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Edition 2.0 2019-11

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NORME INTERNATIONALE

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Reliability testing – Compliance test plans for success ratio

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RELIABILITY TESTING – COMPLIANCE TEST PLANS FOR SUCCESS RATIO

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International Standard IEC 61123 has been prepared by IEC technical committee 56, Dependability.

This second edition cancels and replaces the first edition published in 1991. This edition constitutes a technical revision.

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

a) The sequential probability ratio test (SPRT) [1, 2][1] has been significantly developed in recent years [3, 4, 5]. This edition contains shorter and accurate tests, a wide range of test plans, and significant additional characteristic data, as follows:
   – the tests are significantly truncated (the maximum trial numbers are low) without substantially increasing the expected number of trials to decision (ENT);
   – the true producer's and consumer's risks (α', β') are given and very close to the nominal (α, β);

[1] Numbers in square brackets refer to the bibliography.

- the range of the test parameters is wide (failure ratio, risks and discrimination ratio);
- the test plans include various risk ratios (not restricted to equal risks only);
- the values of ENT are accurate and given in the relevant region (for practical use);
- guidelines for extension of the test sets (interpolation and extrapolation) are included.

b) In Annex C, the use of the cumulative binomial distribution function of Excel that simplifies the procedure of designing has been added (Clause C.3).

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

FDIS	Report on voting
56/1852/FDIS	56/1873/RVD

Full information on the voting for the approval of this International Standard 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 document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
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- replaced by a revised edition, or
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INTRODUCTION

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

The test serves to verify the compliance with the specified probability that an item will perform as required. The outcome of each trial of the test is either success or failure.

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

This document is dedicated to sampling plans for the tests.

The procedures are based on the assumption that trials of the test are statistically independent and the probability of success, q in them is constant. This document also applies the probability of failure $p = 1 - q$.

The tests are characterized by operating characteristic (OC) and number of trials to decision.

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):

– $(p_0, 1 - \alpha)$ are the coordinates of the producer's risk point (PRP);

– (p_1, β) are the coordinates of the consumer's risk point (CRP).

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The number of trials to reaching a decision regarding the test is a random value and in this document is usually characterized by its expected (ENT) and maximum (MaxNT) values.

This document contains two types of tests:

– truncated sequential probability ratio test (SPRT);

– fixed trial/failure terminated test (FTFT).

The FTFT is characterized by decision rules for accepting or rejecting compliance when the termination trials number n_f (MaxNT) has been reached, or the acceptable number of failures c has been exceeded. This test has the smallest n_f among all tests with specified PRP and CRP. When testing objects with $p \leq p_0$, ENT is close to n_f, and for $p > p_0$, ENT decreases significantly. Another advantage of the FTFT is the ability to conduct all trials simultaneously, but ENT increases and becomes equal to n_f.

In the SPRT, the decision is made after each trial: accept or reject compliance, or continue testing. This document contains a truncated SPRT with MaxNT = n_t. This n_t is 1,1 to 1,2 times greater than n_f of the FTFT with the same PRP and CRP. However, the ENT of the SPRT is significantly smaller than that of the corresponding FTFT, and for $p \leq p_0$ it can be 1,4 to 1,8 times smaller. This is a great advantage of the SPRT. If it is necessary to shorten the calendar time of the SPRT, it is possible to run the trials by small portions of n_t, while the OC and ENT will not change significantly.

The planning of the SPRT is quite complicated so this document contains extensive tables with ready-to-use test plans and their characteristics. Tests are listed for $\alpha = \beta$ as well as for $\alpha \neq \beta$. The tables also allow the design of additional tests by simple interpolation and, for small p_0, by extrapolation.

Some of the tests have a very large sample size, which will probably be used rarely. However, the data allow 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.

The test is used for reliability testing; for example, to check compliance of the reliability of a non-repairable item for a given time interval (warranty period or designed lifetime). The test makes no assumption on whether the failure rate is constant or non-constant. IEC 61124 assumes a constant failure rate and is more statistically efficient since it takes the accumulated operating time into account.

Clause 4 presents the types of tests and recommendations for their selection. It also discusses the ability to reuse items during the test. Clause 5 explains the parameters of the stopping boundaries and the characteristics of the SPRT (their values are given in Annex D). Clause 6 is devoted to the FTFT, a table with parameters of stopping boundaries and characteristics is given. Annex A is devoted to the SPRT and provides examples of choosing a test by cost-benefit considerations, extension of the test set of Clause 5 by extra- and interpolation.

