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Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

Indian Standard

RELIABILITY STRESS SCREENING

PART 2 ELECTRONIC COMPONENTS

ICS 03.120.01; 31.020

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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NATIONAL FOREWORD

This Indian Standard (Part 2) which is identical with IEC 61163-2 (1998) 'Reliability stress screening — Part 2: Electronic components' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendations of the Reliability of Electronic and Electrical Components and Equipments Sectional Committee and approval of the Electronics and Information Technology Division Council.

The text of the 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, references appear to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their places are given 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>
</table>

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

The Technical Committee responsible for the preparation of this standard has reviewed the provisions of the following International Standards and has decided that these 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 60300-3-7</td>
<td>Dependability management — Part 3-7: Application guide — Reliability stress screening of electronic hardware</td>
</tr>
</tbody>
</table>
1 Scope

This part of IEC 61163 provides guidance on reliability stress screening techniques and procedures for electronic components. This standard is not, and cannot be, exhaustive due to the rapid rate of developments in the electronics industry.

This standard is intended for the use of

a) component manufacturers as a guideline,
b) component users as a guideline to negotiate with component manufacturers on stress screening requirements or plan a stress screening process in house due to reliability requirements,
c) subcontractors who provide stress screening as a service.

This standard is not intended to provide test plans for specific electronic components or for delivery of certificates of conformance for batches of components.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61163. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 61163 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.


IEC 60300-1:1993, Dependability management – Part 1: Dependability programme management


IEC 60300-3-7:—, Dependability management – Part 3-7: Application guide – Reliability stress screening of electronic hardware ¹)


¹) To be published.
3 Definitions

For the purpose of this part of IEC 61163, the following definitions as well as those given in IEC 60050(191) and IEC 60300-3-7 apply:

3.1 reliability screening (process)
a process of detection of flaws and removal and repair of weak items for the purpose of reaching as rapidly as possible the reliability level expected during the useful life

NOTE 1 – IEC 60050(191) defines in 191-17-02, 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 where in many cases no failures occur.

NOTE 2 – IEC 60050(191) defines, in 191-14-09, the term "screening test". This term, however, is defined too broadly to be applicable in the present context because it encompasses screening of any types of non-conformities. Furthermore, reliability screening is a process, not a test.

NOTE 3 – Repair is not applicable in the case of electronic components.

3.2 reliability stress screening (process)
a process using environmental and/or operational stress as a means of detecting flaws by precipitating them as detectable failures

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

3.3 weak item
an item which has a high probability of failure in the early failure period due to a flaw (see also 3.8: early failure period)

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

NOTE 1 – Each type of weakness is assumed to be statistically independent of all other such types.

NOTE 2 – A weakness may be either inherent or induced.

3.5 weakness failure
a failure due to a weakness in the item itself when subjected to stresses within the stated capabilities of the item [IEV 191-04-06]

3.6 flaw
a weakness in an item which gives rise to early weakness failures

3.7 inherent flaw
a flaw in an item related to its technology and manufacturing process
3.8
early failure period
that early period, if any, in the lifetime 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 [IEV 191-10-07]
NOTE – The early failure period is the period where the weak items fail.

4 Procedure

4.1 General

In designing a stress programme, it is important to understand the purpose of the programme as to whether it is:

a) to improve the process capability by understanding and eliminating causes of failures;
b) to achieve tighter performance on screened devices compared to published specifications;
c) to understand and improve reliability of new device technologies;
d) to remove weak devices which may fail early.

It is important to note that there are two types of failures:

- time-dependent failures; the mechanisms that cause these failures are stress-dependent and will cause degradation of the device given sufficient time. The techniques used to accelerate these failure mechanisms should not affect good devices;
- time-independent failures; these failure mechanisms are due to latent flaws that do not affect devices in normal operation unless induced by some external events. Care should be taken when choosing the techniques used to accelerate these failures since damage to good components is possible if the screen is too harsh.

