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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Reliability testing – Compliance tests for constant failure rate and constant failure intensity

Essais de fiabilité – Plans d'essai de conformité pour un taux de défaillance constant et une intensité de défaillance constante



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Reliability testing – Compliance tests for constant failure rate and constant failure intensity

Essais de fiabilité – Plans d'essai de conformité pour un taux de défaillance constant et une intensité de défaillance constante

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RELIABILITY TESTING – COMPLIANCE TESTS FOR CONSTANT FAILURE RATE AND CONSTANT FAILURE INTENSITY

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This fourth edition cancels and replaces the third edition published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) The truncated sequential probability ratio test (SPRT) [1], [2], [3][1] has been significantly developed in recent years [4], [5], [6]. In this edition, type A test plans (optimally truncated SPRT) have been significantly changed, as follows:

_____

1 Numbers in square brackets refer to the Bibliography.

- the tests are significantly truncated (the maximal test time is low) without substantially increasing the expected accumulated test time to decision (ETT);
- the true producer's and consumer's risks (α', β') are given and are very close to the nominal values;
- the range of the test parameters is wide (risks and discrimination ratio);
- the test plans include various risk ratios (not restricted to equal risks only);
- the values of the ETT are accurate and given in the relevant region (for practical use);
- guidelines for extension of the tests set (using accurate interpolation) are included.

b) Other ready-to-use test plans (types B, C, D) are not changed, only the form of presentation of the data on their border lines and the characteristics has been changed. This form is made unified for all types of test plans, which helps the comparison of different plans and, accordingly, to facilitate the selection of the most appropriate.

c) FTFT design procedures, to extend the set of test plans B, are significantly changed and make the design accurate and simple. The implementation of this design is given on a spreadsheet program. A unified approach to the calculation of the operational characteristics of all types of test plans is introduced.

The text of this International Standard is based on the following documents:

Draft	Report on voting
56/1980/FDIS	56/1985/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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INTRODUCTION

A compliance test is an essential part of the reliability assurance system [7], [8], [9]. Reliability is affected by many random factors, so its prediction is not accurate. The direct way to check if the item meets its reliability specifications is to perform a compliance test.

The tests described in this document can be applied to items that have a failure rate or failure intensity (denoted by λ) which can be considered as a constant. The procedures are based on the assumption that trials of the test are statistically independent. If it is necessary to test the constant failure rate and constant failure intensity assumption, the procedures given in IEC 60605-6 should be used.

The test serves to verify the compliance with a specified λ_0, that is, to verify that $\lambda \leq \lambda_0$.

The probability of making the correct decision in the test depends on the test duration and on the sample size (number of failures). The tests usually require a large sample size and, accordingly, a large consumption of time and funds. The consumptions are especially high for reliability testing. For this reason, sampling plans of the tests should be carefully planned in order to reduce the consumption.

This document is dedicated to sampling plans for the tests.

The tests are characterized by the operating characteristic (OC) and test duration until the test stops with the accept/reject decision on the compliance.

OC is the probability of accepting an item as meeting the requirements. In this document, the OC is represented by the coordinates of its two points (see ISO 3534-2 [10]):

– $(\lambda_0, 1 - \alpha)$ are the coordinates of the producer's risk point (PRP);

– (λ_1, β) are the coordinates of the consumer's risk point (CRP);

where α and β are producer's and consumer's risks, and $\lambda_1 > \lambda_0$.

The test duration (test time) is a random value and in this document is usually characterized by its expected (ETT) and maximum (MaxTT) values.

This document contains the following types of tests:

– optimally truncated sequential probability ratio test (SPRT, type A);

– maximally truncated SPRT (type C);

– fixed time/failure terminated test (FTFT, type B);

– FTFT – calendar time terminated test without replacement;

– combined test plan (type D).

The tests can be used for testing equipment (repaired or non-repaired) as well as for components (replaced or not replaced when failing).

All the plans in this document are sequential, that is, every time an event occurs during the test, a decision is made to continue or stop the test. An event occurs in two cases: when a failure occurs, or when the acceptance boundary is crossed, which means that there is compliance with the requirements. The decision can be one of three types:

- accept the compliance and stop the test;
- reject the compliance and stop the test;
- continue the test, because there is not enough information to stop it.

The difference between the types of tests is in the shape of border lines.

