



BSI Standards Publication

Guidelines for principal component reliability testing for LED light sources and LED luminaires

National foreword

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Guidelines for principal component reliability testing for LED light sources and LED luminaires

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**GUIDELINES FOR PRINCIPAL COMPONENT RELIABILITY
TESTING FOR LED LIGHT SOURCES AND LED LUMINAIRES**

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62861, which is a Technical Specification, has been prepared by subcommittee 34A: Lamps, of IEC technical committee 34: Lamps and related equipment.

The text of this Technical Specification is based on the following documents:

Enquiry draft	Report on voting
34A/1884/DTS	34A/1966/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

LED products depend generally on how balanced its principal components are in terms of their reliability. It is not only the LED components that determine product performance, but also other parts of the LED product play an equally important role. For instance, electronic subassemblies, optics, mechanics and the involved cooling method play such a role.

This Technical Specification envisions a methodology, which addresses separate subcomponent reliability data, to provide a basis for statistical system reliability design. Standardized reporting formats and flowcharts are presented.

Next, protocols based on accelerated methods are given to estimate system reliability of the final product using subcomponent data.

Verification of LED product lifetime is based on a 'test to pass' principle, which means the components of the product under test are evaluated to give equivalent reliability confidence to that which would be achieved by real-time life testing of the complete LED product. The tests described in this Technical Specification are divided into: initial qualification tests (IQT) giving confidence of basic component robustness, but not linked to any specific lifetime projection, and accelerated stress tests (AST) giving confidence of reliability to a specific lifetime (within the specified constraints of the test).

Since the approach foreseen in this Technical Specification covers a generic methodology, it can be seen as guidance related to relevant product performance standards, such as the LED lamp performance standard IEC 62612, the LED module performance standard IEC 62717 and LED luminaire performance standard IEC 62722-2-1. This Technical Specification is not recommended for use as a normative reference to the LED product performance standards.

This Technical Specification addresses the need for a document giving guidance that is developed according to consensus procedures and in itself is normative in nature, while at the same time recognizing that LED technology for lighting products is still in an emerging phase. This Technical Specification approaches an International standard in terms of detail and completeness.

GUIDELINES FOR PRINCIPAL COMPONENT RELIABILITY TESTING FOR LED LIGHT SOURCES AND LED LUMINAIRES

1 Scope

This Technical Specification provides guidelines for establishing confidence in product reliability using principal component testing for LED light sources and LED luminaires for general lighting. It includes methods and criteria using initial qualification tests and accelerated stress tests of the principal components. The performance of any principal component will influence the performance of the final product.

Techniques to validate full lifetime claims and lumen maintenance projection are outside the scope of this Technical Specification.

The following principal components are included in the testing if they are used as an integral part for the LED light source or LED luminaire:

- LED package and interconnects;
- optical materials;
- electronic subassemblies;
- cooling systems, both active (e.g. fans) and passive (e.g. thermal interface material);
- construction materials.

This Technical Specification is not recommended for use as a normative reference to the LED product performance standards.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-20:2008, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

IEC 60068-2-27:2008, *Basic environmental testing procedures – Part 2: Tests – Test Ea and guidance: Shock*

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

IEC 60068-2-42:2003, *Environmental testing – Part 2-42: Tests – Test Kc: Sulphur dioxide test for contacts and connections*

IEC 60068-2-43:2003, *Environmental testing – Part 2-43: Tests – Test Kd: Hydrogen sulphide test for contacts and connections*

IEC 60068-2-58:2015, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60068-2-60:2015, *Environmental testing – Part 2-60: Tests – Test Ke: Flowing mixed gas corrosion test*

IEC 60529:2013, *Degrees of protection provided by enclosures (IP Code)*

IEC 60929:2011, *AC and/or DC-supplied electronic control gear for tubular fluorescent lamps – Performance requirements*
IEC 60929:2011/AMD1:2015

IEC 62504, *General lighting – Light emitting diode (LED) products and related equipment – Terms and definitions*

