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Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड़ नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”

Indian Standard

RELIABILITY STRESS SCREENING

PART 1 REPAIRABLE ASSEMBLIES MANUFACTURED IN LOTS

( First Revision )

ICS 03.120.01; 03.120.30; 21.020

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 16
NATIONAL FOREWORD

This Indian Standard (Part 1) (First Revision) which is identical with IEC 61163-1 : 2006 ‘Reliability stress screening — Part 1: Repairable assemblies manufactured in lots’ issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Reliability of Electronic and Electrical Components and Equipment Sectional Committee and approval of the Electronics and Information Technology Division Council.

This standard was originally published in 2004 which was identical with IEC 61163-1 : 1995. The first revision of this standard has been undertaken to align it with the latest version of IEC 61163-1 : 2006.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appear referring to this standard, they should be read as ‘Indian Standard’.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

<table>
<thead>
<tr>
<th>International Standard</th>
<th>Corresponding Indian Standard</th>
<th>Degree of Equivalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 60050 (191) : 1990 International Electrotechnical Vocabulary (IEV) — Chapter 191: Dependability and quality of service</td>
<td>IS 1885 (Part 39) : 1999 Electrotechnical vocabulary: Part 39 Dependability of electronic and electrical items (second revision) IS 1885 (Part 45) : 1977 Electrotechnical vocabulary: Part 45 Capacitors IS 9000 (Part 3/Sec 1 to 5) : 1977 Basic environmental testing procedures for electronic and electrical items: Part 3 Dry heat test, Section 1 General Section 2 Dry heat test for non-heat dissipating items with sudden change of temperature Section 3 Dry heat test for non-heat dissipating items with gradual change of temperature Section 4 Dry heat test for heat dissipating items with sudden change of temperature Section 5 Dry heat test for heat dissipating items with gradual change of temperature</td>
<td>Technically Equivalent do</td>
</tr>
</tbody>
</table>

IS 15444 (Part 1) : 2012
IEC 61163-1 : 2006

Reliability of Electronic and Electrical Components and Equipment Sectional Committee, LITD 02
<table>
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<tbody>
<tr>
<td>IEC 60068-2-6 Environmental testing — Part 2-6: Tests — Test Fc: Vibration (sinusoidal)</td>
<td>IS 9000 (Part 8) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 8 Vibration (sinusoidal) test, IS 9001 (Part 13) : 1981 Guidance for environmental testing: Part 13 Vibration (sinusoidal) tests, IS 9000 (Part 14/Sect 1 to 3) : 1988 Basic environmental testing procedures for electronic and electrical items: Part 14 Test N: Change of temperature, Section 1 Test Na: Rapid change of temperature (thermal shock) with prescribed time of transition — Two chamber method (first revision) Section 2 Test Nc: Change of temperature (temperature cycling) with specified rate of change — One chamber method (first revision) Section 3 Test Nc: Rapid change of temperature (thermal shock) — Two fluid bath method (first revision)</td>
<td>Technically Equivalent</td>
</tr>
<tr>
<td>IEC 60068-2-29 Environmental testing — Part 2-29 Tests — Test Eb and guidance: Bump</td>
<td>IS 9000 (Part 5/Sect 2) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 5 Damp heat (cyclic) test, Section 2 12 + 12h cycle</td>
<td>do</td>
</tr>
<tr>
<td>IEC 60068-2-30 Environmental testing — Part 2-30 Tests — Test Db: Damp heat, cyclic (12 h + 12 h cycle)</td>
<td>IS 9000 (Part 4) : 2008 Basic environmental testing procedures for electronic and electrical items: Part 4 Damp heat (steady state) (first revision)</td>
<td>Identical</td>
</tr>
<tr>
<td>IEC 60068-2-78 : 2001 Environmental testing — Part 2-78 Tests — Test Cab: Damp heat, steady state</td>
<td>IS 11717 : 2000 Vocabulary on vibration and shock (first revision)</td>
<td>do</td>
</tr>
</tbody>
</table>

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

<table>
<thead>
<tr>
<th>International Standard</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 60068-2-64</td>
<td>Environmental testing — Part 2-64: Test methods — Test Fh: Vibration, broadband random (digital control) and guidance</td>
</tr>
<tr>
<td>IEC 60300-2</td>
<td>Dependability management — Part 2: Guidelines for dependability management</td>
</tr>
</tbody>
</table>
Only the English language text has been retained while adopting it in this Indian Standard and as such the page numbers given here are not the same as in the IEC Publication.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (revised)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.
INTRODUCTION

Quality control and good design are prerequisites for reliability. However, in cases where an assembly has an unacceptably low reliability in the early failure period, a reliability screening process may be necessary.

An unacceptably low reliability level can be different from one customer to another, or can be based on general market requirements.

Reliability stress screening (RSS) and reliability growth programmes both aim at improvements in the reliability found by the user. However, the two methods are different in principle:
– a reliability growth programme is a development activity, the purpose of which is to improve the inherent reliability performance of the assemblies by effecting changes to the design (see IEC 61014 and IEC 61164);
– the purpose of reliability stress screening is to detect and remove flaws; it is part of the production process, and should not be relied upon to reveal inadequacies in design.

Furthermore, the two methods affect the reliability performance differently. This is illustrated in Figure 1. In principle, a reliability screening programme "cuts away" the early failure period (or part thereof), while a reliability growth programme reduces the overall failure rate level. A reliability growth programme may affect the need for a reliability screening programme if the flaws are of such a nature that they can be prevented from being present at all.

The user of this standard should be aware that reliability stress screening does not improve the intrinsic reliability of the assemblies under consideration and, where possible, should be made unnecessary by reliability growth programmes and/or quality control.

In this standard the term “Item” is used when it is not necessary to distinguish between components, assemblies and system(s).

The specific purpose of carrying out a reliability screening process is to detect and remove flaws in hardware assemblies before they reach the customer, or are assembled into higher-level products. This means that, in principle, every hardware assembly under consideration should be included when a reliability screening process is introduced into a production process.

Reliability screening may cover hardware assemblies of different types and at different levels of the manufacturing process. This standard covers composite items – assemblies which are intended to be repaired. Once the allowable fraction of weak assemblies has been specified, the methods in this standard lead to the most economical screening process for assemblies that are manufactured in lots. This is because not all types of assemblies need to be subjected to a reliability screening process. Only the types of assemblies likely to contain flaws should be included. Furthermore, the extent (stress conditions, duration, etc.) to which these selected assembly types will be subjected to screening needs to be minimized.

In reliability stress screening the flaws are precipitated into failures by exposure of the assemblies to a suitable stress, for example environmental stress, operational stress, or a combination of these. Reliability stress screening is often called environmental stress screening (ESS).
If rogue components are known about and proved to originate in the component manufacturing process, it is much more effective to use screening e.g. burn-in of the rogue components in question instead of the assembly. However screening a component cannot remove flaws introduced in the assembly process (e.g. soldering, handling (ESD) etc.).

The typical steps in a reliability stress screening process are illustrated in Figure 2.

NOTE This standard addresses reliability screening only. For reliability growth see IEC 61014 and IEC 61164.

**Figure 1 – Conceptual difference between reliability screening and growth**
Specify the maximum allowable fraction of weak assemblies
J.2 step 1

Evaluate the actual fraction of weak assemblies
J.2 step 2

Is the actual fraction of weak assemblies equal to or lower than the specified value?

Yes
Reliability stress screening is not necessary
8.5 and J.2 step 2

No
Reliability stress screening is necessary
J.2 step 2

Perform the reliability stress screening, collect and analyse the failure information generated 1)
6.3, 7, 8 and J.3

Design of modify (if necessary) the reliability stress screening
6.2 and J.2 step 3 to step 5

Start

Stop

1) The result of the analysis of the failure causes may be used in a reliability growth and quality control programme.

Figure 2 – Typical flow for the design and modifications of reliability stress screening processes for repairable assemblies
1 Scope

This part of IEC 61163 describes particular methods to apply and optimize reliability stress screening processes for lots of repairable hardware assemblies, in cases where the assemblies have an unacceptably low reliability in the early failure period, and when other methods, such as reliability growth programmes and quality control techniques, are not applicable. The reasons for using reliability stress screening may be time constraints and/or the very nature of the deficiencies that the reliability stress screening is designed to catch.

The processes apply to any stage of a series production of repairable assemblies (see Figure 3). The methods for setting up a process can be used during production planning, during pilot-production, as well as during well-established running production.

A prerequisite for the application of the methods is that a certain level of flaws remaining in the outgoing assembly can be specified.

The processes described are general processes for reliability stress screening in cases where no specific process is described in a product standard. They are also intended for use by IEC committees in connection with preparation of product standards. A reliability stress screening process can form part of an overall reliability programme (see IEC 60300-2).

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): International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service

IEC 60068-2-2: Environmental testing – Part 2-2: Tests – Test B: Dry heat

IEC 60068-2-6: Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)

IEC 60068-2-14: Environmental testing – Part 2-14: Tests – Test N: Change of temperature

IEC 60068-2-29: Environmental testing – Part 2-29: Tests – Test Eb and guidance: Bump

IEC 60068-2-30: Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)

IEC 60068-2-64: Environmental testing – Part 2-64: Test methods – Test Fh: Vibration, broadband random (digital control) and guidance

IEC 60068-2-78: Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state
Possible applications of reliability stress screening process for repairable items as indicated by the arrows below.

NOTE  Screening may be made on subsystems (left black circle and open circle) or on system level (right black circle).

Figure 3 – Typical flow of hardware assemblies from the component manufacturer to the end user
3 Terms and definitions

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

NOTE 1 Unless otherwise stated, general reliability terms used in this standard conform to IEC 60050(191).

NOTE 2 Terms of particular importance for reliability stress screening of repairable assemblies are quoted with the IEC 60050(191) reference number stated in square brackets. Where certain notes do not apply, the term "modified" has been used. All comments on an IEV term, relevant to reliability stress screening, are stated as "additional notes".

NOTE 3 Other terms defined in this clause are specific to reliability stress screening.

3.1 reliability improvement

process undertaken with the deliberate intention of improving the reliability performance by eliminating causes of systematic failures and/or by reducing the probability of occurrence of other failures

[IEV 191-17-05]

ADDITIONAL NOTE Reliability stress screening reduces the probability of occurrence of other failures. The systematic failures are principally catered for by a reliability growth programme, but some may appear during reliability screening.

3.2 reliability screening

process of detection of flaws and removal or repair of weak assemblies for the purpose of reaching rapidly the reliability level expected during the useful life

NOTE 1 IEV 191-17-02 defines the term "burn-in". This term, however, is used by many manufacturers to describe a so-called "soak test", which is only one of many possible ways of screening. Furthermore, "burn-in" may include ageing, the purpose of which is to stabilize parameters, and in many cases where no failures occur.

NOTE 2 IEV 191-14-09 defines the term "screening test". This term, however, is defined too broadly to be applicable in the present context, because it encompasses screening for any type of non-conformities. Furthermore, reliability screening is a process, not a test.

3.3 reliability stress screening

reliability screening process using environmental and/or operational stresses as means of detecting flaws by precipitating them as detectable failures

NOTE Reliability stress screening is designed with the intention of precipitating flaws into detectable failures. An ageing process designed with the intention of stabilizing parameters is not a reliability screening process, and therefore, lies outside the scope of this standard.

3.4 item

any part, component, device, subsystem, functional unit, equipment or system that can be individually considered

NOTE 1 An item may consist of hardware, software or both, and may also, in particular cases, include people.

NOTE 2 In French the term "entité" is preferred to the term "dispositif" due to its more general meaning. The term "dispositif" is also the common equivalent for the English term "device".

NOTE 3 In French the term "individu" is used mainly in statistics.

NOTE 4 A number of items, for example a population of items or a sample, may itself be considered as an item.

[IEV 191-01-01]

ADDITIONAL NOTE 1 In this standard the term “item” is used when there is no need to distinguish between components, assemblies and system(s)
ADDITIONAL NOTE 2  In the context of reliability screening, only the hardware part of an item is relevant. Current examples are electronic components, assemblies, equipment, and hardware parts of systems.

