$$t_{test, condition\ i} = t_{test, CC}.$$

<u>Test temperature coolant:</u>
The test temperature shall be selected according to the Arrhenius model as per Annex C.1 (normally $T_{cool,max}$).
<u>Test temperatures ambient temperature:</u>
The test temperatures shall be calculated iteratively according to the following algorithm based on the temperature distribution profile of the ambient temperature of the working condition i considered (Table 107).

Table 107: Temperature distribution profile ambient

Temperature in °C	Distribution in %
$T_{field.1}$	p_1
$T_{field.2}$	p_2
…	…
$T_{field.n}$	p_n

1. Start of iteration (m = 0):
   The first partial test shall be carried out at test temperature $T_{field, n}$ with the test duration $t_{test, T\_field, n} = t_{operation} * p_n$ (where $t_{operation}$ corresponds to the field operating time of the considered working condition i in hours).

2. First iteration (m = 1):
   The 1st partial test covers a part of the test duration of working condition i $t_{test, condition\ i}$, so that a remaining test duration results, which shall be covered by the further partial tests:

   $$t_{Rest, 1} = t_{test, condition\ i} - t_{test, T\_field, n}.$$

   Additionally the first partial test covers the portion p_n of the temperature distribution of the ambient temperature. Therefore this portion p_n shall be set to $p_n = 0$ for further calculation.
   To define the test temperature for the 2nd partial test (m = 1) first of all the test temperature $T_{adapted}$ shall be determined by means of the Arrhenius model according to C.1 / C.3 in such a way that for the ambient temperature distribution (adapted with $p_n = 0$) a test duration equal to the remaining test duration of $t_{Rest, 1}$ results.
   If the resulting adapted test temperature is $T_{adapted} < T_{field, n-1}$, the 2nd partial test shall be carried out at the test temperature $T_{field, n-1}$ for the test duration

   $$t_{test, T\_field, n-1} = t_{operation} * p_{n-1}$$

   and at least one additional iteration step shall be carried out.
   However, if the resulting adapted test temperature is $T_{adapted} > T_{field, n-1}$, the 2nd partial test shall be carried out at the test temperature $T_{adapted}$ for the test duration

   $$t_{test, T\_field, n-1} = t_{rest, 1}$$

   and no further iteration step needs to be carried out (end of iteration).

3. Further iterations (m = 2, 3, …)
   The first m partial tests cover a part of the test duration for the working condition i $t_{test, condition\ i}$, so that a remaining test duration results, which shall be covered by the further partial tests:

   $$t_{rest, m} = t_{prüf, condition, i} - \sum_{k=0}^{m-1} t_{test, T_{field, n-k}}$$

   Additionally the first m partial tests cover the portions p_{n-k} with $k = 0, 1, \ldots, (m-1)$ of the temperature distribution of the ambient temperature. Therefore these portions p_{n-k} shall be set to $p_{n-k} = 0$ for the further calculations.
   To define the test temperature for the (m+1)-th partial test, first of all the test temperature $T_{adapted}$ shall be determined by means of the Arrhenius model according to C.1 / C.3 in such a way that for the ambient temperature distribution (adapted with $p_{n-k} = 0$) a test duration equal to the remaining test duration of $t_{rest, m}$ results.
   If the resulting adapted test temperature is $T_{adapted} < T_{field, n-m}$, the (m+1)-th partial test shall be carried out at the test temperature $T_{field, n-m}$ for the test duration

$$t_{test,\ T\_field,\ n\text{-}m} = t_{operation} * p_{n\text{-}m}$$

and at least one additional iteration step shall be carried out.
However, if the resulting adapted test temperature is $T_{adapted} > T_{field,\ n\text{-}m}$, the (m+1)-th partial test shall be carried out at the test temperature $T_{adapted}$ for the test duration

$$t_{test,\ T\_field,\ n\text{-}m} = t_{rest,\ m}$$

and no further iteration step needs to be carried out (end of iteration).

Case B: $t_{test,\ ambient} > t_{test,\ CC}$

Test duration:
For $t_{test,\ ambient} > t_{test,\ CC}$, the test duration for working condition i is

$$t_{test,\ condition\ i} = t_{test,\ ambient}.$$

Ambient test temperature:
The test temperature shall be selected according to the Arrhenius model as per Annex C.1 / C.3 (normally T_{max} / T_{max} and $T_{op,\ max}$).

Test temperature coolant:
The test temperatures shall be calculated iteratively based on the temperature distribution profile of the coolant temperature of the considered working condition i (Table 108).

Table 108: Temperature distribution profile coolant temperature

Temperature in °C	Distribution in %
$T_{field.1}$	p_1
$T_{field.2}$	p_2
…	…
$T_{field.n}$	p_n

1. Start of iteration (m = 0):
   The first partial test shall be carried out at test temperature $T_{field,\ n}$ with the test duration $t_{test,\ T\_field,\ n} = t_{operation} * p_n$ (where $t_{operation}$ corresponds to the field operating time of the considered working condition i in hours).