ANSI/ESDA/JEDEC JS-001-2014, *Electrostatic discharge sensitivity testing human body model (HBM) – Component level*

ASTM D5470 – 12, *Standard test method for thermal transmission properties of thermally conductive electrical insulation materials*

ASTM D7027 – 13, *Standard test method for evaluation of scratch resistance of polymeric coatings and plastics using an instrumented scratch machine*

ASTM E595 – 07, *Standard test method for total mass loss and collected volatile condensable materials from outgassing in a vacuum environment*

IPC-9591, *Performance parameters (mechanical, electrical, environmental and quality/reliability) for air moving devices*

J-STD-002D, *Solderability tests for component leads, terminations, lugs, terminals and wires*

J-STD-020E, *Moisture/reflow sensitivity classification for nonhermetic surface mount devices*

JESD22-A101C, *Steady-state temperature humidity bias life test*

JESD22-A104D, *Temperature cycling*

JESD22-A108D, *Temperature, bias, and operating life*

JESD22-A113F, *Preconditioning of plastic surface mount devices prior to reliability testing*

JESD22-B103B, *Vibration, variable frequency*

JESD51-51, *Implementation of the electrical test method (static test method) for the measurement of the real thermal resistance and impedance of light emitting diodes with exposed cooling surface*

MIL-C-48497A, *Durability requirements for coating, single or multilayer, interference*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62504 and the following apply.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

acceleration factor

AF

ratio of the time it takes for a certain fraction of the population to fail, following application of one stress or use condition, to the corresponding time at a more severe stress or use condition

Note 1 to entry: The failure mode and the type of the failure distribution (lognormal, Weibull, exponential or alike) within the two stress conditions should be identical.

Note 2 to entry: Acceleration factors can be calculated for several stresses that can affect the reliability of the unit under test, such as temperature, electrical, mechanical loads, light exposure, chemical, moisture or other stresses. Annex B presents commonly known acceleration models.

3.2

activation energy

E_a

excess free energy over the ground state that is required in order that a particular process occurs

Note 1 to entry: The activation energy is used in the Arrhenius equation for the thermal acceleration.

3.3

Boltzmann's constant

k_B

constant equal to $1,381 \times 10^{-23}$ J/K or $8,617 \times 10^{-5}$ eV/K

Note 1 to entry: Boltzmann's constant is used in the Arrhenius equation.

3.4

failure mechanism

process that leads to failure

Note 1 to entry: The process may be physical, chemical, logical, or a combination thereof.

[SOURCE: IEC 60050-192:2015, 192-03-12.]

3.5

failure mode

manner in which failure occurs

Note 1 to entry: A failure mode may be defined by the function lost or other state transition that occurred.

[SOURCE: IEC 60050-192:2015, 192-03-17, modified – do not use the wording "DEPRECATED: fault mode".]

3.6

failure rate

probability that a system will fail during the next specified time increment, given that it has survived up to the current point in time

Note 1 to entry: The failure rate of a system usually depends on time, with the rate varying over the lifecycle of the system.

Note 2 to entry: Failure rate is expressed in % failures per time unit.

3.7**application profile**

mission profile

user profile

profile describing the environmental loads that are imposed upon the product under normal operation conditions

Note 1 to entry: Annex A presents two example application profiles.

3.8**mean time to failure**

MTTF

average period of time for a system to operate without failure

3.9**power factor**

ratio of the real power flowing to the load to the apparent power in the circuit

3.10**reliability**

<of an item> ability to perform as required, without failure, for a given time interval, under given conditions

Note 1 to entry: The time interval duration may be expressed in units appropriate to the item concerned (e.g. calendar time, operating cycles, distance run) and the units should always be clearly stated.

Note 2 to entry: Given conditions include aspects that affect reliability, such as: mode of operation, stress levels, environmental conditions, and maintenance.

Note 3 to entry: Reliability may be quantified using measures defined in Section 192-05, Reliability related concepts: measures.

[SOURCE: IEC 60050-192:2015, 192-01-24.]

