EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

DRAFT
prEN 45552

October 2018

ICS 13.020.20

English version

General method for the assessment of the durability of energy-related products

Méthode générale pour l'évaluation de la durabilité des produits liés à l'énergie

Allgemeines Verfahren zur Bewertung der Lebensdauer energieverbrauchsrelevanter Produkte

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/CLC/JTC 10.

If this draft becomes a European Standard, CEN and 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.

This draft European Standard was established by CEN and CENELEC in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN and CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.

CEN-CENELEC Management Centre:
Rue de la Science 23, B-1040 Brussels

Ref. No. prEN 45552:2018 E

Contents

Page

European foreword

This document (prEN 45552:2018) has been prepared by Technical Committee CEN/CLC/JTC 10 “Energy-related products - Material Efficiency Aspects for Ecodesign”, the secretariat of which is held by NEN/NEC.

This document is currently submitted to the CEN Enquiry.

The dual logo CEN-CENELEC standardization deliverables, in the numerical range of 45550 – 45559, have been developed under standardization request M/543 of the European Commission and are intended to potentially apply to any product within the scope of the Energy-related Products (ErP) Directive (2009/125/EC).

Topics covered in the above standardization request are linked to the following material efficiency aspects:

a) Extending product lifetime;

b) Ability to re-use components or recycle materials from products at end-of-life;

c) Use of re-used components and/or recycled materials in products

These standards are general in nature and describe or define fundamental principles, concepts, terminology or technical characteristics. They can be cited together with other product-specific or product group standards, e.g. developed by product technical committees.

The present standard is intended to be used by product technical committees when producing product specific or product group standards.

Introduction

As Energy-related Products (ErP) can often not be completely recycled and the benefits associated with material recovery cannot fully compensate the energy (and material) demand of the whole production chain, each disposed ErP also means losses in energy and materials. Therefore, increasing durability of ErPs can contribute to reduce the material and energy demand and related environmental impacts.

When considering durability, the trade-off between longer lifetime (reducing impacts related to the manufacturing and disposal of the product) and reduced environmental impacts of new products compared to worse and/or decreasing energy efficiency of older products needs to be considered. Considerations such as these are addressed in the preparatory studies commissioned under Directive 2009/125/EC. Whilst such aspects establish a relevant context for this standard, they are not addressed in this document.

This standard covers a general method for the assessment of the durability of ErPs. To cover the whole lifetime of a product, the generic standards on “Ability to repair, reuse and upgrade – CLC/prEN 45554:2019”, “Ability to re-manufacture – CLC/prEN 45553:2019”, (bothcurrently under preparation) or similar standards can be taken into consideration.

This document describes general assessment approaches that can be adapted for application at a product-specific level In order to assess the durability of ErP. Reliability is an element of durability, representing the assessment of the time from first use to first failure or in-between failures, whilst durability is the whole assessment from production to end of life.

1 Scope

This document defines parameters and methods as a framework in order to assess the durability of ErP. It is intended to be used in preparation of product-specific standardization deliverables on durability assessment.

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.

EN 12973:2000, *Value management*

CLC/prEN 45559, *Methods for providing information relating to material efficiency aspects of energy-related products*

EN 62308:2006, *Equipment reliability - Reliability assessment methods*

EN 62506:2013, *Methods for product accelerated testing*

EN 60812, *Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA)*

3 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

Note 1 to entry: See CLC/prTR 45550 for additional definitions.

3.1
durability
durability <of a part or a product>
ability to function as required, under defined conditions of use, maintenance and repair, until a final limiting state is reached

Note 1 to entry: The degree to which maintenance and repair are within scope of durability will vary by product or product group.

Note 2 to entry: The final limiting state has to be defined by the user of this document. For more information see Figure D.1.

3.2
limiting event
event which results in a primary or secondary function no longer being delivered

Note 1 to entry: Examples of limiting events are failure, wear-out failure or deviation of any analogue signal.

3.3
limiting state
condition after one or more limiting event

3.4
maintenance
action carried out to retain a product in a condition where it is able to function as required

Note 1 to entry: Examples of such actions include inspection, adjustments, cleaning, lubrication, testing, and replacement of wear-out part. Such actions could be performed by users in accordance with instructions provided with the equipment (e.g. replacement or recharging of batteries); or the actions could be performed by service personnel in order to ensure that parts with a known time to failure are replaced in order to keep the product functioning.

3.5
reliability
probability that a product functions as required under given conditions, including maintenance, for a given duration without failure

Note 1 to entry: The intended function(s) and given conditions are described in the user instructions provided with the product.

Note 2 to entry: Duration can be expressed in units appropriate to the part or product concerned, e.g. calendar time, operating cycles, distance run, etc., and the units should always be clearly stated

3.6
primary function
function fulfilling the intended use

Note 1 to entry: There can be more than one primary function.

3.7
secondary function
function that enables, supplements or enhances the primary function(s)

[SOURCE: EN 62542:2017; 5.14,]

3.8
tertiary function
function other than a primary or a secondary function

[SOURCE: EN 62542:2017; 5.16, modified examples deleted]

3.9
functional analysis
process that describes the functions of a product and their relationships, which are systematically characterised, classified and evaluated

3.10
normal environmental conditions
characteristics of the environment in the immediate vicinity of the product during transport, storage, use, maintenance and repair life phases, which may affect its performance during normal use

Note 1 to entry: Examples of environmental conditions are pressure, temperature, humidity, radiation, vibration.

Note 2 to entry: Given normal environmental conditions and defined environmental conditions of transport, storage, use, maintenance and repair, refer to a specified subset of normal environmental conditions which are used for the assessments.

3.11
normal use
use of a product, including its transport and storage, or a process, in accordance with the provided information for use or, in the absence of such, in accordance with generally understood patterns of usage

Note 1 to entry: Normal use should not be confused with intended use. While both include the concept of use as intended by the manufacturer, intended use focuses on the purpose while normal use incorporates not only the purpose, but transport and storage as well

[SOURCE: IEV 871-04-22]

3.12
normal operating conditions
characteristic in operation which may affect performance of the product during intended use

Note 1 to entry: Examples of operating conditions are, modified environmental conditions when the product operates (Self-heating, condensation), characteristics of the power supply, duty cycle, load factor, vibration due to operation.

Note 2 to entry: Given normal operating conditions and defined operating conditions of use, maintenance and repair, refer to a specified subset of normal operating conditions which are used for the assessments.

3.13
intended use
use in accordance with information provided with a product or system, or, in absence of such information, by generally understood patterns of usage

Note 1 to entry: Intended use should not be confused with normal use. While both include the concept of use as intended by the manufacturer, intended use focuses on the purpose while normal use incorporates not only the purpose, but transport and storage as well.

