INTERNATIONAL STANDARD

ISO 16750-1

First edition
2003-12-15

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

Part 1:
General

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

Partie 1: Généralités

Reference number
ISO 16750-1:2003(E)

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Published in Switzerland

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16750-1 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

ISO 16750 consists of the following parts, under the general title *Road vehicles — Environmental conditions and testing for electrical and electronic equipment*:

— *Part 1: General*

— *Part 2: Electrical loads*

— *Part 3: Mechanical loads*

— *Part 4: Climatic loads*

— *Part 5: Chemical loads*

Introduction

The objective of ISO 16750 as a whole is to assist the user in systematically defining and/or applying a set of internationally accepted environmental conditions, tests and operating requirements, based on the anticipated actual environment in which the equipment will be operated and to which it will be exposed during its life cycle.

The following environmental factors have been considered in the development of ISO 16750.

— **World geography and climate**

  Road vehicles are owned and operated in nearly all land regions of the earth. Significant variation in environmental conditions owing to climatic environment, including diurnal and seasonal cycles, can therefore be expected. Consideration has been given to worldwide ranges in temperature, humidity, precipitation and atmospheric conditions, including dust, pollution and altitude.

— **Type of vehicle**

  Environmental conditions in and on road vehicles can depend on vehicle design attributes such as engine type, engine size, suspension characteristics, vehicle mass, vehicle size, electrical supply voltage and so on. Consideration has been given to typical types of vehicles, including commercial vehicles (heavy trucks), passenger cars and trucks, and diesel and gasoline engines.

— **Vehicle use conditions and operating modes**

  Environmental conditions in and on the vehicle vary significantly with road quality, type of road surface, road topography, vehicle use (commuting, towing, cargo transport, etc.) and driving habit. Operating modes such as storage, starting, driving, stopping and so on have been considered.

— **Equipment life cycle**

  Electrical and electronic equipment must also be resistant to environmental conditions experienced during manufacture, shipping, handling, storage, vehicle assembly and vehicle maintenance and repair. Such conditions and test (e.g. handling drop test) are within the scope of ISO 16750.

— **Vehicle supply voltage**

  Supply voltage varies with vehicle use, operating mode, electrical distribution system design and even climatic conditions. Faults within the vehicle electrical system, such as alternator overvoltage and intermittences in connection systems, may occur. Such conditions are within the scope of ISO 16750.

— **Mounting location in the vehicle**

  In current or future car concepts, systems/components are mounted in almost any location of the car. The environmental requirements for each specific application greatly depend on its mounting location. Each location in a car has its own distinct set of environmental loads. As an example, the range of temperatures in the engine compartment differs a lot from the range in the passenger compartment. This is also true for the vibration loads. But in this case, not only the vibration levels are different, the type of vibration load also varies. Body mount components are typically exposed to random vibrations, whereas, for engine mount systems/components, the additional sine vibration from the engine has to be considered. Additionally, devices installed in doors are exposed to a high number of mechanical shocks from door slamming.

It is desirable for the car manufacturer to group the different environmental load types and levels in a reasonable number of standard requirement sets. This strategy makes it possible to carry systems/components from one car project to another. Furthermore, the exact requirement levels are often unknown when designing a component for a future car concept. The expected environmental loads are usually compiled from other car concepts with similar conditions. The grouping is normally done by mounting location. But it is difficult to define the correct number of different mounting locations and respective load profiles owing to a conflict of aims between having only a few requirement classes and tailoring to the requirement levels for each application. The reason is that environmental loads are not only dependent on mounting location. Other major factors affect the stress levels for systems/components. For example, body styles, drive train concepts or package densities can create absolutely different requirement levels for devices that are installed in different cars at almost the same location.

The concept of ISO 16750 is to define requirement classes for separate load types. The Standard distinguishes between electrical, mechanical, thermal, climatic and chemical loads. For each load type, several requirement classes are defined. Every requirement class is determined by a specific code letter. The complete environmental requirement set is created by defining the code letter combination. The code letters are defined in the relevant parts of ISO 16750. A Table in Annex A of relevant parts of ISO 16750 gives the usual mounting locations together with examples of their respective code letters. For normal applications, these are the code letters to be used. If an application is very specific and because of this the given code letter combinations cannot be used, it is possible to create new code letter combinations to serve this purpose. In order that none of the given code letters is reused, new requirement levels can be created by using the code letter “Z”. In this case, the specific requirements need to be defined separately but it is desirable not to change the test methods.