3.11**sample size**

representative quantity of units under test extracted from a batch of reference units

3.12**system**

set of interacting or interdependent components forming an integrated whole

3.13**system reliability**

probability that a system, including all hardware, firmware, and software, will satisfactorily perform the task for which it was designed or intended, for a specified time and in a specified environment

3.14**solder point temperature** t_s

temperature of the point near the LED package interconnect as specified by the manufacturer of the package

3.15**cooling performance**

function of a device providing cooling in an amount to maintain the performance of the component to which it pertains

3.16**Weibull distribution**

continuous probability distribution described by two parameters: scale parameter α and shape parameter β

3.17**accelerated stress test****AST**

test for which a reliability model exists for assessing reliability over a shorter time period than a test under normal application conditions by applying an accelerating stress factor

Note 1 to entry: The reliability model can apply to components and materials.

3.18**initial qualification test****IQT**

test to demonstrate a basic level of robustness by applying a non-accelerating stress factor

Note 1 to entry: An IQT is employed when an accelerated reliability model is not appropriate.

3.19**validated AST time**

mathematical product of the AST duration used for validation and the acceleration factor

4 Component test conditions

Clauses 5, 6, 7, 8 and 9 specify minimum stress-test driven qualification and reliability requirements for the principal components of LED products. It includes references to test conditions for each component. The purpose is to give guidance for establishing a level of reliability for which a product is specified. What the exact level is depends on the product specification and depends on the application profile. Stress test qualification of the principal components is defined as successful completion of the test requirements outlined in each clause for each principal component. Each clause specifies a set of qualification tests that shall be considered for new LED product qualifications. In case of requalification associated with a design or process change, a limited set of qualification tests may be considered.

This Technical Specification describes two types of qualification tests. A test for which a reliability model exists is called an accelerated stress test (AST) for assessing reliability results over a much shorter test time period. When a reliability model is not appropriate, then the test is termed an initial qualification test (IQT) and used to demonstrate a basic level of robustness. Tests in this Technical Specification are classified as either IQT or AST. The stressors or loads that are imposed upon LED products in two example environmental conditions are described in Annex A. These stressors also apply to the principal components.

NOTE In general, it is assumed that passing the harsher test conditions implies that the more relaxed conditions would also be passed.

For principal components that have failed the acceptance criteria of tests required by this Technical Specification, it is recommended to understand the failure mechanism, determine the root cause and take corrective actions. To confirm that the failure mechanism is understood and contained, and appropriate corrective and preventive actions are effective, it is recommended to repeat the applicable qualification test(s) successfully.

This Technical Specification makes reference to other IEC standards or standards from other organizations. Where relevant, further details on the tests can be found in these documents. Test conditions in this document may deviate from test conditions in the reference documents. In such a case, further specifications in the reference document should still be applied as appropriate.

5 LED package and interconnects

5.1 General

The purpose of Clause 5 is to determine that an LED package is capable of passing the specified stress tests and thus can be expected to give a certain level of reliability in general lighting applications. LED packages and interconnects of different types exist. There is currently no official LED classification; they can be classified by colour (red, orange, blue, green), mechanical outline (round, square, rectangular, surface), by materials used (full epoxy resin packaging, metal base, ceramic base epoxy resin packaging and glass packaging)¹ and/or by luminous intensity (general, high-brightness, ultra-high brightness). While it is not the intention of this Technical Specification to specify an LED classification, the following are different common types of LED packages:

- high-power LEDs (includes high-brightness):
 - wire-bonded types;
 - flip-chip types;
 - wafer level chip types.
- mid-power LEDs:
 - mainly wire-bonded types;
 - chip-on-board types (usually not reflow or wave soldering but mechanically mounted).
- lower-power LEDs:
 - mainly wire-bonded types.

Subclauses 5.11, 5.12 and 5.13 specify a set of qualification tests that shall be considered for new LED package and interconnects qualifications. Where appropriate, family qualifications can be done, according to:

- same chip technology in different LED packages;
- same phosphor systems in different LED packages;
- same package footprint in different LED packages.

An example qualification flowchart is depicted in Figure D.1.

