

BS EN 61124:2012

Incorporating corrigendum January 2013



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

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National foreword

This British Standard is the UK implementation of EN 61124:2012. It is identical to IEC 61124:2012, incorporating corrigendum January 2013. It supersedes BS EN 61124:2006 which is withdrawn.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by IEC corrigendum January 2013 is indicated in the text by AC1 AC1.

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English version

**Reliability testing -
Compliance tests for constant failure rate
and constant failure intensity
(IEC 61124:2012)**

Essais de fiabilité -
Plan d'essais de conformité d'un taux
de défaillance constant et d'une intensité
de défaillance constante
(CEI 61124:2012)

Prüfungen der Funktionsfähigkeit -
Prüfpläne für konstante Ausfallrate
und konstante Ausfalldichte
(IEC 61124:2012)

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Foreword

The text of document 56/1461/FDIS, future edition 3 of IEC 61124, prepared by IEC/TC 56 "Dependability" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61124:2012.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-03-27
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-06-27

This document supersedes EN 61124:2006.

EN 61124:2012 includes the following significant technical changes with respect to EN 61124:2006:

- a number of new test plans have been added based on the Russian standard GOST R 27.402, and it is intended to align the new edition of MIL-HDBK-781 with this edition. Algorithms for optimizing test plans using a spreadsheet program are given and a number of optimized test plans are listed. Furthermore, emphasis is laid on the fact that the test should be repeated following design changes;
- discrepancies in test plans A, B as well as Annexes A and B that originated in IEC 60605-7, now withdrawn, have been corrected so these test plans differ from those given in previous edition of EN 61124. As requested by the National committees, mathematical background material and spreadsheet program information has been moved to informative annexes. In addition, the symbol lists have been divided, so that some annexes have separate lists of symbols;
- guidance on how to choose test plans has been added as well as guidance on how to use spreadsheet programs to create them. Test plans A.1 to A.9 and B.1 to B.13 have been corrected;
- Subclauses 8.1, 8.2, 8.3, Clause 9, Annex C, Clauses G.2, I.2, I.3 and Annex J are unchanged, except for updated terminology and references;
- corrections to the second edition proposed by National Committees have been implemented.

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Endorsement notice

The text of the International Standard IEC 61124:2012 was approved by CENELEC as a European Standard without any modification.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-191	-	International Electrotechnical Vocabulary (IEV) - Chapter 191: Dependability and quality of service	-	-
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	1991	Reliability testing - Compliance test plans for - success ratio	-	-

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

1 Scope

This International Standard gives a number of optimized test plans, the corresponding operating characteristic curves and expected test times. 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 standard specifies procedures to test whether an observed value of

- failure rate,
- failure intensity,
- mean 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 constant.

Four types of test plans are described as follows:

- truncated sequential tests;
- time/failure terminated tests;
- fixed calendar time terminated tests without replacement;
- combined test plans.

This standard 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 standard 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, 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 60050-191, *International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service*

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 61123:1991, *Reliability testing – Compliance test plans for success ratio*

3 Terms, definitions, abbreviations and symbols

3.1 Terms and definitions

For the purposes of this document the terms and definitions given in IEC 60050-191 apply.

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

3.2 Abbreviations and symbols

3.2.1 Abbreviations

MTBF	mean operating time between failures
MTTF	mean time to failure
OC	operating characteristic
SPRT	sequential probability ratio test (in some literature called probability ratio sequential test (PRST)).

3.2.2 Symbols

The generic symbol λ is used in the following 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 time to failure, MTTF.

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

$$\lambda = \frac{1}{m}$$

Sequential test plans (see Clause 6) and fixed time/failure terminated test plans (see Clause 7) are based on m as a reliability measure, thus in these cases:

$$m = \frac{1}{\lambda}$$

c	acceptable number of failures during the test
D	discrimination ratio; $D = m_0/m_1$ or $D = \lambda_1/\lambda_0$
k	summation variable for failures

MTBF	mean operating time between failures
MTTF	mean time to failure
m	true MTBF or MTTF
m_0	specified MTTF or MTBF $m_0 = 1/\lambda_0$ (design goal)
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 at time t
r	observed number of failures during the test
r_0	test truncation failure number for sequential tests (SPRT)
T^*	accumulated test time
T_a^*	accumulated test time stated as accept criterion
$T_{a, \min}^*$	minimum test time for $r = 0$ stated as accept criterion
T_e^*	expected accumulated test time to decision
$T_e^*(+)$	expected accumulated test time to acceptance
T_r^*	accumulated test time stated as reject criterion
T_t^*	accumulated test time stated as termination criterion
t	test time
t^*	test truncation time
t_t^*	test time for each test item (assumed here to be the same for all test items)
t_i	life time of failed item i
$t_{\text{cal}, t}^*$	calendar test time stated as termination criterion
$P(r)$	probability of r failures
$\Delta\mu_0$	auxiliary quantity for determination of c , $\Delta\mu_0 = c - \mu_0$
α	nominal producer's risk (type I risk)
α'	true producer's risk (type I risk)
β	nominal consumer's risk (type II risk)
β'	true consumer's risk (type II risk)
λ	true failure rate per item
λ_0	expected failure rate per item (design goal)
λ_1	upper limit for constant failure rate per item

μ expected number of failures during the test at the true λ

NOTE μ is not necessarily an integer.

μ_0 expected number of failures during the test at the specified λ_0 as parameter of the Poisson distribution $\mu_0 = T_t^* / m_0 = \lambda_0 T_t^*$

4 General requirements and area of application

4.1 Requirements

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 constant. Under this assumption there is no difference between failure rate and failure intensity. Therefore they are both called λ and referred to in the following as failure rate.

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

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

4.2 Applicability to replaced and repaired items

The sequential 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;

under the assumption that

- an item can be replaced by repair of the item itself;
- the accumulated test time is calculated as elapsed operating item-time, in accordance with 5.4;
- replaced items belong to the same population as the original items;
- repaired items can be considered to have the same failure intensity after repair as they had before they failed.

The calendar time/failure terminated test plans in Clause 9, however, are applicable to cases where failed items are not replaced and where a fixed number of items are placed on test for a fixed calendar time. This means that the test is running, even though the number of items under test may not remain constant because some items may not survive.

4.3 Types of test plans

4.3.1 General

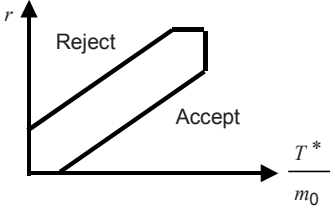
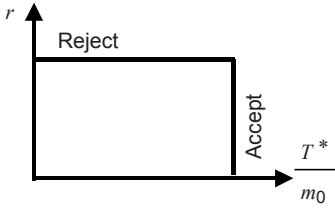
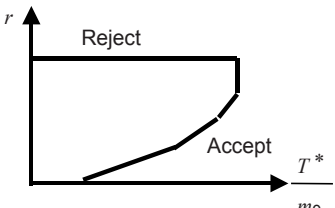
Test plans are given for four types of tests:

- truncated sequential tests (see Clause 6);
- time/failure terminated tests (for fixed time/failure terminated tests see Clause 7, and for alternative time/failure terminated tests, see Clause 8);
- calendar time terminated tests without replacement (see Clause 9);
- combined test plans (see Clause 10).

4.3.2 Advantages and disadvantages of the different test plan types

The different test plan types are shown in Table 1.

Table 1 – Advantages and disadvantages for the different test plan types

Test plan type	Advantages	Disadvantages
Truncated sequential Test plans in Clause 6 (Table 2), Annex A and Annex D 	Assures highest test efficiency (shortest test time). For the A test plans the user can develop new test plans using a spreadsheet program. The C test plans have true alpha and beta risks which are closer to the nominal risks than the A test plans	Complicated to administer. For marginal reliability, the test time is longer than for time/failure terminated and combined test plans. The test plans in Annex D are created using an iterative process. They cannot be computed using the spreadsheets described in Annex F
Time/Failure terminated Test plans in Clause 7 (Table 3) and Annex B 	Simple to understand and to administer. For marginal reliability, the test time is often shorter than for sequential test plans. The user can develop new test plans using a spreadsheet program. More failure information is collected for a test, analyse and fix program (TAAF) using these test plans	For very reliable, or very unreliable test items, the test time is much longer than for the sequential test plans, or for the combined test plans (in case of high reliability)
Combined Test plans in Clause 10 (Table 4) and Annex D 	Combines the advantages of the time/failure terminated test plans and the sequential test plans. Very reliable test items will be accepted quickly while test items with early failures will not be rejected early in the test. More failure information is collected for a TAAF (test, analyse and fix program) using these test plans	More complicated to administer. For test items of marginal reliability, the test may last longer than a sequential test plan. The test plans in Annex D are created using an iterative process. They cannot be computed using the spreadsheets described in Annexes F and H

5 General test procedure

5.1 Test conditions

A guide on how to plan, perform, analyse and report a test can be found in IEC 60300-3-5. Test conditions can be found in IEC 60605-2 and IEC 60300-3-5.

All of these test types can be accelerated to accommodate high reliability requirements and enable shorter time to market. Mission and life-cycle environment profiles and test conditions are provided as follows:

- The mission profiles should be used to determine the environmental specifications and should be derived from the operational life profile defined by the equipment or system

requirements. If this information is not provided in the original contractual documentation, provision should be made to derive the mission profiles and the equipment environmental specifications. Here, the term "equipment" is used in place of the more appropriate general term "item" to match the terminology of the referenced standards.

- This derivation should make use of historical data on similar equipment applications and mounting platforms and the effect of equipment location in the platform should be accounted for. Each significant life-cycle event has to be considered including transportation, handling, installation and testing as well as for platform category and operational conditions.
- Environmental test conditions (for reliability growth, qualification, acceptance tests) should be used. All of the test types should be performed under combined influence of the appropriate test conditions which are expected to be combined in the use environments.
- The test level for these test conditions should be derived from the equipment's mission and environment profiles:
 - when the equipment is designed for one application with a single mission or one type of repetitive mission, there is a simple relationship between the test profile, mission profile and life-cycle environmental profile. The tests conditions should simulate the stress level during the mission;
 - if the equipment is designed for multi-missions and environmental conditions, the test profile should represent a composite of those missions, with the test levels and durations being rated according to the percentage of each mission type expected during the equipment's life-cycle. In order to derive realistic test conditions and levels, the actual environments (especially temperature and vibration) should be measured at the location where the equipment is to be mounted during actual operation;
 - if design changes are made during the test, the accumulated test time shall start from 0 after the changes have been incorporated in the test items, unless specifically agreed between the parties and justified in the test report (see IEC 60300-3-5).