3.5 assembly
any composite item which is intended to be repaired

3.6 weak assembly
assembly which has a high probability of failing early in life, due to a flaw

3.7 component
any single item which is not intended to be repaired

3.8 component class
group of components characterized by having one or more of the following features in common
– technology;
– type;
– manufacturer;
– batch

3.9 rogue component class
component class, which is likely to contain components with inherent and/or induced flaws

NOTE The lifetime distribution of a rogue component class can, for the purpose of reliability stress screening, be approximated with a bimodal distribution. This means that the individual component may be either weak or strong.

3.10 relevant failure
failure that should be included in interpreting test, or operational results, or in calculating the value of a reliability performance measure

NOTE The criteria for inclusion should be stated.

[IEV 191-04-13]

ADDITIONAL NOTE The criterion for inclusion here is that the failure is caused by either an induced or an inherent flaw.

3.11 weakness
any imperfection (known or unknown) in an assembly, capable of causing one or more weakness failures

NOTE Each type of weakness is assumed to be statistically independent of all other such types.

3.12 weakness failure
failure due to weakness in the assembly itself when subjected to stress within the stated capability of the assembly

NOTE A weakness may be either inherent or induced.

[IEV 191-04-06, modified]
3.13 flaw
weakness in hardware which gives rise to early weakness failures

NOTE A flaw is localized to a component, or to an interaction between components, with characteristics close to the margins of the design requirements.

3.14 inherent flaw
flaw in an assembly related to its technology and manufacturing process

3.15 induced flaw
flaw in an assembly related to assembling, testing, handling, or other manipulation of the assembly after it has been manufactured

NOTE The induction may take place at the component manufacturer’s plant, during transportation or at the system manufacturer’s plant.

3.16 early failure period
that early period, if any, in the life of an item, beginning at a given instant of time and during which the instantaneous failure intensity for a repaired item, or the instantaneous failure rate for a non-repaired item, is considerably higher than that of the subsequent period

[IIEV 191-10-07, modified]

ADDITIONAL NOTE The early failure period is the period where the weak assemblies fail.

4 Symbols

For the purposes of this standard, the following symbols apply.

- $m_{F_1}$: the mean time to failure for the weak components in the rogue component classes lumped together
- $m_{F_s}$: the mean time to first failure for the weak assemblies among the assemblies under consideration
- $N$: the sum of the numbers of components in the rogue component classes
- $p_B$: the acceptable fraction of weak assemblies remaining after reliability stress screening
- $p_c$: the fraction of weak components in the rogue component classes lumped together
- $p_s$: the fraction of weak assemblies before reliability stress screening
- $T_B$: average duration of reliability screening per assembly
- $T_M$: the failure-free period an assembly has to survive before submission to the next production step or to the customer

5 General description

5.1 The reliability stress screening principle

The general principle of reliability stress screening is shown on the flow diagram in Figure 4. According to this principle, an assembly shall survive a so-called "failure-free period", $T_M$, before it is released to the next step of production, or to the customer. Other screening principles may be possible, but are not covered by this standard.
Stress conditioning

Testing

Function Ok? Yes

Release

Start

Testing

Function Ok? No

Scraping? Yes

Stop

Function Ok? No

Repair

Monitoring type?

First partial stress conditioning

First testing

Function OK? Yes

Second partial stress conditioning

Second testing

Function Ok? Yes

Final testing

Function Ok? No

Release

Release

Release

Yes

No

Yes

No

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The flow diagram shows three alternatives in connection with stress conditioning:

- alternative A shows two function checks, one before and one after the stress conditioning;
- alternative B shows performance monitoring at discrete points in time with time intervals, preferably selected according to a logarithmic scale, so that the closest monitoring takes place at the beginning of the stress conditioning;
- alternative C shows continuous monitoring during the entire stress conditioning. This alternative is preferable, especially for complex products, because of:
  - time and cost saving;
  - detection of intermittent failures and of failures present only during the action of the stress;
  - avoidance of stressing after a failure.

Performance monitoring is of particular importance during pilot-production reliability stress screening. During reliability stress screening of mature production the performance monitoring under stress conditioning may be deleted, according to the circumstances. However, the two function checks, one before and one after the stress conditioning period, can never be omitted. It is essential that assemblies are not put directly under stress conditioning without the initial function check.

The extent and the details of the functional checking before, during and after the stress conditioning depend strongly on the nature and intended function of the assemblies in question. This standard contains no guidance in that respect. The procedures described hereafter, however, presume that the function checks are efficient in evidencing failures.

The further details of the screening procedures depend on the time phase from product design to mature production. Three stages are considered:

- planning of reliability stress screening;
- pilot-production reliability stress screening;
- mature production reliability stress screening.

5.2 Failure categories

Assemblies that fail during a reliability stress screening shall be carefully examined in order to establish the failure modes, mechanisms, and/or causes.

For the purpose of defining corrective actions, the failure shall be classified according to the following three categories, based on an assessment of the above-mentioned examination result:

a) inadequate product design;

b) inherent flaws;

c) induced flaws.

Referring to Figure 5, the classification may differ depending on whether the assessment takes place at the component manufacturer’s or at the assembly manufacturer’s.

Inadequate component design and flaws induced into the component by the component manufacturer become inherent flaws for the assembly manufacturer.
In most cases, only the induced and inherent flaws can be weeded out by the screening process. However, in some cases a screening process may be applied to cater for marginal design problems, and/or for processes, which are difficult to control.

![Figure 5 – Dependency of categories of failures](image)

### 5.3 Time of occurrence of failures

The time of occurrence of failures shall be recorded and evaluated. This is a vital part of the reliability stress screening process, making it possible to monitor it permanently in order to ensure that the failure data used for the design of the process are still relevant.

### 6 Planning

#### 6.1 Stress conditioning

##### 6.1.1 General

Stress conditioning is composed of the screening duration and the stress conditions as illustrated in Figure 6. Stress conditions are defined in terms of levels, cycles and type.

![Figure 6 – Elements of stress conditioning](image)

##### 6.1.2 Stress conditions

Preferably, the stress conditions should be tailored for the assemblies under consideration. They shall aim at excitation of flaw-related failure mechanisms likely to create failures in the field, without altering the characteristics of sound assemblies or sound parts of an assembly.
The procedure for the choice of stress condition is as follows:

a) consider the expected field conditions, i.e. the operational and environmental stresses in the field, and list as far as possible the weaknesses likely to give early failures under these conditions, taking into account the design and the manufacturing process of the assembly. The weaknesses considered should not only include previously seen failures but also failure modes that, from an engineering point of view, are possible.

b) group the weaknesses listed into the following three groups:
   1) weaknesses that can be removed cost-effectively by design or process modifications. Reliability stress screening should not be applied to remove weaknesses of this kind.
   2) weaknesses that can be removed cost-effectively by some kind of inspection or process control during production. These should not be taken care of by reliability stress screening. Visual inspection, process control or reliability indicator screening should be used.
   3) the remaining weaknesses constitute the flaws that can be removed by reliability stress screening.

   NOTE In cases 1 and 2 screening can be used until the changes are implemented and effective.

c) consider the flaws and evaluate the environmental and/or operational stresses which are most likely to develop these flaws into failures. Guidance concerning the effect of different stress conditions can be found in Annexes B to G.

d) select among the stresses identified the most efficient stress condition/conditions, including their sequence and/or combinations. The stresses selected may not be directly related to the field conditions. Guidance concerning preferred stress conditions and their efficiency can be found in Annex A.

e) for each stress condition, evaluate the maximum stress level, which can be used without overstressing any component in the assembly under consideration. This will normally mean that the stress should be within the specified operating limits of the assembly, rather than the constituent component, unless specifically agreed upon (‘highly accelerated stress screening’).

6.1.3 Screening duration

The screening duration is the accumulated relevant time during which an assembly is exposed to the screening stress conditions. It is a stochastic variable, which depends on how many times the assembly has to be repaired before it has survived a predetermined failure-free period (see Figure 7).

For an assembly without flaws, the screening duration is likely to be one failure-free period.

For an assembly with many flaws, or susceptible to induction of flaws (for example during repair), the screening duration will generally be longer. For technical and/or economical reasons, it may be necessary to limit the maximum permissible number of repairs. Assemblies exceeding that number shall be scrapped (see Figure 4). A method for the calculation of the average screening duration appears in Annex I.
NOTE 1 The total length of the "thick" lines constitutes the screening duration.

NOTE 2 The assembly should show a failure-free period \( T_M \) before being accepted.

**Figure 7 – Assembly showing screening duration**

### 6.2 Evaluation of the failure-free period \( T_M \)

#### 6.2.1 General considerations

If sufficient information is available, for example from previous similar products, the failure-free period may be estimated as shown in 6.2.3 and 6.3. After the pilot production screening (see Clause 7) the estimated \( T_M \) is updated.

If sufficient information is not available, the pilot production screening can be made with a \( T_M \) that is of sufficient length that all flaws are expected to be precipitated. The analysis of the pilot production screening will confirm if this is the case (the failure curve will have levelled out – see Figure J.4) and thus allow the optimum, shorter \( T_M \) to be estimated.

#### 6.2.2 Collection of information

The necessary information for the determination of the failure-free period, \( T_M \), includes the following:

- the fraction of weak components in each of the rogue component classes;
- the mean time to failure for the weak components in each of the rogue component classes;
- the sum of the numbers, \( N \), of components in the rogue component classes;
- the acceptable fraction, \( p_B \), of weak assemblies that can be submitted to the next level of production, or to the customer.

The first step is to identify the rogue component classes, which for a good design should be few. Previous experience from reliability stress screening and/or field failure reports on systems, for which similar assembling and component technology has been applied, can be used.

For the determination of the fraction of weak components and the mean times to failure of the weak components in the rogue component classes, it is necessary to make some educated guesses, which also can be based on previous experience as indicated above. The values of the mean times to failures should be assessed for the proposed stress screening conditions.
A very high degree of accuracy is not necessary in the planning procedure, as corrections can be made after pilot production and/or during actual production. If sufficient information is not available, it is recommended that a large $T_M$ be chosen, as described in 6.2.1 and that the estimate be updated after the pilot-production screening.

The value of $N$ is accurately calculated by counting the number of components in the rogue component classes in the assembly.

Finally, the choice of a value for $p_B$ is a decision, which should be based on market requirements and customer requirements.

For reliability stress screening on several production levels, the value of $p_B$ for the final product should be decided first. The $p_B$ values for the intermediate production levels should then be determined in order to achieve the final value.

### 6.2.3 Determination of the failure-free period $T_M$

The analysis of the pilot-production screening is based on the Weibull distribution. However, for the first determination of the failure free period, a simpler model is used. This model for screening assumes that the lifetime distribution for the weak assemblies is exponential and that the strong assemblies in practical terms have infinite lifetimes. This assumption is useable for engineering purposes.

The procedure for the determination of the failure-free period, $T_M$, consists of six steps.

**Step 1**: The various rogue component classes are lumped together as one "anonymous" component class.
- the early failure fraction, $p_c$, is set equal to the largest of the values evaluated under 6.2.2.
- the mean time to failure, $m_{F1}$, for the weak components in this class is set equal to the largest of the values evaluated under 6.2.2.

**Step 2**: Compute the expected fraction, $p_s$, of weak assemblies at time zero before screening, using the following formula:

$$ p_s = 1 - (1 - p_c)^N $$

where

- $p_c$ is the early failure fraction of the "anonymous" rogue component class;
- $N$ is the total number of components in the "anonymous" rogue component class in the assembly.

**Step 3**: Compare $p_B$ with the value of $p_s$ determined in step 2.

- If $p_B > p_s$ screening is not necessary.
- If $p_B < p_s$ screening is necessary. Then proceed to step 4.
Step 4: Look up the time graph in 6.3 that corresponds to the early failure fraction, $p_c$ (see step 1). If $p_c$ is not on the graphs, then choose the nearest value and recalculate the $N$ values on the graphs by:

$$N_n = N' \frac{p_c'}{p_c}$$  \hspace{1cm} (2)

where

- $N'$ and $p_c'$ are the printed values on the actual time graph;
- $N_n$ is the recalculated $N$ values corresponding to the present value of $p_c$.

Step 5: Find the value of $p_B$ on the vertical scale on the selected time graph and draw a horizontal line to intersect the curve for the specific value of $N$, the total number of components in the "anonymous" rogue component class.

Step 6: At the point of intersection, read off the value on the horizontal scale. This is the failure-free period, normalized with respect to $m_{F1}$ (see step 1). Multiply this value by $m_{F1}$ to find the failure-free period $T_M$.