2. First iteration (m = 1):
   The first partial test covers a part of the test duration of working condition i $t_{test,\ condition\ i}$, so that a remaining test duration results, which shall be covered by the further partial tests:

   $$t_{rest,\ 1} = t_{test,\ condition\ i} - t_{test,\ T\_field,\ n}.$$

   Additionally the first partial test covers the portion p_n of the temperature distribution of the coolant temperature. Therefore this portion p_n shall be set to $p_n = 0$ for further calculation.

To define the test temperature for the second partial test (m = 1) first of all the test temperature $T_{adapted}$ shall be determined by means of the Arrhenius model according to C.1 in such a way that for the coolant temperature distribution (adapted with $p_n = 0$) a test duration equal to the remaining test duration of $t_{rest, 1}$ results.
If the resulting adapted test temperature is $T_{adapted} < T_{field, n-1}$, the second partial test shall be carried out at the test temperature $T_{field, n-1}$ for the test duration

$$t_{test, T\_field, n-1} = t_{operation} * p_{n-1}$$

and at least one additional iteration step shall be carried out.
However, if the resulting adapted test temperature is $T_{adapted} > T_{field, n-1}$, the 2nd partial test shall be carried out at the test temperature $T_{adapted}$ for the test duration

$$t_{test, T\_field, n-1} = t_{Rest, 1}$$

and no further iteration step needs to be carried out (end of iteration).

3. Further iterations (m = 2, 3, …)
   The first m partial tests cover a part of the test duration for the working condition i $t_{test, condition\ i}$, so that a remaining test duration results, which shall be covered by the further partial tests:

$$t_{rest, m} = t_{test, operation\ i} - \sum_{k=0}^{m-1} t_{test, T_{field, n-k}}$$

   Additionally the first m partial tests cover the portions p_{n-k} with k = 0, 1, …, (m-1) of the temperature distribution of the ambient temperature. Therefore these portions p_{n-k} shall be set to
   $p_{n-k} = 0$ for the further calculations.
   To define the test temperature for the (m+1)-th partial test, first of all the test temperature $T_{adapted}$ shall be determined by means of the Arrhenius model according to C.1 in such a way that for the coolant temperature distribution (adapted with $p_{n-k} = 0$) a test duration equal to the remaining test duration of $t_{rest, m}$ results.
   If the resulting adapted test temperature is $T_{adapted} < T_{field, n-m}$, the (m+1)-th partial test shall be carried out at the test temperature $T_{field, n-m}$ for the test duration

$$t_{test, T\_field, n-m} = t_{operation} * p_{n-m}$$

   and at least one additional iteration step shall be carried out.
   However, if the resulting adapted test temperature is $T_{adapted} > T_{field, n-m}$, the (m+1)-th partial test shall be carried out at the test temperature $T_{adapted}$ for the test duration

$$t_{test, T\_field, n-m} = t_{rest, m}$$

   and no further iteration step needs to be carried out (end of iteration).

C.6 Example Arrhenius model for use with components connected to coolant circuits

For a control unit attached to the coolant circuit with the following temperature distribution profile for the ambient temperature and the coolant temperature

Table 109: Sample temperature distribution profile ambient temperature

Temperature in °C	Distribution in %
-40	6
23	20
50	65
100	8
105	1

Table 110: Sample temperature distribution profile coolant temperature

Temperature in °C	Distribution in %
-40	6
23	20
40	65
75	8
80	1

and an operating time of 8 000 h, the test duration for the life test high-temperature endurance test is calculated as follows:

<u>Test duration:</u>
Calculation of the test duration for ambient temperature and coolant temperature using the Arrhenius model:

$$t_{test,\ ambient} = 1143\ h$$
$$t_{test,\ CC} = 2009\ h$$

As $t_{test,\ ambient} < t_{test,\ CC}$ the calculation is carried out according to case A of Annex C.5. The test duration for the ambient temperature shall be adapted to $t_{test,\ condition,i} = t_{test,\ CC}$ = 2009 h.

<u>Test temperature coolant:</u>
According to the temperature distribution profile, the test temperature for the coolant is $T_{CC,\ max} = T_{field,\ 5}$ = 80°C.

<u>Iterative calculation of test temperatures ambient temperature:</u>

1. Start of iteration:
   The first partial test is carried out at $T_{field,\ 5}$ = 105 °C. The test duration is $t_{test,\ T\_field,\ 5} = t_{operation} * p_5$ = 8000 h * 1 % = 80 h.

2. First iteration:
   The first partial test already covered a part of the test duration of working condition i $t_{test,\ condition\ i}$; the remaining test duration shall therefore be recalculated as follows: $t_{rest,\ 1} = t_{test,\ condition\ i} - t_{test,\ T\_field,\ 5}$ = 2009 h – 80 h = 1929 h.

As the first partial test covers the portion p_5 of the temperature distribution, p_5 is set to $p_5 = 0$ in the following calculations according to Arrhenius, as per the following table.