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RELIABILITY TESTING – COMPLIANCE TEST PLANS FOR SUCCESS RATIO

1 Scope

This international standard is intended to define a procedure to verify if a reliability of an item/system complies with the stated requirements. The requirement is assumed to be specified as the percentage of success (success ratio) or the percentage of failures (failure ratio).

This document can be used where a number of items are tested (number of trials performed) and classified as passed or failed. It can also be used where one or a number of items are tested repeatedly. The procedures are based on the assumption that the probability of success or failure is the same from trial to trial (statistically independent events). Plans for fixed trial/failure terminated tests as well as truncated sequential probability ratio tests (SPRTs) are included. This document contains extensive tables with ready-to-use SPRT plans and their characteristics for equal and non-equal risks for supplier and customer.

In the case of the reliability compliance tests for constant failure rate/intensity, IEC 61124 applies.

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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.

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IEC 60050-192:2015, *International Electrotechnical Vocabulary – 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*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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

3.1.1
success ratio
probability that an item will perform as required or that a trial will be successful under stated conditions

Note 1 to entry: An observed success ratio is the ratio of the number of non-faulty items or of successful trials at the completion of testing, to the total number of test items or number of trials.

3.1.2
failure ratio
probability that an item will fail or that a trial will be unsuccessful under stated conditions

Note 1 to entry: An observed failure ratio is the ratio of the number of faulty items or of unsuccessful trials at the completion of testing, to the total number of test items or number of trials.

3.2 Abbreviated terms and symbols

3.2.1 Abbreviated terms

AQL acceptable quality level

CRP consumer’s risk point

ENT expected number of trials to decision

FTFT fixed trial/failure terminated test

LQ limiting quality

MaxNT maximal number of trials to decision

OC operating characteristic

PRP producer’s risk point

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

3.2.2 Symbols

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α nominal producer's risk (type I risk)

α' true producer's risk (type I risk)

β nominal consumer's risk (type II risk)

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

c acceptable number of failures or unsuccessful events during the test

D nominal discrimination ratio, $D = p_1 / p_0 = (1 - q_1) / (1 - q_0)$

D' true discrimination ratio

h_a intercept value of the accept line on the vertical axis of the SPRT diagram (Figure 2)

h_r intercept value of the reject line on the vertical axis of the SPRT diagram (Figure 2)

n number of items, number of trials, number of events, sample size

n_e ENT

$n_{e,j}$ indexed n_e , where $j = L, 0, M, 1, H$ (which are related to five values of p as in Figure 4)

n_f number of items, number of trials, number of events, sample size required for acceptance in an FTFT

n_s accumulated number of trials in a sequential test plan

n_t number of items, number of trials, number of events, sample size at truncation in an SPRT

p true failure ratio, $p = 1 - q$

p_0 specified acceptable failure ratio, corresponding to acceptable quality level (AQL)

p_1 unacceptable failure ratio, corresponding to limiting quality (LQ), $p_1 = p_0 D$

P_a probability of acceptance

q true success ratio, $q = 1 - p$

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

q_1 unacceptable success ratio, $q_1 = 1 - p_1$

r number of relevant failures or relevant unsuccessful events

r_t number of relevant failures or relevant unsuccessful events at truncation

s slope of accept and reject lines in the sequential test diagram (see Figure 2)

4 General requirements and area of application

4.1 Reliability requirement

The requirement is assumed to be specified as:

– acceptable success ratio, q_0 or

– acceptable failure ratio, p_0 (p_0 = 1 – q_0).

In addition, a fixed time interval must be specified (see 3.1.1 and definition of reliability in IEC 60050-192:2015, 192-05-05).

These test plans are based on the assumption that each trial is statistically independent and that the probability of success (or failure) is constant (do not change from one trial to another), i.e. the binomial distribution assumptions apply. The true producer's and consumer's risks for the fixed trial/failure terminated test plans (Tables E.1 to E.3) differ from the nominal characteristics, α and β, due to the necessary approximations to whole numbers. For the SPRT (Table D.1), the true risks are equal to the nominal (exceptional case – see Note 1 of Table 2).

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4.2 Repair and replacement

The test plans given in this document are applicable to reused as well as non-reused (one-shot) items. Reused items may be repaired between successive trials, provided that the state and performance are the same at the start of all trials. For non-reused items, a separate test item (having the same performance) is used for each trial.

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4.3 Types of test plans

4.3.1 General

Test plans are given for two types of tests:

– truncated sequential probability ratio test (SPRT);

– fixed trial/failure terminated test (FTFT).

For SPRT see Clause 5. Clause 6 includes ready-to-use FTFT plans. Clause 7 includes guidelines for planning additional FTFTs which are not covered in Clause 6.

