

Maintainability of equipment —

Part 3: Verification and collection, analysis and presentation of data

The European Standard EN 60706-3:2006 has the status of a
British Standard

ICS 03.120.01; 21.020

National foreword

This British Standard was published by BSI. It is the UK implementation of EN 60706-3:2006. It is identical with IEC 60706-3:2006. It supersedes BS 6548-3:1992 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee DS/1, Dependability and terotechnology.

A list of organizations represented on DS/1 can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2006

© BSI 2006

ISBN 0 580 49314 8

Amendments issued since publication

Amd. No.	Date	Comments

Maintainability of equipment
Part 3: Verification and collection, analysis and
presentation of data
(IEC 60706-3:2006)

Maintenabilité de matériel
Partie 3: Vérification et recueil,
analyse et présentation de données
(CEI 60706-3:2006)

Instandhaltbarkeit von Geräten
Teil 3: Verifizierung und Erfassung,
Analyse und Darstellung von Daten
(IEC 60706-3:2006)

This European Standard was approved by CENELEC on 2006-07-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 56/1094/FDIS, future edition 2 of IEC 60706-3, prepared by IEC TC 56, Dependability, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60706-3 on 2006-07-01.

The following dates were fixed:

- | | | |
|--|-------|------------|
| – latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2007-04-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2009-07-01 |

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60706-3:2006 was approved by CENELEC as a European Standard without any modification.

CONTENTS

INTRODUCTION.....	5
1 Scope	6
2 Normative references.....	6
3 Terms and definitions	7
4 Introduction to maintainability verification.....	7
4.1 Objective of verification	7
4.2 Maintenance support concepts influencing maintainability verification	8
4.3 Methods of verification.....	8
4.4 Verification process	8
4.5 Conditions and constraints.....	9
4.6 Qualitative and quantitative verification procedures	10
5 Procedures for verification of qualitative maintainability	11
5.1 Design review.....	11
5.2 Review of test experience	11
5.3 Ease-of-maintenance studies	12
5.4 Review of maintenance task analysis	12
5.5 Review of operational experience.....	12
6 Procedures for verification of quantitative maintainability	13
6.1 Maintainability predictions.....	13
6.2 Verification based on demonstration tests	13
6.3 Verification based on field data	13
7 Demonstration procedures	14
7.1 General.....	14
7.2 Demonstration process	14
7.3 Demonstration planning	14
7.4 Conditions and constraints.....	15
7.5 Demonstration after modification.....	15
8 Elements of the verification procedure	16
8.1 Utilization of data sources.....	16
8.2 Data acquisition and analysis.....	16
8.3 Evaluation	17
8.4 Comparison	18
9 Collection, analysis and presentation of maintainability data	18
9.1 General	18
9.2 Maintenance concept.....	18
9.3 Data sources	19
9.4 Item demonstration and field data	20
9.5 Analysis procedures	20
9.6 Data presentation	21
Annex A (normative) Maintainability demonstration procedures.....	24
Annex B (normative) Maintainability demonstration test methods	27
Annex C (normative) Analysis of maintainability related data	35
Annex ZA (normative) Normative references to international publications with their corresponding European publications	

Bibliography	37
Figure B.1 – Test method 8: Sequential test plan	34
Table 1 – Qualitative and quantitative maintainability verification procedures	11
Table 2 – Active repair task data summary form	23
Table 3 – Active repair time summary form	23
Table 4 – Preventive maintenance summary	23
Table A.1 – Test methods	24
Table B.1 – Test method 7: Acceptance and rejection numbers	33
Table B.2 – Sampling plans for specified p_0 , p_1 , α , β ($p_0 < 0,2$)	34
Table C.1 – Critical values of d	36

INTRODUCTION

The design of an item includes the need for efficient maintenance techniques to ensure that the item continues to operate properly. Before it is put into service it is necessary to verify that the proposed maintenance procedures can be executed as designed and the collection and analysis of data is an essential part of the verification process.

The data used for verification may come from a variety of sources and what is used in particular circumstances will depend on many factors, including what historical data are available and the status of the design. For verification that maintainability targets have been met, it is preferable to conduct tests that generate data on the product under review. Historical data have to be sorted for relevance to the project and when useful data have been selected, they are analysed to provide the information required.

There are a number of verification procedures that are explained in this standard with the associated analysis techniques. They are designed to check the adequacy of the maintenance procedures, the tools and equipment supplied for maintenance, the adequacy of the technical publications and the ease of maintenance of the item. This enables improvements to be made to the maintenance procedures and, if necessary, modifications to be carried out on the item to improve maintainability. It is important to include any required changes to the design of the item as early as possible, if possible before the start of production, in order to minimize costs.

This initial analysis is, in most cases, a statistical analysis based on a small sample of data. It is therefore preferable that the collection and analysis of data should go on after the item enters service so that the results achieved by the verification process are refined and improved. These data are important to determine the adequacy of the maintenance support, as this is not so easy to assess in an initial verification analysis.

IEC 60706-3 forms part of a hierarchy of standards dealing with dependability, as described below.