The user of ISO 16750 would be well advised to consider at least the following mounting locations for a device under test (DUT) with respect to thermal, mechanical, climatic and chemical load.

a) Responsibility of manufacturer

Due to technological limitations or variations in vehicle design, the vehicle manufacturer could be required to place a component in a location where it cannot withstand the environmental conditions specified in ISO 16750. Under these circumstances, it is the responsibility of the vehicle manufacturer to provide the necessary environmental protection.

b) Applicability to wiring harnesses, cables and electrical connectors

Although some environmental conditions and tests in ISO 16750 could be relevant to vehicle wiring harnesses, cables and connectors, its scope is not sufficient to be used as a complete standard. Therefore, ISO 16750 is not designed to be directly applied to such devices and equipment. Other, applicable standards have to be taken into account.

c) Applicability to parts or assemblies in or on equipment

ISO 16750 specifies environmental conditions of, and tests for, electrical and electronic equipment directly mounted in or on the vehicle. On the one hand, it is not intended for direct application to parts or assemblies that are part of the equipment. For example, ISO 16750 is not to be directly applied to integrated circuits (ICs) or discrete components, electrical connectors, printed circuit boards (PCBs), gauges, displays, controls, etc. that are attached in or on the equipment. Electrical, mechanical, climatic and chemical loads for such parts and assemblies can be quite different to those it describes. On the other hand, it is desirable to use ISO 16750 to help derive environmental conditions and test requirements for parts and assemblies that are intended for use in road vehicle equipment. For example, a temperature range of –40 °C to + 90 °C could be specified for an assembly contained inside a piece of equipment having a temperature range of –40 °C to + 70 °C and a temperature rise of 20 °C.

d) Applicability relative to system integration and validation

The user of ISO 16750 is cautioned to understand that its scope is limited to conditions and testing at the equipment level and therefore does not represent all conditions and testing necessary for complete verification and validation of the vehicle system. Environmental and reliability testing at equipment part and vehicle system levels could be required. For example, ISO 16750 does not necessarily ensure that environmental and reliability requirements for solder joints, solderless connections, integrated circuits, and so on are met. Such items must be assured at the part, material or assembly level. Likewise, vehicle and system level testing is required to validate the equipment in the vehicle application.

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

Part 1:
General

1 Scope

This part of ISO 16750 gives definitions and general specifications for the potential environmental stresses, that can affect electric and electronic systems and components in respect of their mounting location directly on or in road vehicles and specifies the corresponding tests and requirements. It does not cover electromagnetic compatibility (EMC).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16750-2:2003, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

ISO 16750-3:2003, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 3: Mechanical loads*

ISO 16750-4:2003, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 4: Climatic loads*

ISO 16750-5:2003, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 5: Chemical loads*

DIN 40050-9, *Road vehicles — Degrees of protection (IP-code) — Protection against foreign objects, water and contact — Electrical equipment*

3 Terms and definitions

For the purposes of this document and the other parts of ISO 16750, the following terms and definitions apply.

3.1
nominal voltage
U_N
voltage value used to describe the electrical system of a vehicle

3.2
supply voltage
voltage of the electrical system of a vehicle that varies with the system load and the operating condition of the alternator/generator

3.3
test voltage
voltage or voltages applied to the device under test (DUT) during a test

3.4
minimum operating temperature
T_{min}
minimum value of the ambient temperature at which the systems/components can be operated

3.5
maximum operating temperature
T_{max}
maximum value of the ambient temperature at which the systems/components can be operated continuously

3.6
hot-soak temperature
$T_{max,HS}$
maximum value of the ambient temperature which can temporarily occur in the engine compartment after the vehicle has stopped and the engine is turned off

3.7
paint repair temperature
$T_{max,PR}$
maximum temperature which can occur during vehicle paint repair

4 Classification by mounting location

4.1 Engine compartment

Device under test (DUT) mounted

- to the body,
- to the frame,
- on the flexible plenum chamber, not rigidly attached,
- in the flexible plenum chamber, not rigidly attached,
- on the engine,
- in the engine,
- on the transmission/retarder, or
- in the transmission/retarder.

