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colour inside

Methods for product accelerated testing

Méthodes d'essais accélérés de produits

IEC 62506:2013

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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METHODS FOR PRODUCT ACCELERATED TESTING

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FDIS	Report on voting
56/1503/FDIS	56/1513/RVD

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This publication 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 web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

Many reliability or failure investigation test methods have been developed and most of them are currently in use. These methods are used to either determine product reliability or to identify potential product failure modes, and have been considered effective as demonstrations of reliability:

– fixed duration,
– sequential probability ratio,
– reliability growth tests,
– tests to failure, etc.

Such tests, although very useful, are usually lengthy, especially when the product reliability that has to be demonstrated was high. The reduction in time-to-market periods as well as competitive product cost, increase the need for efficient and effective accelerated testing. Here, the tests are shortened through the application of increased stress levels or by increasing the speed of application of repetitive stresses, thus facilitating a quicker assessment and growth of product reliability through failure mode discovery and mitigation.

There are two distinctly different approaches to reliability activities:

– the first approach verifies, through analysis and testing, that there are no potential failure modes in the product that are likely to be activated during the expected life time of the product under the expected operating conditions;
– the second approach estimates how many failures can be expected after a given time under the expected operating conditions.

Accelerated testing is a method appropriate for both cases, but used quite differently. The first approach is associated with qualitative accelerated testing, where the goal is identification of potential faults that eventually might result in product field failures. The second approach is associated with quantitative accelerated testing where the product reliability may be estimated based on the results of accelerated simulation testing that can be related back to the use of the environment and usage profile.

Accelerated testing can be applied to multiple levels of items containing hardware or software. Different types of reliability testing, such as fixed duration, sequential test-to-failure, success test, reliability demonstration, or reliability growth/improvement tests can be candidates for accelerated methods. This standard provides guidance on selected, commonly used accelerated test types. This standard should be used in conjunction with statistical test plan standards such as IEC 61123, IEC 61124, IEC 61649 and IEC 61710.

The relative merits of various methods and their individual or combined applicability in evaluating a given system or item, should be reviewed by the product design team (including dependability engineering) prior to selection of a specific test method or a combination of methods. For each method, consideration should also be given to the test time, results produced, credibility of the results, data required to perform meaningful analysis, life cycle cost impact, complexity of analysis and other identified factors.

METHODS FOR PRODUCT ACCELERATED TESTING

1 Scope

This International Standard provides guidance on the application of various accelerated test techniques for measurement or improvement of product reliability. Identification of potential failure modes that could be experienced in the use of a product/item and their mitigation is instrumental to ensure dependability of an item.

The object of the methods is to either identify potential design weakness or provide information on item dependability, or to achieve necessary reliability/availability improvement, all within a compressed or accelerated period of time. This standard addresses accelerated testing of non-repairable and repairable systems. It can be used for probability ratio sequential tests, fixed duration tests and reliability improvement/growth tests, where the measure of reliability may differ from the standard probability of failure occurrence.

This standard also extends to present accelerated testing or production screening methods that would identify weakness introduced into the product by manufacturing error, which could compromise product dependability.

2 Normative references

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

IEC 60068 (all parts), *Environmental testing*

IEC 60300-3-1:2003, *Dependability management – Part 3-1: Application guide – Analysis techniques for dependability – Guide on methodology*

IEC 60300-3-5, *Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles*

IEC 60605-2, *Equipment reliability testing – Part 2: Design of test cycles*

IEC 60721 (all parts), *Classification of environmental conditions*

IEC 61014:2003, *Programmes for reliability growth*

IEC 61164:2004, *Reliability growth – Statistical test and estimation methods*

IEC 61124:2012, *Reliability testing – Compliance tests for constant failure rate and constant failure intensity*

IEC 61163-2, *Reliability stress screening – Part 2: Electronic components*

IEC 61649:2008, *Weibull analysis*

IEC 61709, *Electronic components – Reliability – Reference conditions for failure rates and stress models for conversion*

IEC 61710, *Power law model – Goodness-of-fit tests and estimation methods*

IEC 62303, *Radiation protection instrumentation – Equipment for monitoring airborne tritium*

IEC/TR 62380, *Reliability data handbook – Universal model for reliability prediction of electronics components, PCBs and equipment*

IEC 62429, *Reliability growth – Stress testing for early failures in unique complex systems*

3 Terms, definitions, symbols and abbreviations

For the purposes of this document, the term and definitions given in IEC 60050-191:____, as well as the following, apply.