Table 111: Adapted ambient temperature distribution profile after the first partial test

Temperature in °C	Distribution in %
-40	6
23	20
50	65
100	8
~~105~~	~~0~~

To define the test temperature for the 2nd partial test, the test temperature $T_{adapted}$ shall be calculated by means of the Arrhenius model according to C.1 in such a way that a test duration equal to the remaining test duration of $t_{rest,\,1}$ = 1929 h results. Taking into account the adapted temperature distribution of the ambient temperature the necessary test duration results of 1929 h at a temperature of $T_{adapted}$ = 89,5°C (exact value: 89,46 °C).
However, as $T_{adapted} < T_{field,\,4}$ (i.e. 89,5 °C < 100 °C), the 2nd partial test shall be carried out at test temperature $T_{field,\,4}$ = 100 °C.
The test duration for the 2nd partial test is $t_{test,\,T\_field,\,4} = t_{operation} * p_4$ = 8000 h * 8 % = 640 h.

3. Second iteration
The 2nd partial test covered another part of the test duration of working condition i $t_{test,\,condition\,i}$, the remaining test duration therefore results as:
$t_{rest,\,2} = t_{test,\,condition\,i} - (t_{test,\,T\_field,\,5} + t_{test,\,T\_field,\,4})$ = 2009 h – 80 h - 640 h= 1289 h.
The first and second partial tests covered the portions p_5 and p_4 of the ambient temperature distribution profile. Therefore these portions are set to $p_4 = p_5 = 0$ for the further iteration, as per the following table.

Table 112: Adapted ambient temperature distribution profile after the 1st and 2nd partial test

Temperature in °C	Distribution in %
-40	6
23	20
50	65
~~100~~	~~0~~
~~105~~	~~0~~

To define the test temperature for the 3rd partial test, the test temperature $T_{adapted}$ shall be calculated by means of the Arrhenius model according to C.1 in such a way that a test duration equal to the remaining test duration of $t_{rest,\,2}$ = 1289 h results. Taking into account the adapted temperature distribution of the ambient temperature the necessary test duration results of 1289 h at a temperature of $T_{adapted}$ = 82 °C (exact value: 82,17 °C).

As $T_{adapted} > T_{field, 3}$ (i.e. 82 °C > 50 °C), no further iteration is necessary. The 3rd and last partial test shall therefore be carried out at $T_{adapted}$ = 82 °C for the test duration $t_{test, T\_field, 3} = t_{Rest, 3}$ = 1289 h.

Altogether 80 h shall be tested at 105 °C ambient temperature, 640 h at 100°C ambient temperature and 1289 h at 82 °C ambient temperature.
In this example the coolant temperature is constantly 80 °C over the entire test duration.

Annex D (normative)

Calculation models for the life test 'Temperature cycle endurance test'

D.1 Coffin-Manson model

The calculation of the test duration for the life test temperature cycle endurance test is based on the average temperature change of the component in the field ΔT_{field} (refer to Table 96) and the number of temperature cycles during service life in the field $N_{TempCyclesfield}$.
Typically 2 temperature changes per day can be assumed for the number of temperature cycles in the field. This results in:

$$N_{TempCyclesfield} = 2 * 365 * 15 \text{ (years)} = 10\,950 \text{ cycles}$$

Depending on the average temperature change in the field, the acceleration factor of the Coffin-Manson model is calculated as follows:

$$A_{CM} = \left(\frac{\Delta T_{test}}{\Delta T_{field}}\right)^{c} \quad (3)$$

where:

A_{CM}	Acceleration factor of the Coffin-Manson model
ΔT_{test}	Temperature difference during a test cycle ($\Delta T_{test} = T_{max} - T_{min}$)
ΔT_{field}	Average temperature difference during service life in the field
c	Parameter of the Coffin-Manson model In this standard a fixed value of 2,5 is used for c

The total number of test cycles is calculated according to

$$N_{test} = \frac{N_{TempCyclefield}}{A_{CM}} \quad (4)$$

where:

N_{test}	Required number of test cycles
$N_{TempCyclesfield}$	Number of temperature cycles during service life in the field
A_{CM}	Acceleration factor of the Coffin-Manson model according to equation (3)

D.2 Example:

For a control unit with T_{min} = -40 °C and T_{max} = 105 °C, a service life of 15 years in the field and an average temperature difference in the field of ΔT_{field} = 40 °C, the number of test cycles (N_{test}) is calculated as described below:

1. The number of temperature cycles in the field:

   $N_{TempCyclesfield}$ = 2 * 365 * 15 (years) = 10 950 cycles

2. Temperature difference during a test cycle:

   ΔT_{test} = 105 °C – (-40 °C)= 145 °C.

3. The acceleration factor of the Coffin-Manson model is calculated as A_{CM} = 25,02 by means of equation (3).

4. This results in a number of test cycles by means of equation (4) of:

   $$N_{test} = \frac{10950 \text{ cycles}}{25{,}02} = 438 \text{ cycles}$$

5. The soak time is the time until the component attains complete thermal equilibrium plus 15 min. Assuming that the component attains complete thermal equilibrium after 20 min, the soak time is 35 min.