4.2 Passenger compartment

DUT mounted in a position

- without special requirements,
- exposed to direct solar radiation, or
- exposed to radiated heat (other than solar radiation).

4.3 Luggage compartment/load compartment

DUT mounted

- inside.

4.4 Mounting on the exterior/in cavities

DUT mounted

- to the body,
- to the frame,
- on the underbody/in the wheel housing
  1) sprung masses, or
  2) unsprung masses (wheel, wheel bracket, axle),
- in/on a passenger compartment door,
- to the engine compartment cover,
- to the luggage compartment lid/door,
- to the trunk lid/door,
- in cavities
  1) open towards exterior, or
  2) open towards interior,
- in special compartments (e.g. battery box).

4.5 Other mounting locations

For some locations with special environmental conditions (e.g. exhaust system), no standard specifications can be given. In these cases, the load shall be stated in the specification of the DUT.

5 Operating modes

The following operating modes apply.

a) Operating mode 1

No voltage is applied to the DUT.

- Operating mode 1.1: DUT not connected to wiring harness.
- Operating mode 1.2: DUT connected to wiring harness simulating vehicle installation.

b) Operating mode 2

The DUT is electrically operated with supply voltage U_B (battery voltage) as in a vehicle with shut-off engine and with all electrical connections made.

- Operating mode 2.1: system/component functions are not activated (e.g. sleep mode)
- Operating mode 2.2: systems/components with electric operation and control in typical operating mode.

c) Operating mode 3

The DUT is electrically operated with supply voltage U_A (engine/alternator operative) and all electrical connections made.

- Operating mode 3.1: system/component functions are not activated.
- Operating mode 3.2: systems/components with electric operation and control in typical operating mode.

6 Functional status classification

6.1 General

This element describes the functional status of a DUT during and after a test.

The minimum functional status shall be given in each test. An additional test requirement may be agreed between device supplier and vehicle manufacturer.

Vehicle manufacturer and device supplier shall specify operations that are not allowed.

6.2 Class A

All functions of the device/system perform as designed during and after the test.

6.3 Class B

All functions of the device/system perform as designed during the test. However, one or more may go beyond the specified tolerance. All functions return automatically to within normal limits after the test. Memory functions shall remain Class A.

6.4 Class C

One or more functions of a device/system do not perform as designed during the test but return automatically to normal operation after the test.

6.5 Class D

One or more functions of a device/system do not perform as designed during the test and do not return to normal operation after the test until the device/system is reset by simple “operator/use” action.

6.6 Class E

One or more functions of a device/system do not perform as designed during and after the test and cannot be returned to proper operation without repairing or replacing the device/system.

7 Tests and requirements

7.1 General

The values specified in ISO 16750-2 to ISO 16750-5 cover basic requirements.

DUT with several mounting locations shall be tested to meet the most severe requirements.

7.2 General test conditions

Unless otherwise specified, all tests shall be performed at a room temperature (RT) of + 23 °C ± 5 °C and a relative humidity of 25 % to 75 %.

The test voltages shall be in accordance with Table 1 unless other values are specified in a different part or parts of ISO 16750 or are agreed upon by the users of ISO 16750, in which case such values shall be documented in the test reports.

Table 1 — Test voltages for Operating modes 2 and 3 (see Clause 5)

Test voltage	12 V system V	24 V system V
U_A	14 ± 0,2	28 ± 0,2
U_B	12 ± 0,2	24 ± 0,2
U_A = engine/alternator operative (Operating mode 3). U_B = battery voltage (Operating mode 2).		

7.3 Test sequence

Prior to testing, a test sequence plan shall be agreed upon, stating the type, number, combination and sequence of the individual tests.

A life test is to be defined specifically for the product and to be taken into account in the test sequence plan.

See Annex A for an example.

8 Designation

8.1 General

In accordance with Figure 1, the referred tests for the devices should be described by a code form for technical specifications or other documentation.

8.2 Use of Code Z "As agreed"

ISO 16750 accommodates special needs and situations through the use of Code Z "As agreed". The use of Code Z should be restricted to cases where the equipment supplier or vehicle manufacturer or both determine that the conditions or tests defined in ISO 16750 are

— unsuitable for achieving desired product quality/reliability objectives, and/or

— not practical.