6.3 Time graphs for determination of the failure-free period

Figures 8a to 8h give the normalized failure-free period $T_M$ as function of the fraction $p_B$ of weak assemblies remaining after reliability stress screening and as a function of the total number, $N$, of components in the "anonymous" rogue components class.
Figures 8a and 8b – Time graphs for the determination of the failure free period
Figures 8c and 8d – Time graphs for the determination of the failure free period (continued)
Figures 8e and 8f – Time graphs for the determination of the failure free period (continued)
Figures 8g and 8 h – Time graphs for the determination of the failure free period (continued)
7 Pilot-production screening

7.1 General

The reliability stress screening is carried out as planned according to Clauses 5 and 6 for all assemblies manufactured during the pilot-production phase.

Careful monitoring (preferably alternative C in Figure 4) is very important here in order to obtain as much information as possible.

7.2 Collection of information

A suitable subset of assemblies is marked for the collection of further information through a prolonged screening. As a rule of thumb, 30 assemblies monitored for a time of \(7T_M\) should provide enough information for a decision for a possible revision.

The information collected for the whole pilot production lot, as well as the subset, shall comprise:

– the type and cause of failures;
– the time to first failure of the assemblies under consideration.

7.3 Evaluation of information

Consideration should be given as to whether the failures are relevant. If they are not, the selected stress condition/conditions (stress types, levels and cycles) should be reconsidered.

If the failures are relevant, a Weibull plot of the times to first failure (see Annex H and IEC 61163-1) shall be made. The shape of the Weibull plot shall be evaluated and it shall be noted whether the curve levels off after the first rise (see Figure 9). If not, the stress conditioning (stress conditions and duration) shall be reconsidered.

NOTE 1 The Weibull plotting technique has been selected, because it is easy to use and caters for the exponential case. However, other plotting techniques may be used as well.

NOTE 2 For determining the parameters of the curve see Annex H where the figure is repeated as Figure H.2.
If a levelling off can be identified, determine the number $N$ of components in the "anonymous" rogue component class that the screening has revealed.

The fraction of weak assemblies (the "horizontal" part of the Weibull curve) is then derived from the Weibull plot. This is the value $p_s$ (the fraction of weak assemblies before screening).

Then calculate the fraction, $p_c$, of the "anonymous" rogue component class using the following formula:

$$p_c = 1 - (1 - p_s)^{1/N} \quad (3)$$

Finally the value of $m_{F_1}$ is calculated with reasonable engineering accuracy using the following formula:

$$m_{F_1} = \frac{m_{F_s} p_c N}{p_s} \quad (4)$$

where $m_{F_s}$ is the mean time to first failure of the weak assemblies (see Annex H).

### 7.4 Re-evaluating the failure-free period $T_M$

With the values of $N$, $p_c$, and $m_{F_1}$ derived in the manner shown above, the failure-free period can be found in the same way as shown in 6.2 (Annex J shows a worked example).
8 Mature production screening

8.1 General
The planned or possible revised reliability stress screening is carried out for all assemblies of the type under consideration.

8.2 Collection of information
The assemblies being screened should preferably still be monitored for failures according to alternative C of Figure 4. In this way, it is possible to investigate failure causes and to make a plot of lifetimes (times to first failure) for each production batch being screened. However, as the failure-free period is $T_M$, there will be no monitoring beyond this time limit.

8.3 Evaluation of information
The failure pattern of the production batch may be different from that of the pilot-production batch in any of the following ways:

a) the components contributing to the failures do not belong to the rogue component classes identified earlier;

b) the failure fraction is different from the value observed previously;

c) the failures occur either much earlier or later than expected;

d) the slope of the early part of the graph as plotted on Weibull paper, is different from that previously observed.

8.4 Dealing with discrepancies

8.4.1 New failure modes
If the rogue component classes in the production batch turn out to be different from those identified during the pre-production screening, a detailed investigation to trace the cause should be carried out. Special attention should be given to handling procedures, production techniques and test procedures.

When the cause has been found, corrective actions should be taken as a matter of course (on the design, the manufacturing process and/or the screening process).

On a short-term basis, the following recommendations may be followed:

- if the overall failure pattern for the assembly still resembles the pattern found during pilot-production, even though the rogue component classes are different, the failure-free period for screening need not be changed;

- if the cumulative pattern of failures shows no indication of levelling off on the Weibull plot, then as an intermediate measure $T_M$ should be doubled for the next few production batches until the root cause of failure (new failure modes) has been found and corrected.
8.4.2 New failure fractions

It sometimes happens that the failing components are the same as those identified during the pilot-production experiments, but the failure fraction after time $T_M$ is significantly different from the expected value. The following recommendations can be followed.

- if the Weibull plot still flattens out at time $T_M$, then $T_M$ need not be changed;
- if the curve does not flatten out, $T_M$ should be doubled;
- in either case, the cause of the change from pre-production results should be found.

As a special case, consider the situation where no early failures are observed during the reliability stress screening, that is all assemblies in the production batch go through the period $T_M$ with no failures. In general, this state of affairs is due to corrective actions having taken place between the time of the pilot-production screening experiments and the full-scale or mature production, and also, of course, due to ongoing corrective actions triggered by the results of screening of the first few production batches. The corrective actions typically may be corrections of bad handling procedures during assembly, correction of poor soldering practices, etc.

The non-existence of early failures is a good sign. In most instances it will, however, be recommended to continue reliability stress screening as a safeguard against bad component batches or out-of-control production procedures.

In many cases, it may be desirable on economic grounds to reduce the failure-free period, and to introduce a new, shorter failure-free period more or less permanently. In the long term, sample monitoring of production batches can be introduced (see 8.5).

8.4.3 Changes in characteristic lifetimes

If the characteristic lifetimes of any of the rogue component classes should become shorter, the Weibull plot will respond by shifting to the left. The value of $T_M$ can be reduced, but the reason for the change in pattern should be investigated beforehand.

A lengthening of the characteristic lifetime in any of the rogue component classes can be more troublesome. As an intermediate measure, the failure-free period shall be doubled. Thereafter, a new Weibull plot is made to determine the new optimum failure free period. The long-term cure is to find the root cause of the change and correct the trouble where it arises.

8.4.4 Changes in Weibull shape parameters

Variation in the slope of the early failures is usually not troublesome in itself. As a rule of thumb, if the Weibull shape parameter ($\beta$) lies between 0.7 and 1.3, there is no need to change the screening procedure, unless a definite trend in the shape parameter values is observed over several production batches. In the case of such a trend, the Weibull plot can still be used to determine the optimum failure free period. However the reason for the trend should be found as a shift in shape parameter often indicates changed failure modes. Once the root cause has been found, the trouble should be corrected where it arises.
8.5 Eliminating reliability stress screening

If no early failures occur during the failure-free period $T_M$, and there is reasonable certainty that this is due to corrective actions or to a learning process having taken place, it will be advantageous for economic reasons to eliminate reliability stress screening (see also 8.4). However, it is recommended to maintain some monitoring, for example monitoring of samples from the production batches.
Stress conditions – General information

A.1 Background information

Stress conditions, for reliability screening purposes, have strong connections with traditional environmental testing, but there are important differences.

Environmental testing makes use of a great variety of environmental parameters and severities. The philosophy is to expose sample assemblies to well-defined and reproducible standardized test conditions, designed to develop the same mechanisms of failure as in real life and which are covered by the test (use, transportation, storage, etc.). This does not necessarily imply a close reproduction of these conditions, but reproduction of the harmful effects on the assembly. The test severities should be related to those of real life in a manner dependent on the type of information wanted from the test.

For short-term performance, the extreme values with a low probability of being exceeded are relevant; for long-term reliability, the average levels and their time distributions are relevant.

Reliability stress screening is fundamentally different from environmental testing in the following ways:

– not just samples, but all assemblies of the lot are exposed to the stress conditions;
– after the exposure to the stress conditions, the assemblies are considered as new;
– reliability stress screening is not a test, and does not imply accept/reject criteria.

This means that the stress conditions should not degrade sound assemblies significantly.

As a rule of thumb, stress screening should not use more than 10 % of the lifetime of components where wear out can be a problem during normal operation. This can be verified by testing a sample for a period of $10 T_M$ multiplied by the maximum permissible number of repairs (see 6.2.1). This narrows the choice of usable stress conditions compared with environmental testing. Therefore, the stress conditions should be carefully designed as concerns the choice of stress types and the selection and control of stress levels.

A.2 Stress types

The commonly used stress types are listed in Table A.1, together with an indication of the intensity of their stress and the magnitude of cost for their application. These indications are to be understood as tendencies only, because no general values can be given concerning the sensitivity of an "average flaw" to a specific stress type, or to the costs of handling, set-up, and equipment.
It is generally understood that stress types with a low intensity of stress generally need a long screening duration in order to be efficient. Magnitude of cost in Table A.1 refers to the screening process and the necessary equipment only. It does not take into account possible costs related to the value of unsold assemblies for the period of the duration of the screening process.

A combination of stress types is often used. In order to simplify the description and avoid repetitions, not all combinations are discussed in this standard. Generally the effect of the combined stress types is the sum of the failure modes of the stresses. However the stress types may interact so that their combined acceleration of the precipitation of flaws into failures is much larger than that achieved with the stresses applied separately.

**EXAMPLE** A high temperature may change the stiffness of plastic parts, so that random vibration causes parts to collide.

### Table A.1 – Stress types – Indication of cost of application

<table>
<thead>
<tr>
<th>Stress type</th>
<th>Intensity of stress</th>
<th>Magnitude of cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>– Temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant high temperature</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>low/high temperature</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>– Vibration and bump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fixed frequency sinusoidal vibration</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>swept frequency sinusoidal vibration</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>random vibration</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>bump</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>– Combination of temperature cycling and random vibration</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>– Combined temperature cycling, random vibration and voltage stress</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>– Humidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant high humidity and temperature cycling</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>high humidity and temperature cycling</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>– Operational stress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant operational stress</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>operational stress cycling</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>– Voltage stress</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>– High rate of temperature change, 6-axis pneumatic actuated vibrations and operational stress</td>
<td>Very high</td>
<td>Very high</td>
</tr>
</tbody>
</table>

Note that the stress type/types should be chosen from those likely to develop the expected flaws into failures (see 6.1.1). The indications of intensity of stress and magnitude of cost should be used only as guidance if more than one stress type are suitable. Stress types can be combined. Any combination of stresses appropriate to precipitate flaws as failures in the product can be used.

### A.3 Stress level

The stress level is a description, using suitable parameters, of the characteristics of the stress; which, together with the stress type, unambiguously defines the stress conditions (see Figure 6). The term "stress level" should therefore be distinguished from the term "severity" generally used in connection with environmental testing (see the IEC 60068 series).
The main difference is that "severity" also incorporates the duration. Another important difference is that in environmental testing, a characterization of the test conditions independent of the assembly under test is aimed at. For practical and economic reasons, this is usually not possible in reliability stress screening.

The stress level is usually not only dependent on the settings of the machinery used for application of the stress, but also dependent on the assemblies under stress. If more than one assembly is stressed at the same time, the stress level may be different from assembly to assembly. To some degree this has to be accepted for practical reasons, but it is important to be aware of such differences in order to avoid misinterpretation of the results.

Annexes B to G give more details of each stress type, together with definitions of stress levels, including factors influencing variations, characteristic examples of effects, and commonly used stress levels.
Annex B
(informative)

Stress conditions – Temperature

B.1 Constant high temperature

B.1.1 Definition of stress level

The stress level is defined by the temperature of the assembly under stress. Where the assembly is not heat dissipating, the temperature depends on the environment only. Normally, there will be insignificant differences between the temperatures of the air, the surfaces "seen" by the assembly by radiation, and the possible objects connected to it by conductive paths. This means that the stress level is characterized by that common temperature.

Where the assembly is heat dissipating, the temperature distribution will not be uniform. The temperature at a specific point (component) will depend on the power dissipated by that particular component, its surface area, surface emissivity, nearby air velocity, and the radiative and conductive environment for that particular component.