[SOURCE: ISO/IEC Guide 51:2014; 3.6, modified Note 1 to entry added]

3.14
wear-out failure
failure due to cumulative deterioration caused by the stresses imposed in use

Note 1 to entry: The probability of occurrence of a wear-out failure typically increases with the accumulated operating time, number of operations, and/or stress applications.

Note 2 to entry: In some instances, it may be difficult to distinguish between wear-out and ageing phenomena.

[SOURCE: IEV 192-03-15]

3.15
repair
process of returning a faulty product to a condition where it can fulfil its intended use (3.13)

3.16
part
hardware or software constituent of a product

[SOURCE: CLC/prEN 45554; 3.2]

4 Concept and process overview

4.1 Concept

There are some key concepts to consider when addressing durability. The durability can be limited by fatigue/ageing of a part, which can cause a limiting event. A limiting event occurs when a primary or secondary function is no longer delivered. This results in the product being in a limiting state. The durability assessment can take into account a number of maintenance and repair actions. The maintenance and repair actions shall be included in the given normal environmental and operating conditions. Durability is usually expressed as time, number of cycles or distance.

The reliability of a product is directly related to its probability of failure or its failure rate (examples are available in EN 61703:2016) under given normal environmental and operating conditions. When carrying out a reliability assessment, the statistical distribution of limiting events is considered.

The time at which a certain percentage of products have reached a limiting state (e.g. time by which 10 % will fail) is used to assess and compare the time to a limiting event. However, other reliability assessments such as mean time to failure (MTTF), mean time to first failure (MTTFF) and mean time between failures (MTBF) are also used. The reliability assessment between the first use of the product and the first limiting event does not take repair into account. However, the reliability assessment between two consecutive limiting events takes into account the effects of a previous repair.

NOTE Reliability and durability are defined in the standardization framework and are relevant methods to estimate the technical lifetime of a product. Whilst “Minimum Lifetime” can be specified this requires a wider consideration than reliability and durability assessment, as it could include additional aspects such as economic, social or regulatory requirements.

4.2 Process overview and guidance

The users of this document shall specify the product group in terms of functions and, if applicable, in accordance with relevant product group standards (see subclause 5.1).

The users of this document shall use the results of the functional analysis (see subclause 5.1), environmental and operating conditions (see subclause 5.2) and additional input data (see subclause subclause 5.3) in order to conduct a product group specific reliability analysis developed for a product group (see subclause 6.2). The result is a rank-ordered list of functions and parts providing the functions linked to

— failure modes,

— failure sites, and

— failure frequencies.

Consecutively, the reliability of the functions/parts should be validated by either existing methods or methods which have to be developed (see subclause 6.3). In succession, the reliability of the product should be validated (see subclause 6.4). These can then be used for conformity assessment of individual products in the respective product group.

NOTE 1 Product group, as used in this document, refers as an umbrella term to a group of products with similar properties and main function(s).

NOTE 2 Software and/or firmware are also considered as part.

For the durability analysis of a product group (see subclause 7.3), the user of this document shall take into account among others, repair considerations, special environmental conditions and misuse (see subclause 7.2). Consecutively, the durability of the product should be validated (see subclause 7.4).

Results of the reliability and durability analysis may be reported according to Clause 8.

Figure 1 illustrates the key stages and the information required for an assessment of the reliability and durability. The user of this document shall use the standard in accordance to it.

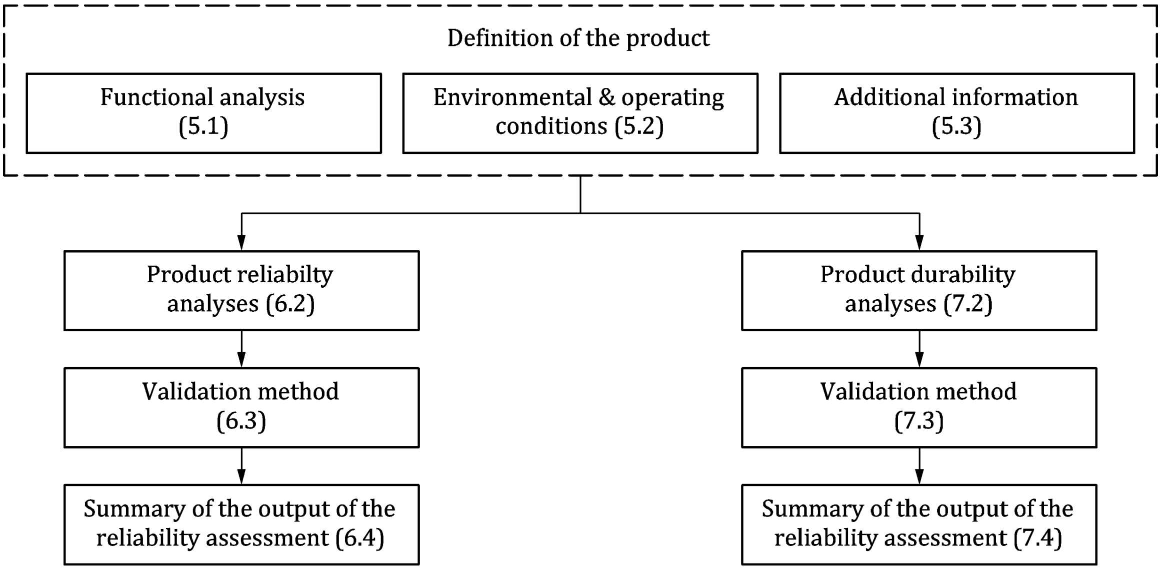


Figure 1 — General reliability and durability assessment procedure

5 Definition of the Product

5.1 Functional analysis

The product group being addressed shall be defined in terms of functions. Functional analysis is a process that results in a comprehensive description of the functions and their relationships, which are systematically characterized and classified. Any complete functional analysis enables a detailed understanding regarding the product characteristics, how the functionality can be achieved embedding constraints coming from regulatory framework (such as EMC). Functional analysis in accordance with EN 12973:2000 A.1.2 or equivalent should be applied to determine all functions of the product group during its lifecycle. Functional analysis is a restricted data in accordance with CLC/prEN 45559.

NOTE However focusing to the assessment method of durability the scope of the functional analysis might cover only transportation, storage, use, maintenance and repair phases. As example of functional analysis, the FAST methodology could be applied (EN 12973:2000; A.1.2.2.3.c) to assess an existing product or to design a product.

There are three types of functions:

— primary function(s);

— secondary function(s);

— tertiary function(s).

The user of this document shall select functions which are representative for the majority of the products of a product group as input to the reliability analysis described in subclause 6.2 and durability analysis described in subclause 7.2. The user of this document shall identify those parts of the products that are involved in providing a specific secondary function. If a specific function can be achieved by different technologies, each technology shall be assessed individually.