When Code Z "As agreed" is used, the following should be documented:

— the rationale (reason) for not using the provided conditions or tests;

— the complete description of the "As agreed" condition or test;

— the data and rationale for supporting the suitability of the "As agreed" condition or test;

— any specific information regarding Code Z "As agreed" given in ISO 16750-1 to ISO 16750-5.

In addition, the equipment supplier and vehicle manufacturer shall agree that the "As agreed" documentation is adequate.

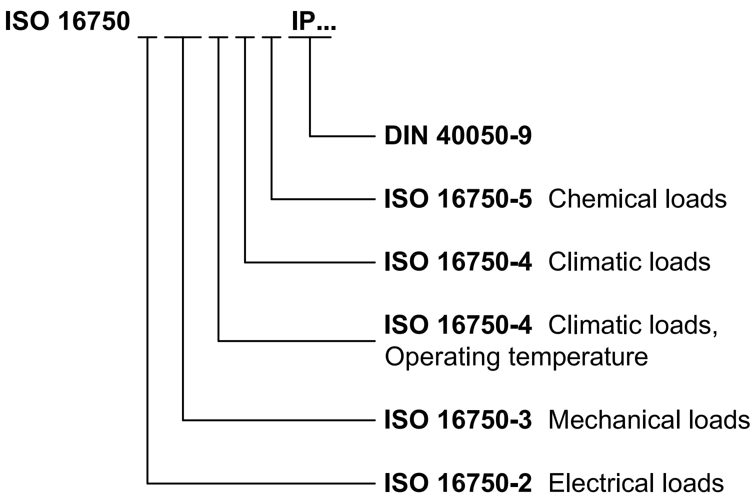


Figure 1 — Coding architecture

8.3 Example designation

The designation of an environment requirement for a system/component with electric load A according to ISO 16750-2, with mechanical load, vibration AA, according to ISO 16750-3, operating temperature code H and climatic requirement A according to ISO 16750-4, chemical load A according to ISO 16750-5 and protection class IP6K9K according to DIN 40050-9 will be

ISO 16750-A-AA-H-A-A-IP6K9K

8.4 Code allocation

Figure 2 shows how the complete code is composed in relation to the requirements of the different parts of ISO 16750 on a component for road vehicles.