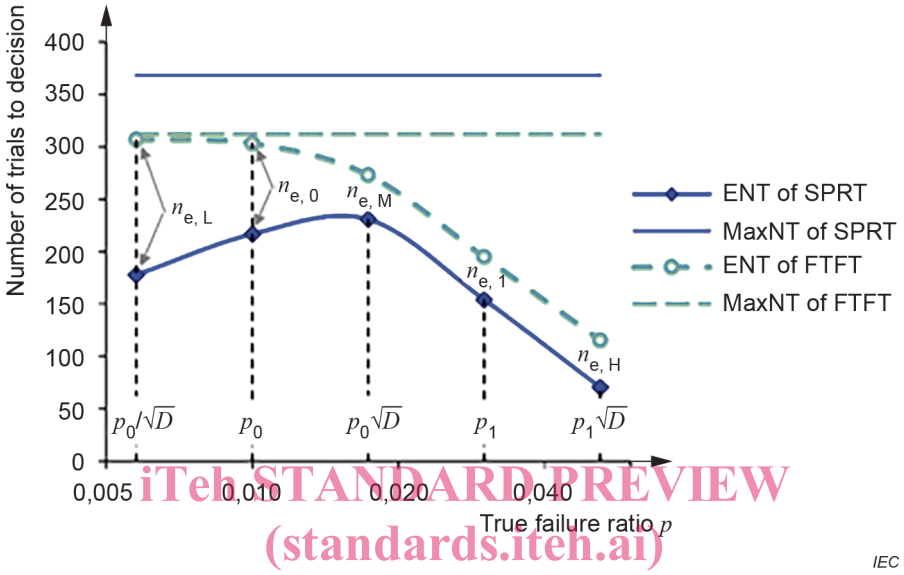
The detailed reliability test specification shall state which type of test and which test plan are to be used. Guidance on the choice of type of test is similar to that given in IEC 60300-3-5 for SPRTs and FTFTs for the case in which the failure rate/intensity is a function of time.

4.3.2 Features of the test plan types

In order to choose between the two types of test for a specified OC, it is necessary to make a comparison between their MaxNT and ENT. A qualitative comparison between SPRT and FTFT is given in the Introduction. In Figure 1 and Table 1, data is given for a quantitative comparison. Table 1 shows some of the ready-to-use test plans available in this document. For each test, two parameters of the number of trials to decision are listed: MaxNT (n_t for SPRT or n_f for FTFT) and point $n_{e,0}$ of ENT (see Figure 1). For the SPRT, for $p \leq p_0$ or $p \geq p_1$, there is a very small probability that the number of trials to decision will reach n_t. ENT of the FTFT, shown in Figure 1, is obtained when the FTFT is conducted sequentially and after each trial a decision is made to stop/continue the test. When all FTFT trials are conducted simultaneously, the

calendar test time is shortened, but the number of trials increases and becomes equal to MaxNT.

In addition to choosing either SPRT or FTFT, Table 1 helps the users choose the relevant area of the desired test characteristics (OC and the number of trials). Table 1 contains only part of the ready-to-use test plans available in this document. Information about all these plans is given in Clause 5 (for SPRT) and in Clause 6 (for FTFT).



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NOTE This figure is drawn for p_0 = 0,01, D = 3 (p_1 = 0,03), $\alpha' = \beta'$ = 0,094.

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Figure 1 – Expected and maximal number of trials for SPRT and FTFT with the same risks

4.4 General test procedure

The test items should be subjected to the number of trials according to the relevant test plan. For reused, replaced or repaired items, the detailed reliability test specifications should preferably state the number of test items as well as the maximum number of trials for each test item.

A trial is defined as the operation or cycle as described in the detailed reliability test specification.

4.5 General decision criteria

All test plans and decision criteria are based on either:

– an acceptable number of relevant failures for a specified number of trials; or
– an acceptable number of trials for a specified number of relevant failures.

The numbers of trials and relevant failures (see IEC 60300-3-5) are counted and compared with the decision criteria of the test plan.

The detailed decision criteria for the two types of test plans are given in 5.2, 6.2 and 7.7, respectively.