5.2 Environmental and operating conditions

The given normal environmental and operating conditions are a set of parameters reflecting the expected application and use patterns. The user of this document shall define these parameters for the respective product group. Examples of environmental and operational conditions are given in Annex A.1.

5.3 Additional information

Apart from the selected functions (see subclause 5.1) and the given normal environmental and operating conditions (see subclause 5.2), additional information is needed to conduct a reliability and durability analysis. Information shall be representative in terms of geographical, time-related and technological coverage.

The following sources of information related to failures can be considered as input for the reliability and durability analysis:

— Experience from past or current products;

— Field data;

— Failure Mode and Effect Analysis (FMEA), see A.3, and Fault Tree Analysis (FTA), see EN 61025;

— Manufacturers constraints;

— Regulations;

— Stress analysis (see Annex A.2) and Damage modelling (see A.4);

— Test results already available;

— Consumers expectations;

— Risk assessment.

FMEA shall be in accordance with EN 60812. It shall include any foreseeable misuse and limiting events.

NOTE 1 Information on limiting events and states can be found in Annex D.

In order to evaluate the product in relation to all input parameters, data collection and analysis is necessary. Existing testing data may include parts level tests under several conditions and with several samples. This data may also include information on misuses and failures from past or current operations experience, field experience, consumer expectations, manufacturer’s constraints and regulations, as well as risk assessments.

Additional considerations affecting the reliability (e.g. MTBF) and durability assessments are as follows:

— Repair, reuse and upgrade considerations (see CLC/prEN 45554 or similar standard and C.1);

— Refurbishment considerations.

NOTE 2 Reliability data on electronic parts contained within the product can be available within published reliability handbooks (See IEC/TR 62380 or similar standard).

6 Reliability

6.1 General considerations

For the purpose of conducting reliability analysis, given normal environmental and operating conditions shall be considered. The analysis links functions to failure modes and failure sites. The result of the analysis may be expressed as failure rate, probability of failure or survival, or time to failure (TTF). The failure mechanisms likely to be experienced by the product will determine which of the reliability criteria is appropriate and relevant. These shall be followed by an analysis of parts responsible for causing the respective failures as described in subclause 6.2, leading to a ranked list. The results of subclause 6.2 shall be used to identify or develop a validation method according to subclause 6.3. The procedure described in this paragraph shall be repeated if design or input data have been modified.

6.2 Reliability analysis

The reliability method shall take into account each function selected in subclause 5.1 according to EN 62308:2006 or similar standards. This analysis should consider additional information (see subclause 5.3). The user of this document shall specify what constitutes a failure within the product group in the intended application.

The analysis allows the identification of the failure mode, the location(s) of the failure and the parts which are involved in the failure for each analysed function. An FMEA or similar analysis shall be conducted (see A.3). The user of this document shall establish the results as a list of failure sites, mechanisms, and modes. Failure modes affecting selected functions should be listed and ranked according to likelihood. The failures most likely to occur affecting selected functions shall be determined and the related parts identified.

Users of this document shall state, if applicable (e.g. MTBF), in which way and to which extent repair and refurbishment is considered for the respective product group.

6.3 Validation method

The purpose of the validation is to determine the reliability of a product and to establish, if applicable, measurement methods for testing or accelerated testing of a defined set of functions or parts of a product for a product group selected in subclause 5.2.

NOTE 1 On accelerated testing see also Annex B.2 for further information.

In general, preference shall be given to existing methods. However, the user of this document shall ensure that these methods are appropriate or check if they need to be adapted for the purpose of reliability validation. If no applicable validation method exists, it shall be developed in accordance with related standards. Any developed validation method shall be technically justified and produce results within defined confidence limits without being prohibitively expensive or being overly time consuming. When accelerated tests can be carried out, EN 62506:2013 or similar standard shall be applied, which provides guidance on the application of various accelerated test techniques for measurement. Measurement uncertainties shall be stated for any developed test method.

NOTE 2 Related standards for the development of a method are e.g. IEC 61123, IEC 61124 or similar standards.

NOTE 3 If the test is accelerated, the sample size and the test time can be reduced. The larger number of failures reduces the statistical uncertainty, but the technical uncertainty is higher, since the accelerated test conditions can cause failure modes that do not occur in the field. If accelerating factors (see Annex A.5) are used, they are chosen so as to avoid the introduction of failure mechanism which differs from those occurring in the field.

Methods (existing or developed) shall be applied in order to validate the reliability according to the following priorities:

1) Failure rate, time to failure or survival of the whole ErP;

2) functions/parts selected in subclause 5.1/6.2 integrated in the ErP;

3) functions/parts selected in subclause 5.1/6.2 not integrated in the ErP.

For each specific product group and intended use case the validation method(s) shall be one or more of the following:

— physical testing and/or

— calculation from available data (e.g. reliability figures or test results for parts) and/or

— Calculation from field data.

The selected method may be different when assessing the whole product or specific parts; it may also be different depending on the stress against which the product or part is assessed (see B.1).

The tests shall be specified in terms of test parameters and if applicable test apparatus (arrangement and dimension of test equipment) and a description how to conduct the test. The test shall be accompanied by a sampling plan. Testing procedures shall be tailored to reflect the given normal environmental and operating conditions and stresses that the product will be exposed to in the use phase.

6.4 Summary of outputs of the reliability analysis

The user of this document shall require the following outputs to be available:

— List of failures, parts and functions as selected in subclause 6.2;

— Environmental and operating conditions as defined in subclause 5.2;

— Reliability results;

— Failure rates and confidence intervals as appropriate;

— Applicable and applied validation methods.

7 Durability

7.1 General considerations

Durability analysis within this standard shall investigate the ability of any function or part selected in subclause 5.1 to function as required including possible maintenance, repair and refurbishment actions (see also C.1). The verification and validation of the durability assessment for products should be considered separately, including or excluding repair. For each product addressed, it may be necessary to tailor the approach to determine the limiting event using reliability analysis (see subclause 6.2) based upon the available information and the selected functions (see subclause 5.1).

A durability analysis examines the response of a product to the stresses imposed by operating and environmental conditions in lifecycle stages such as use, maintenance, repair, transport, storage.

Limiting events are usually assumed to be reversible by e.g. repair of the product, and occur due to a variety of causes, such as defects in the product, improper use, damage due to unusual conditions, inadequate maintenance or repair, etc.

7.2 Durability analysis

Users of this document shall state, if applicable, in which way and to which extent maintenance, repair and refurbishment is considered for the respective product group.