5.2 General characteristics of the test plans

All test plans and decision criteria are based on either of two characteristics, as follows:

- an acceptable number of failures in a specified test time;
- an acceptable test time for a specified number of failures.

The detailed criteria for test plans, with variants, are given in 6.3, 7.3, 8.4 and 9.3.

5.3 Data to be recorded

In order to apply the statistical procedures defined in this standard, the following data shall be recorded:

- the observed number of failures;
- the accumulated test time.

If it is necessary to test the assumption stated in 4.1, the following data shall also be recorded:

- the time of occurrence of each failure.

5.4 Calculation of accumulated test time, T^*

Whenever the term time is used in this standard it can be replaced by other similar measures of the duration of the operation for the item(s) under test, e.g. distance driven, operating cycles, start and stop cycles, etc. (see IEC 60605-2).

The accumulated test time T^* is calculated as the sum of the test time(s) accumulated by each item in the test. For more than one repaired item under test, the accumulated test time is the sum of all elapsed operational times (excluding all repair and other down times).

When n items are put on test at the same time, the accumulated test time can be determined using the following formulae:

$$T^* = n \times t^* \quad \text{for tests with replacement of failed items}$$

$$T^* = (n - r) \cdot t^* + \sum_{i=1}^r t_i \quad \text{for tests without replacement of failed items}$$

where

n is the number of items at the beginning of the test;

t^* is the test truncation time;

t_i is the life time of failed items;

r is the number of failed items.

It is necessary to monitor the test items during the test in order to replace failed items, register accumulated test time and, where required, record time to failures (see 5.3).

Several items can be tested simultaneously or sequentially. The recommended sample size is $n \geq 1$ with replacement and $n \geq r_0 + 1$ (Clause 6 and 10) respective $n \geq c + 1$ (Clauses 7, 8 and 9) without replacement.

Calendar time is used to state the test time when more than one item is on test simultaneously (see Clause 9).

For guidance on how to calculate accumulated test time when items enter the test after the test has started, or are removed from the test before the test ends (censoring) see IEC 60300-3-5 and Annex C of IEC 60605-4:2001.

The accumulated test time is normally counted as the operating time. If the parties to the test wish to include other operational modes such as "idle" or "stand by" in the test time, for example in a test cycle, this shall be specified and agreed before the test is started (see IEC 60605-2).

5.5 Number of failures

In this standard the test result is determined by the test time and the number of failures. But in practice failures can have very different consequences. Therefore, the user should consider if there are failures that are so critical that the test is failed even though the total number of failures are not exceeded. Alternatively, there can be failures where the consequences are so insignificant that they should not be considered as relevant failures. All failures are counted except when they can be classified as non-relevant, e.g. caused by factors not relevant for the reliability of the item in the field. Such classification rules should be agreed between the parties before start of the test (see IEC 60300-3-5). Re-classification of failures requires agreement between the parties and shall be justified in the test report.

6 Sequential test plans

6.1 General

Sequential test plans are characterized by decision rules for accepting or rejecting compliance or continuing the test at any test time. They are determined by selected values of risks and discrimination ratio. To implement a test plan, m_0 needs to be specified. An overview of test plans is given in 6.4. The test plans and the corresponding operating characteristic curves and expected test times are stated in Annexes A and D. Examples and a mathematical reference are given in Annex E. Sequential test plans derived using a different methodology based on GOST R 27.402 are numbered C1 to C8 and are included in Annex D. In order to facilitate comparison between the C test plans and the combined test plans they have been plotted together in Annex D. Descriptions of the iterative procedure for creating those test plans can be found in Annex K.

6.2 Common test procedure

The test procedure should include the following steps:

- decide the combined environmental conditions to be applied during the test based on analysis to determine appropriate test conditions (see 5.1 and IEC 60300-3-5:2001);
- specify m_0 , according to requirement or agreement;
- choose risks, α and β , and discrimination ratio, D , considering that low values of α , β and D make a more powerful test, but require longer test time and/or more items;
- select α and β . These are generally chosen to be equal (shared risk) for easier calculations and agreements;
- select an appropriate test plan from Table 2 and Annex A or Annex D;
- note the test times, T_a^* for accept, and T_r^* for reject;
- perform the test and apply the decision criteria in accordance with 6.3.

6.3 Decision criteria

The accumulated test time and the number of failures shall be compared with the accept and reject criteria continuously during the test, or at intervals not greater than the length of the test cycle or the monitoring interval (see 5.1 and 7.1.3 of IEC 60300-3-5:2001). The following criteria shall apply:

- | | |
|------------------|---|
| Accept the test | if the elapsed $T^* \geq T_a^*$ for the observed $r \leq r_0$.
The specified requirement is regarded as being complied with. |
| Continue testing | if the elapsed T^* is between the limits $T_r^* < T^* < T_a^*$ for the observed $r \leq r_0$.
No decision can be taken. |
| Reject the test | if the elapsed $T^* \leq T_r^*$ for the observed $r \leq r_0$, or if $r \geq r_0 + 1$.
The specified requirement is regarded as not being complied with. |

6.4 Overview of test plans

Table 2 summarizes the sequential test plans given in Annex A and D. These annexes provide, for each test plan, a decision graph, decision table, graphs of operating characteristic curve and expected test time to decision.

Table 2 – Overview of the sequential test plans given in Annex A and D

Test plan No.	Characteristics of the plan		Minimum test time (Acceptance at 0 failures)	Expected time for decision in multiples of m_0 for $m = m_0$	Test truncation time in multiples of m_0	True risks for		
	Nominal risks					Discrimination ratio	$m = m_0$	$m = m_1$
	α %	β %	D	$\frac{T_{a,min}^*}{m_0}$	$\frac{T_e^*}{m_0}$	$\frac{T_t^*}{m_0}$	α' %	β' %
A.1	10	10	1,5	4,39	17,88	33,04	12,03	9,77
A.2	10	10	2	2,20	5,37	10,30	13,39	9,62
A.3	10	10	3	1,098	1,77	3,152	15,09	9,43
A.4	10	10	5	0,549	0,65	1,102	16,81	9,24
A.5	20	20	1,5	2,77	8,00	14,37	24,32	18,92
A.6	20	20	2	1,39	2,31	4,73	27,27	18,18
A.7	20	20	3	0,693	0,72	1,54	31,03	17,24
A.8	30	30	1,5	1,69	2,93	5,41	37,70	26,70
A.9	30	30	2	0,847	0,79	1,91	43,24	24,32
C.1	5	5	1,7	7,584	23,89	29,300	5,00	5,00
C.2	10	5	1,7	5,032 9	16,57	24,240	9,998	5,00
C.3	10	10	1,7	4,429 4	13,28	18,030	10,00	9,999
C.4	15	5	1,7	5,836 6	16,40	19,900	14,999	5,001
C.5	20	10	1,7	4,023 2	10,00	12,600	19,998	10,002
C.6	20	20	1,7	2,342 4	5,62	8,300	19,992	20,016
C.7	30	20	1,7	2,102 1	3,95	5,500	29,990	20,014
C.8	30	30	1,7	1,275 7	2,13	3,800	30,056	29,912

7 Fixed time/failure terminated test plans – Fixed duration test plans

7.1 General

Fixed time/failure terminated test plans are characterized by decision rules for accepting or rejecting compliance when the test time for termination has been reached, or the acceptable number of failures has been exceeded. The test plans are determined by selected values of risks and discrimination ratio. To implement a test plan, m_0 needs to be specified (or derived).

There are four types of fixed duration tests:

- time terminated tests with replacement;
- time terminated tests without replacement;
- failure terminated tests with replacement;
- failure terminated tests without replacements.

Test plans are given in 7.4. Operating characteristics and expected test times are given in Annex B, examples and a mathematical reference are given in Annex G.

7.2 Common test procedure

The test procedure should include the following steps:

- decide the combined environmental conditions to be applied during the test based on analysis to determine appropriate test conditions (see 5.1 and IEC 60300-3-5:2001);
- specify m_0 according to requirement or agreement;
- choose risks, $\alpha = \beta$ (shared risk) or α not equal to β , and discrimination ratio, D , considering that low values of α , β and D make a more powerful test, but require longer time and/or more items. It is important that α , β and D is selected together considering the risk for the producer, the risk for the consumer as well as m_1 determined by D ;
- select an appropriate test plan from Table 3, consulting Annex B;
- determine the test time for termination, T_t^* , and the acceptable number of failures, c ;
- perform the test and apply the decision criteria according to 7.3.

7.3 Decision criteria

The following decision criteria shall apply:

- Accept the test if $r \leq c$ at T_t^* .
The specified requirement is regarded as being complied with.
- Reject the test if $r > c$ at or before T_t^* .
The specified requirement is regarded as not being complied with.

7.4 Test plans

Table 3 summarizes the recommended time/failure terminated test plans. The test time is accumulated until either a predetermined amount of test time has been reached (accept), or a predetermined number of failures has been exceeded (reject). Graphs of operating characteristic curves and expected accumulated test time to decision are given in Annex B.

Table 3 – Fixed time/failure terminated test plans

Test plan No.	Characteristics of the plan			Test time for termination	Acceptable number of failures	True risks for	
	Nominal risks		Discrimination ratio			$m = m_0$	$m = m_1$
	α %	β %	D	T_t^*/m_0	c	α' %	β' %
B.1	5	5	1,5	54,10	66	4,96	4,84
B.2	5	5	2	15,71	22	4,97	4,99
B.3	5	5	3	4,76	8	5,35	5,40
B.4	5	5	5	1,88	4	4,25	4,29
B.5	10	10	1,5	32,14	39	10,00	10,20
B.6	10	10	2	9,47	13	10,00	10,07
B.7	10	10	3	3,10	5	9,40	9,90
B.8	10	10	5	1,08	2	9,96	9,48
B.9	20	20	1,5	14,30	17	19,49	19,94
B.10	20	20	2	3,93	5	20,40	20,44
B.11	20	20	3	1,47	2	18,37	18,40
B.12	30	30	1,5	5,41	6	29,99	29,95
B.13	30	30	2	1,85	2	28,28	28,54

NOTE The test termination time (in multiples of m_0) is equal to the expected number of failures during the test at the specified λ_0 that is $T_t^*/m_0 = T_t^* \times \lambda_0 = \mu_0$.

8 Design of alternative time/failure terminated test plans

8.1 General

Alternative time/failure terminated test plans are characterized by decision rules for accepting or rejecting compliance when the test time for termination has been reached or the acceptable number of failures has been exceeded. The test plans are determined by selected values of risks and test time. The test time is chosen independently of λ_0 which enables test plans to be designed individually to meet particular needs including, for example, economy, resources or time scheduling.

The derived discrimination ratio is used to evaluate the test plan. In order to implement a test plan, λ_0 needs to be specified (or derived). The transformation between failure rate and mean time to failure or mean operating time between failures to λ_0 is given in 3.2.2.

It is also possible to choose different test plan parameters and determine unknown parameters as indicated in Annex C and Annex I.

Graphs for determining test plan parameters are given in Annex C, including the associated operating characteristic curves. Examples and a mathematical reference are given in Annex I.

8.2 Design procedures

The procedures given in Annex C may be applied directly to tests in which

- replacement occurs, and replacement/repair times are negligible;
- replacement does not occur, and $\lambda_0 t_t^* < 0,1$ is valid.

In such cases, $T_t^* = n t_t^*$.

However, the procedures may also be applied to tests in which

- replacement occurs, and replacement times are long (e.g. by repair),
- replacement does not occur, and $\lambda_0 t_t^* > 0,1$.

In such cases, the formulae involving accumulated test time, T_t^* (see 5.4) shall be used, and in the formulae $n t_t^*$ shall be replaced by T_t^* . This implies that n and t^* cannot be separated, as in Clause C.2.

In each case, when applicable, the values of α and β , as stated in Table 3, shall be considered as preferred values.

Annex C describes how test plans are derived and examples are included.

8.3 Common test procedure

The test procedure should include the following steps:

- decide the combined environmental conditions to be applied during the test based on analysis to determine appropriate test conditions (see 5.1 and IEC 60300-3-5);
- specify the acceptable λ_0 , according to requirement or agreement;
- choose risks, α and β , test time for each item, t_t^* , and number of test items, n , according to resources;

- design the test plan according to Annex C and Annex I using the figures in Annex C;
- evaluate the test plan especially regarding the derived discrimination ratio D , and perhaps redesign with modified parameters to satisfy the need;
- perform the test with the stated test time, $T_t^* = n t_t^*$ and the derived acceptable number of failures, c , and apply the decision criteria according to 8.4.

8.4 Decision criteria

The following decision criteria shall apply:

- | | |
|-----------------|---|
| Accept the test | if $r \leq c$ at T_t^* ; The specified requirement is regarded as being complied with. |
| Reject the test | if $r > c$ at or before T_t^* ; The specified requirement is regarded as not being complied with. |

9 Calendar time/failure terminated test plans for non-replaced items

9.1 General

Fixed calendar time/failure terminated test plans for non-replaced items are characterized by decision rules for accepting or rejecting compliance when the test time for termination has been reached, or the acceptable number of failures has been exceeded. The test plans are determined by selected values of risks and discrimination ratios. To implement a test plan, λ_0 needs to be specified (or derived). The transformation of m_0 to λ_0 is indicated in 3.2.2.

Since no replacement takes place, the number of items under test will generally not remain constant, and the accumulated time of operation is not relevant. Thus, the compliance test plans for success ratio, Table 2 of IEC 61123:1991, should be used.

However, if the number of items is large compared to the number of failures, the time/failure terminated test plans (see Clause 7) may be used.

Examples and a mathematical reference are given in Annex J.

9.2 Common test procedure

The test procedure should include the following steps:

- decide the combined environmental conditions to be applied during the test based on analysis to determine appropriate test conditions (see 5.1 and IEC 60300-3-5:2001);
- specify λ_0 , according to requirement or agreement;
- choose risks, $\alpha = \beta$, and discrimination ratio, D , considering that low values of α , β and D make a more powerful test but require longer time and/or more items;
- choose test termination time, $t_{cal,t}^*$, or number of items, n , and calculate according to 9.4.2 or 9.4.3, respectively;
- select an appropriate test plan from Table 2 of IEC 61123:1991, using the derived q_0 and the found n , to give the acceptable number of failures c ;
- perform the test and apply the decision criteria according to 9.3.

9.3 Decision criteria

The decision criteria include the following:

Accept the test if $r \leq c$ at $t_{\text{cal},t}^*$; The specified requirement is regarded as being complied with;

Reject the test if $r > c$ at or before $t_{\text{cal},t}^*$; The specified requirement is regarded as not being complied with.

9.4 Use of Table 2 of IEC 61123:1991 for fixed calendar time tests

9.4.1 General

Two procedures may be used. The first one, given in 9.4.2, is used when the (maximum available) test time is given. The second one, given in 9.4.3, is used when the (maximum available) number of items is given.

The following formulae apply:

$$p_0 = 1 - q_0 = 1 - e^{-t/m_0} = 1 - e^{-\lambda_0 t} \quad (1)$$

where $t = t_{\text{cal},t}^*$

and the derived

$$t_{\text{cal},t}^* = -m_0 \cdot \ln(1 - p_0) = -m_0 \cdot \ln(q_0) \quad (2)$$

where

p_0 is the acceptable failure ratio;

q_0 is the acceptable success ratio, $q_0 = 1 - p_0$.

NOTE 1 According to the normal use of IEC 61123, p_0 or q_0 is specified, but in this case p_0 is derived from the specified m_0 or λ_0 , according to Formula (1). For further information on p_0 and q_0 , see IEC 61123.

NOTE 2 In this case, p_0 expresses the failure probability $1-R(t)$ for $t = t_{\text{cal},t}^*$.

NOTE 3 The procedures can only determine the product nt^* .

9.4.2 Procedure when the test time is given

The test procedure should include the following steps:

- choose $t_{\text{cal},t}^* \leq 0,223 m_0 = \frac{0,223}{\lambda_0}$ (to be within the range of Table 2 of IEC 61123:1991);
- calculate p_0 using Formula (1);
- adjust $t_{\text{cal},t}^*$ if necessary to fit a $q_0 = 1 - p_0$ stated in Table 2 of IEC 61123:1991 using Formula (2);
- select a relevant test plan from Table 2 of IEC 61123:1991 fulfilling the required D and $\alpha = \beta$, and thereby determine n and c .

9.4.3 Procedure when the number of items is given

The test procedure should include the following steps:

- a) select a relevant test plan from Table 2 of IEC 61123:1991 fulfilling the required D and $\alpha = \beta$, and with n close to the indicated n , and thereby determine $q_0 = 1 - p_0$, n and c ;
- b) calculate $t_{\text{cal},t}^*$ using Formula (2).

10 Combined test plans

10.1 General

The combined test plans use a reject line with a constant number of failures, while the accept line is curved (see Table 1). Therefore, test items with a high reliability will be accepted early while items with many early failures will not be rejected immediately. Test plans are also suitable for a test, analysis and fix program (TAAF) as more information is collected about the failure modes than for a sequential test. The test plans are derived using an iterative procedure that is described in Annex K.

10.2 Common test procedure

The test procedure should include the following steps:

- decide the combined environmental conditions to be applied during the test based on analysis to determine appropriate test conditions (see 5.1 and IEC 60300-3-5:2001);
- specify m_0 , according to requirement or agreement;
- choose risks, α and β , and discrimination ratio, D , considering that low values of α , β and D make a more powerful test, but require longer time and/or more items;
- select an appropriate test plan from Table 4 and Annex D;
- note the test times, T_a^* for accept;
- perform the test and apply the decision criteria in accordance with 10.3.

10.3 Decision criteria

The accumulated test time and the number of failures shall be compared with the accept and reject criteria continuously during the test; or at intervals not greater than the length of the test cycle or the monitoring interval (see 5.1 and 7.1.3 of IEC 60300-3-5:2001).

The following criteria shall apply:

- | | |
|------------------|--|
| Accept the test | if the elapsed $T \geq T_a^*$ for the observed $r \leq r_0$.
The specified requirement is regarded as being complied with. |
| Continue testing | if $T^* < T_a^*$ for the observed $r \leq r_0$. No decision can be taken. |
| Reject the test | If the number of failures $\overline{AC1} \ r \geq r_0 + 1 \ \overline{AC1}$ during the test.
The specified requirement is regarded as not being complied with. |

10.4 Test plans

Table 4 – Combined test plans in Annex D

Test plan	Characteristics of the plan		Discrimination ratio D	Minimum test time (Acceptance at 0 failures) $T_{a,min}^*/m_0$	Expected time for decision in multiples of m_0 for $m = m_0$ T_e^*/m_0	Test truncation time in multiples of m_0 T_t^*/m_0	Acceptable number of failures r_0
	Nominal risks α %	β %					
D.1	5	5	1,7	6,454 0	22,07	29,463 2	38
D.2	10	5	1,7	4,721 9	16,59	24,517 0	30
D.3	10	10	1,7	4,426 4	13,12	18,183 9	23
D.4	15	5	1,7	5,732 0	16,22	19,989 8	24
D.5	20	10	1,7	3,949 5	9,80	12,757 3	15
D.6	20	20	1,7	2,436 5	5,60	8,568 4	10
D.7	30	20	1,7	2,144 1	3,96	5,714 6	6
D.8	30	30	1,7	1,219 4	2,30	4,388 1	4

11 Performing the test

Guidance on test conditions and practical management of the test can be found in 5.1 of this standard, in IEC 60300-3-5 and in IEC 60605-2.

12 Presentation of results

When presenting the results, the following information shall be given:

- test conditions (see 5.1 of this standard and IEC 60300-3-5);
- identification of test items, number of items on test and possible replacement during test;
- the test plan used;
- specified acceptable λ_0 or m_0 ;
- nominal test plan parameters given or derived, for example risk levels, discrimination ratio, accumulated test time for termination, acceptable number of failures;
- true test plan parameters, if required;
- observed number of failures and justification for any failures classified as non-relevant;
- definition of accumulated test time especially if test cycles or several mission modes are used;
- accumulated test time when the test is stopped;
- result(s) of other analyses, if required;
- conclusions.

Annex A (normative)

Tables and graphs for sequential test plans

NOTE 1 See Clause 6.

NOTE 2 This annex uses the symbols listed in 3.2.

A.1 Test plan A.1 – $\alpha = 0,10$; $\beta = 0,10$; $D = 1,5$

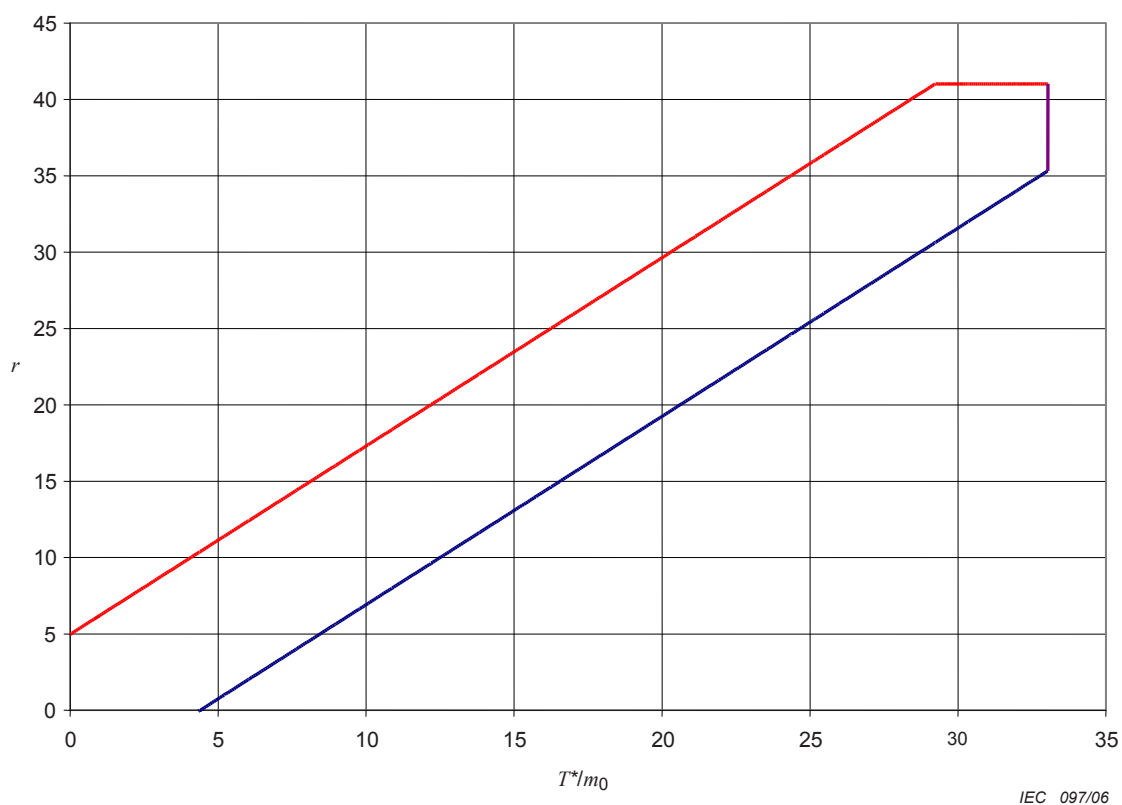


Figure A.1 – Accept and reject lines for test plan A.1

Table A.1 – Accept and reject lines for test plan A.1

r	T_r^*/m_0 Reject (equal or less)	T_a^*/m_0 Accept (equal or more)	r	T_r^*/m_0 Reject (equal or less)	T_a^*/m_0 Accept (equal or more)
0	–	4,39	21	13,00	21,42
1	–	5,21	22	13,81	22,23
2	–	6,02	23	14,62	23,05
3	–	6,83	24	15,43	23,86
4	–	7,64	25	16,24	24,67
5	0,025	8,45	26	17,05	25,48
6	0,836	9,26	27	17,87	26,29
7	1,65	10,07	28	18,73	27,10
8	2,46	10,88	29	19,49	27,91
9	3,27	11,69	30	20,30	28,72
10	4,08	12,50	31	21,11	29,53
11	4,89	13,31	32	21,92	30,34
12	5,70	14,13	33	22,73	31,16
13	6,51	14,94	34	23,54	31,97
14	7,32	15,75	35	24,35	32,78
15	8,13	16,56	36	25,16	33,04
16	8,94	17,37	37	25,97	33,04
17	9,76	18,18	38	26,79	33,04
18	10,57	19,00	39	27,60	33,04
19	11,40	19,80	40	28,41	33,04
20	12,19	20,61	$r_0=41$	29,22	33,04
			42	33,04	N/A

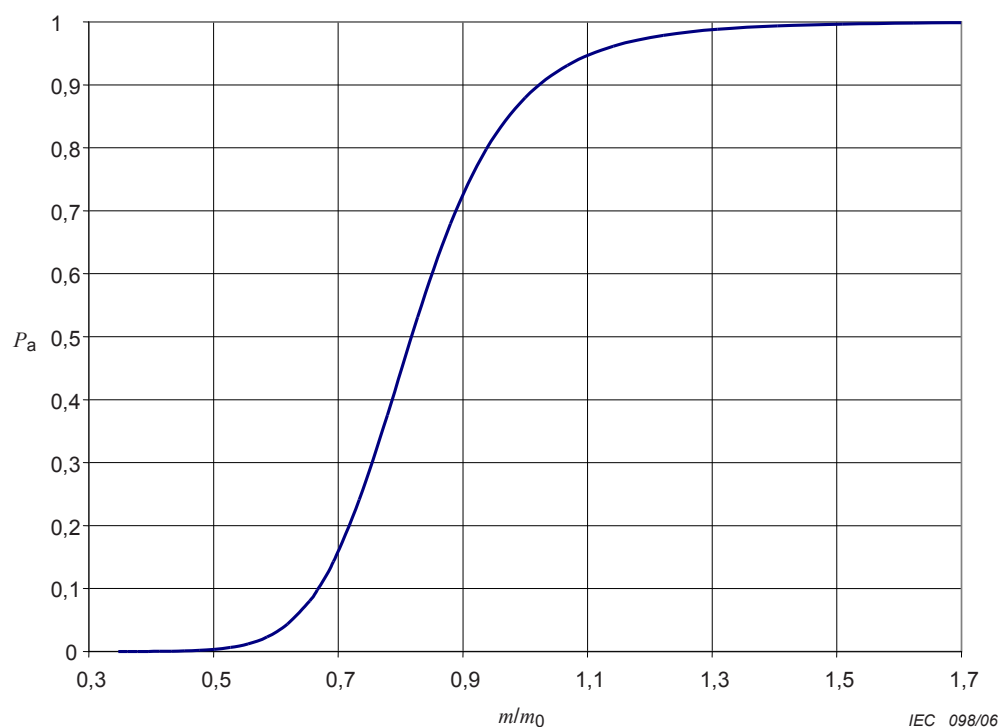


Figure A.2 – Test plan A.1 – Operating characteristic curve

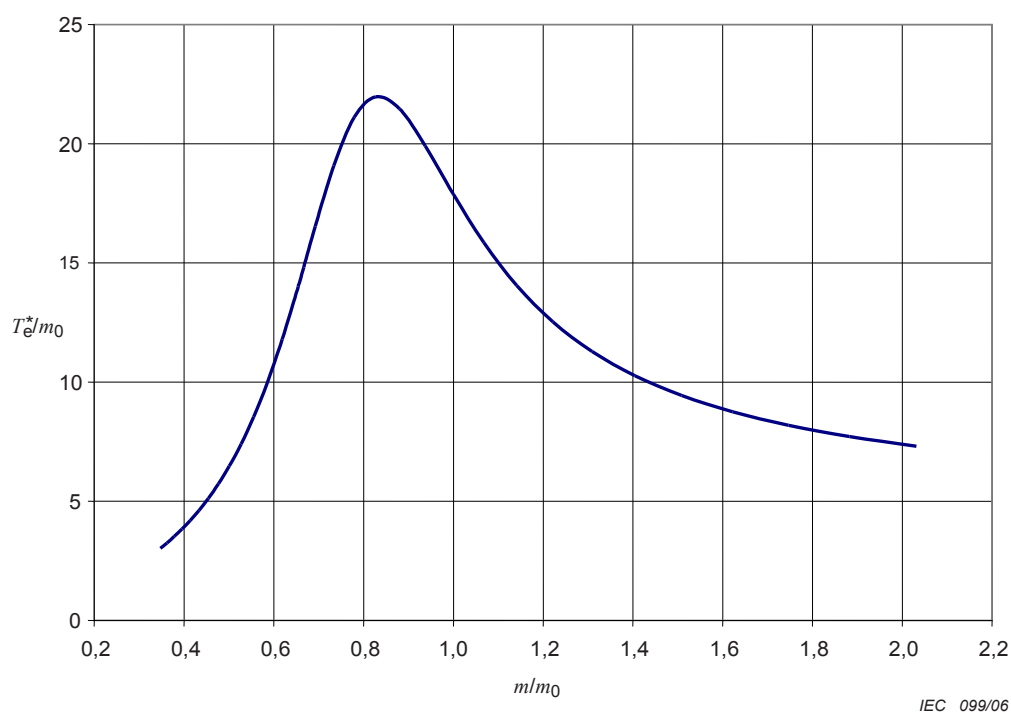


Figure A.3 – Test plan A.1 – Expected accumulated test time to decision

A.2 Test plan A.2 – $\alpha = 0,10$; $\beta = 0,10$; $D = 2,0$

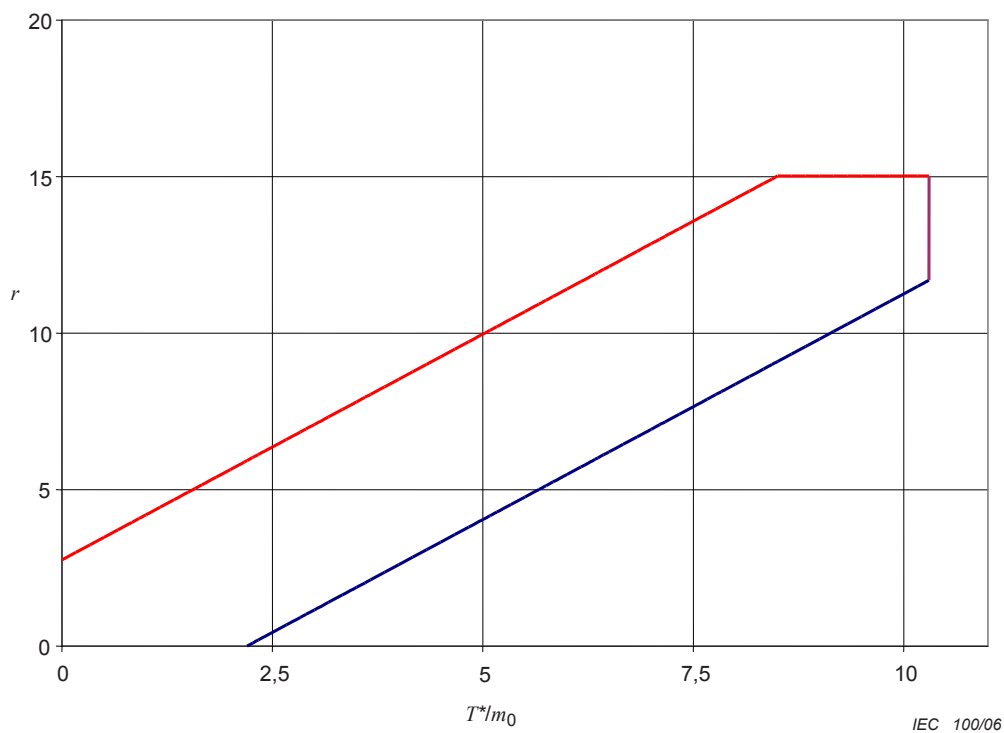
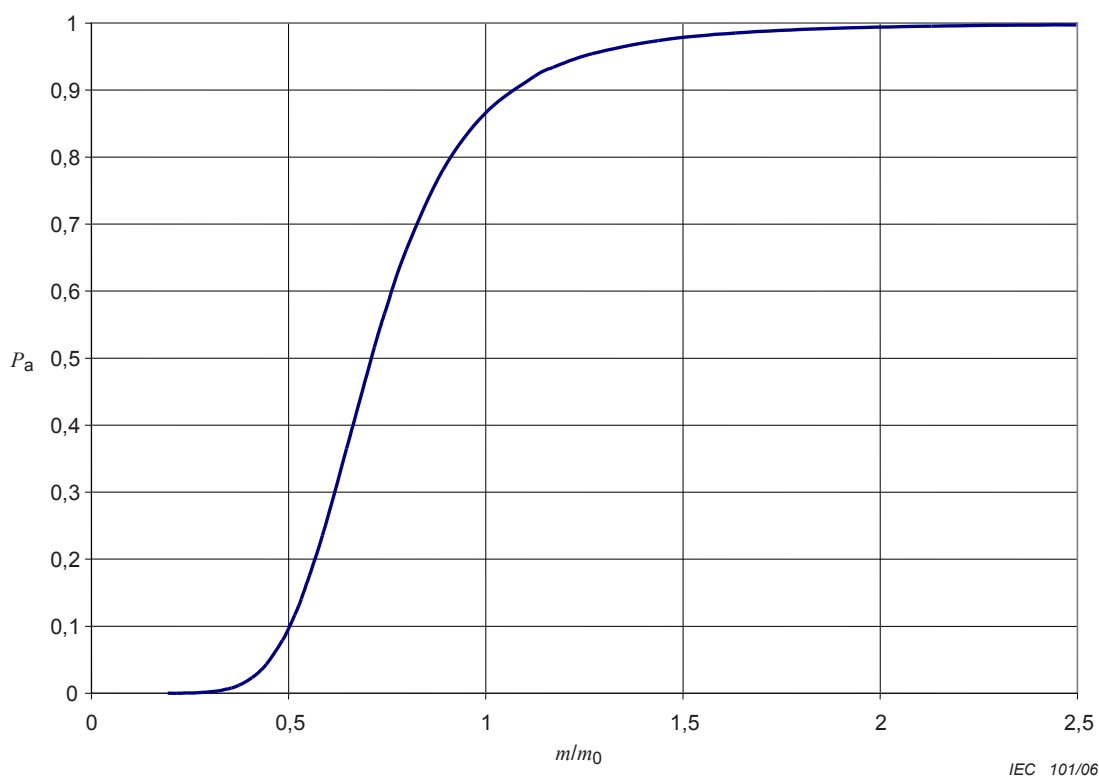


Figure A.4 – Accept and reject lines for test plan A.2

Table A.2 – Accept and reject lines for test plan A.2

r	$T_r^* I m_0$ Reject (equal or less)	$T_a^* I m_0$ Accept (equal or more)
0	–	2,20
1	–	2,89
2	–	3,58
3	0,170	4,28
4	0,863	4,97
5	1,56	5,66
6	2,25	6,36
7	2,94	7,05
8	3,64	7,74
9	4,33	8,44
10	5,02	9,13
11	5,72	9,82
12	6,41	10,30
13	7,10	10,30
14	7,79	10,30
$r_0 = 15$	8,49	10,30
16	10,30	N/A



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Figure A.5 – Test plan A.2 – Operating characteristic curve

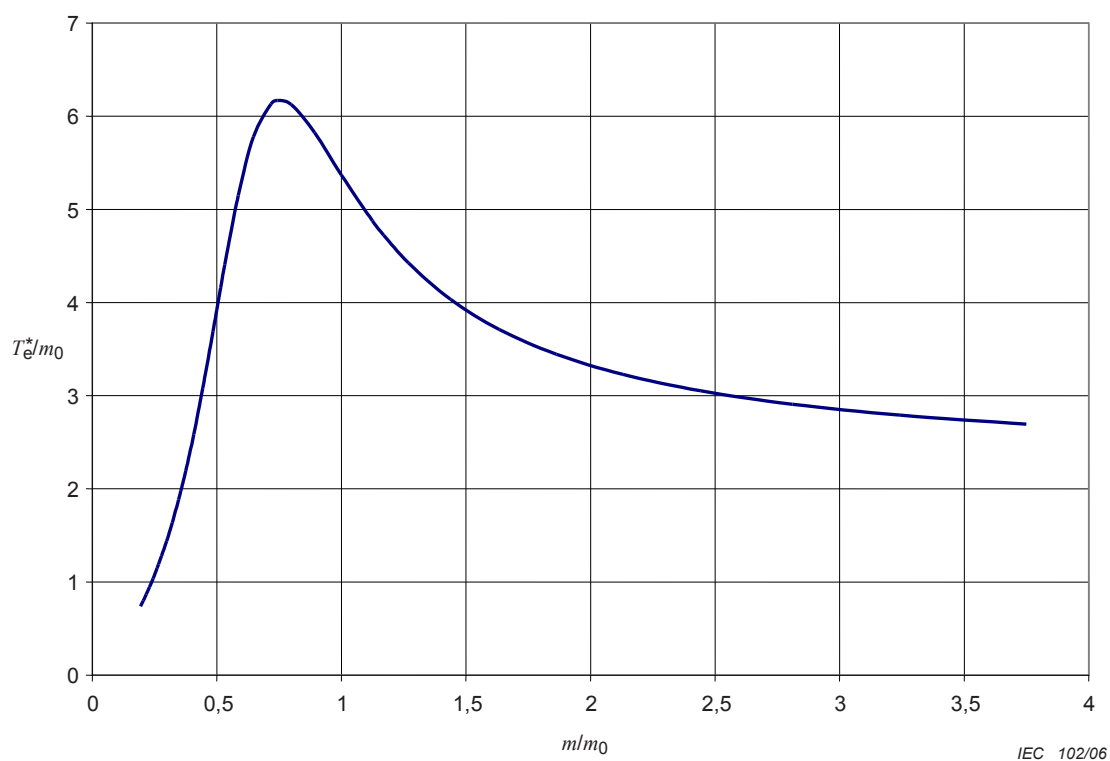


Figure A.6 – Test plan A.2 – Expected accumulated test time to decision

A.3 Test plan A.3 – $\alpha = 0,10$; $\beta = 0,10$; $D = 3,0$

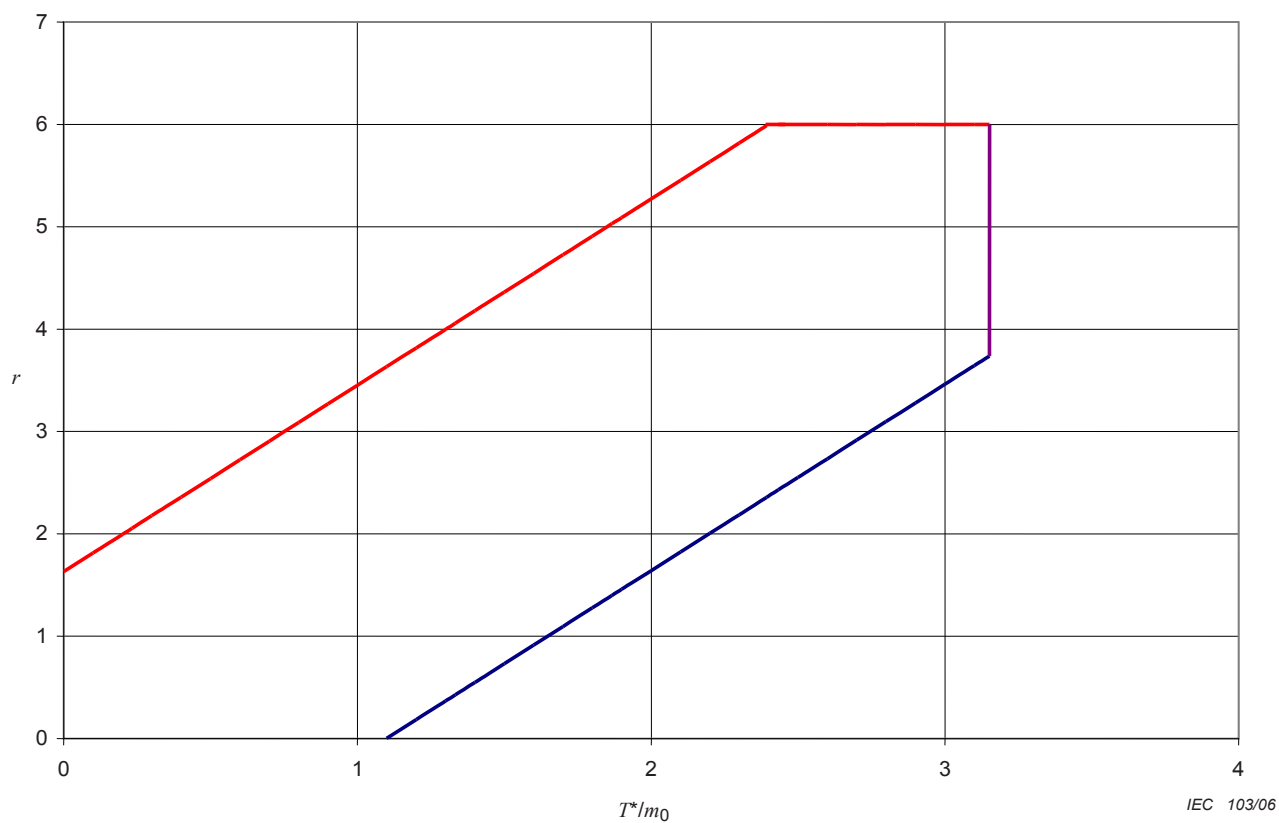


Figure A.7 – Accept and reject lines for test plan A.3

Table A.3 – Accept and reject lines for test plan A.3

r	T_r^* / m_0 Reject (equal or less)	T_a^* / m_0 Accept (equal or more)
0	–	1,098
1	–	1,648
2	0,203	2,197
3	0,752	2,747
4	1,301	3,152
5	1,851	3,152
$r_0 = 6$	2,400	3,152
7	3,152	N/A

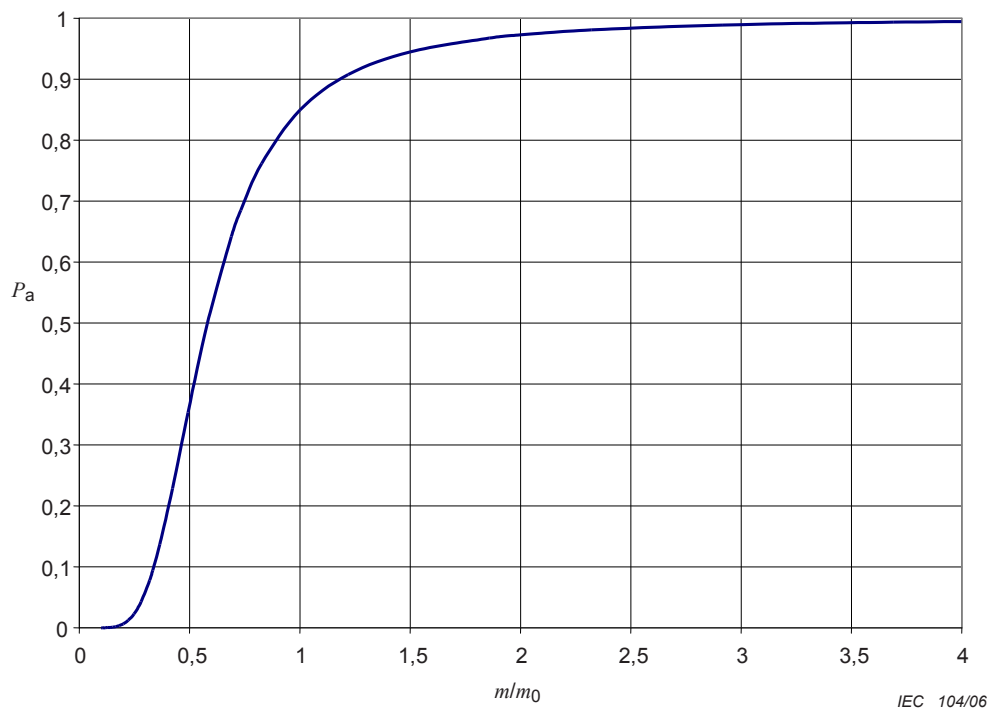


Figure A.8 – Test plan A.3 – Operating characteristic curve

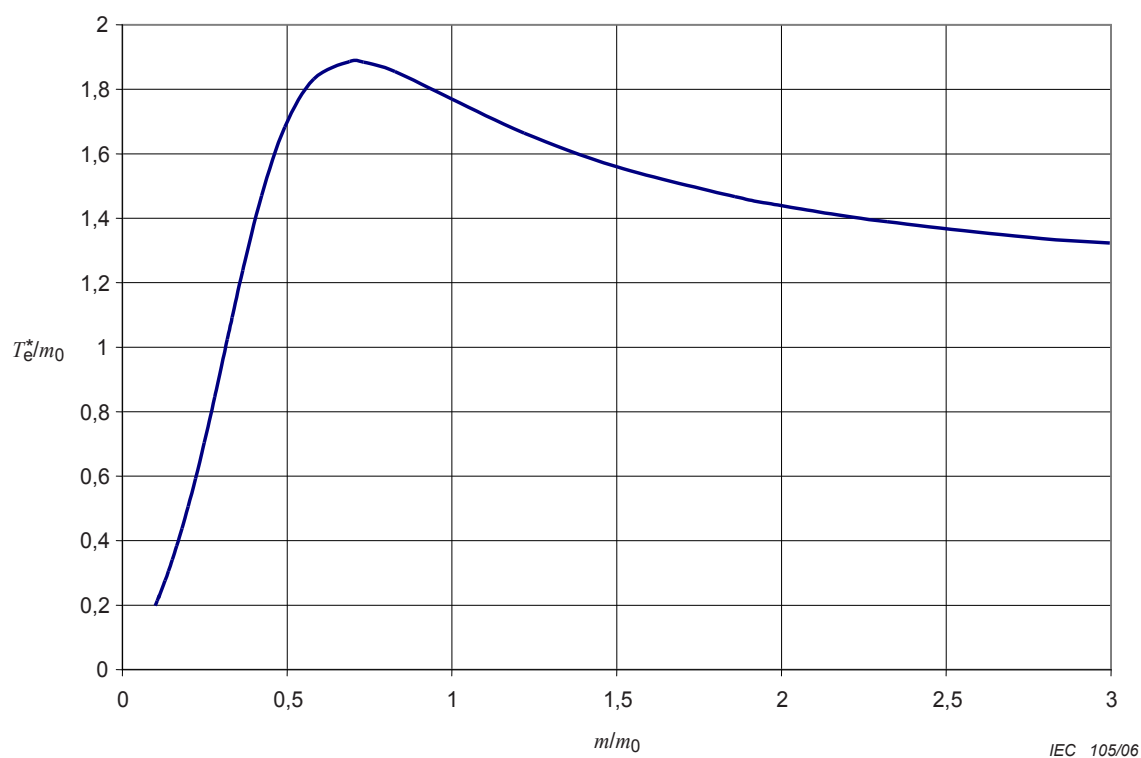


Figure A.9 – Test plan A.3 – Expected accumulated test time to decision

A.4 Test plan A.4 – $\alpha = 0,10$; $\beta = 0,10$; $D = 5,0$

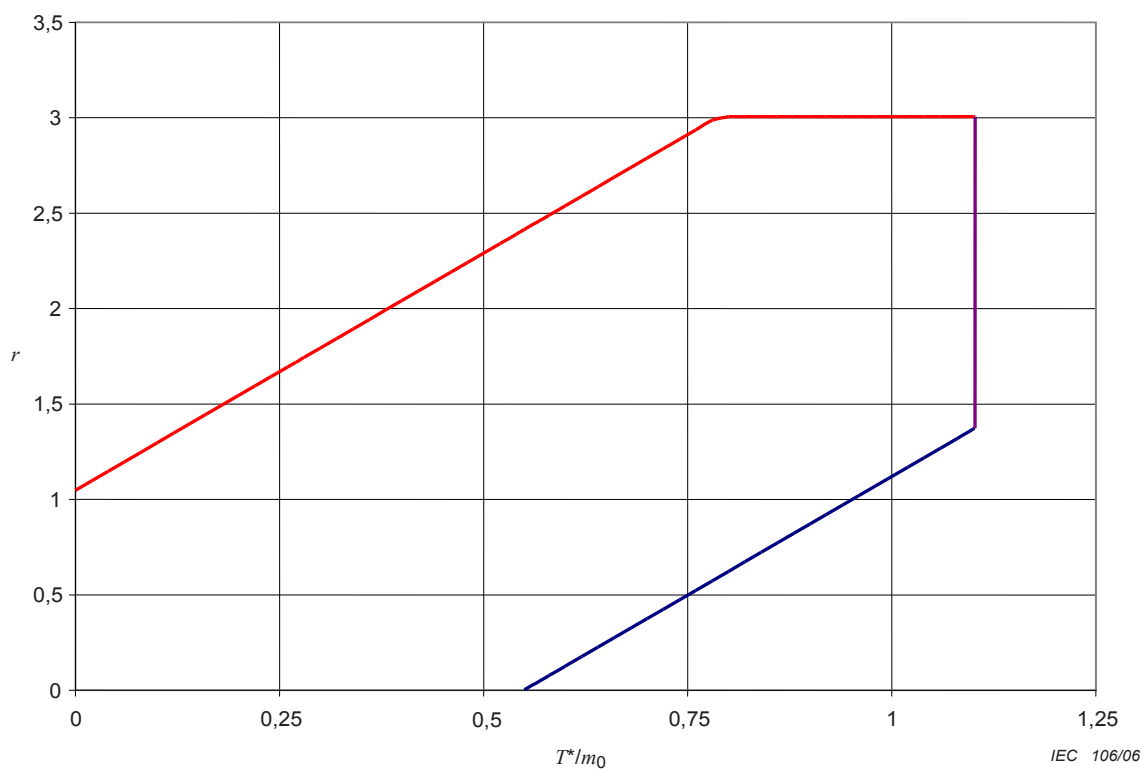


Figure A.10 – Accept and reject lines for test plan A.4

Table A.4 – Accept and reject lines for test plan A.4

r	T_r^* / m_0 Reject (equal or less)	T_a^* / m_0 Accept (equal or more)
0	–	0,549
1	–	0,951
2	0,383	1,102
$r_0 = 3$	0,785	1,102
4	1,102	N/A

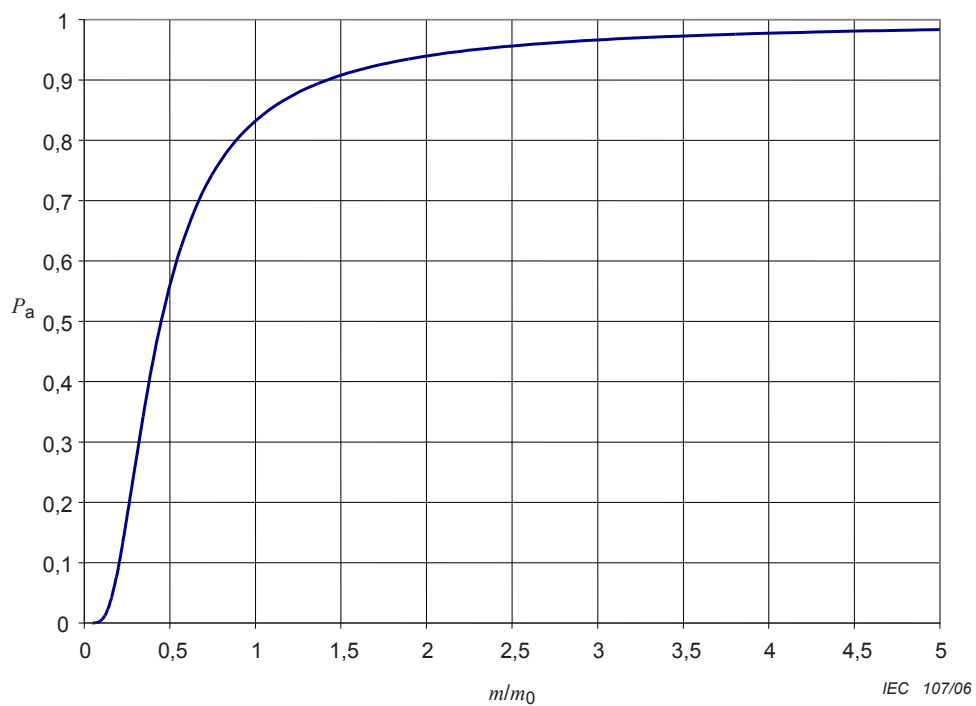


Figure A.11 – Test plan A.4 – Operating characteristic curve

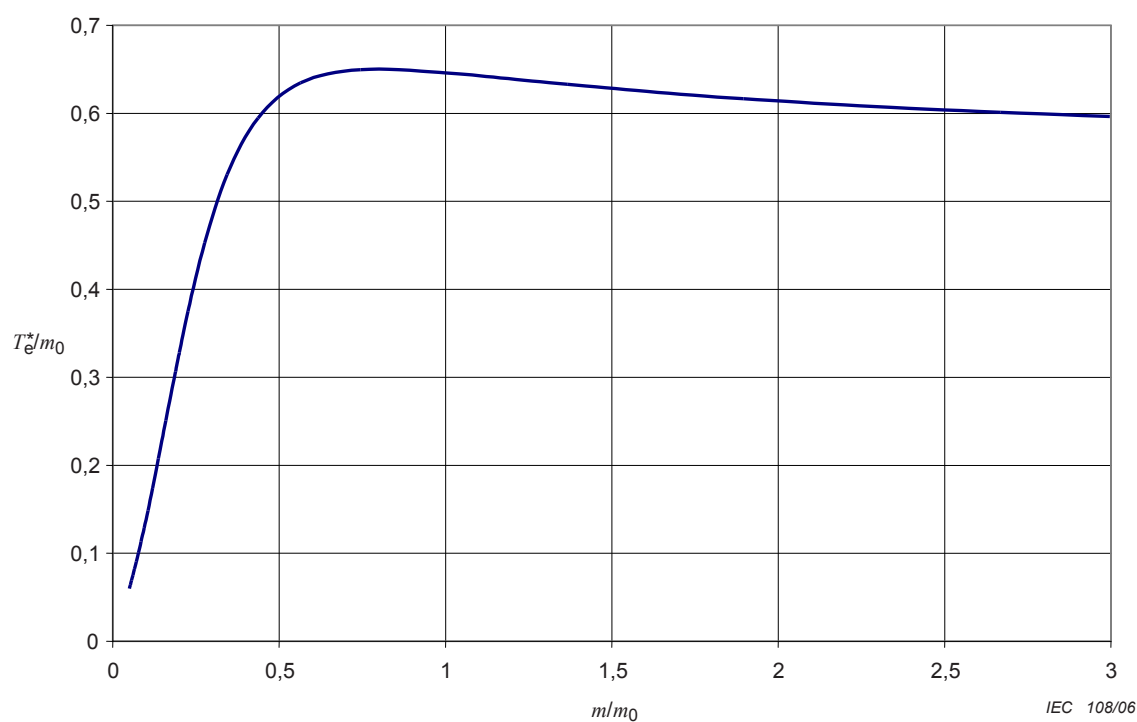


Figure A.12 – Test plan A.4 – Expected accumulated test time to decision

A.5 Test plan A.5 – $\alpha = 0,20$; $\beta = 0,20$; $D = 1,5$

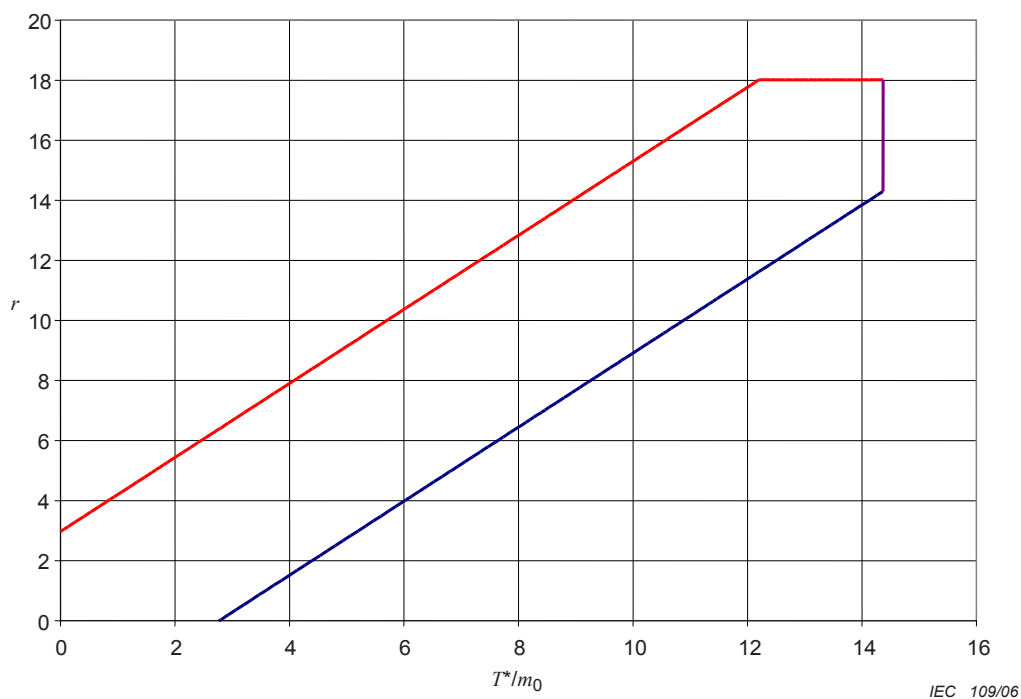


Figure A.13 – Accept and reject lines for test plan A.5

Table A.5 – Accept and reject lines for test plan A.5

r	T_r^*/m_0 Reject (equal or less)	T_a^*/m_0 Accept (equal or more)
0	–	2,77
1	–	3,58
2	–	4,39
3	0,025	5,21
4	0,836	6,02
5	1,65	6,83
6	2,46	7,64
7	3,27	8,45
8	4,08	9,26
9	4,89	10,07
10	5,70	10,88
11	6,51	11,69
12	7,32	12,50
13	8,13	13,31
14	8,95	14,13
15	9,76	14,37
16	10,57	14,37
17	11,38	14,37
$r_0 = 18$	12,19	14,37
19	14,37	N/A

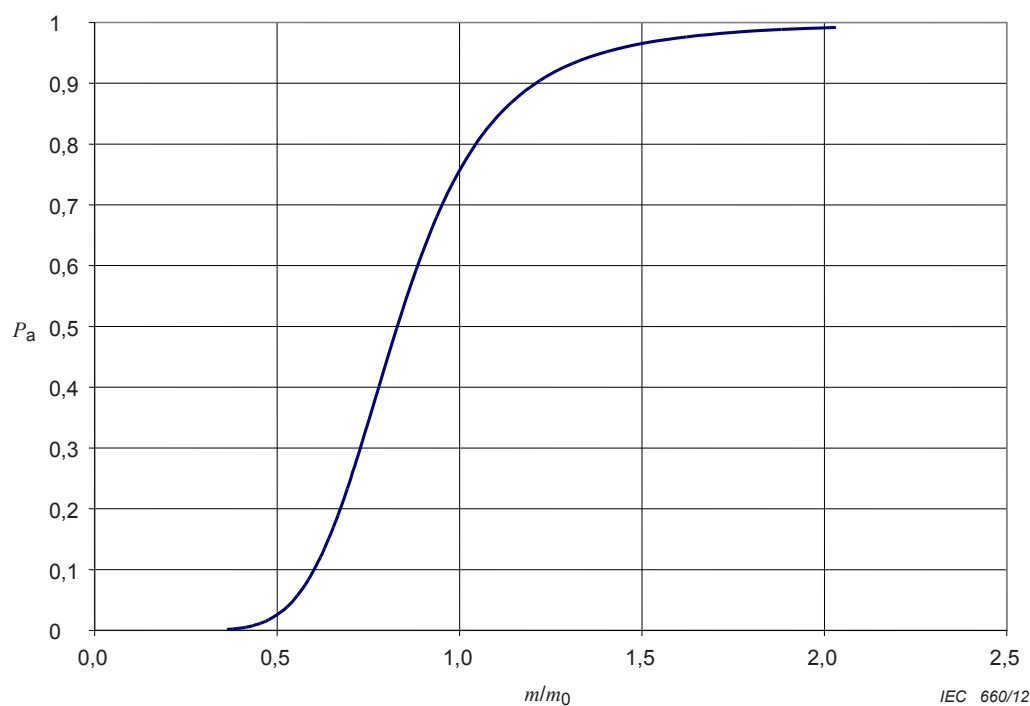


Figure A.14 – Test plan A.5 – Operating characteristic curve

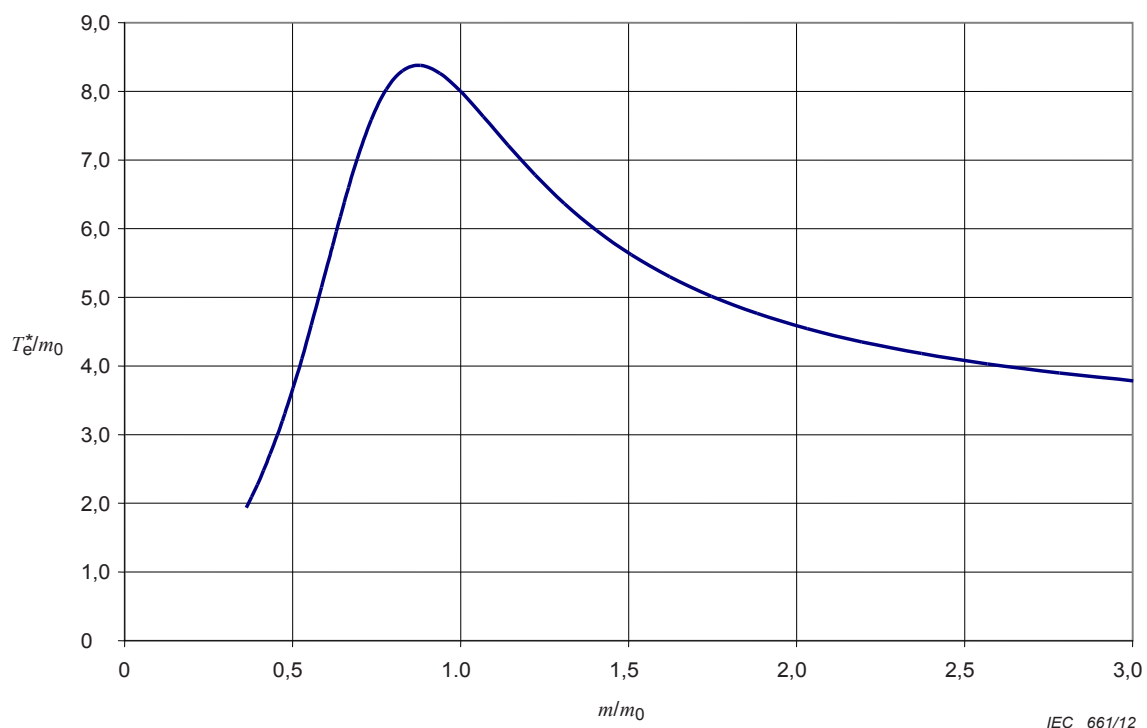


Figure A.15 – Test plan A.5 – Expected accumulated test time to decision

A.6 Test plan A.6 – $\alpha = 0,20$; $\beta = 0,20$; $D = 2,0$

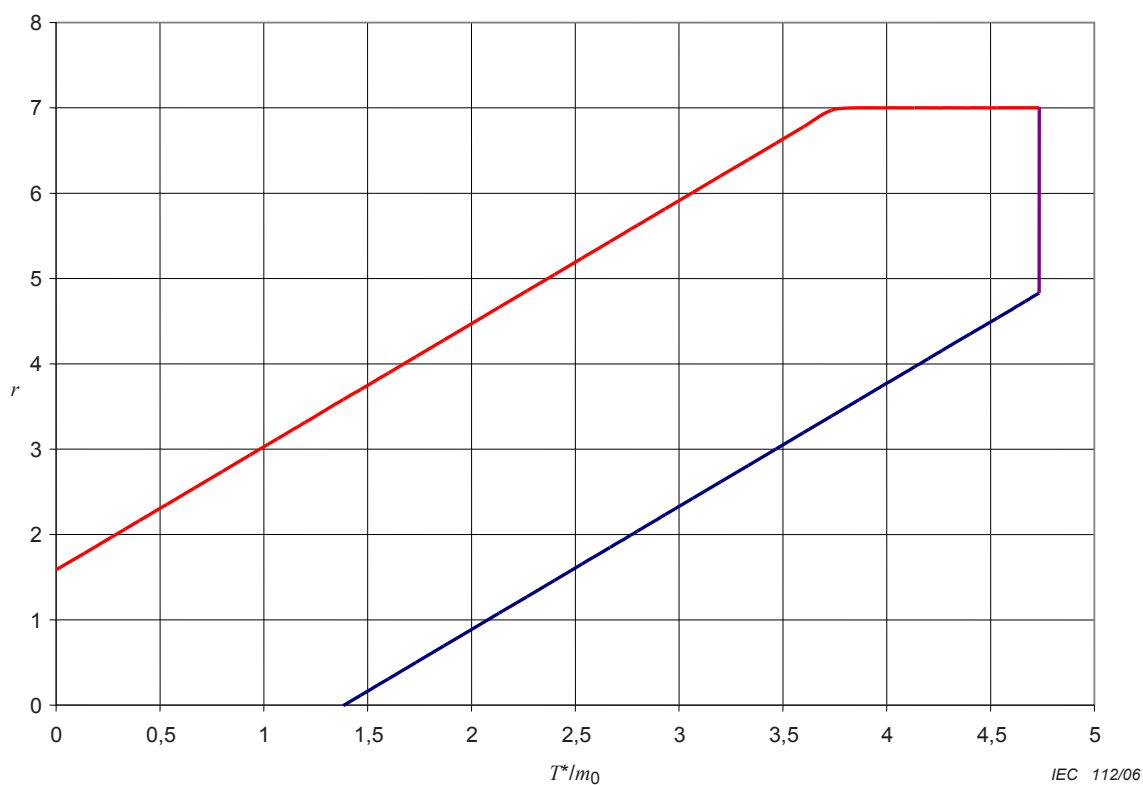


Figure A.16 – Accept and reject lines for test plan A.6

Table A.6 – Accept and reject lines for test plan A.6

r	T_r^* / m_0 Reject (equal or less)	T_a^* / m_0 Accept (equal or more)
0	–	1,39
1	–	2,08
2	0,288	2,77
3	0,981	3,47
4	1,67	4,16
5	2,37	4,73
6	3,06	4,73
$r_0 = 7$	3,75	4,73
8	4,73	N/A

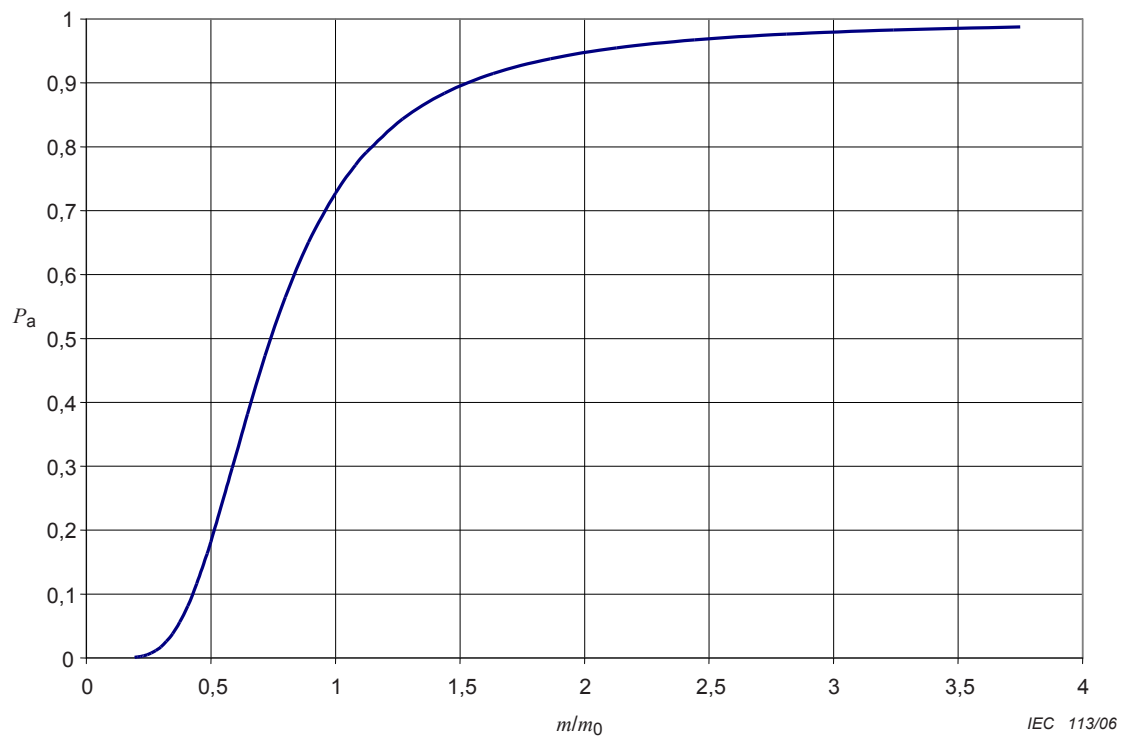


Figure A.17 – Test plan A.6 – Operating characteristic curve