In all the above cases, the screening will start at 100 %, gradually reduce and finally be eliminated after analysis of failures is made and follow-up actions are taken.
Figure 1 - Component reliability screening process
(general flow chart)
It is important that the aim for a reliability stress screening be carefully considered. No reliability stress screening procedure should be used routinely. There is to be a clear reason why reliability stress screening is chosen (for example economic reasons).

In order to get the best possible results from a stress screen, it is necessary to fully understand the failure mechanisms of the components to be screened and how the application of any particular screen will affect these mechanisms. Care should be taken so that only the failure mechanisms likely to occur while the component is operating in the field are accelerated by the screen, since it is relatively easy to induce unlikely failure mechanisms by misapplication of screening stress.

Before and after any screen is applied, functional testing of each part to be screened should be performed. Firstly, this testing is done so that only those parts that fail as a result of the stress screen should be recorded as failing for that reason. Secondly, the stress screen is applied to every component for the specified period of time and under the specified conditions. Thirdly, every component is tested functionally again, in order to remove any failed parts from the good product population.

Functional testing may not be sufficient for components which are particularly delicate or costly, such as lasers. In these cases, a parametric test may be necessary.

The reliability stress screening performed in this manner can be used to determine the yield of the screen for the lot of components screened. This screen yield data may be compared to data for yield without screen application and both these types of data may be compared in turn to system yield data, and ultimately to system field return data, all in order that the effectiveness of the screen may be monitored.

In order to use reliability stress screening of electronic components effectively, the type of failure(s) expected should be understood. Then the details of the stress screen programme, including stress levels and screen durations, should be planned.

The reliability stress screening methodology cannot be described in detail since there are many different component types. Therefore, it is not advisable to comprehensively list reliability screening procedures for particular component types. A general procedure, however, can be recommended for designing a specific reliability stress screening plan (see 4.2). It is important to note that all the steps of such a procedure need not be used in designing every reliability stress screening plan.

4.2 Programme definition

The following procedure for setting up and running a reliability stress screening process is recommended:

- establish contact between the two parties involved
- identify the possible flaws and failure modes for each component
- select stress types, stress levels and stress sequence to be used in order to precipitate failures
- determine the duration of the reliability stress screening process
- mathematically analyze initial test results
- perform failure analysis
- perform stress sequence on the components
- determine approval or rejection criteria
- develop closed-loop corrective action process
- provide feedback to the component manufacturers
- discontinue the reliability stress screening process
In the following subclauses, each step is discussed. Annex C gives examples of how a reliability stress screening process could be designed for different component types. These examples should not be used uncritically for reliability stress screening of components of the same family, but only regarded as illustrations of the step-by-step method described in the following subclauses.

4.3 Establish contact between the two parties involved

Before performing a reliability stress screening process, it is necessary to gather as much information about the component to be screened as possible. This can best be achieved by contacting the component manufacturer. The manufacturer will be aware of all the processes used in the production of the component and how they affect the end product. He will be able to provide insight into the failure modes and mechanisms that may be expected from good components as well as from less robust components. Information on methods of diagnosing flaws without having to perform a stress test may also be available.

In some cases, it may prove more economical to allow the component manufacturer to perform the stress test, as he will inevitably be performing such tests already. If stress testing by the component manufacturer is unavailable for some reason, then useful information about the design and operation of a stress test may be obtained from him.

4.4 Identify the possible flaws and failure modes for each component

After contact with the manufacturer, a list of the potential flaws in the component should be developed. Table A.1 shows potential flaws for different generic component types and technologies. If experience from failure analysis of failed components exists, this will give important information about possible flaws. After the potential flaws have been listed, each should be evaluated to determine if the flaw will develop into a failure in the environment of the finished product. Further, the aim of the reliability stress screening process should be taken into account. This evaluation results in a list of potential flaws with their probability of occurrence.