5.2 Sampling requirements

Unless specified otherwise, a total of at least 30 LED packages taken from three different batches of 10 each shall be used. For family qualification, the three different batches shall be considered to represent the variety of the qualification family.

Exceptions to the specified sample size shall be noted with the reasoning that justifies equivalent reliability still being demonstrated. This may be appropriate where multiple LED dies are incorporated in the package, for example chip-on-board devices.

5.3 Production requirements

All qualification LED packages shall be produced on tooling and processes representative for those that will be used to support LED package deliveries at projected production volumes. Sample details shall be reported in the principal component test report (Annex F).

¹ Adapted from source: LEDinside, with the permission of the author(s).

5.4 Assembly of LED packages on test boards

LED packages may need to be assembled on test boards. An appropriate choice of test board, interconnect material and process shall be made by the manufacturer. The choice of test board, interconnect material and process shall be documented for each individual test in the principal component test report (Annex F).

5.5 Moisture preconditioning

Moisture preconditioning is applicable to surface-mountable devices designed for reflow soldering. LED packages shall be subjected to moisture preconditioning according to J-STD-020E for tests specified in 5.11.2.1, 5.11.2.2, 5.11.2.3, 5.11.3.1, 5.11.4.1 and 5.11.4.2. The choice of the preconditioning level shall be documented for each individual test in the principal component test report (see Annex F). The initial electrical and photometric test (see 5.7) shall be executed after the moisture preconditioning.

5.6 Thermal characteristics

The value of either the solder point temperature (t_s), junction temperature (t_j) or thermal resistance (R_θ) shall be determined according to JESD51-51.

5.7 Pre- and post-stress electrical and photometric requirements

Electrical and photometric values shall be measured at the test conditions as specified in the product specification before and after stress testing. Intermediate measurements (read points) are permitted and may be used for diagnostic purposes. All LED packages used for qualification shall meet the product specification parameters measured at the test conditions before stress testing. LED packages shall be tested at the operating current specified in the appropriate LED package specification (manufacturer datasheet) prior to and after the qualifications tests. The following parameters shall be measured:

- luminous flux or radiant power (whichever is appropriate);
- forward voltage;
- colour coordinates or dominant/peak wave length (whichever is appropriate).

5.8 Pre- and post-stress visual inspection

The construction, marking and finishing of the LED package should be inspected according to JESD22-B101B prior to and after the qualification tests.

5.9 Solderability and resistance to soldering heat

5.9.1 Solderability

The objective of the solderability test is to verify the solderability of the devices. This verification is made on the ability of the pins to be wetted or coated by solder. The solderability of the LED package shall be tested and meeting the compliance criteria according to IEC 60068-2-58. The solderability of the LED package with leads shall be tested and meet the compliance criteria according to IEC 60068-2-20. Alternatively J-STD-002D may be applied.

5.9.2 Resistance to soldering heat (RSH-reflow) test

The objective of the resistance to soldering heat test is to evaluate the performance of the LED package under stress due to soldering heat. The LED package shall be tested and meet the compliance criteria according to J-STD-020E. This test applies only to LED packages that are specified for reflow soldering.

5.10 Failure criteria

The LED package and interconnects principal components are considered to have failed if any of the following criteria applies for each item in the test.

- a) Forward voltage V_f at the specified operating current I_f deviates by more than $\pm 15\%$ from the initial value. Radiant power or luminous flux or intensity at the specified operating current I_f deviates by more than $\pm 20\%$ from the initial value.
- b) Chromaticity ($u'v'$) at the specified operating current I_f of LED packages emitting white light after the qualification test deviates by more than 0,006 from the initial value, where $\Delta u'v' = \text{SQRT}((\Delta u')^2 + (\Delta v')^2)$.

NOTE $\Delta u'$ and $\Delta v'$ are defined in ISO 11664-5:2009.

- c) The LED package exhibits externally visible physical damage attributable to the qualification test. However, if the cause of failure is agreed to be due to mishandling or electrostatic discharge (ESD), the failure shall not be counted, but reported as part of the principal component test report.
- d) The LED package interconnects to the test board failed, visually observed with zero light output. Perform cross-sectional analysis on failed samples in order to discriminate other failure modes from solder joint failures (Annex E).