6. This results in a cycle time:

   $$t_{cycle} = 2 \cdot \left(\frac{(T_{max} - T_{min})}{4\,°C/min} + t_{soak\ time} \right)$$

7. In the example: $t_{cycle} = 2 \cdot \left(\frac{(105\,°C - (-40\,°C))}{4°C/min} + 35\text{min} \right) = 142{,}5\ min$
8. For 438 cycles the total test duration is therefore 1040 h.

D.3 Coffin-Manson model for use with components connected to coolant circuits

For components connected to the coolant circuit all relevant working conditions i (see Figure 22; i corresponds to the consecutive number of the working conditions) with its corresponding temperature deltas for ambient temperature and coolant circuit shall be considered.
As described below, for the life test temperature cycle endurance the minimum and maximum temperatures and the number of test cycles shall be calculated for each relevant working condition i; the total number of test cycles is the sum of all part test cycles for each relevant working condition i.

To calculate the test duration for each relevant working condition i, the number of test cycles for the ambient temperature and the coolant circuit shall initially be calculated separately according to the Coffin-Manson model as per Annex C.7.
Given that the resulting numbers of test cycles $N_{test, ambient}$ and $N_{test, CC}$ normally differ, an equalization of the number of test cycles between ambient temperature and coolant circuit is necessary, because the component can only be tested at a consistent number of test cycles for the each working condition i.

In doing so the smaller of the two numbers of test cycles $N_{test, ambient}$ and $N_{test, CC}$ shall be adapted to the larger number of test cycles as the test is separated into three partial tests. During this process, one partial test shall take place at full temperature delta between T_{min} and T_{max}; the two other tests shall take place at reduced temperature delta between T_{min} and T_{RT} / between T_{RT} and T_{max}.

Case A: $N_{test, ambient} > N_{test, CC}$

<u>Number of test cycles:</u>
For $N_{test, ambient} > N_{test, CC}$, the number of test cycles for working condition i is

$$N_{test, condition\ i} = N_{test, ambient}.$$

<u>Number of test cycles for coolant:</u>

The number of test cycles for the coolant $N_{test, CC}$ shall be adapted to the larger number of ambient test cycles $N_{test, ambient}$. The test cycles shall be carried out at the following three temperature ranges:

1. x_{CC} test cycles shall be carried out between $T_{CC, min}$ and $T_{CC, max}$.
   The acceleration factor $A_{CM, CC, 1}$ shall be calculated according to the Coffin-Manson model using $\Delta T_{test, 1} = T_{CC, max} - T_{CC, min}$
2. ½ * ($N_{test, condition\ i} - x_{CC}$) test cycles shall be carried out between $T_{CC, min}$ and T_{RT}.
   The acceleration factor $A_{CM, CC, 2}$ shall be calculated according to the Coffin-Manson model using $\Delta T_{test, 2} = T_{RT} - T_{CC, min}$.
3. ½ * ($N_{test, condition\ i} - x_{CC}$) test cycles shall be carried out between T_{RT} and $T_{CC, max}$.
   The acceleration factor $A_{CM, CC, 3}$ shall be calculated according to the Coffin-Manson model using $\Delta T_{test, 3} = T_{CC, max} - T_{RT}$.

From 1 to 3, $N_{test, condition\ i}$ temperature cycles result in total.

In analogy with equation (4) in Annex D.1, this results in:

$$N_{TempCyclesfield} = x_{CC} \cdot A_{CM,CC,1} + \frac{1}{2} \cdot \left(N_{test,\ condition\ i} - x_{CC}\right) \cdot A_{CM,CC,2} + \frac{1}{2} \cdot \left(N_{test,\ condition\ i} - x_{CC}\right) \cdot A_{CM,CC,3}$$

From this equation, the number of test cycles x_{CC} can be calculated as follows:

$$x_{CC} = \frac{N_{TempCyclesfield} - \frac{N_{test,\ condition\ i}}{2} \cdot \left(A_{CM,CC,2} + A_{CM,CC,3}\right)}{A_{CM,CC,1} - \frac{1}{2} \cdot \left(A_{CM,CC,2} + A_{CM,CC,3}\right)}$$

Inserting x_{CC} into points 1 to 3 above results in the number of test cycles for the three partial tests.

If $T_{CC,\ op,\ max} < T_{CC,\ max}$ or $T_{CC,\ op,min} > T_{CC,\ min}$ or $T_{ambient,\ op,\ max} < T_{ambient,\ max}$ or $T_{ambient,\ op,min} > T_{ambient,\ min}$, additional holding times at the respective temperatures shall be taken into account according to Figure 45 in Section 16.3.2.1.
During a test the temperature cycles for the ambient temperature and the cooling circuit run synchronously.