IEC 60300-1 and IEC 60300-2 are the IEC top-level standards that provide guidance on how to incorporate dependability, incorporating reliability, availability and maintainability, into manufactured products. The top-level standard on maintainability is the application guide for maintainability, IEC 60300-3-10, which forms part of the IEC 60300-3 series of standards. It can be used to implement a maintainability programme covering the initiation, development and in-service phases of a product, which form part of the tasks described in IEC 60300-2. It also provides guidance on how the maintenance aspects of the tasks should be considered in order to achieve optimum maintainability.

MAINTAINABILITY OF EQUIPMENT –

Part 3: Verification and collection, analysis and presentation of data

1 Scope

This part of IEC 60706 describes the various aspects of verification necessary to ensure that the specified maintainability requirements of an item have been met and provides suitable procedures and test methods. While maintainability verification as such should be a mandatory part of any maintainability programme (see IEC 60300-3-10), each individual case requires appropriate methods to be carefully selected in order to ensure overall cost-effectiveness.

This standard also addresses the collection, analysis and presentation of maintainability related data, which may be required during, and at the completion of, design and during item production and operation.

2 Normative references

The following referenced documents are indispensable for the application 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(191):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service*

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

IEC 60300-3-10:2001, *Dependability management – Part 3-10: Application guide – Maintainability*

IEC 60300-3-12, *Dependability management – Part 3-12: Application guide – Integrated logistic support*

IEC 60300-3-14, *Dependability management – Part 3-14: Application guide – Maintenance and maintenance support*

IEC 60706-2, *Maintainability of equipment – Part 2 – Section Five: Maintainability studies during the design phase*¹

IEC 61160, *Design review*

IEC 61649, *Goodness-of-fit tests, confidence intervals and lower confidence limits for Weibull distributed data*

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

¹ To be published.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050(191), together with the following definitions, apply.

3.1

customer selected equipment

portion of the item under consideration which has been specially selected by the customer

NOTE Generally the supplier has no control over the maintainability of this portion, but it should be considered in the design of the item. Cooperation between customer and supplier is clearly desirable.

3.2

maintainability demonstration

activity performed on individual items or samples to indicate achievement of a specific maintainability requirement and/or to generate maintainability data

3.3

maintainability verification

monitoring actions, inspections or both for the purpose of determining compliance by the contractor with the maintainability requirements specified for an item

3.4

maintenance concept

interrelationship between the maintenance echelons, the indenture levels and the levels of maintenance to be applied for the maintenance of an item

3.5

maintenance policy

general approach to the provision of maintenance and maintenance support based on the objectives and policies of owners, users and customers

3.6

software support centre

centralized software maintenance service

4 Introduction to maintainability verification

4.1 Objective of verification

The objective is to verify that both qualitative and quantitative maintainability requirements have been met within the specified performance limitations. This includes verification that the defined maintenance activity has restored the item to the specified performance level. The verification is applicable to hardware, software and maintenance facilities.

Maintainability verification is a process of assessing the results of maintainability experience. This assessment can begin as soon as data and results are available and may continue throughout the project and extend into field use.

This is further expanded with respect to

- qualitative maintainability requirements, see Clause 5,
- quantitative maintainability requirements, see Clause 6.

Demonstration procedures are described in Clause 7.

4.2 Maintenance support concepts influencing maintainability verification

When performing maintainability verification, it should be borne in mind that the following maintenance support elements have a decisive influence on the effectiveness of the maintenance process:

- maintenance facilities;
- support equipment;
- material support;
- maintenance personnel and training;
- technical documentation and manuals;
- transportation, handling and storage conditions.

IEC 60300-3-14 contains further details on maintenance support.

4.3 Methods of verification

Maintainability verification is a continuous process of generating, collecting, analysing and evaluating maintainability related data as they become available in the course of project development, and comparing results with specified maintainability requirements.

Methods of maintainability verification differ according to the programme phase, as follows:

- a) analysis and review. This includes analysis of historical data, comparisons with the results of design reviews and maintainability predictions. This may include analysis of field data later in the life cycle;
- b) special studies. Conducted during the concept and definition or design and development phases to investigate general or detailed problems. Examples include ease-of-maintenance studies, maintenance task analysis and simulation studies;
- c) demonstration tests. Performed at the end of the design and development phase on prototype or early production items, if the analytical means or special studies do not give sufficient evidence as to whether maintainability conforms to specified requirements.
- d) review of operational experience. Verification may be left to operational experience and review of field data, correlated, if appropriate, with the review and analysis of historical data;
- e) spatial imaging simulation. Three-dimensional computer simulations of maintenance actions may be performed at appropriate times throughout the design process to verify that the proposed sequence of actions, access and other workspace considerations support the achievement of the required level of maintainability.