It is therefore recommended that the stress level be measured by considering the temperature of the important components of the assembly. Important components in this context mean both the rogue components, which should be properly stressed, and the heat-sensitive components, which should not be overstressed. The most important single factor besides the temperature itself is the air velocity, which depends upon the chamber, as well as the mechanical form of the assembly, and the position of the assembly in relation to the direction of the airflow. If the air velocity is not uniform within the chamber used for the high temperature exposure, care should be taken not to exceed temperature limits of assemblies, or components of heat-dissipating assemblies, in areas of the chamber with low air velocity. Temperature differences of 20 °C are not unusual.

B.1.2 Effects

Effects of constant high temperature in combination with possible flaws include, but are not limited to the following:

- oxidation of unprotected metal surfaces leading to bad contacts or mechanical blocking (seizing). Unprotected metal surfaces may be a result of insufficient force in screw joints, etc. or of holes and fissures in protective coatings;
- diffusion between materials, for example between a base material and overplating, between solder material and components, between semiconductor material with weaknesses in insulation barriers, and metallization;
- drying-out of liquids, for example through small leaks in electrolytic capacitors and in batteries. Note, however, that reducing the relative humidity will prevent potential failures caused by humidity;
- softening of thermoplastics, leading to creeping if these parts are under excessive mechanical tension;
- softening or creeping of incorrectly applied protective compounds and impregnating waxes;
— increased speed of reaction of chemical processes in general, and therefore also of many processes around any enclosed contaminating particles;
— dielectric breakdown of partly damaged insulation.

If the failure mechanisms do not shift (for example by crossing a melting or softening point), the general effect of high temperature is an acceleration of time for those failure mechanisms influenced. If the relative humidity is low, care should be taken to avoid any electrostatic discharge problems created by the reliability stress screening itself.

B.1.3 Commonly used stress levels

The stress levels may be chosen from the following temperatures:

40 °C; 55 °C; 70 °C; 85 °C and 100 °C.

For heat dissipating assemblies, the temperature should be related to the rogue components and a certain defined operational stress. At the same time, however, it should be assured that the temperature limit of the most heat-sensitive components is not exceeded.

Methods for high temperature stress application are described in IEC 60068-2-2.

B.2 Low/high temperature cycling

B.2.1 Definition of stress level

The stress level is defined in principle by the time history of temperature at any point of the assembly. However, this is not practical to manage. Therefore, the time history of temperature of the air in the temperature chamber is used instead. The situation is similar to that of heat dissipating assemblies subjected to constant temperature, as regards heat exchanged with the surroundings. This makes air velocity an important factor in combination with the heat capacity of the different parts of the assembly.

The stress level of temperature cycling is characterized by the upper and the lower value of temperature, the rate of change of temperature and the dwell time at the upper and lower values of temperature at a suitable reference point. This stress condition may be applied to an assembly in a non-heat-dissipating state, in a heat-dissipating state, or in combination with operational stress cycling. Operational stress cycling is described in Clause E.2.

Hence, it is recommended to let a suitable reference point represent the temperature of the important components of the assembly. In this connection, the important components mean both the rogue components, which should be properly stressed, and the temperature-sensitive components, which should not be overstressed. The choice of reference point, therefore, can be very difficult.

The most important single factor, besides the time history of the temperature itself, is the air velocity. Besides being dependent on the chamber, the assembly form, and the assembly position, the air velocity is also affected by temperature cycling itself. If the air velocity is not uniform within the chamber used, care should be taken that the intended stress is also reached for components of assemblies in areas of the chamber with low air velocity. For heat-dissipating assemblies, care should also be taken not to exceed maximum temperature limits of assemblies, or components of assemblies, in areas of the chamber with low air velocity.
Generally, the problems related to the choice of a suitable temperature reference point are fewer for chambers with high air velocity.

a) temperature range

temperature cycling produces mechanical stresses inside the assemblies and the components of the assemblies. If an assembly is made of different materials with different thermal expansion coefficients, these stresses are proportional to the deviation of temperature that occurs from the time when the assembly was amassed. Independently of the rate of temperature change, these stresses depend mainly on the temperature range.

the temperature range is therefore a general stress determining parameter.

b) rate of change of temperature

if the assembly is made of components with different size and shape, they will have different thermal time constants (the product of heat capacity and thermal resistance to the ambient temperature). Exposed to a changing temperature, there will be a temperature lag proportional to the time constant (the product of time constant and rate of change of temperature). This will lead to temperature gradients and stresses, which depend mainly on the rate of change of temperature, independent of a possible equality of thermal expansion coefficients.

a high rate of change of temperature is particularly important if the rogue components are small. In order to utilize a high rate of change of temperature, it is necessary that the chamber air velocity is high.

the rate of change of temperature is also a general stress-determining parameter, because it partly determines the number of cycles per unit of time.

c) dwell time

the role of the dwell time is mainly to allow those components of the assemblies having a large thermal time constant to reach the extreme temperatures of the range.

a sufficient dwell time is particularly important if the rogue components are physically large.

the dwell time is also a general stress determining parameter, because it partly determines the number of cycles per unit of time.

B.2.2 Effects

The effects of temperature cycling in combination with possible failure mechanisms include, but are not limited, to the following:

- deepening of all sorts of microcracks in coatings, materials or leads;
- loosening of imperfectly glued joints;
- loosening of incorrectly bolted or riveted joints;
- loosening of press-fit joints with insufficient mechanical tension;
- developing badly soldered joints into increased contact resistance or open circuits.
B.2.3 Commonly used stress levels

The lower temperature may be selected from the following temperature values:

\[-55 \, ^\circ C; -40 \, ^\circ C; -25 \, ^\circ C; -10 \, ^\circ C; +5 \, ^\circ C \text{ and } +25 \, ^\circ C.\]

The upper temperature may be selected from the following temperature values:

\[40 \, ^\circ C; 55 \, ^\circ C; 70 \, ^\circ C \text{ and } 85 \, ^\circ C.\]

The rate of temperature change may be selected from the following values:

\[5 \, ^\circ C/\text{min}; 10 \, ^\circ C/\text{min}; 15 \, ^\circ C/\text{min} \text{ and } 20 \, ^\circ C/\text{min}.\]

The dwell time may be selected from the following values:

\[0.5 \, \text{h}; 1.5 \, \text{h}; 3 \, \text{h}.\]

The air velocity has an important influence, but normally it is not possible to set a selected value on conventional test chambers. It is important, however, in the arrangement of the assemblies in the test chamber to observe that, as far as possible, the air velocity be constant over the used part of the chamber volume. It is also important to observe the direction of the airstream, because a small component may be more or less sheltered from the airstream by larger components, which will largely influence the thermal resistance from the component to ambient temperature, and thus its thermal time constant.

Methods for temperature cycling stress application are described in IEC 60068-2-14.

\[1\] 15 \, ^\circ C/\text{min} \text{ and } 20 \, ^\circ C/\text{min} \text{ may be costly to realize except in highly accelerated stress screening.}\]
Annex C
(informative)

Stress conditions – Vibration and bump

C.1 Fixed frequency sinusoidal vibration

C.1.1 Definition of stress level

In a vibration stress conditioning test, the forces of excitation are applied to the assembly through the point/points of fixation. The primary parameters of characterization are the peak acceleration and the frequency. The forces are modified through the transmission path and this modification may cause an attenuation or an increase of the acceleration. This modification is characterized by the multiplication factor, $Q$: $Q$ being the ratio between the actual acceleration and the input-exciting acceleration (for a definition of $Q$ see ISO 2041).

In practice, assemblies have one or more natural resonance frequencies. When the vibration frequency coincides with one of the natural frequencies, $Q$ will typically be in the range of 5 to 20, depending on the internal damping of the assembly.

The presence of a high $Q$ resonance makes the exact frequency of the imposed vibrations critical. The resonance frequency may change during the vibration due to changes in damping (friction and elasticity).

Another conditioning parameter is the direction of vibration in three-dimensional space, and the orientation of that direction relative to the direction of gravity.

The applied vibration may cause components that are heavy in proportion to their rigidity to move with a high amplitude. This movement may cause collision with neighbouring objects.

Components that have low mass in proportion to their rigidity (for example rigidly mounted small components) will, on the other hand, have a small amplitude. They may, however, be damaged through the relative movement of their points of fixation. The movements may change, depending on the mode of vibration (direction and harmonics) that is predominant at the actual frequency. The direction, for example, is not only given by the direction of excitation, but also by actual compliance, in different directions at different harmonics of the excitation frequency. For that reason, the joints between the components are often the points of interest, for example the fixation points of components to a printed circuit board. The periodically acting forces create a number of load and relaxation cycles proportional to the vibration frequency and the duration.

A rogue component in an assembly may be exposed to the intended stress by carefully selecting the frequency, the point/points of fixation, and the direction of the acceleration applied to the assembly.

Sensitive components of an assembly may be protected by choosing a vibration frequency far from their resonance frequencies, choosing a direction of the acceleration that minimizes their vibration, and choosing a frequency that causes a vibration mode with low stress at the components and their mountings.
It will be seen that the severity of a fixed frequency vibration condition depends on many parameters and is difficult to control. Fixed frequency sinusoidal vibration is, however, recommended in special cases, for example if there is one kind of rogue component, and the vibration frequency can be adjusted to the resonance frequency of that kind of component, and in that way, stress the probable flaws.

A fixed frequency sinusoidal vibration screening should also be considered where the final product will experience a dominant vibration frequency in actual use, for example an equipment mounted on rotating machinery with a fixed velocity of rotation. This consideration should, however, primarily include an evaluation of the ability of that kind of stress condition to develop the probable flaws into failures (see C.1.2).

C.1.2 Effects of fixed frequency sinusoidal vibration

Effects of vibration in combination with possible flaws and failure mechanisms include, but are not limited to the following:

– fatigue in structural parts, wiring or component leads, especially such flaws as nicked wires, micro-cracks and similar;
– wear of cabling, for example at sharp edges of loose cable ties;
– loosening of screw joints not properly made;
– ICs, not properly mounted, worked loose from their sockets;
– high stress on bus-bars and their solderings to the circuit board, causing weak soldering to fail;
– break of insufficiently relieved component leads bridging parts with relative motion, e.g. front panel LEDs or power transistors on back panel heatsinks connected to circuit boards;
– cracks in damaged or improperly mounted brittle insulation material.

C.1.3 Commonly used stress levels

The acceleration may be selected from the following values:

\[ \frac{1}{s^2};\ \frac{2}{s^2};\ \frac{5}{s^2};\ \frac{10}{s^2};\ \frac{20}{s^2};\ \frac{30}{s^2};\ \frac{50}{s^2};\ \frac{100}{s^2};\ \frac{150}{s^2};\ \frac{200}{s^2};\ \frac{300}{s^2};\ \frac{500}{s^2}. \]

The amplitude (maximum displacement) may be selected from the following values:

– for frequencies below 9 Hz: \( 7,5\ mm;\ 10\ mm;\ 15\ mm; \)
– for frequencies below 62 Hz: \( 0,035\ mm;\ 0,075\ mm;\ 0,15\ mm;\ 0,35\ mm;\ 0,75\ mm;\ 1,0\ mm;\ 1,5\ mm;\ 2,0\ mm;\ 3,5\ mm. \)

The selection of point/points of fixation, direction/directions of vibration and orientation concerning the direction of gravity is important. The choice of these conditions, however, is specific to the assemblies, and general recommendations cannot be given.

Methods for fixed frequency sinusoidal vibration stress application are described in IEC 60068-2-6.
C.2 Swept frequency sinusoidal vibration

C.2.1 Definition of stress level

As for fixed frequency, the primary parameters are peak acceleration and frequency, in this case variables. For higher frequencies, this is an adequate characterization, but for low frequencies, a fixed acceleration would cause an unrealistically high amplitude. For this reason, a cross-over frequency is specified, below which the amplitude is a stated constant value. The stress level of conditioning by swept frequency sinusoidal vibration is therefore characterized by the following:

- the minimum and the maximum frequency;
- the amplitude below a specified cross-over frequency;
- the acceleration above this frequency;
- the sweep-rate (octaves per minute).

In a swept frequency screening, the resonance frequencies of a number of rogue components may be covered; but at the same time, it is increasingly difficult to avoid resonance frequencies of sensitive components not belonging to the rogue component class. The factors mentioned for fixed frequency sinusoidal vibration also apply in this case. The sinusoidal sweep will excite the components in sequence as their resonance frequency is reached. This may cause collision with the surroundings.