For LED packages a destructive physical analysis (DPA) should be performed according to Annex E on two random samples of surviving units after completion of the following tests where applicable according to the application profile: TMCL test, WHTOL test and H2S test.

For LED package interconnects a destructive physical analysis (DPA) should be performed according to Annex E on two random samples of surviving units after completion of the following tests where applicable according to the application profile: TMCL test and VVF test. The post electrical and photometric test of these samples shall be executed before the destructive physical analysis.

It is recommended that failures found during the qualification test be fully investigated until the root cause is found.

5.11 Initial qualification tests for LED packages

5.11.1 General

The initial qualification tests for LED packages are grouped as follows:

- temperature and operation stress:
 - Low temperature operating life (LTOL);
 - High temperature operating life (HTOL);
 - Pulsed operating life (PLT).
- thermo-mechanical stress:
 - Temperature cycling (TMCL);
 - Vibrations variable frequency (VVF).
- temperature and humidity stress:
 - Wet high temperature operating life (WHTOL);
 - Damp heat cycling (DHC).
- electrical stress:
 - Electrical stress – ESD-HBM.
- environmental stress:
 - Hydrogen sulphide (H2S);

- Flowing mixed gas corrosion (FMGC);
- SO₂ test (SO₂).

5.11.2 Temperature and operation stress

5.11.2.1 Low temperature operating life (LTOL)

The purpose of this IQT is to evaluate the performance of the LED package under stress due to low ambient temperature (t_{amb}) operation. The test shall be conducted according to JESD22-A108D; the following test conditions apply:

- duration 1 000 h;
- $t_{amb} = -40\text{ °C}$.

The LED package shall be operated at the corresponding maximum rated operating current and t_s , t_j or R_{θ} shall be reported.

Compliance is checked by applying the failure criteria of 5.10 to the test results obtained from the pre- and post-stress tests according to 5.7 and 5.8.

5.11.2.2 High temperature operating life (HTOL)

The purpose of this IQT is to evaluate the performance of the LED package under stress due to high temperature operation. The test shall be conducted according to JESD22-A108D; the following test conditions apply.

For each test condition, a minimum total of 78 LED packages taken from 3 different batches of 26 each shall be used:

- duration 1 000 h;
- testing shall be done at:
 - the maximum operating current at the corresponding allowed t_{amb} ; and
 - the maximum t_{amb} with the corresponding allowed operating current.

NOTE The maximum operating current and the maximum t_{amb} can occur at the same condition.

In all cases t_s , t_j or R_{θ} shall be reported.

Compliance is checked by applying the failure criteria of 5.10 to the test results obtained from the pre- and post-stress tests according to 5.7 and 5.8.

5.11.2.3 Pulsed operating life (PLT)

The purpose of this IQT is to evaluate the performance of the LED package under stress due to pulsed operation, for example for pulsed width modulation. The LED package shall be tested according to JESD22-A108D, the following test conditions apply:

- duration 1 000 h;
- $t_{amb} = 55\text{ °C}$;
- pulse width 100 μs , duty cycle 3 %.

The LED package shall be operated at the corresponding maximum rated operating current.

Compliance is checked by applying the failure criteria of 5.10 to the test results obtained from the pre- and post-stress tests according to 5.7 and 5.8.

5.11.3 Thermo-mechanical stress

5.11.3.1 Temperature cycling (TMCL)

The purpose of this IQT is to evaluate the performance of the LED package, chip and wire/chip bond integrity under mechanical stress due to extreme temperature cycles without operation of the LED package. The LED package shall be tested according to JESD22-A104D. A minimum total of 78 LED packages taken from three different batches of 26 each shall be used. The following test conditions apply:

- duration with a minimum of 500 cycles;
- soak mode 4 (minimum soak time 15 min).

The following minimum and maximum temperatures for t_{amb} shall be chosen by the manufacturer:

- TMCL condition: $t_{amb,min} = -40\text{ °C}$; $t_{amb,max}$ as specified by the manufacturer with the minimum value of 85 °C .