4.4 Verification process

The procedural elements of the verification process are as follows:

- a) identification and activation of possible sources of data
in the early project phases, only historical data of comparable previous items can be used. Later, design, manufacturing, test and finally field data become available. Maintainability demonstrations in this context provide a special data source for the generation of maintainability data under simulated conditions;

- b) acquisition and analysis of data
data collection, review and screening to ensure their applicability;
- c) evaluation
processing of data using mathematical models or checklists to obtain quantitative characteristics or qualitative properties of maintainability;
- d) comparison with requirements
the results of the evaluation are compared with specified maintainability characteristics and properties to check whether maintainability requirements are met;

In addition, the following information is necessary for a complete maintainability verification.

- e) item maintenance plan
the item maintenance plan is the application of the maintenance concept to that item and should be defined for the interpretation of both historical data and data from other sources. The maintenance plan also defines conditions and constraints on maintenance and support to be considered in the process of maintainability verification;
- f) reliability data
relevant reliability indices, such as the expected frequency of maintenance actions, may be required for the calculation of some maintainability indices from estimated or observed times for single maintenance actions. Reliability data will also affect aspects of verification such as establishing priorities, thus giving prerequisites for evaluation. If this information is not available or is incomplete, assumptions should be stated. The quality of available information and the assumptions made will affect the relevancy of verification results.

4.5 Conditions and constraints

Methods should be specified by the customer or selected by the contractor and described in the maintainability programme plan (as detailed in IEC 60706-2). The following should be considered in deciding between alternative verification procedures related to each maintainability requirement.

- a) resources available
if a budget limit is contractually specified, this will influence the selection of verification methods. Possible future usability of verification facilities should be taken into account;
- b) acceptance criteria
The acceptance criteria for each specified maintainability requirement should be considered in a trade-off against cost and time requirements;
- c) time constraints
The choice between verification methods may be restricted by requirements affecting the timely availability of results. The procedure should be structured in accordance with the overall development programme schedule;
- d) spatial imaging simulation
This may be used if test samples and support equipment are not available when needed;

- e) availability of test samples and/or support equipment
especially when maintainability demonstration tests are to be conducted, it should be ensured that the test schedule is in agreement with the overall programme schedule, and that the test samples and the support equipment required are readily available during the time period envisaged for the test;
- f) skill level and experience of maintainability analysts
maintainability verification, based on design reviews or analysis, calls for highly qualified and experienced personnel to analyse drawings and plans;
- g) risk of wrong decisions
These should be assessed with regard to the item's complexity and the quality and amount of historical data;
- h) special support requirements
the necessary checkout equipment, facilities, personnel qualification, etc. need to be available at the appropriate time in the schedule;
- i) influence of environmental conditions or assumptions
Any deviation from the operational environment in terms of maintenance/checkout equipment, facilities, spares, personnel skill level, etc. should be particularly assessed;
- j) data collection
the requirements concerning the collection of representative maintainability data during test and operation should be clearly identified. This includes formats, codes and data processing;
- k) customer-contractor relationship
any monitoring, rejection or control authority assumed by the customer should be clearly defined;
- l) maintainability warranties and guarantees
Contractual consequences of not meeting maintainability requirements or acceptance criteria should be specified, for example, in terms of penalties or loss of incentives;
- m) realism of verification
The maintainability verification should include realistic representation of the operational environment and maintenance technicians that are representative of those that would be expected in the operational environment.

4.6 Qualitative and quantitative verification procedures

The maintainability verification process is directed towards providing adequate and timely information concerning the degree of achievement of maintainability requirements. Since these requirements may be expressed in qualitative or in quantitative form, the maintainability verification procedure shall be designed accordingly, using one of the following methods of verification or a combination of them:

- analysis and review;
- design studies, tests and spatial imaging simulation;
- demonstration by testing or during operational use.

Both qualitative and quantitative aspects of maintainability verification can be covered by an appropriate choice of methods, as indicated in Table 1.

Table 1 – Qualitative and quantitative maintainability verification procedures

Type of procedure		Analysis and review	Design studies and tests	Demonstration	During operational use
Qualitative verification procedures	Design review	X			
	Review of test experience	X	X	X	
	Ease-of-maintenance studies		X		
	Review of maintenance task analysis	X		X	
	Review of operational experience				X
	Spatial imaging simulation		X	X	
Quantitative verification procedures	Maintainability prediction	X	X		
	Verification based on test data		X	X	
	Verification based on field data				X

5 Procedures for verification of qualitative maintainability

5.1 Design review

Qualitative maintainability can be verified during the general product design review by evaluating design documentation against a set of design requirements and engineering standards (see IEC 61160).

Depending on the nature of the project, a checklist addressing specific maintainability features should be used as a guideline.

This type of investigation requires good engineering assessment of maintainability characteristics of a design and should be based on previous experience. It can be applied in the design stage as part of normal engineering practice for step-by-step design improvement. For maintainability verification purposes, design review is generally used only in combination with some other method.

5.2 Review of test experience

Data from operational use are usually unavailable or too late for timely maintainability verification. However, such data might be gained in earlier project stages in development trials or by special demonstration tests in a realistic, simulated environment. To be representative and reproducible, the test conditions should be clearly defined. Any deviations from reality should be assessed. The main discrepancies can be discovered when alternative approaches are still possible.