The FTFT is characterized by decision rules for accepting or rejecting compliance when the MaxTT has been reached, or the acceptable number of failures has been exceeded. This test has the smallest MaxTT among all tests with specified PRP and CRP. If, for a tested item $\lambda \leq \lambda_0$, then ETT is close to MaxTT; otherwise, if $\lambda > \lambda_0$, then ETT decreases. In fact, the only advantage of the FTFT over the SPRT is the simplicity of designing new test plans. A detailed procedure for the design is provided in this document.

The optimally truncated SPRT (type A) has a MaxTT of 1,1 to 1,2 times greater than the FTFT with the same PRP and CRP. However, the ETT of the SPRT is significantly smaller than that of the corresponding FTFT, and for $\lambda \leq \lambda_0$ it can be 1,4 to 1,8 times smaller. This is a great advantage of the SPRT. This document contains an extensive set of ready-to-use type A plans. The set also allows the design of additional tests by simple interpolation according to the procedure provided in this document.

The maximally truncated SPRT (type C) has a MaxTT, like the FTFT; however, its ETT is less than that of the FTFT, but greater than that of the type A SPRT.

In the combined test plan (type D), test items with early failures will not be rejected in the initial stages of the test.

Some of the ready-to-use tests listed in this document have a very large maximal acceptable number of failures, which is why they are likely to be rarely used. However, the data allows the user of this document to assess the economic benefit of the OC test requirements and, in general, to assess the advisability of performing the test.

Accumulated test time can be reduced by accelerated testing (see IEC 62506 [11]).

An example of objects covered by this document can be electronic equipment and its components, which usually have a failure rate or failure intensity that can be considered constant.

Clause 4 presents the requirements and area of application of the tests and recommendations for their selection. Clause 5 explains the general elements of the test procedure. Clause 6 explains the characteristics of the ready-to-use SPRT and the parameters of the border lines (their values are given in Annex A). Extension of the set of SPRT tests are given in Annex C. Clause 7 is devoted to the ready-to-use FTFT. Clause 8 presents the design of FTFT plans that are not covered in the tables of this document. Mathematical references and procedures of the design of FTFT plans are given in Annex E and in Annex F. Clause 9 is devoted to the calendar FTFT for non-replaced items (examples and mathematical references of their design are given in Annex G). Clause 10 is devoted to the combined test plans (parameters of their border lines are given in Annex B). Clause 11 explains how to perform the test and presentation of results. Annex D presents the approximation of OC by Wald's formula. Annex H is devoted to the mathematical reference for the test plans of GOST R 27.402 [12].

RELIABILITY TESTING – COMPLIANCE TESTS FOR CONSTANT FAILURE RATE AND CONSTANT FAILURE INTENSITY

1 Scope

This document gives a number of optimized test plans, the corresponding border lines and characteristics. In addition, the algorithms for designing test plans using a spreadsheet program are also given, together with guidance on how to choose test plans.

This document specifies procedures to test whether an observed value of

– failure rate,
– failure intensity,
– mean operating time to failure (MTTF),
– mean operating time between failures (MTBF),

conforms to a given requirement.

It is assumed, except where otherwise stated, that during the accumulated test time, the times to failure or the operating times between failures are independent and identically exponentially distributed. This assumption implies that the failure rate or failure intensity is assumed to be constant.

Four types of test plans are described as follows:

– truncated sequential probability ratio test (SPRT);
– fixed time/failure terminated test (FTFT);
– fixed calendar time terminated test without replacement;
– combined test.

This document does not cover guidance on how to plan, perform, analyse and report a test. This information can be found in IEC 60300-3-5.

This document does not describe test conditions. This information can be found in IEC 60605-2 and in IEC 60300-3-5.

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 60050-192, *International Electrotechnical Vocabulary (IEV) – Part 192: Dependability*, available at http://www.electropedia.org

IEC 60300-3-5:2001, *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 60605-4:2001, *Equipment reliability testing – Part 4: Statistical procedures for exponential distribution – Point estimates, confidence intervals, prediction intervals and tolerance intervals*

IEC 60605-6, *Equipment reliability testing – Part 6: Tests for the validity and estimation of the constant failure rate and constant failure intensity*

IEC 61123:2019, *Reliability testing – Compliance test plans for success ratio*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document the terms and definitions given in IEC 60050-192 apply.

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

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

The terms "failure rate" and "failure intensity" are used as meaning constant failure rate and constant failure intensity.