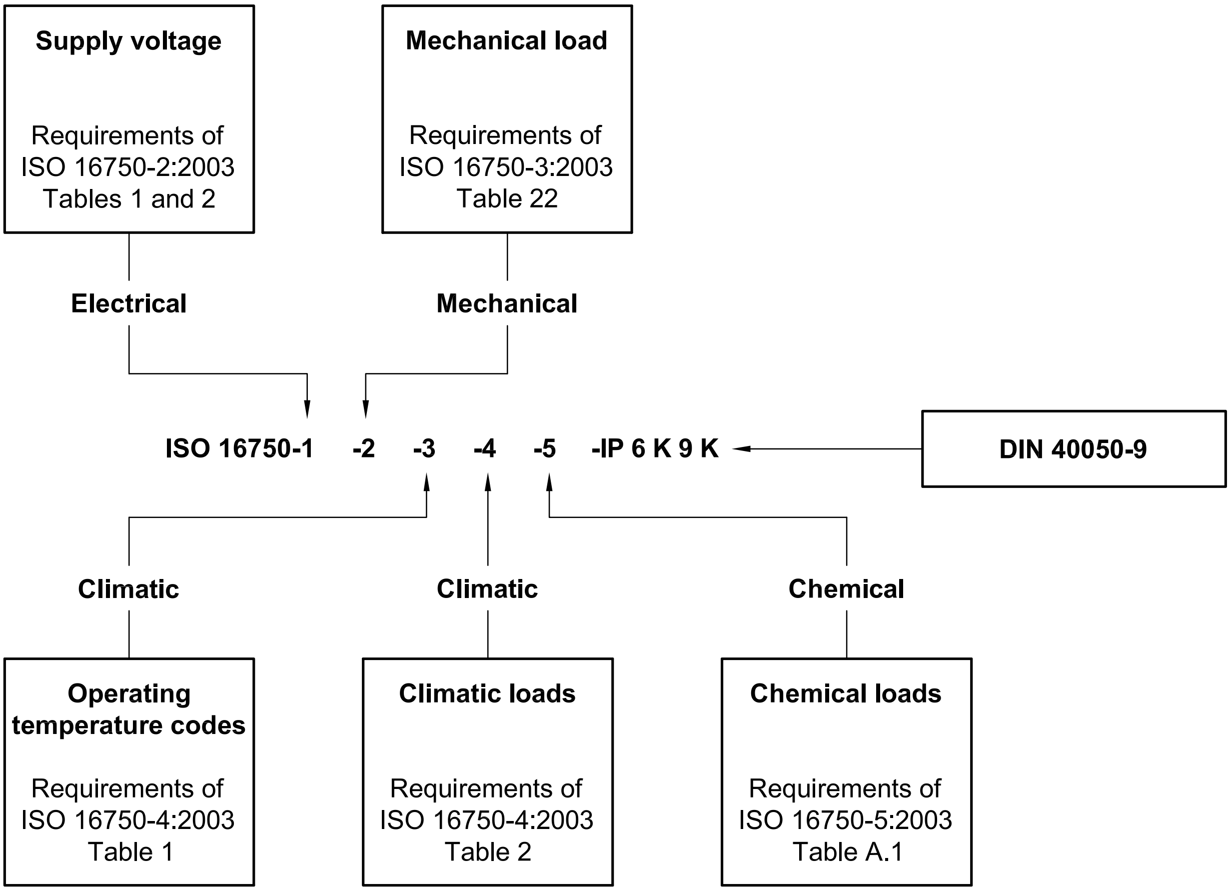
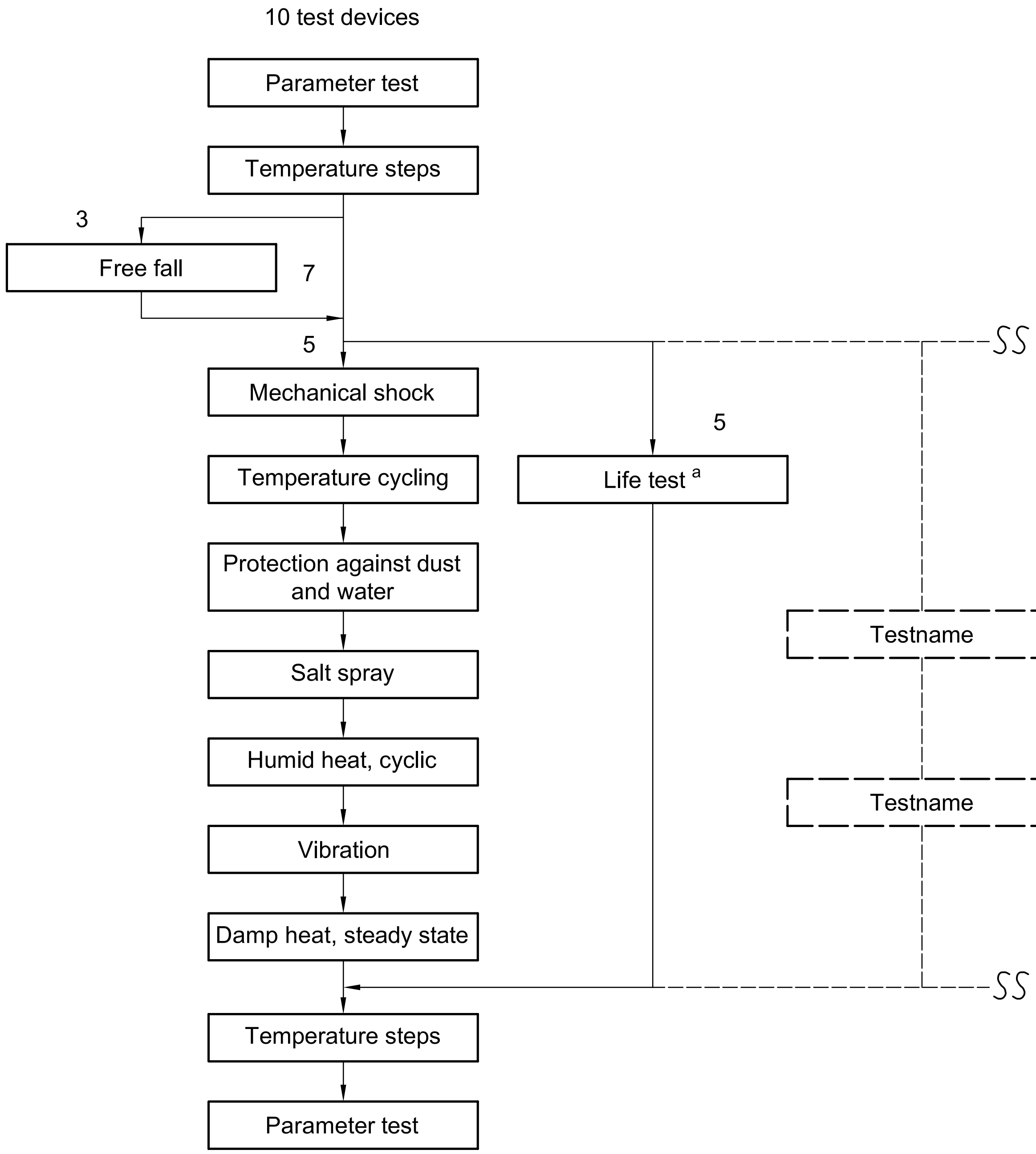