A swept frequency sinusoidal vibration screening should be considered where the final product will experience a series of dominant vibration frequencies in actual use, for example for equipment mounted on rotating machinery with a varying velocity of rotation. This consideration should, however, primarily include an evaluation of the ability of this kind of stress condition to develop the probable flaws into failures (see C.2.2).

C.2.2 Effects of swept frequency vibration

The effects of swept frequency sinusoidal vibration are the same as for fixed frequency sinusoidal vibration (see C.1.2).

C.2.3 Commonly used stress levels

The frequency range may be selected from the following ranges:

- 10 Hz to 55 Hz; 10 Hz to 150 Hz; 10 Hz to 500 Hz; 10 Hz to 2 000 Hz; 10 Hz to 5 000 Hz;
- 55 Hz to 500 Hz; 55 Hz to 2 000 Hz; 55 Hz to 5 000 Hz; 100 Hz to 2 000 Hz.

Acceleration at 8 Hz to 9 Hz cross-over 2):

- 1 m/s²; 2 m/s²; 5 m/s²; 10 m/s²; 20 m/s²; 30 m/s²; 50 m/s².

The amplitude and acceleration at a cross-over frequency in the range 57 Hz to 62 Hz may be selected from the following values:

- 0,035 mm – 5 m/s²; 0,075 mm – 10 m/s²; 0,15 mm – 20 m/s²;
- 0,35 mm – 50 m/s²; 0,75 mm – 100 m/s²; 1,0 mm – 150 m/s²;
- 1,5 mm – 200 m/s²; 2,0 mm – 300 m/s²; 3,5 mm – 500 m/s².

---

2) The amplitude is not listed, as all frequencies are above the cross-over frequency.
The sweep rate should be one octave per minute.

The selection of point/points of fixation, direction/directions of vibration and orientation concerning the direction of gravity is important. The choice of these conditions, however, is specific to the assemblies, and general recommendations cannot be given.

Methods for swept frequency sinusoidal vibration stress application are described in IEC 60068-2-6.

C.3 Random vibration

NOTE In operation and during transportation most products experience random vibrations.

C.3.1 Definition of stress level

The stress level of a random vibration is specified by the frequency range and the acceleration spectral density (ASD), measured in m²/s³. An r.m.s. value may be calculated from the ASD spectrum.

In random vibration, the assembly is stressed with different frequencies simultaneously, so that in practice more than one resonance frequency may be excited at the same time. This means that adjacent components with different resonance frequencies may move at the same time, and therefore the probability of collision of improperly mounted components is increased.

Since the random vibration can keep more components excited at the same time, the duration of a random screening may be reduced to approximately one-third to one-fifth of the duration required for a stress screening using swept frequency sinusoidal vibration.

A random vibration exhibits the same problems in selecting frequencies as a swept frequency sinusoidal vibration, which will stress the rogue components and not the sensitive components. It will often be appropriate to use a shaped spectrum with a high ASD level in the frequency range around the resonances of the rogue components, and a low ASD level around the resonances of sensitive components intended to be kept at low stress. The r.m.s. value of the spectrum will normally be between 1 m/s² and 100 m/s².

Where the final product experiences a mixed frequency spectrum with no predominant frequency during operation, random vibration screening may be relevant to the same degree as swept frequency screening was relevant, as mentioned in C.2.1.

Random vibration screening may be relevant, however, even if the product does not experience any vibration during actual use. This is because the evaluation of the applicability of random vibration (as for any stress type) should include its ability to develop probable flaws into failures, independently of how these flaws become failures in real life. The slow action of the realistic stress types should not be awaited if a suitable shortcut can be obtained, using a completely different stress type to precipitate the same flaws into failures. Random vibration may be such an alternative stress type, for example for flaws such as particle contamination in encapsulations, or "cold" solderings.
C.3.2 Effects of random vibration

The effects of random vibration are the same as for fixed frequency sinusoidal vibration (see C.1.2), but with more complex failure mechanisms and three to five times faster progress in the development of failures. This is due to the interaction of many resonances activated simultaneously.

C.3.3 Commonly used stress levels

The frequency range may be selected from the following ranges:

- 20 Hz to 150 Hz; 20 Hz to 500 Hz; 20 Hz to 2 000 Hz; 20 Hz to 5 000 Hz.

The ASD level may be selected from the following values:

- 0.005 m²/s³; 0.01 m²/s³; 0.02 m²/s³; 0.05 m²/s³; 0.1 m²/s³; 0.2 m²/s³;
- 0.5 m²/s³; 1 m²/s³; 2 m²/s³; 5 m²/s³; 10 m²/s³; 20 m²/s³; 50 m²/s³.

Shaping of the spectrum, selection of point/points of fixation, direction/directions of vibration and orientation concerning the direction of gravity are important. The choice of these conditions, however, is specific to the assemblies, and general recommendations cannot be given.

Methods for random vibration stress application are described in IEC 60068-2-64.

C.4 Bump

NOTE Most products experience bumps during transportation.

C.4.1 Definition of stress level

For bumps, the stress level is characterized by the pulse peak acceleration and the pulse duration.

As with a random vibration, bumps will excite more than one resonance frequency at the same time. The bump pulse is approximately a half-sine oscillation that, through Fourier analysis, may be resolved into a large number of discrete frequencies.

Bump conditioning claims one property that vibration conditioning does not: the bump pulse has a specific direction. Whereas a complete vibration cycle may move a part out of position and back again, a bump may leave it in a new position. The next bump may further add to the movement. In many other senses, bump conditioning has similar properties to random vibration, but is much cheaper.

A bump screening should be considered where the final product experiences an environment with a series of bump impulses as a predominant factor in actual use. This may apply to portable equipment, and to other equipment exposed to transport, for example by rail. This consideration should, however, primarily include an evaluation of the ability of this kind of stress condition to develop the probable flaws into failures (see C.4.2).
C.4.2 Effects of bumps

The effects of bump conditioning are almost the same as those of random vibration (see C.3.2). However, the following effects apply only to bump conditioning:

- movement in one direction of components that are fixed by friction (for example transformers screwed to base plate);
- change of adjustment (for example potentiometers);
- movement of hinged lids, doors, etc. causing blocked movement (for example caused by loose screws);
- movements of connectors out of contact.

C.4.3 Commonly used stress levels

The stress levels are defined as a combination of peak acceleration and pulse duration, as follows:

100 m/s$^2$ – 16 ms; 150 m/s$^2$ – 6 ms; 250 m/s$^2$ – 6 ms; 400 m/s$^2$ – 6 ms; 1 000 m/s$^2$ – 2 ms

Selection of point/points of fixation, direction-directions of the bump pulse, and orientation concerning the direction of gravity are important. The choice of these conditions, however, is specific to the assemblies and general recommendations cannot be given.

Methods for bump stress application are described in IEC 60068-2-29.
Annex D
(informative)

Stress conditions – Humidity

D.1 Constant high humidity and temperature

D.1.1 Definition of stress level

The stress level is defined by the water content in the air, and the temperature of the assembly under stress. A subsequent heating of the assembly under low humidity conditions may eliminate the effect of a previous humidity condition. This may, in particular, be the case if the assembly is heat dissipating during the humidity condition.

Where the assembly is not heat dissipating, both parameters depend on the environment only. In practice, the commonly used characteristics are chamber air temperature and relative humidity, but absolute humidity may be used as well.

Where the assembly is heat dissipating, the temperature distribution is not uniform (see B.1.1). For that reason, the distribution of relative humidity will also not be uniform. As a rule of thumb, the deviation will be around 5 % for 1 °C of temperature difference.

This situation can generally be neglected in practice, since the over-temperature of a component will bring about a drying out of water. It is, therefore, not important for the humidity stress conditions to be well defined on heat-dissipating parts of an assembly as this combination is not likely to precipitate any flaws into failures 3).

Chamber air temperature and relative humidity are, therefore, suitable characteristics for defining the stress condition in all cases.

D.1.2 Effects of damp heat

Humidity acts on electrical and electronic assemblies in three ways:

– Surface absorption

This is evident in connection with flaws related to contamination of the surface. As an example, the sodium chloride of a fingerprint can initiate development of a film of liquid water already at 75 % r.h. of the surrounding air. Failures are likely to occur within a few hours if the function of the assembly requires a high surface resistance. If corrosion is the relevant mechanism, failures are likely to occur within a few days, for example due to formation of corrosion products, or discolouring of bright metal surfaces.

3 Heat-dissipation may cause other problems, however. It may be the intention to impose stress on a non-heat-dissipating part of an assembly, but heat dissipation by other parts of the assembly may load the chamber, so that the intended stress condition cannot be obtained.
Capillary condensation
This is evident in connection with flaws composed of cracks, fissures, and pores. Failures are likely to occur if the water can penetrate the protective cover layers in this way, and act on materials that are intended to be protected. This mechanism is also rather fast, taking from some hours to a few days.

Diffusion through bulk material
This is not normally related to possible flaws, and is scarcely relevant. The mechanism is generally slow, taking from several days to some months.

D.1.3 Commonly used stress levels
Stress levels may be chosen from the following values:

- temperature: 30 °C; 40 °C; 55 °C; 70 °C; 85 °C
- relative humidity: 85 %, 93 %

Methods for constant damp heat stress application are described in IEC 60068-2-78.

D.2 High humidity and temperature cycling

D.2.1 Definition of stress level
Stress is very complex and cannot be considered as just a combination of temperature cycling and steady state humidity (see B.2.1 and D.1.1, respectively). A subsequent heating of the assembly under low humidity conditions may eliminate the effect of a previous high humidity and temperature cycling condition. This may, in particular, be the case if the assembly is heat dissipating during conditioning.

In order to keep things as simple as possible, the following provisions should be applied:

- the time for the temperature change should be long enough to facilitate a uniform distribution of temperature and humidity in the chamber during the change;
- the dwell times at the upper and lower temperature should be long enough to obtain thermal equilibrium between parts of the assembly with small and with large thermal time constants.

The conditioning then basically depends on the upper temperature, the lower temperature, the temperature rate of change and the relative humidity.

D.2.2 Effects of high humidity and temperature cycling
One effect of high humidity and temperature cycling is condensation of water on the outer surfaces of the assembly. This enhances the capillary condensation mentioned in D.1.2, but adds the extra effect of a water layer over virtually the whole surface of the assembly, and not only in the pores. The water layer will, in many cases, exclude the use of high humidity and temperature cycling as a usable screening condition, if the assembly under screening is not designed to withstand such a water layer.

---

4) IEC 60068-2-78 describes a standardized test at 30 °C and 40 °C and 85 % and 93 % r.h.
The most important effect of the temperature cycling is "breathing". This means that the repeated expansion and contraction of air, due to the temperature changes, will bring humidity into hollow spaces in the assembly. This stress condition is therefore recommended, if flaws sensitive to humidity (see D.1.2) are expected to exist in spaces not completely airtight, or if the flaws expected are leaks in the walls of spaces intended to be airtight.

D.2.3 Commonly used stress levels

Stress levels may be chosen from the following values:

- lower temperature: 25 °C;
- upper temperature: 40 °C; 55 °C
- humidity: close to saturation
- rate of temperature change: 15 °C/h; 30 °C/h.

Methods for cyclic damp heat stress application are described in IEC 60068-2-30.
E.1 Constant operational stress

E.1.1 Definition of stress level

The stress level is related to the specific function of the assembly and its possible functional conditions. It cannot be defined generally.

The functional and/or supply condition may be chosen to impose operational stress on specific groups of components in an assembly incorporating the rogue components. The operational stress is then suitably characterized by load and supply parameters for the rogue components, for example power supply voltage, frequency, output power, bias voltage, fan-out, torque, supply of cooling medium, etc.

Constant operational stress is sometimes used as a supplement to constant high temperature, and it may then be suitable to use the temperature of the important components to characterize the stress level (see B.1.1).

E.1.2 Effects

The effects of operational stress cannot be given a general description because they are closely related to details of the design and the functions of the assembly.

For constant operational stress used as a supplement to constant high temperature, it may be suitable to consider the corresponding list (see B.1.2).

High bias voltage may cause dielectric breakdown of partly damaged insulation.

E.1.3 Commonly used stress levels

Not applicable.

E.2 Operational stress cycling

E.2.1 Definition of stress level

Operational stress cycling in combination with temperature cycling is the most commonly used stress combination. The varying power dissipation produces mechanical stresses inside the assemblies and the components of the assemblies. The stress distribution will be different from that produced by temperature cycling.