Durability analysis shall be carried out according to EN 62308:2006; 9.3, as follows:

1) identify applicable environmental and operating conditions (see subclause 5.2) and related stresses (A.2);

2) identify transfer functions (see subclause 5.1);

3) identify magnitude and locations of stresses (A.2);

4) identify likely failure sites, mechanisms and modes (part of the subclause 6.2);

5) identify the durability using appropriate damage model(s) (A.4) and acceleration factors (A.5).

7.3 Validation method

The purpose of the validation is to determine the durability and to establish, if applicable, measurement methods for testing or accelerated testing of a defined set of functions or parts identified in subclause 7.2.

NOTE On accelerated testing see also B.2 for further information.

In general, preference shall be given to existing methods. However, the user of this document shall ensure that these methods are appropriate or check if they need to be adapted for the purpose of durability validation. If no applicable validation method exists, it shall be developed in accordance with related standards. Any developed validation method shall be reliable, repeatable and reproducible without being prohibitively expensive or being overly time consuming. When accelerated tests can be carried out, EN 62506:2013 or similar standards shall be applied, which provides guidance on the application of various accelerated test techniques for measurement. Measurement uncertainties shall be stated for any developed test method.

For each specific product group and intended use case the validation method(s) shall be one or more of the following:

— physical testing and/or

— calculation from available data (e.g. reliability figures or test results for parts) and/or

— field data.

The selected method may be different when assessing the whole product or specific parts; it may also be different depending on the stress against which the product or part is assessed (see B.1).

The tests shall be specified in terms of test parameters and if applicable test apparatus (arrangement and dimension of test equipment) and a description of how to conduct the test. The test shall be accompanied by a sampling plan. Testing procedures shall be tailored to reflect the given normal environmental and operating conditions and stresses that the product will be exposed to in the use phase.

The user of this document shall differentiate when durability only focuses on aging, fatigue and wear-out due to environmental and operating conditions, or when the durability assessment also considers maintenance and repair actions, until end of product life.

It is necessary to carry out a durability analysis to validate a durability of a product or part under given environmental and operating condition.

7.4 Summary of outputs of the durability analysis

The user of this document shall require the following outputs to be available:

— List of failures, parts and functions as selected in subclause 7.2;

— Environmental and operating conditions as defined in subclause 5.2;

— Durability results related to e.g. aging, fatigue and wear-out in terms of expected agreed output units (time, cycle, distance…) without maintenance, repair, reuse, upgrade and refurbishment;

— Durability results of expected agreed output units (time, cycle, distance…) including maintenance and when considered applicable, repair, reuse, upgrade and refurbishment;

— Applicable and applied validation methods.

8 Reporting reliability and durability aspects

8.1 General

The user of this document shall ensure that their standards include requirements for reporting material efficiency aspects as follows:

— The assessment of reliability and durability of product(s) shall be documented in a report.

— The assessment report itself is likely to be considered as data sensitivity level <3> in accordance to CLC/prEN 45559

— The assessment report shall also include data and information of importance for any results published in data sensitivity levels < 2 and / or 1 > , for the different stakeholders.

— Special care shall be taken to demonstrate transparency and the correlation between information on the results of the assessment and the input data and assumptions used.

8.2 Elements of the assessment report

The user of this document shall ensure that their standard(s) sufficiently cover that when reporting material efficiency aspects results, data, methods, assumptions, limitations and conclusions shall be completely and accurately reported.

The report shall follow the following structure:

A. General aspects

1) Instigator of the assessment

2) Date of report, place, etc.

3) List of standards applicable to the assessment

B. Scope of assessment

1) Description of product assessed

2) Description of cut-off rules applied (see subclause 6.2 and 7.2)

C. Input data and approach for the assessment of reliability and durability

1) Description of data and other information used/needed for the assessment (see Clause 5)

2) Methods or tools used in the assessment (see subclause 6.2, 6.3, 7.2 and 7.3)

D. Output of the assessment

1) Result of the assessment covering a list of qualitative and quantitative reliability and durability content that could be reported for different stakeholders (see subclause 6.4 and 7.4)

2) List of applicable references (incl. standards, requirements and policies).

Annex A
(informative)

Additional details on durability and reliability analysis

A.1 Environmental and operating conditions

The normal environmental and operating conditions are usually a list of defined constraint values or ranges within a product specific standard reflecting standardized values surrounding the product for an expected application (home, building, industrial, etc.) and operation.

The given normal environmental and operating conditions in this document are a list of values or ranges to carry out the reliability and durability analyses within the normal environmental and operating conditions.

It may not be possible to quantify all the necessary information regarding operational and environmental conditions. Many of the relevant conditions occur only in certain phases of the equipment's expected life. It is important to determine or arrive at a credible estimate of the duration of such conditions.

Examples for operating conditions:

— electrical stresses due to the operation of the equipment;

— transient voltage, electrostatic discharge, frequency variation;

— steady-state temperature due to self-heating;

— temperature variations due to turning the equipment on and off;

— mechanical stresses: pressures, forces, torques, shocks, vibration, drop, mechanical impacts

— moisture conditions due to humidity and condensation; and

— electromagnetic field emission.

Examples for environmental conditions:

— temperature and humidity (including variations, time, expected total duration along life time);

— variations of supplies such as frequency, voltage, as well capability such as power and cooling;

— ambient chemical contaminants, particles and deposit;

— electromagnetic field in the environment; and

— mechanical vibration.

A.2 Stress analysis

Stress-strength analysis is a method to determine capability of a part or product to withstand electrical, mechanical, environmental, or other stresses that might be a cause of a failure. These analyses determine the physical effect of stresses on a part or product, as well as its mechanical or physical ability. Primary uses are:

— To determine the reliability or the durability of specific mechanical or electrical parts;

— To determine likelihood of occurrence of a specific failure mode due to an individual cause in a part.

Stress analysis requires a detailed knowledge of properties such as the part materials and construction, and proper modelling of expected stresses. Such analyses can provide realistic insights into part or part reliability in relation to the expected failure mechanisms, and can account for the way in which stresses change with different design variations.

Probability of failure (reliability) is directly related to the applied stresses. Part structural reliability is the capability of a part to withstand environmental, electrical, mechanical or other stresses, which depends on strength or load-carrying capability. Determination of this load-carrying capability and stress involves uncertainty, so they are modelled as random variables. The overlap of these random variables in a distribution represents the degree of probability that the stress will exceed the strength and a failure will occur. An evaluation of the mean values and variances of the random variables is often simplified to one stress variable compared to strength of the part. In general terms, the strength and stress is represented by a performance function or state function that is representative of a multitude of design variables including capabilities and stresses. A positive value for this function represents the safe state while a negative value represents the failure state.