Case B: $N_{test,\ ambient} < N_{test,\ CC}$

Number of test cycles:
For $N_{test,\ ambient} < N_{test,\ CC}$, the number of test cycles for working condition i is

$$N_{test,\ condition\ i} = N_{test,\ CC}.$$

Number of ambient test cycles:

The number of ambient test cycles $N_{test,\ ambient}$ shall be adapted to the larger number of test cycles for the coolant $N_{test,\ CC}$. In this process the test cycles shall be carried out at the following three temperature ranges:

1. $x_{ambient}$ test cycles shall be carried out between $T_{ambient,\ min}$ and $T_{ambient,\ max}$. The acceleration factor $A_{CM,\ ambient\ ,\ 1}$ shall be calculated according to the Coffin-Manson model using $\Delta T_{test,\ 1} = T_{ambient,\ max} - T_{ambient,\ min}$.
2. ½ * ($N_{test,\ condition\ i} - x_{ambient}$) test cycles shall be carried out between $T_{ambient,\ min}$ and T_{RT}. The acceleration factor $A_{CM,\ ambient,\ 2}$ shall be calculated according to the Coffin-Manson model using $\Delta T_{test,\ 2} = T_{RT} - T_{ambient,\ min}$.
3. ½ * ($N_{test,\ condition\ i} - x_{ambient}$) test cycles shall be carried out between T_{RT} and $T_{ambient,\ max}$. The acceleration factor $A_{CM,\ ambient,\ 3}$ shall be calculated according to the Coffin-Manson model using $\Delta T_{test,\ 3} = T_{ambient,\ max} - T_{RT}$.

From 1 to 3, $N_{test, condition\ i}$ temperature cycles result in total.

In analogy with equation (4) in Annex D.1, this results in:

$$N_{TempCyclesfield} = x_{ambient} \cdot A_{CM,\,ambient,\,1} + \frac{1}{2} \cdot \left(N_{test,\,condition\ i} - x_{ambient}\right) \cdot A_{CM,\,ambient,\,2} + \frac{1}{2} \cdot \left(N_{test,\,condition\ i} - x_{ambient}\right) \cdot A_{CM,\,ambient,\,3}$$

From this equation, the number of test cycles $x_{ambient}$ can be calculated as follows:

$$x_{ambient} = \frac{N_{TempCyclesfield} - \frac{N_{test,\,condition\ i}}{2} \cdot \left(A_{CM,\,ambient,\,2} + A_{CM,\,ambient,\,3}\right)}{A_{CM,\,ambient,\,1} - \frac{1}{2} \cdot \left(A_{CM,\,ambient,\,2} + A_{CM,\,ambient,\,3}\right)}$$

Inserting $x_{ambient}$ into points 1 to 3 above results in the number of test cycles for the three partial tests.

If $T_{ambient,\,op,\,max} < T_{ambient,\,max}$ or $T_{ambient,\,op,min} > T_{ambient,\,min}$ or $T_{CC,\,op,\,max} < T_{CC,\,max}$ or $T_{CC,\,op,min} > T_{CC,\,min}$, additional holding times at the respective temperatures shall be considered, according to Figure 45 in Section 16.3.2.1.
During a test the temperature cycles for the ambient temperature and the cooling circuit run synchronously.

D.4 Example Coffin-Manson model for use with components connected to coolant circuits

For a control unit connected to a coolant circuit having an ambient temperature range from $T_{ambient, min}$ = -40 °C to $T_{ambient, max}$ = 120 °C and a coolant temperature range from $T_{CC, min}$ = -40 °C to $T_{CC, max}$ = 80 °C, a service life in the field of 15 years, an average ambient temperature delta in the field of $\Delta T_{field, ambient}$ = 60 K and an average coolant temperature delta in the field of $\Delta T_{field, CC}$ = 36 K, the number of test cycles for working condition i can be calculated as follows:

Number of ambient and coolant test cycles:
The calculation of the numbers of ambient and coolant test cycles according to the Coffin-Manson model as per Annex D.1 results in the following values:

$$N_{test, ambient} = 943 \text{ cycles}$$
$$N_{test, CC} = 540 \text{ cycles}$$

As $N_{test, ambient} > N_{test, CC}$, the number of test cycles for working condition i is $N_{test, condition\ i} = N_{test, ambient}$ = 943 cycles. The number of test cycles for the coolant shall be adapted.

Adaptation number of cycles coolant:
Adapting the number of test cycles of the coolant to $N_{test, condition\ i}$ = 943 cycles is carried out in three parts:

1. x_{CC} test cycles shall be carried out between $T_{CC, min}$ = -40 °C and $T_{CC, max}$ = 80 °C. The acceleration factor $A_{CM, CC, 1}$ calculated according to the Coffin-Manson model results in = $\left(\frac{80°C-(-40°C)}{36°C}\right)^{2,5}$ = 20,29.
2. ½ * (943 – x_{CC}) test cycles shall be carried out between $T_{CC, min}$ = -40 °C and T_{RT} = 23 °C. The acceleration factor $A_{CM, CC, 2}$ calculated according to the Coffin-Manson model results in = $\left(\frac{23°C-(-40°C)}{36°C}\right)^{2,5}$ = 4,05.
3. ½ * (943 – x_{CC}) test cycles shall be carried out between T_{RT} = 23 °C and $T_{CC, max}$ = 80 °C. The acceleration factor $A_{CM, CC, 3}$ calculated according to the Coffin-Manson model results in = $\left(\frac{80°C-23°C}{36°C}\right)^{2,5}$ = 3,15.