NOTE Symbols for reliability, availability, maintainability and safety measures follow those of IEC 50060-191:1990, where available.

3.1 Terms and definitions

3.1.1
item
subject being considered

Note 1 to entry: The item may be an individual part, component, device, functional unit, equipment, subsystem, or system.

Note 2 to entry: The item may consist of hardware, software, people or any combination thereof.

Note 3 to entry: The item is often comprised of elements that may each be individually considered. See "sub-item", definition 191-41-02 and "indenture level", definition 191-41-05.

Note 4 to entry: IEC 60050-191:1990, first edition, identified the term "entity" as a synonym, which is not true for all applications.

Note 5 to entry: The definition for item given in the first edition is a description rather than a definition. This new definition provides meaningful substitution throughout this standard. The words of the former definition form the new note 1.

[SOURCE: IEC 60050-191:—, definition 191-41-01] [1][1]

3.1.2
step stress
step stress test
test in which the applied stress is increased, after each specified interval, until failure occurs or a predetermined stress level is reached

Note 1 to entry: The 'intervals' could be specified in terms of number of stress applications, durations, or test sequences.

Note 2 to entry: The test should not alter the basic failure modes, failure mechanisms, or their relative prevalence.

[SOURCE: IEC 60050-191:—, definition 191-49-10]

3.1.3
acceleration factor
ratio between the item failure distribution characteristics or reliability measures (e.g. failure intensities) of an item when it is subject to stresses in expected use and those the item acquires when the higher level stresses are applied for achieving a shorter test duration

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1 Figures in square brackets refer to the Bibliography.

Note 1 to entry: For a test to be effectively accelerated, the acceleration factor is >1.

Note 2 to entry: When the failure distribution Poisson is assumed with constant failure rate, then the acceleration factor corresponds to the ratio of time under stress in use vs. time under increased stress in test.

3.1.4
highly accelerated limit test
HALT
test or sequence of tests intended to identify the most likely failure modes of the product in a defined stress environment

Note 1 to entry: HALT is sometimes spelled out as the highly accelerated life test (as it was originally named in error). However, as a non-measurable accelerated test, it does not provide information on life duration, but on the magnitude of stress which represents the limit of the design.

3.1.5
highly accelerated stress test
HAST
test where applied stresses are considerably increased in order to reduce duration of their application

3.1.6
highly accelerated stress screening
HASS
screening intended to identify latent defects in a product caused by manufacturing process or control errors

3.1.7
highly accelerated stress audit
HASA
process monitoring tool where a sample from a production lot is tested to detect potential weaknesses in a product caused by manufacturing

3.1.8
activation energy
E_a
empirical factor for estimating the acceleration caused by a change in absolute temperature

Note 1 to entry: Activation energy is usually measured in electron volts per degree Kelvin.

3.1.9
event compression
increasing stress repetition frequency to be considerably higher than it is in the field

3.1.10
time compression
removal of exposure time at low or deemed non damaging stress levels from a test for purpose of acceleration

3.1.11
precipitation screen
screening profile to precipitate, through failure, conversion of latent into permanent faults

3.1.12
detection screen
low stress level exposure to detect intermittent faults

3.2 Symbols and abbreviated terms

Symbol/ Abbreviation	Description
$R(t)$	reliability as a function of time; probability of survival past the time t

NOTE 1 IEC 60050-191:1990, definition 191-12-01 uses the general symbol $R(t_1,t_2)$. Time may be substituted by cycles, measure of distance, etc.