The results of stress analysis are usually reported graphically, with the areas of greatest stress being highlighted in some easily detectable way. An example of given normal environmental conditions are shown below:

Low air temperature:	+5°C with a tolerance of 0 °C +2 °C:	10 days / year
Average air temperature	+20°C:	345 days / year
High air temperature:	+40°C with a tolerance of −2 °C 0 °C:	10 days / year

This type of analysis would not be accurate enough to assess durability based on damage modelling even if in Europe temperate conditions are met according to EN 60721-2-1.

As an example Figure A.1 shows two curves of temperature distribution lower than 20 °C as yearly average of two temperate climates met in Europe such as Stockholm (Sweden) and Malaga (Spain), which will be influenced by the building construction, internal waste and all device influencing the temperatures surrounding the ErP.

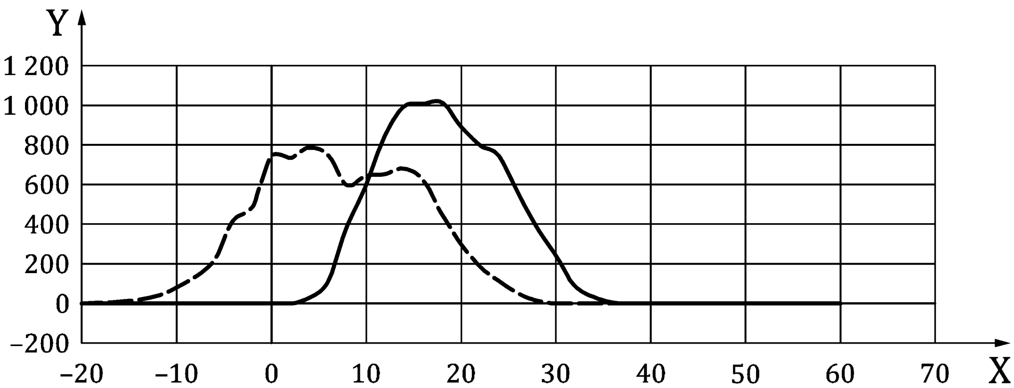


Figure A.1 — Example of temperature distribution

A.3 Damage modelling

After the types, locations and magnitudes of the stresses are identified, their effect in causing wear-out failures is determined. This is done using damage models, which are mathematical equations that predict how long a given part or product withstands a given stress before failure due to wear-out. Whilst useful for predicting wear-out failures due to the accumulation of damage caused by operating or environmental stresses, such models are not applicable to failures due to overstress.

Damage models may also be used in accelerated testing to estimate the behaviour of a part or product over a longer time at a lower stress level, based on its behaviour in a shorter time at a higher stress level.

The main damage models (Arrhenius, Inverse power law, Eyring…) can be found in EN 62308:2006 standard (Annex B - Durability analysis), EN 61709 standard (Reference conditions for failure rates and stress models for conversions), EN 62506:2013 standard (Methods for product accelerated testing) or similar standards. These standards also describe parameters influencing the energy of activation.

NOTE Most life-stress models (see EN 62308:2006; 13.1 and 13.2) contain an empirical constant A, which is usually unknown a priori and can only be obtained by testing for a specific failure mechanism under specific test conditions. Also the measure of life will affect the value of A, for example product's life can be measured as MTBF, MTTF, B10-life, Weibull characteristic life η or even as time to the first failure. Therefore, it is more common to analyse test data based on acceleration factor, AF.

Damage models are, by nature, inexact. The most effective models usually represent a compromise between the extremes of:

— attempting to describe the situation so completely that they become so complex and data hungry that they are unusable, and

— being so simple that they are inaccurate.

A.4 Acceleration factors (AF)

The acceleration factor is a ratio of the life at a use level of stress to the life at the elevated level of stress.

It is common to analyse test data based on acceleration factor, AF (see EN 62506:2013). Each assessed part or material requires the knowledge of their energy of activation. Figure A.2 highlights three examples based on temperature variations, and Arrhenius ageing model related to an energy of activation at 0.9 ev. The three examples of the Figure A.2 show the importance of accurate input data and testing data related to the durability and reliability assessments influenced by the various acceleration factors.

The three examples are as follows:

EXAMPLE 1 Three cases of thermal environmental or operating conditions and one case for testing temperature (constant) modify the ageing rate of the product with 3 respective ageing factors.

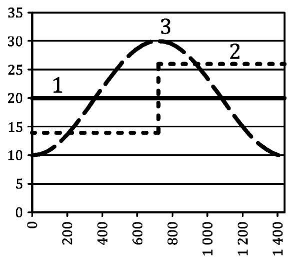
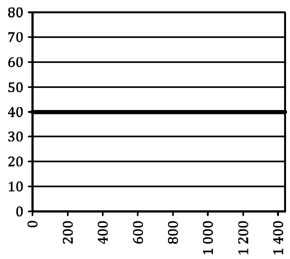
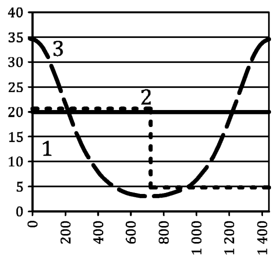
EXAMPLE 2 One case of thermal environmental or operating conditions (constant), and three cases for testing temperatures modify the ageing rate of the product with 3 respective ageing factors.

EXAMPLE 3 One case of thermal environmental or operating conditions (cycle), and three cases for testing temperatures (cycles) modify the ageing rate of the product with 3 respective ageing factors.

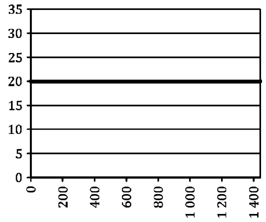
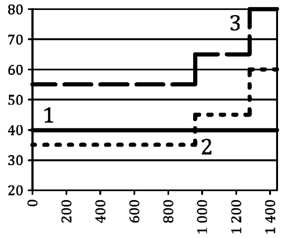
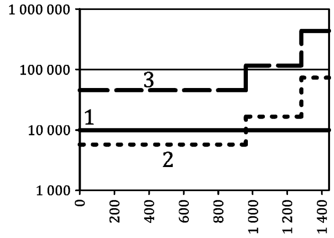
The example 2 and 3 show step stress tests, where stress is increased, after each specified interval, until failure occurs or a predetermined stress level is reached (See EN 62506:2013, 5.6.2.2).

The results for each example are the various acceleration factors. The acceleration factor assumes the relation between the time to failure in use conditions (field) and the time under testing conditions (test).