For x_{CC} the following number of cycles therefore results:

$$x_{CC} = \frac{N_{TempCyclesfield} - \frac{N_{test, condition\ i}}{2} \cdot (A_{CM,CC,2} + A_{CM,CC,3})}{A_{CM,CC,1} - \frac{1}{2} \cdot (A_{CM,CC,2} + A_{CM,CC,3})} = \frac{10950 - \frac{943}{2} \cdot (4{,}05 + 3{,}15)}{20{,}29 - \frac{1}{2} \cdot (4{,}05 + 3{,}15)} = 453$$

cycles

The following numbers of test cycles therefore result for the three temperature ranges, calculated according to points 1 to 3:

1. 453 test cycles shall be carried out between $T_{CC, min}$ = -40 °C and $T_{CC, max}$ = 80 °C
2. 245 test cycles shall be carried out between $T_{CC, min}$ = -40 °C and T_{RT} = 23 °C
3. 245 test cycles shall be carried out between T_{RT} = 23 °C and $T_{CC, max}$ = 80 °C

Adding the partial test cycles results in the total number of test cycles for working condition i $N_{test, condition\ i}$ = 943 cycles.

During a test the temperature cycles for the ambient temperature and the cooling circuit run synchronously.

Annex E (normative)

Calculation models for test 'Damp heat, steady state - severity 2'

E.1 Lawson model

The calculation of the test duration of the damp heat, steady state - severity 2 test is based on the average ambient humidity $RH_{Parking,\ field}$ and the average temperature $T_{Parking,\ field}$ of the component in the parked vehicle.
Unless otherwise specified in the Component Requirement Specifications, the following values shall be assumed for the calculation:

Table 113: Average ambient humidity and temperature in the parked vehicle

Installation location	Average ambient humidity in the parked vehicle $RH_{Parking,\ field}$	Average temperature in the parked vehicle $T_{Parking,\ field}$
In the passenger compartment/trunk	60 % relative humidity	23 °C
Outside the passenger compartment/trunk	65 % relative humidity	23 °C

Depending on the average ambient humidity and temperature in the field, the acceleration factor of the Lawson model is calculated as follows:

$$A_{T/RH} = e^{\left[-\left(\frac{E_A}{k}\right)\left(\frac{1}{T_{Test}+273{,}15}-\frac{1}{T_{Parking,field}+273{,}15}\right)\right]+b\cdot\left[\left(RH_{Test}\right)^2-\left(RH_{Parking,\ Field}\right)^2\right]} \quad (5)$$

where:

$A_{T/RH}$	Acceleration factor of the Lawson model
b	Constant ($b = 5{,}57 \times 10^{-4}$)
E_A	Activation energy ($E_A = 0{,}4$ eV)
k	Boltzmann constant ($k = 8{,}617 \times 10^{-5}$ eV/K)
T_{Test}	Test temperature in [°C]
$T_{Parking,\ field}$	Average temperature in [°C] in the parked vehicle
RH_{Test}	Relative humidity in % during the test
$RH_{Parking,\ field}$	Average relative humidity in % in the parked vehicle
-273,15 °C	Absolute zero of the temperature

The test duration for the damp heat, steady state test - severity 2 - is calculated by means of:

$$t_{Test} = \frac{t_{Parking,field}}{A_{T/RH}} \quad (6)$$

where:

t_{Test} Test duration in [h]

$T_{Parking, field}$ Non-operating time (parking time) in [h] during the service life in the field (131 400 h, in the most unfavorable case if the vehicle is not used)

$A_{T/RH}$ Acceleration factor of the Lawson model according to equation (5)

E.2 Example:

For a control unit mounted in the engine compartment, the test duration is calculated as follows:

1. An average temperature of $T_{Parking, field}$ = 23 °C and a relative humidity of $RH_{Parking, field}$ = 65 % is assumed for the component in the parked vehicle. The test conditions are T_{test} = 65 °C and RH_{Test} = 93 %.

   By means of equation (5), these values result in a combined acceleration factor of the Lawson model of $A_{T/RH}$ = 82,5

2. The parking time in the field is $t_{Parking, field}$ = 131 400 h. This results in a total test duration by means of equation (6) of:

$$t_{Test} = \frac{131400 \text{ hours}}{82{,}5} = 1593 \text{ hours}$$

Annex F (informative)