There may be several different operational stress conditions in the cycle, each characterized by its own set of load and supply parameters and levels.
The timing of the operational stress cycle is important in itself. In combination with temperature cycling, the mutual timing of the two cycles is particularly important. A high stress can often be achieved by turning on the equipment while cold.

Changing electrical parameters produce voltage and current transients in particular parts of the electrical circuits, for example inrush currents.

E.2.2 Effects

The effects of operational stress cycling in combination with possible flaws are, in principle, the same as the effects of temperature cycling (see B.2.2). The difference is that operational on/off cycling concentrates the stress around the parts of the assembly actually loaded.

E.2.3 Commonly used stress levels

Not applicable.
Annex F
(informative)

Voltage stress

The assemblies can be stressed by increasing or decreasing the voltage to the limit of the specification (for example the supply from the mains). For battery supplied equipment, voltage stress is a very important stress factor. The voltage can be cycled between the limits or changed in steps. In the case of stabilized voltage supplies, only a minor part of the circuit is affected, and engineering knowledge is needed to determine how the circuits can be stressed in an appropriate way. The stress can be further increased by introducing transients and periodic intermittency in the voltage supply.
High stress levels can be used in order to reduce the RSS time as much as possible, however it is essential that the specifications of the components are not exceeded, unless decided by a management decision. For consumer products this decision can be taken by the manufacturer after potential safety issues and potential lifetime reduction have been considered. For equipment supplied under contract, approval from the customer and, if relevant, from the component suppliers, has to be obtained before the RSS is started.

Combined stresses, for example combined temperature change and vibration or bumps are especially efficient in precipitating flaws as failures. Before the RSS with high stress levels are started, the operational limits for the assemblies should be determined; proof should be provided, for example by repeating the RSS cycle several times, that the planned RSS cycles reduce the life time of the assemblies by only an insignificant amount, even with repeated RSS, due to the repair of precipitated failures.

By choosing an appropriate RSS cycle with high stress levels, the number of required fault free RSS cycles can often be reduced to one.

Determination of the required cycles is calculated as described in Annex J.
Annex H
(informative)

Bimodal distributions – Weibull plotting and analysis

For the purpose of designing reliability screening processes, the distribution of times to first failure (TTFF), for systems and times to failure (TTF), for components under stress screening conditions can be approximated by bimodal Weibull distributions. For more information concerning Weibull distribution see IEC 61649.

The mathematical description in terms of the cumulative distribution function (c.d.f.), is given by:

\[ F(t) = pF_1(t) + (1 - p)F_2(t) \]

where

- \( t \) is the TTF in case of (non-repairable) components and the TTFF in case of repairable systems;
- \( F_1(t) \) is the c.d.f. describing the TTF/TTFF for weak assemblies;
- \( F_2(t) \) is the c.d.f. describing the TTF/TTFF for strong assemblies;
- \( p \) is the fraction of weak assemblies in the population.

The relevant measure of weak assemblies is characterized by small values of \( t \), while strong assemblies normally exhibit much larger values of \( t \).

For the description of \( F_1(t) \) and \( F_2(t) \), the two-parameter Weibull distribution is used as follows:

\[ F_1(t) = 1 - e^{\left(\frac{t}{\eta_1}\right)^{\beta_1}} \]

\[ F_2(t) = 1 - e^{\left(\frac{t}{\eta_2}\right)^{\beta_2}} \]

where

- \( \beta_1 \) and \( \beta_2 \) are the shape parameters;
- \( \eta_1 \) and \( \eta_2 \) are the characteristic lifetimes.

A bimodal Weibull distribution appears on Weibull graph paper as an S-curve, more or less pronounced, dependent on the separation of \( F_1(t) \) and \( F_2(t) \). An example appears in Figure H.1. In cases where no levelling off (S-curve) appears, stress screening is not an efficient way to reduce the failure level, and the root cause of the failures have to be found and removed.

In cases where the difference between the TTF of the weak and the strong population is small, there is an indication of early wear out. The reason for this should be found and removed (e.g. design error, process problems or component problems) before stress screening is introduced.
The first part of the S has the same slope as $F_1(t)$. The middle part forms a "plateau", where $F_1(t)$ and $F_2(t)$ mix. The last part approaches $F_2(t)$ as $t$ grows larger and larger.

**Figure H.1** – The S-curve for a bimodal Weibull distribution mixed by $F_1(t) = 1 - e^{\left(\frac{t}{30}\right)^{1.5}}$ and $F_2(t) = 1 - e^{\left(\frac{t}{60\,000}\right)^{1}}$ in the proportions 15 % and 85 %, respectively

Experimental values of TTF/TTFFs arising from a test performed on a sample including $n$ assemblies are plotted on Weibull graph paper, using the well-known median rank method. The TTF/TTFF values are organized in increasing order. Each failure is then given a rank order number, $i$, beginning with 1 for the first failure. The median ranks, which constitute estimates of the c.d.f. values, are calculated as follows:

$$\text{Median rank } P_{50}(t_i) = \frac{i - 0.3}{n + 0.4} \times 100 \text{ (as a percentage)}$$

where $t_i$ is the TTF/TTFF for the $i$th failure (see Annex J for a worked example).

Where the number of assemblies under test is reduced for some reason (e.g. only relevant failures are analysed), the method of suspended assemblies should be applied in the calculation of the rank order number. These will then in general be non-integers. For each failure a rank increment $\Delta$ is calculated by
This increment $\Delta$ is added to the previous rank order number to obtain the rank order number for the failure under consideration.

When, after plotting, the points indicate an S-curve or the first part (including the "plateau") of an S-curve, the necessary information for a reliability screening optimization can be derived as shown in Figure H.2. The shape parameter of $F_1(t)$ is taken as the slope of the first part of the S-curve. The fraction $p$ of weak assemblies is approximated by the c.d.f. value, where the S-curve "plateau" begins. The characteristic lifetime $\eta_1$ of the weak assemblies is found by the c.d.f. value, 0.632 $p$ on the S-curve.

![Figure H.2](image_url)

**Key**
1. line with slope = $\beta_1$
2. c.d.f ( % Weibull)
3. experimentally determined S-curve
4. log $t$

**Figure H.2 – Estimation of $p$, $\beta_1$, and $\eta_1$ for the purpose of reliability screening optimization**

The reliability screening optimization is based on the approximation of bimodal Weibull distributions by bimodal exponential distributions.

Such cases are described hereafter using the following mathematical expressions:

\[
F_1(t) = 1 - e^{-\frac{t}{m_{F1}}} \\
F_2(t) = 1 - e^{-\frac{t}{m_{F2}}}
\]
because in this case

\[ \beta_1 = \beta_2 = 1 \]

\[ \eta_1 = m_{F_1} \]

\[ \eta_2 = m_{F_2} \]

\[ m_F \] is the mean time to failure.

The representation on Weibull graph paper of the cumulative distribution function is shown in Figures H.3 for a finite \( m_{F_2} \), as well as for an infinite \( m_{F_2} \) (in the infinite \( m_{F_2} \) case, the strong assemblies are perfect and do not fail at all). The corresponding failure rate functions are shown in Figure H.4 in both cases as well.

Figures H.3 and H.4 show the following:

- For the purpose of optimizing reliability screening, it is easier to interpret the c.d.f. rather than the failure rate function. For example the \( F_1(t) \) graph in Figure H.3 shows that an average screening time of 48 h will weed out about 75\% of the weak assemblies. By that time, the hazard rate has dropped down to about one-fourth of its original value, but this is still considerably higher than the end value. Using the failure rate function may well lead to a wrong conclusion regarding the proximity of a termination of the screening.

- Where reliability screening pays off (that is when \( F_1(t) \) and \( F_2(t) \) are reasonably separated), the approximation \( m_{F_2} \to \infty \) is well justified, as the first part of the S-curve is only marginally affected by \( F_2(t) \).

- For the purpose of reliability screening, an approximation of \( F_1(t) \) with an exponential distribution is reasonable. If the actual slope \( \beta_1 \) is higher than 1, the screening result will be better than expected. If the actual slope \( \beta_1 \) is lower than 1 but higher than 0.7 (which is below the lowest observed), the screening result will be only slightly worse than expected.
Figure H.3 – The c.d.f. curves for bimodal exponential distribution

Key
1  c.d.f ( % Weibull)
2  \( t \) (time units)
Key

1 limiting value \( \lim_{t \to \infty} h(t) = \frac{1}{m_F^2} \)

2 \( t \) (time units)

3 \( h(t); m_{F_1} = 30; m_{F_2} = 6000 \)

4 \( h(t); m_{F_1} = 30; m_{F_2} \to \infty \)

5 limiting value \( \lim_{t \to \infty} h(t) = p \times \frac{1}{m_{F_1}} = (1 - p) \times \frac{1}{m_{F_2}} \)

6 \( h(t) \) failures/1000 time units

Figure H.4 – The hazard rate function for bimodal exponential distribution
I.1 The assembly model

The reliability screening process recommended in this standard is the following: each assembly is subjected to the stress condition until it has experienced a predesignated failure-free period $T_M$. During the stress conditioning, the assembly is monitored for failures. When a failure occurs, the assembly is taken out of conditioning to be repaired. When the failed component has been found, and the repair completed, the assembly is placed in conditioning again, and the "screening duration clock" is started from zero. Eventually, the assembly completes the "failure free" period $T_M$ without failing, is taken out of the reliability screen, and, after a final inspection, is ready to leave the factory, or to go to the next assembly level. This process is illustrated by Figures 4 and 7.

The assembly undergoes a reliability screening in order to weed out all weak components. For the purpose of screening optimization, the assembly is assumed to be a series system in the reliability sense, and every failure is considered a system failure, regardless of any redundancy. In the model, the assembly consists of a number of "perfect" components, that is components which have a negligible probability of failure during early life, and a number of rogue components, $N$, with bimodal failure distributions. The component failures in the series system are statistically independent. Figure I.1 illustrates the basic system.

Key
1 $N$ rogue components
2 perfect components
3 $n$ weak components

Figure I.1 – The basic system
In principle, the analysis may be carried out using several component classes within a total of \(N\) components. However, the additional computational effort in considering more than one rogue component class is very seldom justified. It is, therefore, assumed that only one rogue component class exists, with a bimodal time to failure distribution described by the mixed exponential:

\[
F(t) = p_c F_1(t) + (1 - p_c) F_2(t) = p_c (1 - e^{-\lambda_1 t}) + (1 - p_c) (1 - e^{-\lambda_2 t})
\]

where

- \(p_c\) is the fraction of weak components;
- \(\lambda_1\) is the constant failure rate of the weak subpopulation \(\lambda_1 = \frac{1}{m_{F1}}\);
- \(\lambda_2\) is the constant failure rate of the strong (main) subpopulation \(\lambda_2 = \frac{1}{m_{F2}}\).

### I.2 The principles behind the time graphs for evaluation of the failure-free period

When a single assembly is subjected to a reliability stress screening, it is not known exactly how many weak components are present. The lowest number is zero, the highest number is \(N\). However, assuming the components in the assembly is to be taken from an "infinite" parent population, so that \(p_c\) is unchanged when components are removed, the number of weak components, \(n\), in the assembly follows a binomial distribution, that is:

\[
\pi(i) = P(n = i) = \binom{N}{i} p_c^i (1 - p_c)^{N-i}
\]

where \(i = 0, 1, 2, \ldots, N\) and \(\pi\) is the symbol for the probability in the Markov process.

The number of weak components in the assembly under consideration may thus be expressed by an initial probability vector, \(\pi^0\):

\[
\pi^0 = [\pi(0), \pi(1), \pi(2), \ldots, \pi(i), \ldots, \pi(N)]
\]

Assume for the moment that the actual number of weak components, \(n\), among the \(N\) possible, is known. If the assembly is subjected to the reliability screening, the cumulative distribution of times to failure will be:

\[
F(t) = 1 - e^{-\lambda_{\text{eff}} t}
\]

where \(\lambda_{\text{eff}} = n\lambda_1 + (N - n)\lambda_2 = n(\lambda_1 - \lambda_2) + N\lambda_2\)

All other assemblies of this type, with the same number of weak components, can be described by the same equation. Due to the properties of the components having a constant hazard rate, which is when the failure pattern is "without memory"; there is no difference between a new assembly and an assembly that has been repaired. All these assemblies are said to be in the same state, \(n\).