Example 1:

Use conditions			Testing conditions			Acceleration factor: AF		
Temperatures (°C)/Time, cycle, distance (unit)			Temperatures (°C)/Time, cycle, distance (unit)					
Case 1	Case 2	Case 3	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Average = 20	Average = 20	Average = 20	Average = 40			Average = 10	Average = 13	Average = 14
Ambient air Fixed value	Ambient air 2 thresholds	Ambient air Daily variation	Testing conditions: fixed value			Time to failure: Time (use) = AF * Time (test) Arrhenius: Ea* = 0,9 ev		
								

Example 2:

Use conditions			Testing conditions			Acceleration factor: AF		
Temperatures (°C)/Time, cycle, distance (unit)			Temperatures (°C)/Time, cycle, distance (unit)					
Case 1	Case 2	Case 3	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Average = 20			Average = 40	Average = 40	Average = 60	Average = 10	Average = 16	Average = 104
Ambient air Fixed value			Testing θ	Testing θ 3 thresholds	Testing θ 3 thresholds	Time to failure: Time (use) = AF * Time (test) Arrhenius: Ea* = 0,9 ev		
								

Example 3:

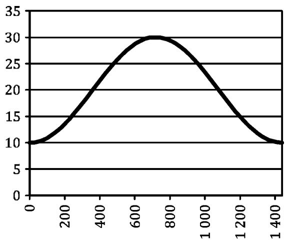
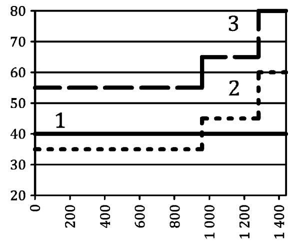
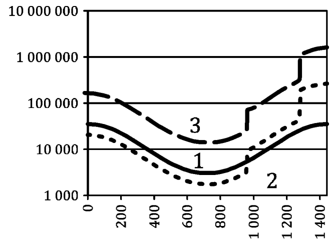
Use conditions			Testing conditions			Acceleration factor: AF		
Temperatures (°C)/Time, cycle, distance (unit)			Temperatures (°C)/Time, cycle, distance (unit)					
Case 1	Case 2	Case 3	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Average = 20			Average = 40	Average = 40	Average = 60	Average = 14	Average = 35	Average = 223
Ambient air daily variation			Testing θ	Testing θ 3 thresholds	Testing θ 3 thresholds	Time to failure: Time (use) = AF * Time (test) Arrhenius: Ea* = 0,9 ev		
								

Figure A.2 — 3 Examples combining use and testing conditions, influencing the acceleration factors

The Table A.1 shows potential observed failures related to the example 2:

Table A.1 — Example of a cumulative damage in % for the example 2

Step	**Use conditions**	**Testing conditions**				**Acceleration Factors (AF)**			Example of cumulative damage (%)		
		Constant	**Step stress tests**		**Test Duration (Time, cycle, distance)**						
	Temperature (°C)	**Temperatures (Test N° 1) (°C)**	**Temperatures (Test N° 2) (°C)**	**Temperatures (Test N° 3) (°C)**		**Test N° 1 Average: 10**	**Test N° 2 Average 16**	**Test N° 3 Average 104**	**Test N°1**	**Test N°2**	**Test N°3**
1	20	40	35	55	960	9.8	5.7	44.9	0	0	0
2	20	40	45	65	320	9.8	16.5	115.1	0	1	4
3	20	40	60	80	160	9.8	72.4	427.8	0	3	9

Example 2 highlights three acceleration factors with the related to the following expectations:

— The analysed part is expected to operate during 5 years under the normal use conditions

— The test time unit is hour

— The energy of activation Ea is 0.9eV and Arrhenius’s law is the damage model

In accordance with these expectations, the preferred test sequence is the N°3 for the following reasons:

Test N°1: AF is 9.8 and the test duration should be 5 × 365 × 24/9.8 = 4469 h > 1440 h

Test N°2: AF is 16 and the test duration should be 5 × 365 × 24/16 = 2737 h > 1440 h

Test N°3: AF is 104 and the test duration should be 5 × 365 × 24/104 = 421 h < 1440 h and if 10 % is the maximum acceptable cumulative damage during the expected lifespan (5 years).

Annex B
(informative)

Additional details on test development

B.1 Stress modelling

The following procedure should be applied:

— identify the relevant stress factors from the field (see the EN 60721 series or similar standard);

— determine which stress types have to be accelerated, which will be nominal and which can be omitted, e.g. because they are covered by other tests;

— determine if the stresses can be applied simultaneously to include stress interactions or whether they will have to be applied sequentially, e.g. in a test cycle (see EN 60605-2 or similar standard);

— determine if the acceleration factor (AF) can be estimated from the test or estimate the acceleration factors based on relevant acceleration equations and relevant empirical factors;

— determine the sample size (see EN 61649, IEC 61123, IEC 61124 or similar standards);

— perform the test (see EN 60300-3-5 or similar standard);

— perform failure analysis;

— analyse the test – each failure mode separately (see EN 61649, EN 61710, EN 61124 or similar standards);

— report test result (see EN 60300-3-5 or similar standard).

EN 62506:2013 or similar standard should be used for more detail about the quantitative test methods, using multiple stresses accelerations and life test (see EN 62506:2013; 5.7.2).

B.2 Accelerated tests

When accelerated tests are carried out the EN 62506:2013 or similar standard should be applied, which provides guidance on the application of various accelerated test techniques for measurement or improvement of product reliability.

EN 62506:2013 standard addresses accelerated testing of non-repairable and repairable products. It can be used for probability ratio sequential tests, fixed duration tests and reliability improvement/growth tests, where the measure of reliability differs from the standard probability of failure occurrence. This standard also includes accelerated testing or production screening methods that would identify weakness introduced into the product by manufacturing error.

Figure B.1 could be applied.

NOTE Figure B1 has been modified from EN 62506:2013 to show the most appropriate accelerated testing methods type B and type C focussing to the useful lifetime under precaution as mentioned by the standard.

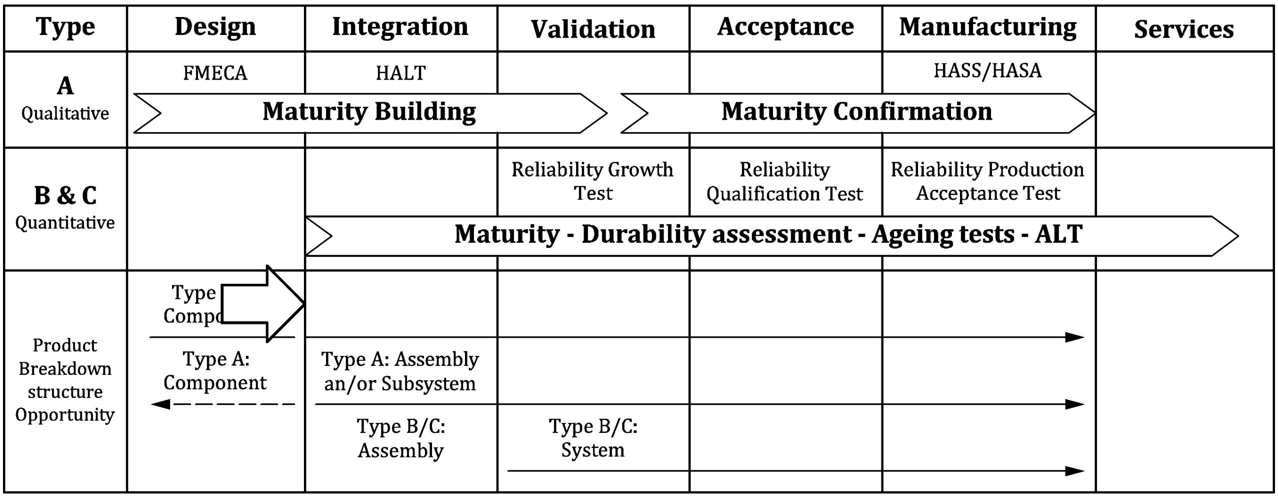


Figure B.1 — Accelerated Life Tests (ALT) - Life tests (EN 62506:2013, modified)