Condensation test, chamber programming and diagrams

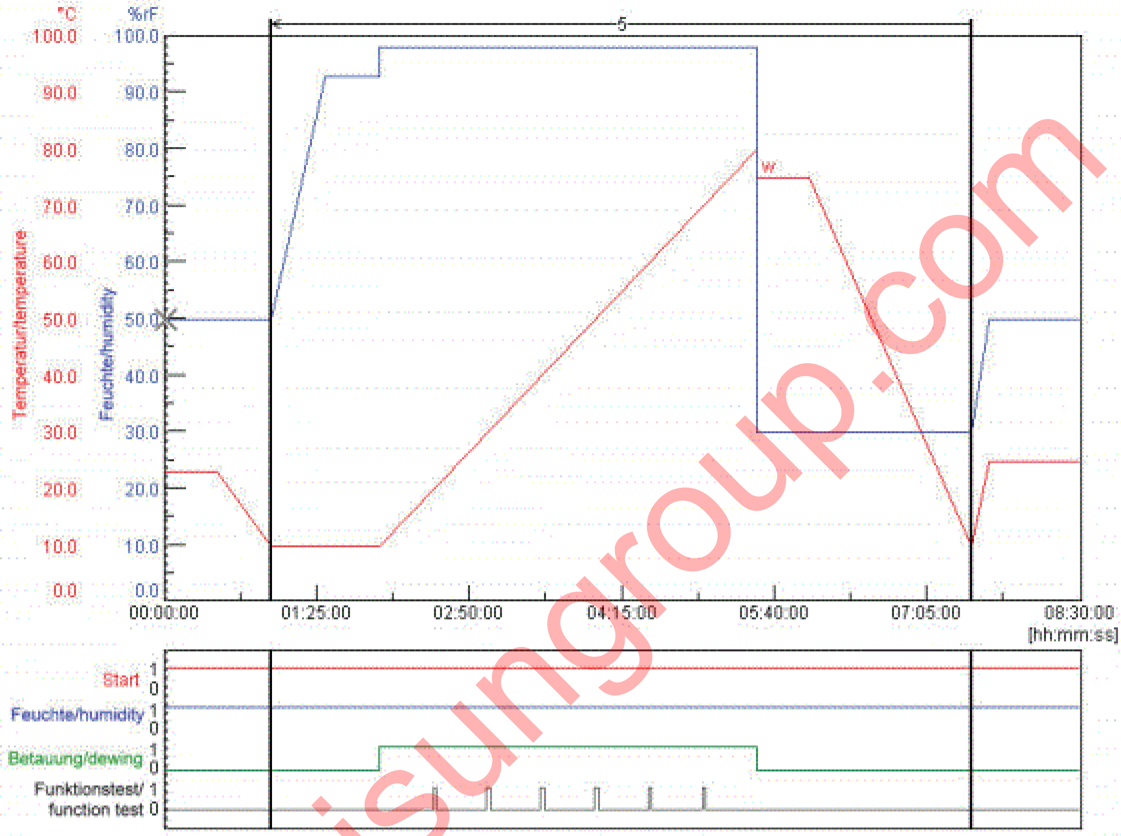


Figure 49: Programming of the test chamber

During the temperature increase, the temperature of the water bath is used as control variable. When 80 °C is reached, the climatic chamber is switched over to temperature control (standard operation).