The following considers what happens to a system with \(n\) weak components during and after the stress screen. If the assembly survives the failure-free period, \(T_m\), it will still contain \(n\) weak components. After the stress screen, it will be in the state \(n_{\text{RE}}\) with \(n_{\text{RE}}\) remaining weak components (see Figure I.2).
The assembly may fail during screening, either because a weak component fails, or because a strong component fails. If a weak component fails, then there are \((n - 1)\) weak components left. If a strong component fails, then there are still \(n\) weak components left in the system (see Figure I.3).

![Diagram of assembly states after failure and repair](image)

**Figure I.4 – Assembly states after failure and repair**
Probability that the assembly will complete the screen without failure:

\[ R_n = \exp\left[ -(n\lambda_1 + (N-n)\lambda_2)T_M \right] \]

Probability of failure:

\[ F_n = 1 - R_n \]

If a failure has occurred, then the probabilities of it occurring in a weak component or in a strong component are, respectively:

\[ P(\text{weak, } n) = \frac{n\lambda_1}{\lambda_{sn}} \]

\[ P(\text{strong, } n) = 1 - \frac{n\lambda_1}{\lambda_{sn}} \]

When a repair is made, the probability of introducing a weak component is \( p_c \), and the probability of introducing a strong component is \( (1 - p_c) \).

It is now possible to write down the probability of state transitions within an assembly containing \( n \) weak components, \( P(n \rightarrow m) \) being the notation for the probability of transition of a state where there are \( n \) weak components to a state where there are \( m \) weak components:

\[
\begin{align*}
  p(n \rightarrow n) &= R_n \\
  p(n \rightarrow n+1) &= F_n \cdot F_p \left( 1 - \frac{n\lambda_1}{\lambda_{sn}} \right) \\
  p(n \rightarrow n) &= F_n \cdot F_p \left[ (1 - p_c) \left( 1 - \frac{n\lambda_1}{\lambda_{sn}} \right) + p_c \frac{n\lambda_1}{\lambda_{sn}} \right] \\
  p(n \rightarrow n-1) &= F_n \cdot F_p \left( 1 - p_c \right) \frac{n\lambda_1}{\lambda_{sn}} 
\end{align*}
\]

The question now is: what will be the state of the assembly after a failure-free period of \( T_M \)?

Even if the number of weak components before the stress screen should actually be known, the number of weak components remaining in the assembly after the screen has been successfully completed can only be expressed as a probability.

The effectiveness of the screen is contained in the probability vector \( \pi_{RE} \):

\[ \pi_{RE} = (\pi_{RE, 1}, \pi_{RE, 2}, ..., \pi_{RE, i}, ..., \pi_{RE, N}) \]

where \( \pi_{RE, i} \) is the probability of having \( i \) weak components in the assembly after the screen.

The evaluation of screening effectiveness may be performed using the theory of Markov chains to mathematically describe the failure/repair situation illustrated above (see IEC 61165).

The outcome will be the Markov result matrix, \( \pi \), in which the probabilities of going from one state to another as a result of a complete screening can be read.
The Markov result matrix, $B$, and the initial probability vector, $\pi_0$ then gives:

$$\pi_{RE} = \pi_0 B$$

With the approximation $\lambda_2 = 0$ (see Annex H) and perfect repair, $p_R = 0$, ($p_R$ is the probability of introducing a new type of weakness by the repair), the results of the Markov computations can conveniently be put into graphs, such as is shown in Figure I.5.

The vertical scale on such a time graph is the probability $p_B$ of one or more weak components remaining in the assembly after a failure-free period of $T_M$ has been demonstrated. It is basically the probability of an early field failure.

![Figure I.5 – Time graph for evaluation of the failure-free screening period](image-url)

**Key**

- $p_c$: fraction of weak components in the rogue component class
- $N$: number of components in the rogue component class

**Figure I.5** - Time graph for evaluation of the failure-free screening period
The horizontal scale on the time graph is the failure-free period normalized with respect to $m_{F1} = 1/\lambda_1$, the mean time to failure of the weak components in the rogue component class. That is:

$$\text{Abscissa } A = \frac{T_M}{m_{F1}}, \text{ or } T_M = A \times m_{F1}$$

For readability and ease of use, the graphs are drawn for a specific value of $p_c$. However, the value of $p_c$ may be changed on any graph if at the same time the values of $N$ marked on the graph are changed so that $p_c N = \text{constant}$ in every case. As an example, if, in Figure I.5, $p_c$ is changed from 0.002 to 0.0002, then all $N$ values have to be multiplied by 10, so that the curves will be marked $N = 3200, 1600, 800, 400, \ldots, 50$.

### I.3 Estimation of the average screening duration

For cost/benefit analysis of the reliability stress screening, the average screening duration $T_B$ per assembly has to be estimated.

This important figure may also be derived from the Markov analysis. As the first step, a vector $T_n$ is derived giving the number of times (including the first time) the assemblies are expected to experience the stress conditions before completing the failure-free period $T_M$, given the number of weak assemblies before the screen.

Multiplying the initial probability vector $\pi_0$ with $T_n$ gives the average number of times the assemblies are expected to go through the screening before completing the failure free period $T_M$.

The average screening duration then becomes

$$T_B = \pi_0 T_n T_M$$

or normalized with respect to $m_{F1}$

$$\frac{T_B}{m_{F1}} = \pi_0 T_n \frac{T_M}{m_{F1}}$$

For practical purposes, time graphs are very convenient for evaluating the failure-free period. Figures I.6a to I.6h show $T_B$ time graphs corresponding to the $T_M$ time graphs in 6.3 (see Figure 8). Actual use of the time graphs is illustrated in Annex J.
Figures I.6a and I.6b – Average screening duration versus the normalized failure-free period $\frac{T_{M/mF_1}}{mF_1} - p_c = 0.0005$ and $p_c = 0.001$
Figures I.6c and I.6d – Average screening duration versus the normalized failure-free period \( \frac{T_M}{m_{F1}} \) for \( p_c = 0.002 \) and \( p_c = 0.005 \).
Figures I.6e and I.6f – Average screening duration versus the normalized failure-free period $\frac{T_M}{mF_1}$. $N = 80$, $p_c = 0.015$ and $p_c = 0.02$.

$N = \text{Number of components in the rogue component class}$

$p_c = \text{Fraction of weak components in the rogue component class}$
Figures I.6g and I.6h – Average screening duration versus the normalized failure-free period $\frac{T_M}{m_{F1}}$ - $p_c = 0.03$ and $p_c = 0.04$

$N$ = Number of components in the rogue component class

$p_c$ = Fraction of weak components in the rogue component class
Annex J  
(informative)

Worked example

J.1 The case

The item under consideration is a printed board assembly (PBA) equipped with 175 components. It serves as a subsystem in a new product, and has been designed in accordance with the manufacturer's standard design rules. The components in use are well known by the designers from experience with previous products aimed for roughly the same market and end-users. The field conditions can be characterized as stationary indoor use. Under working conditions, the product will not be exposed to significant levels of vibration and shock. The temperature and humidity are maintained within limits suitable for the comfort of personnel in the same room. The PBA has been designed for correct functioning within an ambient temperature interval from 5 °C to 70 °C.

From previous experience, it is known that CMOS integrated circuits (ICs) and power transistors exhibit early failures, due to flaws in the components. In the present PBA, there are 16 ICs and eight power transistors among the total of 175 components. The ICs as well as the transistors are plastic encapsulated.

For the purpose of planning a reliability screening programme for the new product, it is decided to optimize a reliability stress screening process for the PBA in accordance with this standard.

J.2 Planning of a reliability stress screening process for the PBAs

The screening process under consideration is to be performed at the subsystem level of the system manufacturer (see Figure 3). The planning comprises a number of main steps.

STEP 1 – Specify the maximum allowable fraction of weak assemblies (see Figure 2). This step is performed by looking at the requirements for the end product in which the PBA is to serve. In the present case, no other parts of the end product contribute to early failures. Therefore, the acceptable fraction of weak assemblies, \( p_B \), remaining after reliability screening is the same for the end product and the PBA. In order to fulfil market requirements, a value for \( p_B \) is chosen:

\[
p_B = 0,02 = 2 \%
\]

STEP 2 – Evaluate the actual fraction of weak assemblies (see Figure 2). Calculations as outlined in 6.2.3, steps 1 and 2, are required. In the present case, there are two rogue component classes: ICs and power transistors. Previous experience shows that about 1 % of the ICs and about 0,5 % of the transistors fail early. Using the higher value gives the fraction of weak components in the rogue component classes lumped together:

\[
p_c = 1 \% = 0,01
\]
With 24 components (16 ICs plus eight transistors) in the "anonymous" rogue component class, the fraction of weak PBAs before reliability stress screening becomes

\[ p_s = 1 - (1 - p_c)^N = 1 - (1 - 0.01)^{24} = 0.214 \]

The necessity for screening is demonstrated by the inequality

\[ p_s \approx 0.21 \gg p_B = 0.02 \]

The fraction of early failures has to be reduced by an order of magnitude before the PBA is mounted into the end product.

STEP 3 – Consider the stress conditions (see 6.1.2). First the flaws are identified. They are expected to be induced by the assembly process.

For the ICs, the following phenomena may appear:

- partial damaging of the internal dielectric barriers due to electrostatic discharge (ESD) in the production handling;
- formation of cracks in the plastic encapsulation due to a difficult manual production process;

For the transistors, the following phenomenon may appear:

- formation of cracks in the plastic encapsulation, due to a difficult manual production process;

In this case, the management has evaluated the situation, and has come to the following conclusions:

- it is not cost effective to replace the screening with an improved production process, in which the inducting of flaws may be reduced; \(^5\)
- none of the weaknesses can be cost effectively removed by design modifications; \(^6\)
- the expected flaws cannot be cost effectively removed by an inspection during production. \(^6\)

After going through Annexes A to F, Table J.1 relating flaws and their sensitivity to different stresses can be set up.

Based on the information in Table J.1, a combination of constant high temperature, low/high temperature cycling and constant operational stress was selected as the most cost-effective stress condition.

\(^5\) These particular problems are not intended to be regarded as general problems in industry. The purpose is only to illustrate the steps in the procedure.
### Table J.1 – Relation between sensitivity of flaws and stresses

<table>
<thead>
<tr>
<th>FLAWS</th>
<th>STRESSES</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial damage of CMOS ICs due to ESD in production handling</td>
<td>Constant high temperature</td>
<td>X Usable</td>
</tr>
<tr>
<td>Cracks in CMOS IC encapsulation due to a difficult manual production process</td>
<td>Low/high temperature cycling</td>
<td>X Usable</td>
</tr>
<tr>
<td>Cracks in power transistor encapsulation due to a difficult manual production process</td>
<td>Fixed frequency sinusoidal vibration</td>
<td>X The item is not designed for a rough, mechanical environment</td>
</tr>
<tr>
<td></td>
<td>Swept frequency sinusoidal vibration</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Random vibration</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Bump</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Constant operational stress</td>
<td>X Usable</td>
</tr>
<tr>
<td></td>
<td>Operational stress cycling</td>
<td>X Usable</td>
</tr>
<tr>
<td></td>
<td>Constant high humidity and temperature</td>
<td>X Suitable for screening – although not expected in field conditions</td>
</tr>
<tr>
<td></td>
<td>High humidity and temperature cycling</td>
<td>X</td>
</tr>
</tbody>
</table>

The temperature limits of all components on the PBA are within the range –10 °C to +70 °C. The lower and upper temperatures were chosen accordingly. The rogue components have rather small dimensions, so a reasonably high rate of change of temperature has to be used. It was chosen to be 5 °C/min. The transition time then becomes approximately 15 min. The dwell time at the lower temperature was chosen to be 30 min and at the higher temperature 1,5 h. During the whole cycle, the PBA are operationally stressed corresponding to the maximum ratings for the PBA. A functional testing in each cycle is performed at the end of the high-temperature phase. The total duration of one cycle adds up to 2,5 h.