There are three distinctly different approaches:

— Type A: qualitative accelerated tests: for detection of failure mode and/or phenomenon; It verifies, through analysis and testing, that there are no potential failure modes in the product that are likely to be activated during the expected life time of the product under the expected operating conditions;

— Type B: quantitative accelerated tests: for prediction of failure distribution in normal use; it estimates how many failures can be expected after a given time under the expected operating conditions. Type B tests use cumulative damage methods to determine product reliability projected to the end of the expected product life.

— Type C: quantitative time and event compression tests: for prediction of failure distribution in normal use. Type C tests are mostly used for estimation of the life time of parts where wear-out in active use is the dominating failure mode; for example switches, keyboards, relays, connectors or bearings. Time compression is achieved by eliminating “OFF-time” (e.g. non-operating time) by compressing the duty cycle through addressing just the ON time.

The purpose of quantitative accelerated tests type B and C, is to estimate one or more measures of reliability, e.g. failure rate, probability of failure or survival, or time to failure (TTF). Often the purpose of quantitative accelerated testing is to determine the life time of parts with a limited life (wear-out), or to determine (quantify) and improve the reliability of products and parts. For this, Weibull analysis is very useful (see EN 61649 or similar standard).

For a quantitative accelerated test (Type B and C test) the number of items are mainly determined by whether the purpose of the test is to estimate the average constant risk (exponential failure distribution assumed) or the purpose is to estimate the time to failure (life time) for the items.

For quantitative accelerated tests (Type B and C) the acceleration factor has to be estimated to link the test time with the equivalent time in the field. Each failure mode has to be analysed separately. Therefore a failure analysis is required for all failures. Once an estimate has been made for each failure mode observed, the failure probability and time to failure can be added to estimate the failure probability of the product as a function of time. Statistical tools that can be used for analysis include the following standards: IEC 61123, IEC 61124, EN 60605-6, EN 61649, EN 62506:2013, EN 62429 or similar standards.

Annex C
(informative)

Maintanance and repair considerations for an increased reliability and durability

C.1 General

This Annex includes considerations relating to the design phase which are not part of the assessment.

Maintenance can in general improve both reliability and durability Note: There might also be trade-offs between durability and reparability, as a design feature which supports durability and reliability could hinder easy repair.

The type and nature of a product affects the durability specifications, and products have varying degrees of reparability. For example, some include maintenance actions and planned exchange of wear-out parts as a normal element of the use cycle and are usually be repaired. While for other products like small consumer products repair is sometimes not foreseen by product design and spare part availability.

Durability and reliability analysis enable the identification of relevant functions and parts, and likely limiting states, which provide product-specific users of this document with insights on the repair and maintenance strategies necessary to reaching durability expectations beyond time to first limiting event. Figure C.1 shows the relation between the functional state, the limiting state reached after a limiting event, the repair period and what is within the durability. When a durability focuses only to the physic of failure such as the fatigue or wear-out the period of durability is limited to the period covered by non-repairable item.

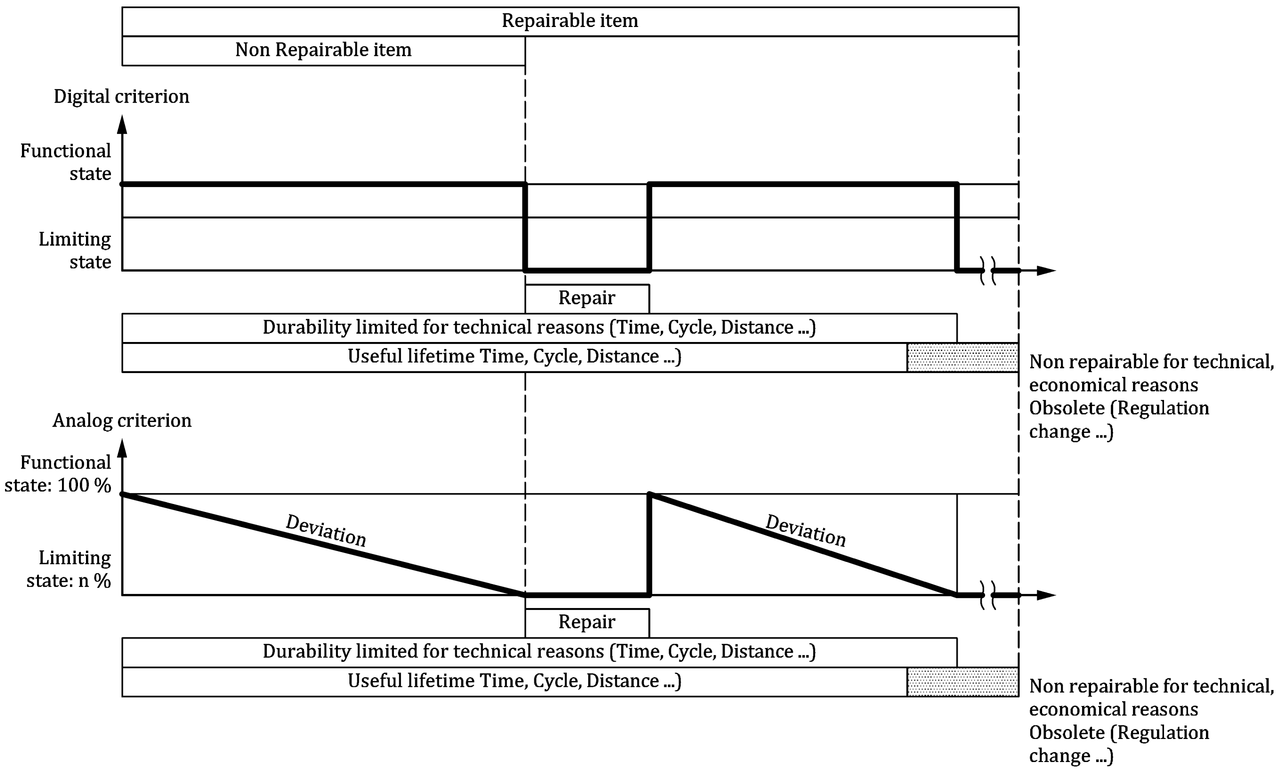


Figure C.1 — Relations between functional state, limiting state, repair and durability

C.2 Wear-out parts and spare parts considerations

Linked to the analysis of repair and maintenance strategies is the identification of replaceable parts to facilitate such actions. It is recommended to classify parts for replacement in accordance with their influence on the targeted product or function.