The TMCL condition closest to the manufacturer's operating temperature range according to the appropriate LED package specification (application profile, manufacturer datasheet) shall be chosen unless the manufacturer wishes to test compliance with a more severe cycle condition. The choice of the TMCL cycle condition and the transfer time shall be reported.

Compliance is checked by applying the failure criteria of 5.10 to the test results obtained from the pre- and post-stress tests according to 5.7 and 5.8.

5.11.3.2 Vibrations variable frequency (VVF)

Testing the LED packages under variable frequency vibrations is in general executed when mounted on a printed circuit board. Subclause 5.12 describes the test parameters accordingly.

Preconditioning according to 5.5 is not required.

Compliance is checked by applying the failure criteria of 5.10 to the test results obtained from the pre- and post-stress tests according to 5.7 and 5.8.

5.11.4 Temperature and humidity stress

5.11.4.1 Wet high temperature operating life (WHTOL)

The purpose of this IQT is to evaluate the performance of the LED package under stress due to temperature and humidity during operation. Temperature, humidity and operating current are used to accelerate the penetration of moisture through any protective material to reveal corrosion or migration mechanisms caused by material incompatibility, misprocessing or mishandling which may lead to reduced reliability. The LED package shall be tested according to JESD22-A101C. A minimum total of 78 LED packages taken from 3 different batches of 26 each shall be used. The following test conditions apply:

- duration 1 000 h;
- $t_{amb} = 85\text{ °C}$;
- 85 % relative humidity;
- power cycle 1 h on/1 h off.

The tests shall be performed at the corresponding maximum rated operating current (i.e. rating at $t_{amb} = 60\text{ °C}$ or $t_{amb} = 85\text{ °C}$).

Compliance is checked by applying the failure criteria of 5.10 to the test results obtained from the pre- and post-stress tests according to 5.7 and 5.8.

5.11.4.2 Damp heat cycling (DHC)

The purpose of this IQT is to evaluate the performance of the LED package under stress due to temperature and humidity cycling. The LED package shall be tested according to IEC 60068-2-30, the following test conditions apply:

- –10 °C/25 °C dry;
- 25 °C/65 °C, 90 % relative humidity;
- 10 cycles;
- 24 h/cycle.

Compliance is checked by applying the failure criteria of 5.10 to the test results obtained from the pre- and post-stress tests according to 5.7 and 5.8.

5.11.5 Electrical stress – ESD-HBM

Electrical stress is tested by an electrostatic discharge, human body model test (ESD-HBM). The objective of this IQT is to verify that the product is robust against electrostatic discharge as specified. The HBM simulates the electrostatic discharge which is typically observed during manual handling of devices by a person without any ESD protection. The LED package shall be tested according to ANSI/ESDA/JEDEC JS-001, using the human body model. The HBM ESD component classification level (voltage level) shall be reported in the principal component test report, see Annex F.

5.11.6 Environmental stress

5.11.6.1 General

Preconditioning according to 5.5 is not required.

The failure criterion in 5.10 a) for radiant power or luminous flux or intensity at the specified operating current does not apply. Instead, the radiant power or luminous flux or intensity shall not decrease by more than 30% from the initial value.

5.11.6.2 Hydrogen sulphide (H₂S)

The objective of this IQT is to determine the corrosive influence of typical operating and storage environments.

The resistance to hydrogen sulphide shall be tested according to IEC 60068-2-43; the following test conditions apply:

- air temperature 25 °C;
- 75 % relative humidity;
- H₂S concentration: 10×10^{-6} to 15×10^{-6} vol/vol (parts per million), balance air;
- duration 504 h.

Compliance is checked by applying the failure criteria of 5.10 to the test results obtained from the pre- and post-stress tests according to 5.7 and 5.8.

5.11.6.3 Flowing mixed gas corrosion (FMGC)

The resistance to corrosive gas atmosphere shall be tested according to IEC 60068-2-60; the following IQT conditions apply: