

Reliability of systems, equipment and components

Part 10. Guide to reliability testing

**Section 10.5 Compliance test plans for
success ratio**

Committees responsible for this British Standard

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AEA Technology
 Association of Consulting Engineers
 Association of Project Managers
 British Gas plc
 British Railways Board
 British Telecommunications plc
 City University
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National foreword

This Part of BS 5760 has been prepared under the direction of the Quality, Management and Statistics Standards Policy Committee. It is identical with IEC 1123 : 1991 *Reliability testing — Compliance test plans for success ratio* published by the International Electrotechnical Commission (IEC).

BS 5760 provides comprehensive guidance on many aspects of reliability management. Eleven Parts of this standard have been published and these may be summarized as follows:

Part 0. Introductory guide to reliability. This Part provides guidance to senior management and non-specialists on the importance of reliability and explains how measures to achieve reliability should be integrated with other aspects of project management.

Part 1. Guide to reliability and maintainability programme management. This Part discusses the essential features of a comprehensive reliability and maintainability programme to produce reliable and maintainable products.

Part 2. Guide to the assessment of reliability. This Part contains guidance on quantitative and statistical aspects of reliability, including reliability modelling, the provision of data, and the concepts of redundancy and simulation.

Part 3. Guide to reliability practices: examples. This Part contains authentic practical examples illustrating the principles established in Parts 1 and 2 of BS 5760.

Part 4. Guide to specification clauses relating to the achievement and development of reliability in new and existing items. This Part provides detailed guidance on the specification of reliability.

Part 5. Guide to failure modes, effects and criticality analysis (FMEA) and (FMECA). This Part gives guidance on the application of these techniques.

Part 6. Guide to programmes for reliability growth. This Part describes procedures to expose and remove weaknesses in hardware and software items in order to achieve acceptable reliability in a product. It explains basic concepts, management and test procedures and describes techniques for analysis and correction of failures.

Part 7. Guide to fault tree analysis. This Part gives guidance on the application of fault tree analysis which may be used to identify factors affecting the reliability, performance and safety characteristics of a system.

Part 9. Guide to the block diagram technique. This Part describes the use of the block diagram technique for modelling and evaluating the reliability of both elementary and more complex systems. The extension of the method to calculate availability is also outlined.

Part 10. Guide to reliability testing:

Section 10.1 General requirements. This Section provides guidance on general principles, procedures and considerations for reliability testing in the laboratory and in the field.

Section 10.3 Compliance test procedures for steady-state availability. This Section provides guidance on techniques for testing the availability performance of frequently maintained items under defined conditions.

Section 10.5 Compliance test plans for success ratio. This Section gives procedures for preparing and applying compliance test plans for success ratio or failure ratio. Plans are provided for three main types of test.

Part 12. Guide to the presentation of reliability, maintainability and availability predictions. This Part gives guidance on the presentation of quantitative predictions of reliability, maintainability and availability. The items to be included when presenting prediction information are listed and explained with the object of facilitating comparisons between projects and reports.

Part 14. Guide to formal design review. This Part provides guidelines for planning and conducting design reviews. It includes details of the specific contributions to be made by various specialists but much of the guidance given is widely applicable and is relevant to the general conduct of design reviews.

Further Parts of BS 5760 are envisaged in order to provide guidance on other techniques of reliability management. At present three further Parts are in the process of being drafted, and these are as follows:

Part 8. Guide to the assessment of reliability of systems containing software. This Part will provide guidance on the assessment of reliability of systems containing software. (This is currently published as DD 198 : 1991.)

Part 11. Guide to the collection of reliability, maintainability, availability and maintenance support data from the field.

Part 13. Guide to preferred test conditions for equipment reliability testing.

Further Sections of Part 10 based on other Parts of IEC 605 and related IEC standards are also planned.

Guidance on specific aspects of maintainability is provided in the various Parts of BS 6548 *Maintainability of equipment*.

Cross-references

International standard	Corresponding British Standard
IEC 50(191) : 1990	BS 4778 <i>Quality vocabulary</i> Part 3 <i>Availability, reliability and maintainability terms</i> Section 3.2 : 1991 <i>Glossary of international terms</i> (Identical)
IEC 605-1 : 1978	BS 5760 <i>Reliability of systems, equipment and components</i> Part 10 <i>Guide to reliability testing</i> Section 10.1 : 1993 <i>General requirements</i> (Identical)
ISO 3534 : 1977	BS 5532 <i>Statistical terminology</i> Part 1 : 1978 <i>Glossary of terms relating to probability and general terms relating to statistics</i> (Identical)

The Technical Committee has reviewed the provisions of IEC 410, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

Textual error. When adopting the text of the international standard, the textual error given below was discovered. It has been marked in the text and has been reported to IEC in a proposal to amend the text of the international standard.

In table 1, for $q_0 = 0,930$, $D = 1.75$ and $\alpha = \beta = 20\%$, the value of n_t should be '143'.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

RELIABILITY TESTING

Compliance test plans for success ratio

1 Scope

This International Standard specifies procedures for applying and preparing compliance test plans for success ratio or failure ratio.

The procedures are based on the assumption that each trial is statistically independent.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(191): 1990, *International Electrotechnical Vocabulary – Chapter 191: Dependability and quality of service*.

IEC 605-1: 1978, *Equipment reliability testing – Part 1: General requirements. Amendment 1 (1982)*.

3 Other references

IEC 410: 1973, *Sampling plans and procedures for inspection by attributes*.

ISO 3534: 1977, *Statistics – Vocabulary and symbols*.

4 Definitions

Terms and definitions are in accordance with IEC 50(191).

In addition, the following definitions are applicable for this International Standard:

4.1 success ratio: The probability that an item will perform a required function or that a trial will be successful under stated conditions.

NOTE - 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.

4.2 failure ratio: The probability that an item will fail or that a trial will be unsuccessful under stated conditions.

NOTE - 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.

5 List of symbols

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)
c	acceptable number of failures or unsuccessful events during the test	
	NOTE - r_{RE} , number of failures for rejection in IEC 605-5, first edition (1982), corresponds to $c + 1$.	
D	nominal discrimination ratio, $D = p_1 / p_0 = (1 - q_1) / (1 - q_0)$	
	NOTE - D_R is the corresponding symbol in IEC 605-5, first edition (1982).	
D'	true discrimination ratio	
h	intercept values of the accept and reject lines on the vertical axis of the sequential test diagram (see figure 1)	
n	number of items, number of trials, number of events, sample size	
n_f	number of items, number of trials, number of events, sample size required for acceptance	
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	
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_a	probability of acceptance	
q	true success ratio, $q = 1 - p$	
	NOTE - R is the corresponding symbol in IEC 605-5, first edition (1982).	

- 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 1)

6 Application

6.1 Reliability requirement

The requirement is assumed to be specified as:

- acceptable failure ratio, p_0 or
- acceptable success ratio, q_0 ($p_0 = 1 - q_0$).

These test plans are based on the assumption that each trial is statistically independent and that the probability of success (or failure) is constant, i.e. the binomial distribution assumptions apply. The true producer's and consumer's risks for the test plans differ from the nominal characteristics α and β due to the necessary approximations to whole numbers and to the truncation of the sequential tests.

6.2 Repair and replacement

The test plans given in this standard 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 is used for each trial.

6.3 Types of test plans

Test plans are given for three types of tests:

- truncated sequential tests (see clause 8);
- fixed trial/failure terminated tests (see clause 9);
- designed trial/failure terminated tests (see clause 10).

The detailed reliability test specification shall state which type of test and which test plan are to be used. Guidance for the choice of type of test is similar to that given in IEC 605-1, 7.3.1, for truncated sequential and time/failure terminated tests for the case in which the reliability measure is a function of time.

6.4 General test procedure

The test items shall 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.

7 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 605-1, 9.2) are counted and compared with the decision criteria of the test plan.

The detailed decision criteria for the three types of test plans are given in 8.2, 9.2 and 10.7, respectively.

8 Truncated sequential test plans

8.1 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 implement a test plan, q_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 1 presents the appropriate test plans for various values of the specified q_0 , D , α and β . The table contains parameter values of h , s , n_t and r_t for each test plan (see figure 1).

NOTE - The truncation affects the values of α' and β' . However, the truncation values of table 1 are chosen so that the maximum values of α' and β' are less than 0,055; 0,105; 0,205 and 0,305, for values of α and β 0,05; 0,10; 0,20 and 0,30 respectively. The truncation values were obtained from a computer program which calculated α' and β' for increasing values of n_t and r_t until the maximum values were within the above stated bounds.

8.2 Decision criteria

The decision criteria are as follows:

- accept if $sn_s - h > r$;
- continue if $sn_s - h < r < sn_s + h$;
- reject if $r > sn_s + h$.

The sequential test plans shall be truncated at lines based on the values given in table 1. The truncation gives rise to the following additional criteria:

- accept if $n = n_t$ 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.