$\lambda(t)$	failure rate as a function of time

NOTE 2 In reliability growth testing, the same symbol normally used for the instantaneous failure rate can be used for variable failure intensity.

HALT	highly accelerated limit test
HASS	highly accelerated stress screening test
HAST	highly accelerated stress test
HASA	highly accelerated stress audit
$\lambda(S)$	failure rate as a function of a stress
UUT	unit under test
A	acceleration, acceleration factor
A_{test}	overall acceleration in a test
ADT	accelerated degradation testing
DSL	design specification limit
RTL	reliability test level
SL	specification limit
DL	destruct limit
LDL	lower destruct limit
UDL	upper destruct limit
OL	operating limit
UOL	upper operating limit
LOL	lower operating limit
SPRT	sequential probability ratio test
RG	reliability growth
URTL	upper reliability test limit
LRTL	lower reliability test limit
THB	temperature humidity bias test
TTF	time to failure
MTBF	mean operating time between failures
MTTF	mean time to failure
AF	acceleration factor
FIT	failure to time
CALT	calibrated accelerated life testing
ADT	accelerated degradation test
t_0	start of a period of in determination of product destruct life rest
t_L	duration of a predetermined time, e. g. life
SPRT	sequential probability ratio tests

4 General description of the accelerated test methods

4.1 Cumulative damage model

Accelerated testing of any type is based on the cumulative damage principle. The stresses of the product in its life cause progressive damage that accumulates throughout the product life. This damage may or may not result in a product's failure in the field.

The strategy of any type of accelerated testing is to produce, by increasing stress levels during testing, cumulative damage equivalent to that expected in the product's life for the type of expected stress. Determination of product destruct limits, without reliability estimation, provides information on whether there exists a sufficient margin between those destruct limits and product specification limits, thus providing assurance that the product will survive its predetermined life period without failure related to that specific stress type. This technique may or may not necessarily quantify a probability of product survival for its life, just assurance that the necessary adjustments in product strength would help eliminate such failure in product use. Where sufficient margins are determined unrelated to the probability of survival, the type of test is qualitative. In tests where this probability of survival is determined, the magnitude of the stress is correlated to the probability that the product would survive that stress type beyond the predetermined life, and this test type is quantitative.

Figure 1 depicts the principle of cumulative damage in both qualitative and quantitative accelerated tests.

In Figure 1, for simplicity, all stresses, operating limits, destruct limits, etc. are shown as absolute values. The specification values for an item are usually given in both extremes, upper and lower, thus the upper and lower (or low) specification limit, USL and LSL with the corresponding design limits (DSL), UDL and LDL, the upper and lower operating limits, UOL and LOL, and also the reliability test limits, URTL and LRTL. The rationale is that the opposite (negative stresses, may also cause cumulative damage probably with a differently failure mechanism, thus the relationship between the expected and specified limits can be illustrated in the same manner as for the high or positive stress. As an example, cold temperature extremes might produce the same or different failure modes in a product. To avoid clutter, the positive and the negative thermal or any other stresses are not separately shown in Figure 1, thus the magnitudes of stresses are either positive or negative, and thus represented as absolute values only as upper or lower limits.