4.5 Select stress types, stress levels and stress sequence to be used in order to precipitate failures

The next step is to select the types of stress that are the most efficient in precipitating the flaw types. Examples are given in annex A. This information, however, should be combined with physical knowledge of the actual component and its possible flaws. Again one can obtain valuable information from the component manufacturer. In order to cover all the relevant flaw types with a manageable number of stress types, one may, in some cases, be forced to use the second or third most efficient stress type. Determination of the optimal mix of stress types that cause the highest stress level for a particular component type and stress types that are readily available in test equipment or are inexpensive to set up should be made. This optimization can take some time and some iterations to complete.

When the stress types have been selected, the maximum level of stress that can be used without significantly reducing the lifetime of the good and sound (unflawed) components should be determined. If no specific information from the component manufacturer is available, the maximum storage temperature for the component type should be chosen when no voltage is applied and the maximum operating temperature when the reliability stress screening is performed under electrical voltage 2).

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2) It is, nevertheless, nearly always possible to use higher stress levels than when the components are mounted in a finished piece of equipment.
In some cases, the stress types are applied separately in sequence. The order of the sequence can be of major importance, e.g. a mechanical shock or vibration creates cracks around the component leads and, therefore, a moisture stress should be performed after the mechanical vibration.

4.6 Determine the duration of the reliability stress screening process

A reliability stress screening evaluation is made initially to find the optimum duration of the reliability stress screening process for the chosen stress types and stress levels. It is recommended to repeat this evaluation for each new component type or in cases where a series of component batches are manufactured.

This initial evaluation should be repeated whenever the average percentage of failures observed after the actual reliability stress screening process has changed significantly, or when failures related to components suspected to be less robust than normal are observed in field use.

The evaluation should always be three to five times longer than the reliability stress screening process itself, in order to detect early failures that occur after the termination of the shorter reliability stress screening process.

The stress screening evaluation can be performed using a sample of the components to be screened. The components are exposed to selected stress screening for sufficient time that a relevant number of weakness failures may occur. The number of failures to be observed is related to the assumed size of the weak population within the sample and the required confidence level. See annex B for further details. In order to estimate the acceleration factor, the equations given in annex B can be used.

During the reliability stress screening process, the percentage of failures observed during the test can change:

a) If the percentage of failures increases, the duration of the test should immediately be doubled.

b) If the percentage of failures decreases, a fresh evaluation should be performed to decide if the duration of the test can be decreased.

b) If the percentage of failures remains constant over a period of time, the evaluation should be repeated at regular intervals. If the components under test are monitored continuously during the actual reliability stress screening process, it is easy to analyze the data and decide when a new reliability stress screening is required. If the components are not monitored continuously, a separate reliability stress screening evaluation should be made.

4.7 Mathematically analyze initial test results

The results from the initial reliability stress screening are analyzed and the duration of the reliability stress screening can be computed using the methods described in annex B.

4.8 Perform failure analysis

It should be emphasized that, when the duration of the reliability stress screening process is optimized, analysis of the observed failures should be simultaneously performed so that the component manufacturer can remove the cause of the failures.

All failure mechanisms observed during the test should be identified. If the mechanisms were induced by handling before or during the test (for example electrostatic discharges, ESD) or the failure mechanism was induced by the test itself, the handling procedure or test stress levels should be reviewed.
In any sample, the identification of both unanticipated and anticipated flaws should be expected, and the non-appearance of anticipated flaws should also be expected.

Failure mechanisms observed in the field and observed in reliability stress screening are the failure mechanisms to focus attention on. If this is a new application, one can use experience with similar applications to judge whether or not a failure mechanism observed in reliability stress screening is likely to be seen in the field.

4.9 Perform stress sequence on the components

In certain cases, for example intermittent failures, continuous monitoring of the components being screened may be necessary. In cases where the components are monitored continuously, screen results can be used to determine a new optimum screen duration.

4.10 Determine approval or rejection criteria

In cases where it is decided to approve or discard the screened components, the decision may be based on different decision rules:
- number of failures observed;
- percentage of components with parameter values outside the limits;
- margin from the distribution to the functional limit (for example 6 σ).

4.11 Develop closed-loop corrective action process

The overall corrective action process should be an effective tool to acquire feedback on failure data, perform analysis and take appropriate action. Figure 2 describes the suggested corrective action process. The corrective action process flow chart describes the actions/strategies in implementing the actions.
Perform initial stress screening

Yes

Failures?

No

Review test procedure

Yes

Perform failure analysis to find root cause

Utilize one of several optimization techniques to determine root cause

Is cause test itself?

No

Is cause manufacturing or engineering?

Engineering

Re-design component

Manufacturing

Correct process

Test new design

Manufacture new components

Test new components

Proceed with sampling plan strategy

Figure 2 – Corrective action process
4.12 Provide feedback to the component manufacturers

If the reliability stress screening is performed by the user, the results from the reliability stress screening process should always be provided to the component manufacturer. This includes results of failure analysis. In some cases, the component manufacturer may be willing to do the failure analysis. The purpose of this feedback is to enable the component manufacturer to improve the component design and the manufacturing processes. If the component manufacturer performs the reliability stress screening to a specification issued by the component user, it is vital that the outcome of the reliability stress screening be reported to the component user so that changes in the specification are introduced when it is appropriate.

4.13 Discontinue the reliability stress screening process

A reliability stress screening process should only be used for as long as is necessary. After a successful change in the component manufacturing process, the reliability stress screening can be discontinued if the results show that the specified requirements can be met without it. In this case, a reliability stress test on a sample of each manufacturing lot should be used to monitor whether the number of flawed components is still within the acceptable range or not.

Where the required reliability cannot or may not be achieved by process improvement (for technical or economical reasons), the reliability stress screening should be maintained as long as is reasonable. This can be the case

- if reliability stress screening is the only way to achieve an acceptable reliability target,
- if lots with fewer, less robust components are to be delivered for high reliability applications,
- if lots with particular properties are to be delivered which are not guaranteed by the standard product specification. For example, if a parameter is of low importance (in standard applications) but gains primary importance for a specific application, reliability stress screening could be the only possible way to obtain items with that property without developing a completely new product with all the costs associated with that process.
It should be noted that some of the tools presented in table A.1 are destructive and hence will damage all components where the technique is applied. This means that it is only possible to use these techniques when determining reliability stress screening for samples of components drawn from lots.

### Table A.1 – Tools for identifying potential flaws

<table>
<thead>
<tr>
<th>Stress tests, procedures and equipment</th>
<th>Potential flaws</th>
<th>Destructive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual inspection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-cap visual inspection of moulded or hermetically sealed components</td>
<td>Visible flaws in the devices</td>
<td>No</td>
</tr>
<tr>
<td>Inspection after DPA (destructive physical analysis) of hermetically sealed components</td>
<td>Visible flaws and assembly problems</td>
<td>Yes</td>
</tr>
<tr>
<td>Scanning acoustic microscopy (this technique uses ultrasound to image the interior of encapsulated components)</td>
<td>Internal defects like short circuits, bonding problems, open contacts, etc. can be identified (weakness in solder joints, chip, attachment to lead frame, moulding compound to lead frame, bondings, welding joints and weak conductive areas such as chip metallization fault, bond wire nicks and insulation weaknesses)</td>
<td>No</td>
</tr>
<tr>
<td>X-ray equipment</td>
<td>Internal defects like short circuits, bonding problems, open contacts, etc. can be identified (weakness in solder joints, chip, attachment to lead frame, moulding compound to lead frame, bondings, welding joints and weak conductive areas such as chip metallization fault, bond wire nicks and insulation weaknesses)</td>
<td>No</td>
</tr>
<tr>
<td>Constant acceleration, mechanical shock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centrifuge capable of achieving required revolutions per minute (RPM) used for components with cavities; hermetically sealed ICs, MCMs, hybrids, etc.</td>
<td>Bad attachments of chips and substrates. Loose or loosely fixed particles such as weld splashes and solderballs. Wires placed too close to each other or to the case</td>
<td>Yes</td>
</tr>
<tr>
<td>Vibration</td>
<td>Bond wire problems. Flawed attachments and joints. Problems due to resonance at joints and junctions. Weak connections, welds, etc.</td>
<td>Yes</td>
</tr>
</tbody>
</table>