Figure 2 — Code allocation

Annex A
(informative)

Example test sequence plan



––––– facultative additional test sequences according to the rules of test tailoring possible

a See Annex B.

Annex B
(informative)

Example life test/statement of reliability

B.1 General

In addition to environmental loads, a product used in the vehicle will be subjected to loads induced by its own function, hereafter referred to as *functional loads*.

These loads are simulated by life tests, which generally comprise a combination of functional loads and relevant environmental loads occurring simultaneously.

These tests are performed according to programs derived from in-practice operation.

B.2 Aim of life tests

Two fundamentally different cases are to be distinguished, depending on the type of the problem.

a) **Potential design weaknesses**

Using real-time life tests or accelerated life tests (with corresponding load increase), the design can be checked for functional loads combined with further environmental loads in order to discover design weaknesses. Generally, only a small number of DUT will suffice to achieve this. This case is by far the more frequent one of the two. However, the results are not suitable for deriving a statement on reliability, as the number of DUT is too low for a statistically correct statement.

b) **Reliability**

Determining reliability is a totally different task. The following step-by-step method is suggested.

1) Determine the type of load relevant for service life and specific to the product, and determine the test to be conducted.

2) Determine the in-practice load, for example running time, mean temperature, etc.

3) Specify the survival probability and confidence levels and calculate the necessary number of DUT or a test duration on the basis of in-practice load — based on statistical correlation. Generally, this calculation requires extensive testing.

4) A reduction of this extensive testing resulting from Step 3 to feasible values can be performed by a permissible increase of load on the basis of an appropriate correlation between in-practice experience and testing. The increase in load shall not lead to a change of the expected damage process. Generally, compared to the check of potential design weaknesses, considerably more extensive testing will be required.

The step-by-step method should also be employed in the Case a) for checking design, but excluding Step 3 (statistics calculation).

B.3 Calculation of characteristic reliability values on the basis of test data

B.3.1 General statistical correlation

If characteristic reliability values are required, e.g. stating the survival probability $R(t)$ for the period of time t, and with a necessarily specified confidence level P_A, these can be evaluated by the statistical calculation given in the Equation B.1, using life test data.

The calculation is based on the following correlation: correlating the Weibull distribution with the binomial distribution yields

$$R \geqslant (1 - P_A)^{\frac{1}{n \times L_v^{\beta}}} \quad \text{(B.1)}$$

where

R is the survival probability;

P_A is the confidence level (assumption);

β is the Weibull form factor;

n is the number of DUT;

L_v is the service life ratio = test duration/specified service life = t/T

When applying this correlation, the following two conditions shall be met.

— There shall be no failures during testing. But if failures do occur, then only the test duration up to the first failure shall be used for the calculation.

— Failures expected in practice shall have Weibull distribution.

Depending on the task, Equation B.1 shall be solved to give the required quantity; other quantities must be known; if this is not the case, these quantities shall be determined by experiment or by using figures based on experience.