3.2 Abbreviated terms and symbols

3.2.1 Abbreviated terms

ADT accept decision time – time that the test was terminated with accept decision

CDF cumulative distribution function

CRP consumer's risk point

ETT expected accumulated test time to accept/reject decision

FTFT fixed time/failure terminated test

MaxTT maximal accumulated test time and accumulated truncation time of the test

MTBF mean operating time between failures

MTTF mean operating time to failure

OC operating characteristic

PDF probability density function

PRP producer's risk point

RDS reject decision segment – segment of time/failure line when the test was terminated with reject (see Figure 2)

SPRT truncated sequential probability ratio test (in some literature called probability ratio sequential test (PRST)).

3.2.2 Symbols

The generic symbol λ is used in this document for failure rate and failure intensity.

The symbol m is used to denote both the following reliability measures:

– mean operating time between failures, MTBF;

– mean operating time to failure, MTTF.

When used, the relationship between the above quantities, under the given assumptions, is:

$$\lambda = 1/m$$

Test plans are based on m as a reliability measure; thus in these cases:

$$m = 1/\lambda$$

c acceptable number of failures during FTFT

D discrimination ratio; $D = m_0/m_1$ or $D = \lambda_1/\lambda_0$

m true MTBF or MTTF

m_j indexed m, where j = L, 1, M, 0, H (as in Figure 1 and in Table 3)

m_0 specified MTTF or MTBF, $m_0 = 1/\lambda_0$

m_1 lower limit for MTTF or MTBF, $m_1 = 1/\lambda_1$

n number of test items at the beginning of the test

P_a probability of acceptance

p_0 acceptable failure ratio

q_0 acceptable success ratio, $q_0 = 1 - p_0$

$R(t)$ reliability function

r observed number of failures during the test

r_0 maximum number of failures where an "accept" decision is possible (see Figure 2)

r_e expected number of failures to reach a decision

T^* accumulated test time

T_a^* accumulated test time stated as accept criterion (ADT)

$T_{a,min}^*$ minimum test time for $r = 0$ stated as accept criterion

T_e^* expected accumulated test time to decision

$T_{e,j}^*$ indexed T_e^*, where j = L, 1, M, 0, H (which are related to the five values of m_j as in Figure 1)

$T_e^*(+)$ expected accumulated test time to acceptance

T_r^* accumulated test time stated as reject criterion

T_t^* accumulated test time stated as termination criterion for FTFT and MaxTT for A, C and D tests

t test time

t^* test time for each tested item

t_e^* expected test time to decision

t_t^* test truncation time

t_i test time of failed item i

$t^*_{cal,t}$ calendar test time stated as termination criterion

R_D optimization criterion, Formula (E.11)

R_R optimization criterion, Formula (E.12)

$P(r)$ probability of r failures

α producer's risk (type I risk)

α' true producer's risk (type I risk)

β consumer's risk (type II risk)

β' true consumer's risk (type II risk)

λ true failure rate per item

λ_0 specified expected failure rate per item (design goal)

λ_1 upper limit for constant failure rate per item

4 General requirements and area of application

4.1 Requirements and characteristics

It is assumed, except where otherwise stated, that during the accumulated test time, the times to failure or the operating times between failures are independent, and identically exponentially distributed. This assumption implies that the failure rate or failure intensity is assumed to be constant. Under this assumption, there is no difference between failure rate and failure intensity. Therefore, they are both called λ and referred to in this document as failure rate.

It is assumed that the requirement is specified in one of the following terms: the acceptable constant failure rate or the acceptable mean number of failures per time unit, λ_0, or the acceptable mean operating time to failure or mean operating time between failures, m_0.

The tests are characterized by an operating characteristic (OC) and test time to decision.

The OC of a test is the probability of accepting an item as meeting the requirements (see example in Figure 3). The OC is a function of the true value of m, or of λ. In this document, the OC is represented by the coordinates of its two points (see ISO 3534-2):

- (m_0, 1 – α) are the coordinates of the producer's risk point (PRP), or (λ_0, 1 – α);
- (m_1, β) are the coordinates of the consumer's risk point (CRP), or (λ_1, β).

The test time to reaching a decision regarding the test is a random value and in this document is usually characterized by its expected (ETT) and maximum (MaxTT) values (see example in Figure 1). ETT is a function of the true value of m, or λ.

It is possible that special treatments will be required to ensure the constant failure rate or failure intensity, for example, screening for the elimination of early life failure period.

If it is necessary to test the constant failure rate/constant failure intensity assumption, the procedures given in IEC 60605-6 shall be used.

4.2 Applicability to replaced and repaired items

The truncated sequential probability ratio test plans (see Clause 6), the time/failure terminated test plans (see Clause 7) and the combined test plans (see Clause 10) are applicable to the following:

– replacement of failed items;

– without replacement of failed items;