Wear-out parts are those expected to need replacement during the product lifetime. When maintenance action is anticipated, it is a condition-based-maintenance action. Spare parts are those made available to replace worn out parts, but also parts in which limiting event has occurred.

Wear-out and spare parts vary depending upon the product design, product specific standard and the manufacturer.

EXAMPLE 1 Parts considered to be affected by wear-out are for example: bulbs, filters, wheels, gaskets.

EXAMPLE 2 Parts considered not to be affected by wear-out are for example: cables, adaptors, thermostat, timers.

Table C.1 gives examples for different types of parts, although the distribution strategy will be the choice of the manufacturer but could be linked to a maintenance strategy.

Table C.1 — Example of parts

		Spare parts	
		Parts identified in 6.2	**Other parts**
	Primary and secondary functions		**Tertiary functions**
Product groups	**Consumable**	**Wear-out part expected to be periodically replaced along cycle, distance, duration**	**Wear-out part not expected to be periodically replaced along cycle, distance, duration**
Example of classification depending linked to the product group	Water, ink cartridge, paper, grease, paper filter, cleaner (powder, liquids), fuse, surge arresters….	bulbs, filters, brushes, hoses, wheels, bearings, gaskets, sealing, spray arms, oil, batteries, tap changer contacts….	Cables, adaptors, remote controls, sensors, thermostat, timers, valves, pumps, motors, thermostats PCBs modules, control buttons, human machine interface, bushings…
NOTE Parts can be subject to more than one category depending on product design, such as batteries.			

Annex D
(informative)

Additional details on limiting event and limiting state

Figure D1 below shows the key states of functional states where the product is running and the limiting state where a limiting event has occurred. A limiting event could be a failure for example be a broken part, an electrical insulation lost, a flash over through electrical insulation material. In addition a limiting event could be a wear-out failure for example a noisy bearing, and also could be a signal out of expected tolerance like a consumption measurement, a LED brightness, a LCD readability, an environmental disturbance (noise, EMF,...) etc.

Product operation and its parts shift between functional states and limiting states on the basis of the transitions such as maintenance and repair actions and the limiting events. If a product is running / functional states and a limiting event occurs, the required function is not delivered. The product will then be in a limiting state. It is transitioned back into a functional state if maintenance or repair action is applied.

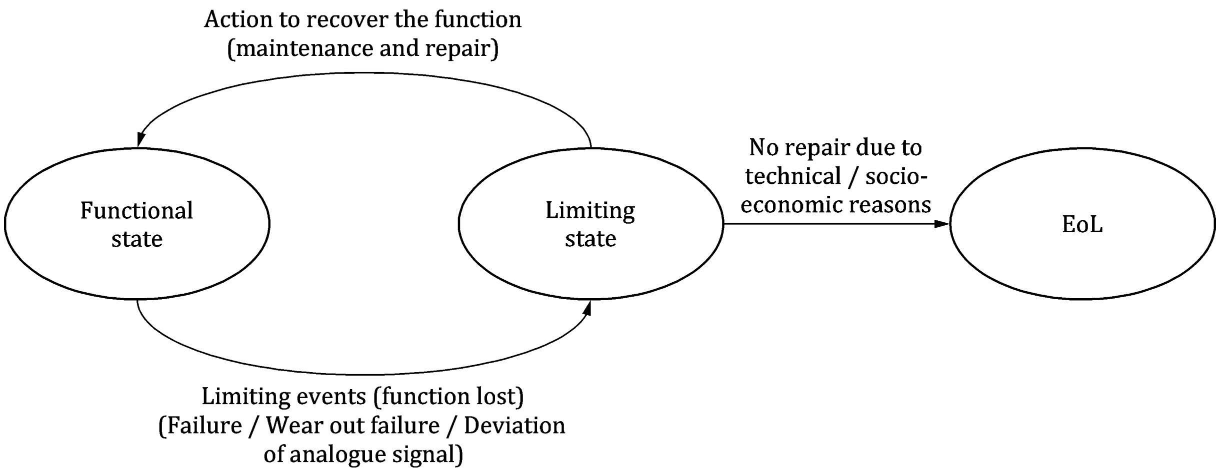


Figure D.1 — Main event and state relation

A limiting state can occur due to part failure or wear-out, or could be from a deviation of an analogue signal. Limiting states can be caused by misuse. For example, the use of an ErP to carry a non-expected load, the use of an ErP outside its scope or its normal environmental and operating conditions. Some misuse are reasonably foreseeable – for example the use of a product, process or service in a way not intended by the manufacturer, but which result from readily predictable human behaviour. For example, a use of hair dryer to dry clothes, reducing the distance so limiting the air flow creating a temperature rise and cause a failure.

Bibliography

[1] CLC/prEN 45554, *General methods for the assessment of the ability to repair, reuse and upgrade Energy-related Products*

[2] EN 60300-3-5, *Dependability management — Part 3-5: Application guide – Reliability test conditions and statistical test principles*

[3] EN 60605 (all parts), *Equipment reliability testing*

[4] EN 60721 (all parts), *Classification of environmental condi0tions*

[5] EN 61025, *Fault tree analysis (FTA)*

[6] EN 61123, *Reliability testing — Compliance test plans for success ratio*

[7] EN 61124, *Reliability testing — Compliance tests for constant failure rate and constant failure intensity*

[8] EN 61649, *Weibull analysis*

[9] EN 61703:2016, *Mathematical expressions for reliability, availability, maintainability and maintenance support terms*

[10] EN 61709, *Electric components — Reliability — Reference conditions for failure rates and stress models for conversion*

[11] EN 61710, *Power law model - Goodness-of-fit tests and estimation methods*

[12] IEC/TR 62380, *Reliability data handbook. Universal model for reliability prediction of electronics components, PCBs and equipment*

[13] EN 62429, *Reliability growth - Stress testing for early failures in unique complex systems*

[14] ISO 14044, *Environmental management — Life cycle assessment — Requirements and guidelines*

[15] EN 62542:2017, *Environmental standardization for electrical and electronic products and systems — Glossary of terms*