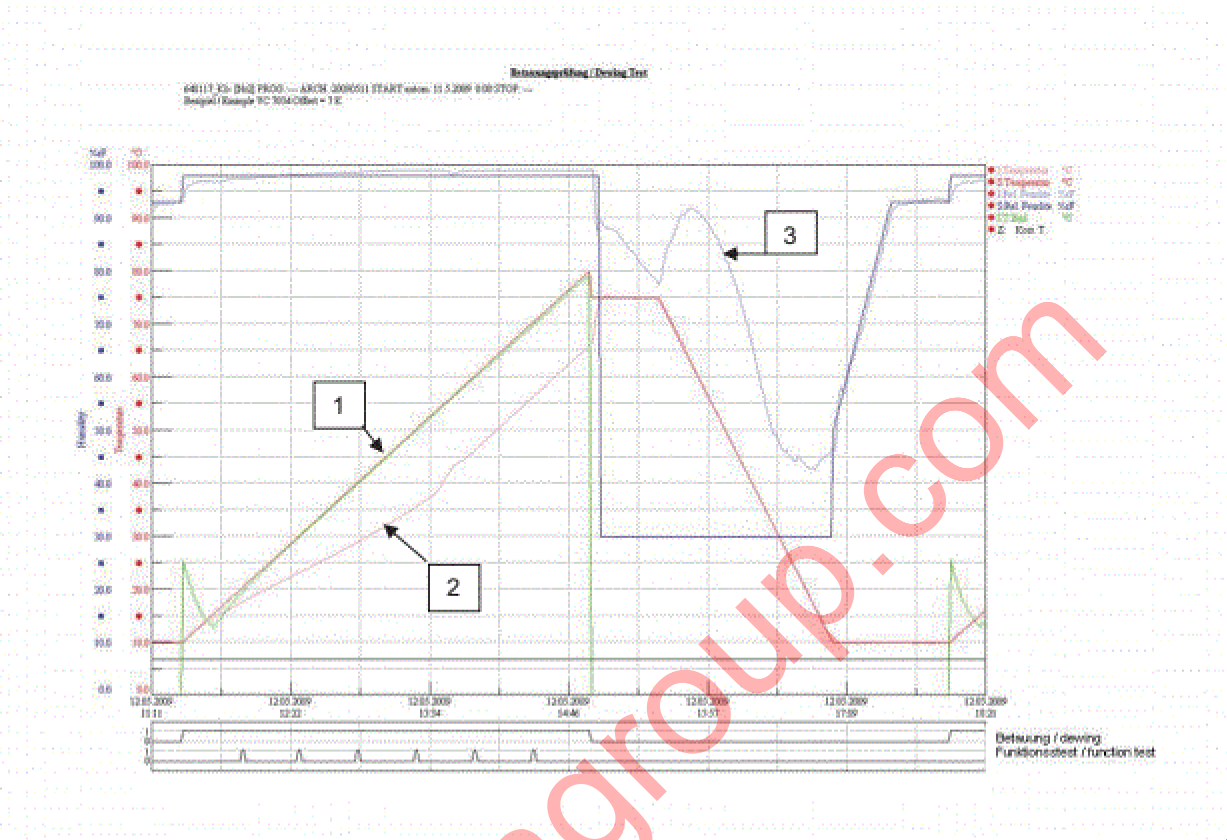


Figure 50: Sequence of the condensation test, 1 cycle

1. Controlled water bath temperature
2. Resulting test room temperature
3. Actual humidity in the test chamber

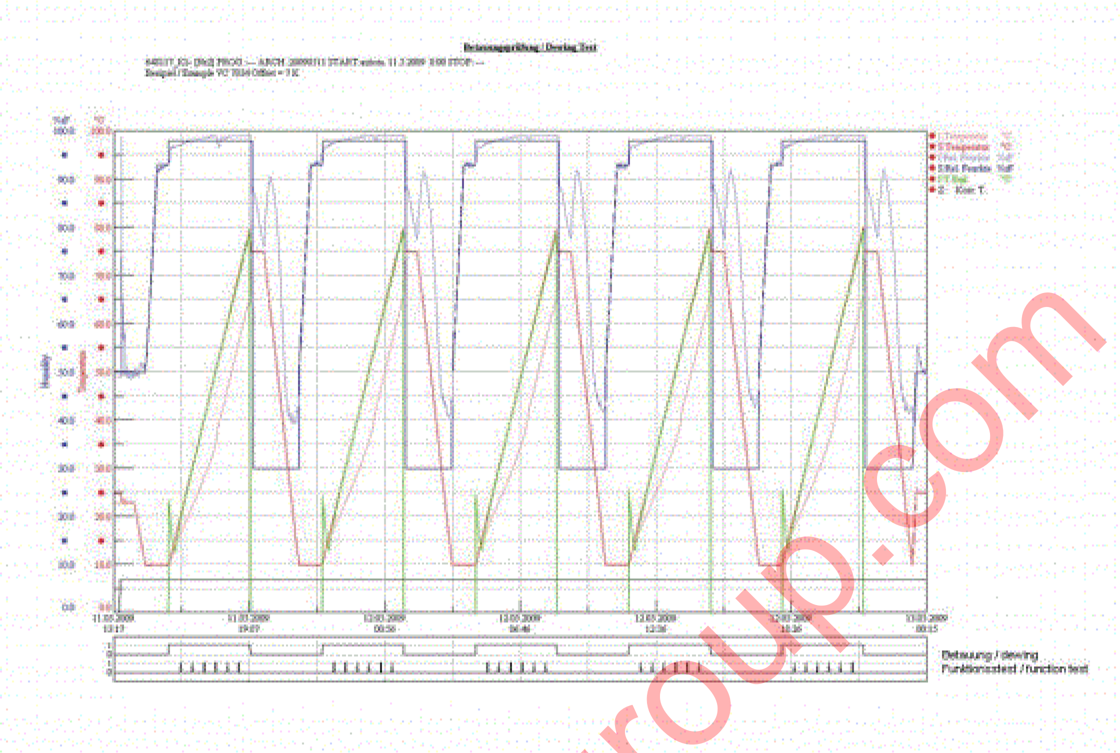


Figure 51: Sequence of the condensation test, 5 cycles

Annex G (informative)

Examples of examination methods for physical analysis

- Screw loosening torques (e.g. housing screw connection, screws for fastening the component, ...)
- Soldering spot failures/defects
- Device / circuit board discolorations (in particular if thermally caused)
- Stiffness/ease of operation, sliding, slackness (where parts are moved mechanically)
- Signs of abrasion
- Breaks, cracks, deformation of materials (in particular of casting and sealing materials). A suitable test method (X-ray, CT, metallographic sections,…) shall be selected by agreement
- Opacity (in particular of parts of optical sensor systems)
- Condition of latch and clip locking mechanisms
- Signs of corrosion and migration, in particular silver and tin migration
- Assessment of plastics for their resistance to hydrolysis (in particular in the case of components with inlaid lead frames and Terminal 30 switch circuits)
- Damage to PCB vias, in particular thermal vias
- Damage to internal connection (paddles) of large electrolytic capacitors after mechanical load (vibration, mechanical shock, free fall)
- Damage to connector pins (e.g. resulting from current, temperature, rubbing, oxidation)
- Other irregularities
- ICT result (where possible)