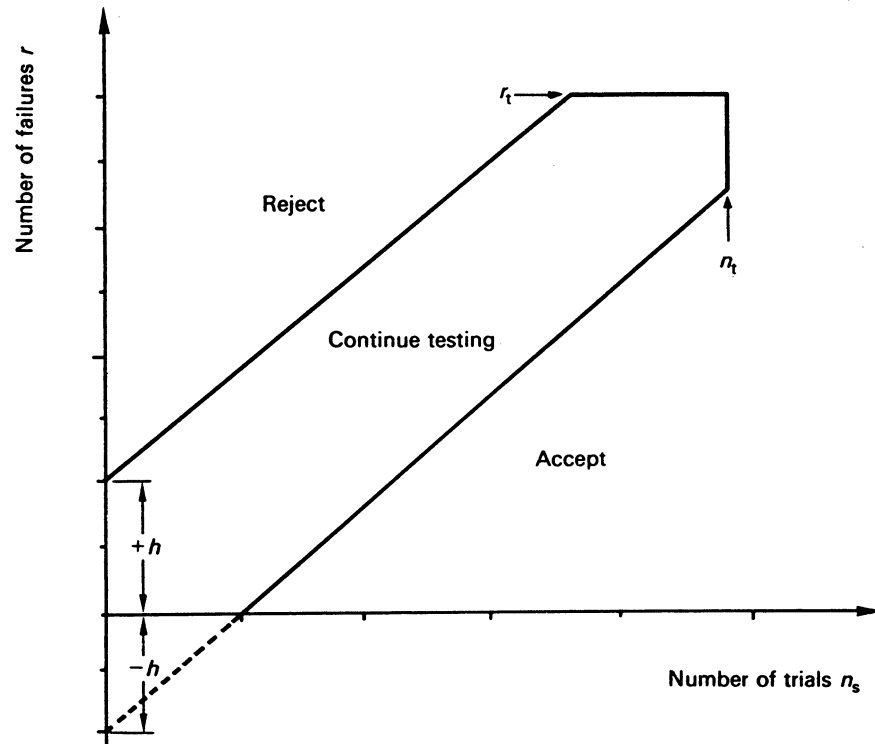


Figure 1 – Truncated sequential test

8.3 Operating characteristic curve

For any of the truncated sequential tests, the following approximate points on the operating characteristic curve are given:

q	P_a
1,0	1,0
q_0	$1 - \alpha$
$1 - s$	0,5
q_1	β
0,0	0,0

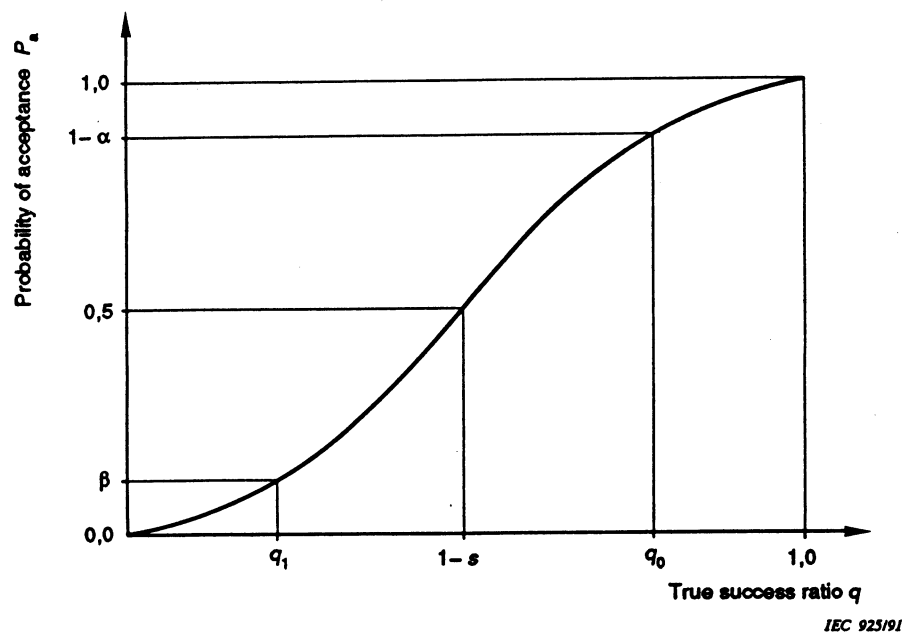


Figure 2 – OC curve

8.4 Expected number of trials to decision

For any of the truncated sequential test plans, the following approximate points can be determined for the curve of the expected number of trials to decision versus the true success ratio:

q	n_s
1,0	$\frac{h}{s}$
q_0	$\frac{h(1-2\alpha)}{s-(1-q_0)}$
$1-s$	$\frac{h^2}{s(1-s)}$
q_1	$\frac{h(1-2\beta)}{(1-q_1)-s}$
0,0	$\frac{h}{1-s}$