The method is explained using the example given in B.3.2.

B.3.2 Example for determination of test duration for a given reliability

B.3.2.1 DUT

A plastic coated coil without moving parts and the following specifications, used in the passenger car engine compartment, was chosen for this example:

— service life, ten years;

— survival probability, R = 0,99 (failure rate 1 %);

— confidence level, P_A = 0,9 (normal value).

B.3.2.2 Determination of load specific to product and relevant for service life

According to experience with these and similar products, the main load can be determined as the load resulting from mechanical stresses due to various thermal expansion processes of the various components caused by temperature cycle stresses.

This results in the temperature cycle test being the test to be applied.

B.3.2.3 Determination of the in-practice load

The highest temperature rise occurring in practice is the temperature rise resulting from heating the engine compartment starting from the cold operating condition. Because of the high thermal load of the vehicle, this temperature rise can only occur for a maximum of twice a day. For ten years (10 a) this results in

7 300 temperature cycles

with a temperature rise (determined by measurement) of

ΔT = 70 K

The numerous small rises in temperature are disregarded for this approximation. Why this is permissible will be shown in B.3.2.5.

B.3.2.4 Calculation of the test duration

The test duration results from the required number of temperature cycles in the test. Using

$$L_{\mathrm{v}} = \frac{N_{1,\mathrm{test}}}{N_{\mathrm{prac}}}$$

and Equation B.1 yields

$$N_{1,\mathrm{test}} = N_{\mathrm{prac}} \left[\frac{\ln\left(1 - P_{\mathrm{A}} \times \frac{1}{n}\right)}{\ln R} \right]^{\frac{1}{\beta}} \quad \text{(A.2)}$$

where

$N_{1,\mathrm{test}}$ is the required number of temperature cycles in the test with in-practice temperature rise

N_{prac} is the number of temperature cycles occurring in practice: 7 300 (in 10 years);

R is the survival probability: 0,99 (specification);

P_{A} is the confidence level (assumption): 0,9;

β is the Weibull form factor: 3 (determined in experiment, for wire fracture);

n is the number of DUT: 45 (small and simple).

With the above values inserted, the result is $N_{1,\mathrm{test}}$ = 12 558, i.e. for an in-practice load of ΔT = 70 K, 12 558 test cycles are necessary to ensure the specified reliability of R = 0,99 (additional condition: no failure).

As such a test duration is not tolerable, a reduction can be achieved by a permissible increase of load (see B.3.2.5.)

B.3.2.5 Load increase

A calculation method suitable for increased load is the Coffin Manson formula. For the case considered here, the formula is as follows:

$$N_{2,\text{test}} = N_{1,\text{test}} \times \left(\frac{\Delta T_{\text{prac}}}{\Delta T_{\text{test}}} \right)^k \tag{B.3}$$

where:

$N_{2,\text{test}}$ is the number of test cycles with test temperature rise;

$N_{1,\text{test}}$ is the number of test cycles with in-practice temperature rise;

ΔT_{prac} is the in-practice temperature rise, 70 K;

ΔT_{test} is the test temperature rise, 160 K (–40 °C/+120 °C, the maximum tolerable temperatures);

k is the exponent depending on the failure process, 5 (determined in experiment, Wöhler gradient).

With the values above, the result is $N_{2,\text{test}}$ = 200 cycles. Because k = 5 is a high exponent, small temperature rises can be disregarded.

B.3.3 Conclusions

The determination of reliability by life tests is governed by the following factors (the required service life with the corresponding minimum reliability is usually given):

- "failure behaviour" (Weibull form factor) has a major impact on the result — higher failure gradient yields shorter test duration,
- especially with low failure gradients, the "number of DUT" has a high impact,
- "confidence level", excessive requirements for the confidence level result in a longer test duration and higher numbers of DUT.

The method described can be used successfully if there is distinct failure behaviour due to wear or fatigue, and if a high increase in load is permissible for testing. This is often applicable to mechanical and electro-mechanical products.

Unfortunately, this method can generally not be used for purely electronic components because the greater accidental failure behaviour (Weibull form factor of approx. 1) leads to intolerably extensive testing (number of DUT and test duration), and an increase in load (e.g. temperature rise) is only possible to a moderate extent.

ICS 43.040.10

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