**Summary of stress conditions:**

- **Lower temperature:** −10 °C
- **Upper temperature:** 70 °C
- **Rate of change of temperature:** 5 °C/min
- **Dwell time:**
  - at lower temperature: 30 min
  - at upper temperature: 1,5 h
- **Constant operational stress:** maximum rated
- **Monitoring (see Figure 4):** type B every 2,5 h.
STEP 4 – Determine the failure free period $T_M$. The graph for $p_c = 0.01$ in Figure 8 fits the purpose. Applying this graph, as shown in Figure J.1, gives:

$T_M / m_{F1} = 2.4$  so  $T_M = 2.4 \times m_{F1}$

![Graph](image-url)

**Key**

- $p_c = 0.01$
- $N$ number of components in the rogue component class
- $p_c$ fraction of weak components in the rogue component class
- 1 fraction of weak assemblies remaining
- 2 $p_B = 0.02$ (actual value)
- 3 $N = 24$ (actual value)
- 4 normalized failure-free period
- 5 $T_M / m_{F1}$ (actual derived value)

**Figure J.1 – Derivation of the failure-free period $T_M$**
From experience it is known that the MTTF for the early failures of the ICs is about 10 h in the chosen environment. For the transistor, the MTTF for the early failures is about 40 h in the chosen environment. According to 6.2.2, step 1, the mean time to failure for the weak components in the rogue component classes lumped together is to be set equal to the highest value, which gives $m_{F1} = 40$ h, and accordingly

$$T_M = 2.4 \times 40 = 96 \text{ h (equal to 4 days or 38.4 cycles)}$$

In round figures, the failure free period to be demonstrated for every PBA is

$$T_M = 38 \text{ cycles}$$

STEP 5 – Determine the average screening duration $T_B$ for each PBA.

$T_B$ can be used in order to estimate the cost of the screening. The graphs in Annex I for $T_B/m_{F1}$ versus $T_M/m_{F1}$ are applied to this specific case in Figure J.2. The specific value of $T_M/m_{F1} = 2.4$ gives $T_B/m_{F1} = 3.0$.

Finally, the average screening duration for each PBA can be derived:

$$T_B = 3.0 \times m_{F1} = 3.0 \times 40 = 120 \text{ h = 5 days}$$
J.3 Revision of the reliability stress screening process

In accordance with Clause 7, the pilot-production run of 100 PBAs goes through the planned reliability stress screening, as described in Clauses J.1 and J.2.

Furthermore, as recommended in 7.1, the PBAs surviving the failure-free period without failure were kept under the stress conditions for a prolonged period of up to 134 cycles, which corresponds to about two weeks. Enough failures, according to the rule of thumb in 7.2, were generated (the period is only about $3.5 \tau_M$, but there are three times as many PBAs as recommended).
The times to first failure, TTFF, observed appear in Table J.2. The table also shows the median rank values for the sample size \( n = 100 \), calculated by:

\[
P_{50}(i) = \left( \frac{i - 0.3}{n + 0.4} \right) \times 100 \quad \text{(as a percentage)}
\]

where

- \( n \) is the number of PBAs;
- \( i \) is the rank of each failure.

**Table J.2 – Observed failure ranks and times to first failure for the pilot production**

<table>
<thead>
<tr>
<th>TTFF (cycles)</th>
<th>Accumulated number of failures ( i )</th>
<th>( P_{50} ) (TTFF) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>6.7</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>11.7</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>13.6</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>16.6</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>18.6</td>
</tr>
<tr>
<td>7</td>
<td>20</td>
<td>19.6</td>
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<tr>
<td>8</td>
<td>21</td>
<td>20.6</td>
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<tr>
<td>9</td>
<td>22</td>
<td>21.6</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>23.6</td>
</tr>
<tr>
<td>16</td>
<td>25</td>
<td>24.6</td>
</tr>
<tr>
<td>19</td>
<td>26</td>
<td>25.6</td>
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<td>28.6</td>
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<tr>
<td>38</td>
<td>30</td>
<td>29.6</td>
</tr>
<tr>
<td>42</td>
<td>31</td>
<td>30.6</td>
</tr>
<tr>
<td>46</td>
<td>32</td>
<td>31.6</td>
</tr>
<tr>
<td>58</td>
<td>33</td>
<td>32.6</td>
</tr>
<tr>
<td>72</td>
<td>34</td>
<td>33.6</td>
</tr>
<tr>
<td>98</td>
<td>35</td>
<td>34.6</td>
</tr>
<tr>
<td>106</td>
<td>36</td>
<td>35.6</td>
</tr>
</tbody>
</table>

In Figure J.3, the observed failure development is plotted on a Weibull graph paper, together with a calculated S-curve based on the following values:

\[ p_s = 0.21, \quad \beta_1 = 1 \quad \text{and} \quad m_{F1} = 40 \text{ h} = 16 \text{ cycles}, \]

from the planning of the screening, and a prediction of the strong PBA population \( \beta_2 = 1 \quad \text{and} \quad m_{Fs2} = 10000 \text{ h} = 4000 \text{ cycles} \).
The failure development observed shows a considerably higher failure fraction (about 0.1) than expected. An investigation of the failure causes reveals that there are more failure causes than the expected ones. The new failure causes are as follows:

a) thermal overload of transistors, due to a high saturation voltage in combination with high current, when the transistor is “on”;

b) thermal overload of transistors, due to an improper fastening of the transistor case to its heat sink;

c) besides ICs and transistors, a diode and a capacitor have failed.

The management has again evaluated the situation and come to the following conclusions:

i) the first cause can be catered for by a design modification;

ii) the second cause can be catered for by an inspection during the assembling of the PBAs;

iii) these two types of failure are regarded as failures that occur randomly with respect to time in the sound PBA population. The remaining failures are the expected IC and transistor failures.

In conclusion, a) and b) type failures have to be regarded as non-relevant failures, and the Weibull plot revised by taking into consideration suspended assemblies (see Annex H). Table J.3 shows the revised rank values, and Figure J.4 shows the Weibull plot for the relevant failures.

As seen in Figure J.4, there is a clear levelling off at about 14%. The slope of the early part is higher than 1, but not in the extreme. By the method described in Annex J (Figure J.4), \( p_s \) and \( m_{Fs} \) are derived:

\[
p_s = 0.14
\]
\[
m_{Fs} \approx 5.1 \text{ cycles}
\]

The next step is to follow 7.3, and evaluate \( p_c \) and \( m_{F1} \) (note that there still are 24 components in the rogue component classes lumped together):

\[
p_c = 1 - (1 - p_s)^{1/N} = 1 - (1 - 0.14)^{1/24} = 0.0063
\]
\[
m_{F1} = m_{Fs} \times \frac{p_c N}{p_s} = 5.1 \times \frac{0.0063 \times 24}{0.14} = 5.5 \text{ cycles}
\]

These problems are not of a general nature, but chosen for the sole purpose of illustrating the procedure for revision of the reliability stress screening.
**Key**

1. c.d.f. ( % Weibull)
2. predicted S-curve $F(t) = 0.21(1-e^{-t/16}) + 0.79 (1-e^{-t/400})$
3. $F_2(t) = 1-e^{-t/400}$ (predicted c.d.f. for the sound PBA population)
4. stop
5. $t$ (cycles)

**Figure J.3 – Weibull plot of the observed and predicted failure pattern for the pilot production PBAs**
### Table J.3 – Revised rank values

<table>
<thead>
<tr>
<th>Event. no.</th>
<th>Non-relevant failures (suspensions)</th>
<th>Relevant failures</th>
<th>No. of assemblies after S</th>
<th>∆</th>
<th>i</th>
<th>$p_{50}$%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>S</td>
<td>F</td>
<td>99</td>
<td>(1)</td>
<td>0.71</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>S</td>
<td>F</td>
<td>1010</td>
<td>(0)</td>
<td>1.71</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>F</td>
<td>1010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td>F</td>
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<td></td>
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<td>2</td>
<td>5</td>
<td>F</td>
<td>1020</td>
<td></td>
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<td>1020</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>S</td>
<td>F</td>
<td>93</td>
<td>1.053</td>
<td>2.76</td>
</tr>
<tr>
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<td>9</td>
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<td>F</td>
<td>1,053</td>
<td>3.073</td>
<td>4.126</td>
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<tr>
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<td>10</td>
<td>S</td>
<td>F</td>
<td>1,053</td>
<td>4,126</td>
<td>3.81</td>
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<td>3</td>
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<td>S</td>
<td>F</td>
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<td>4,126</td>
<td>3.81</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>S</td>
<td>F</td>
<td>1,053</td>
<td>4,126</td>
<td>3.81</td>
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<td>88</td>
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<td>1.088</td>
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<td>6.0</td>
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<tr>
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<td>12,882</td>
<td>12.5</td>
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<td>F</td>
<td>1.101</td>
<td>12,882</td>
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</tr>
<tr>
<td>6</td>
<td>23</td>
<td>S</td>
<td>F</td>
<td>78</td>
<td>1.115</td>
<td>13,997</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>S</td>
<td>F</td>
<td>1.115</td>
<td>13,997</td>
<td>13.6</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>S</td>
<td>F</td>
<td>1.115</td>
<td>13,997</td>
<td>13.6</td>
</tr>
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<td>6</td>
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<td>S</td>
<td>F</td>
<td>1.115</td>
<td>13,997</td>
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<td>74</td>
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<td>14,8</td>
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<td>F</td>
<td>1.160</td>
<td>15,157</td>
<td></td>
</tr>
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In order to recalculate $T_M$ and $T_B$, the graph closest to $p_c = 0,0063$ is chosen. This is the 0,005 graph in Figure 8d. In accordance with 6.2.3, step 4, the $N$ values on the graph are recalculated to cater for the difference between the $p_c$ value for the graphs ($p_{c,\text{graph}} = 0,005$) and the actual $p_c$ value of 0,0063. Figure J.5 shows the corrections.

Using the same method as in Clause 6.3, the failure-free period is derived from the new curves in Figure J.5 and $p_B = 0,02$:

$$\frac{T_M}{m_{F_1}} = 2,0$$

The new value of the failure-free period is then:

$$T_M = 2,0 \times m_{F_1} = 2,0 \times 5,5 = 11 \text{ cycles} = 27,5 \text{ h} (\approx 1 \text{ day})$$
In the same manner, the average duration graph for $p_c = 0.005$ from Annex I is corrected. The result appears in Figure J.6. From Figure J.6, $T_B/m_{F1} = 2.2$ gives an average screening duration:

\[ T_B = 2.2 \times m_{F1} = 2.2 \times 5.5 = 12 \text{ cycles} = 30 \text{ h} \]

Note the reduction in the required number of cycles after the pilot production RSS.

---

**Key**

- $p_c = 0.063$
- $N$ number of components in the rogue component class
- $p_c$ fraction of weak components in the rogue component class
- 1 fraction of weak assemblies remaining
- 2 actual $p_B = 0.02$
- 3 actual $N_{\text{new}} = 24$
- 4 $N_{\text{new}} = N \frac{0.005}{0.003}$
- 5 normalized failure-free period
- 6 actual $T_M/m_{F1} = 2.0$

**Figure J.5 – Time graph (corrected) for determination of the failure-free period**
Key

$P_c = 0.063$

$N$ number of components in the rogue component class

$P_c$ fraction of weak components in the rogue component class

1 $N_{\text{new}} = N \frac{0.005}{0.006}$

2 actual $N_{\text{new}} = 24$

3 actual $T_{B/m_{F1}} = 2.2$

4 actual $T_{M/m_{F1}} = 2.0$

Figure J.6 – Time graph (corrected) for evaluation of the screening duration
### J.4 Production reliability stress screening

Based on the pilot-production screening analysis, this example shows how the following reliability stress screening process is performed on all PBAs.

**Summary of stress conditions:**
- Lower temperature: -10 °C
- Upper temperature: 70 °C
- Rate of change of temperature: 5 °C/min
- Dwell time: at -10 °C, 30 min
  at 70 °C, 1.5 H
- Constant operational stress: maximum rated

**Monitoring:**
- Functional testing in each cycle at the end of the upper temperature phase

**Failure-free period:** 
\[ T_M = 11 \text{ cycles} \]

From the screening process, the following information is extracted and evaluated, in accordance with 8.2:
- failed components;
- failure fraction;
- times to first failures;
- slope of the early Weibull plot.

Any discrepancies are dealt with in accordance with 8.3 and 8.4.
Bibliography

IEC 60068 (all parts), *Environmental testing*

IEC 61014:2003, *Programmes for reliability growth*

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