Table 1 – Overview – Maximal number of trials and expected number of trials at p_0 for SPRT and FTFT

α	β	Test type	Para-meter	p_0 = 0,001				p_0 = 0,01				p_0 = 0,1		
				D =1,5	D = 2	D = 3	D = 5	D =1,5	D = 2	D = 3	D = 5	D =1,5	D = 2	D = 3
0,05	0,05	SPRT	n_t	63 969	18 687	6 015	2 407	6 316	1 866	601	199	558	158	51
			$n_{e,0}$	30 397	9 268	3 106	1 129	3 004	910	303	112	264	78	25
		FTFT	n_f	53 998	15 703	5 232	–	5 320	1 567	521	–	474	135	41
			$n_{e,0}$	53 848	15 624	5 197	–	5 293	1 553	513	–	460	127	36
0,1	0,1	SPRT	n_t	38 019	11 007	3 814	1 590	3 719	1 103	382	116	331	96	33
			$n_{e,0}$	20 464	6 266	2 038	744	2 035	612	199	75	179	52	18
		FTFT	n_f	32 922	10 061	3 090	–	3 215	945	308	–	288	86	25
			$n_{e,0}$	32 675	9 948	3 029	–	3 183	928	299	–	277	80	22
0,2	0,2	SPRT	n_t	16 092	4 790	1 611	782	1 610	479	162	53	146	43	18*
			$n_{e,0}$	9 786	2 936	963	353	961	288	94	39	83	27	8*
		FTFT	n_f	14 291	4 537	1 426	–	1 428	453	142	–	134	39	14
			$n_{e,0}$	13 927	4 374	1 348	–	1 389	435	133	–	127	35	12
0,3	0,3	SPRT	n_t	6 449	2 050	1 075	388*	643	203	105	34*	31*	13	–
			$n_{e,0}$	3 906	1 159	383	234*	383	114	38	23*	23*	9	–
		FTFT	n_f	5 407	1 807	813	–	540	180	81	–	53	18	8
			$n_{e,0}$	5 041	1 645	751	–	502	163	74	–	48	15	6
0,05	0,1	SPRT	n_t	48 380	13 979	4 667	1 864	4 758	1 401	465	188	461	119	40
			$n_{e,0}$	23 649	7 238	2 356	853	2 344	705	231	82	197	61	18
0,1	0,05	SPRT	n_t	48 776	14 295	4 599	1 727	4 803	1 428	461	169	430	121	38
			$n_{e,0}$	27 707	6 225	2 826	1 026	2 732	829	275	99	239	71	22
0,05	0,2	SPRT	n_t	36 138	10 819	3 321	1 345	3 545	1 015	335	139	316	89	28
			$n_{e,0}$	15 876	4 740	1 602	574	1 565	476	155	55	137	40	12
0,2	0,05	SPRT	n_t	36 660	11 232	3 714	1 437	3 655	1 126	364	150	322	97	40
			$n_{e,0}$	21 997	6 642	2 220	820	2 173	650	218	79	192	56	17

NOTE For FTFT, the values of α and β are approximate. For SPRT, the values of α and β are insignificantly different from nominal, except those marked with asterisks, for which the exact values are indicated in Table D.1.

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5 Truncated sequential probability ratio test plans (SPRT)

5.1 Characteristics

Sequential test plans are characterized by decision rules for accepting or rejecting compliance, or for continuing testing, after any number of trials. They are determined by selected values of risks and discrimination ratio. In order to choose a test plan, the acceptable failure ratio, p_0 has to be specified (or derived).

Associated operating characteristic curves and values of the expected relevant number of trials to decision are included.

Table D.1 presents the appropriate test plans for various p_0, D, α' and β'. The table contains parameter values of h_a, h_r, s, n_t, r_t (Figure 2) and n_e (on 5 points, Figure 4) for each test plan.

NOTE n_t and r_t (that determine the truncation) were chosen as small as possible without significantly increasing the ENT [3, 4].

The range of the test parameters in Table D.1 are as in Table 2:

Table 2 – Range of the test parameters

p_0	0,001 0,002 0,005 0,01 0,02 0,05 0,1 0,2																		
D	1,5 1,75 2 3 5																		
α	0,025			0,05				0,1					0,2				0,3	0,4	
β	0,025	0,05	0,1	0,025	0,05	0,1	0,2	0,025	0,05	0,1	0,2	0,4	0,05	0,1	0,2		0,3	0,1	

NOTE 1 For a few short tests, mainly for D = 5 and α and β = 0,3, the deviation from the nominal risks is significant because of the discreteness of the tests, and no suitable test is available.

NOTE 2 Extension of test sets is available, see Clause A.2 and [3, 4, 5].

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5.2 Decision criteria

The decision criteria are as follows:

– accept if $sn_s - h_a \geq r$;

– continue if $sn_s - h_a < r < sn_s + h_r$;

– reject if $r \geq sn_s + h_r$.

The SPRT shall be truncated at lines based on the values n_t, r_t given in Table D.1 .

The truncation gives rise to the following additional criteria:

– accept if $n_s = n_t - r_t + r$ and $r < r_t$;

– reject if $r > r_t$.

The accumulated results are checked against the criteria after each trial and a decision is made whether to accept, continue or reject.