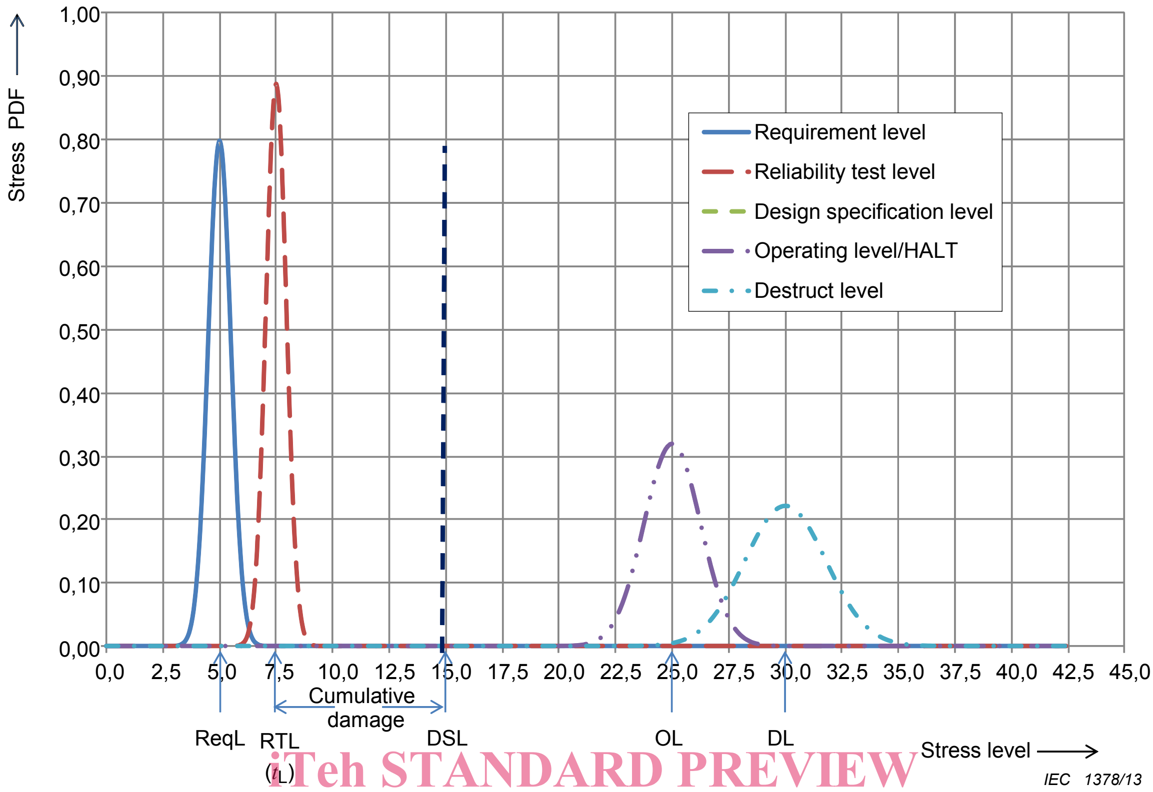

Figure 1 – Probability density functions (PDF) for cumulative damage, degradation, and test types

The graph in Figure 1 shows the required strength of a product regarding a stress for the duration of its lifetime, from beginning of life (e.g. time when the product is made), t_0 through the end of life, t_L. The strength and stresses in tests are also assumed to have a Gaussian distribution.

The different types of accelerated tests can now be illustrated using Figure 1 as a conceptual model.

Functional testing is carried out within the range of the requirement specification and at the level of the specification. In this area no failures should occur during the test; design is validated to allow operation within the upper and lower specification limits. Accelerated testing of Type B and C (4.2.3 and 4.2.4), i.e. accelerated degradation testing (ADT) or cumulative damage testing can be illustrated as the distance between the design specification level (DSL) and the level where the reliability demonstration test should be performed (RTL). When the degradation reduces the performance below the requirement specifications the product can be declared as failed, if this behaviour is defined as a failure. When testing the product at time t_0 no failures should be expected for stress levels up to and including the design specification level (DSL).

The product design specification should take into consideration certain degradation during the product's life which is resultant from the cumulative damage of the stresses expected in life, thus its limit is the design specification limit (DSL) which is higher than the requirement limit (RL) in order to provide the necessary margin. After product degradation resultant from the cumulative damage caused by expected stresses, the reliability test provides information on the existing margin between the test level (the remaining strength) and the requirement. This margin is a measure of reliability at the end of required period, t_L.

The ultimate strength of the design is considerably higher than the design specifications and this is the level determined in the qualitative accelerated test where the goal is to identify