11
Table A.1 (concluded)

<table>
<thead>
<tr>
<th>Stress tests, procedures and equipment</th>
<th>Potential flaws</th>
<th>Destructive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature cycling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature cycling chamber can be dual or single chamber</td>
<td>Weakness in solder joints, chip, attachment to lead frame, moulding compound to lead frame, bondings, welding joints and weak conductive areas such as chip metallization fault, bond wire nicks and insulation weaknesses</td>
<td>Yes</td>
</tr>
<tr>
<td>Thermal shock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation between two different temperatures</td>
<td>Glass feed-throughs, plating problems, etc.</td>
<td>Yes</td>
</tr>
<tr>
<td>High temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heated chamber with temperature monitoring</td>
<td>Precipitate internal flaws in components</td>
<td></td>
</tr>
<tr>
<td>High temperature, only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High temperature with voltage applied and reverse bias</td>
<td>Failures due to contamination in semiconductors</td>
<td>Yes</td>
</tr>
<tr>
<td>High temperature with power applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refrigerated chamber with refrigeration to activate cold temperature</td>
<td>Degradation of transistor (particularly MOS) due to hot carriers</td>
<td>Yes</td>
</tr>
<tr>
<td>The test should be performed with the maximum bias applied to the component</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew-point test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor a parameter continuously while lowering the temperature to a very low temperature like −65 °C. Then raise temperature. If a sharp discontinuity is observed in the measured parameter during fall and rise of temperature, this is the dew point for the enclosed environment. A high dew point indicates high humidity in the cavity due to leaks or manufacturing flaws</td>
<td>Corrosion caused by precipitation of enclosed humidity in humid device cavities</td>
<td>Yes</td>
</tr>
<tr>
<td>Particle impact noise detection (PIND)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same as vibration test and thermal shock. Here each component is placed on a vibration shaker and subjected to vibration followed by shock pulses. The instrumentation indicates any acoustical noise in the system during this agitation. Detected noise indicates loose parts within the package</td>
<td>Small solder balls, weld splash balls, loose particles in the cavity</td>
<td>Yes</td>
</tr>
<tr>
<td>High humidity – high temperature tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chamber capable of achieving high temperature and high humidity. The time of test is reduced by testing at a high temperature (130 °C). Autoclaves capable of high pressure are required to reach 100 % humidity levels</td>
<td>Humidity test will detect components with weak packages, bad adhesion of moulding compounds to terminals causing moisture leakage and corrosion. The test can also detect flaws in the moulding compound due to moisture or contamination</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Annex B  
(informative)

Data analysis

B.1 Symbols

\( \alpha \) constant

\( \beta \) parameter, determines the shape of the distribution

\( \eta \) parameter, also called characteristic lifetime

\( A \) constant

\( C \) voltage acceleration factor in ångströms per volt (Å/V)

\( D \) self-diffusion coefficient, \( D = D_0 \times \exp \left(-EA/k_B T\right) \), in square centimetres per second (cm\(^2\)/s)

\( d_{\text{ox}} \) thickness of oxide in ångströms (Å)

\( E_A \) activation energy in electron-volts (eV)

\( f_1 \) cycling frequency at use conditions

\( f_2 \) cycling frequency at screen conditions

\( F(t) \) distribution function of failures

\( G_1 \) factor, dependent on the maximum temperature \( T_{\text{max},1} \) (use conditions)

\( G_2 \) factor, dependent on the maximum temperature \( T_{\text{max},2} \) (screen conditions)

\( h_1 \) reference level of humidity

\( h_2 \) screen level of humidity

\( i \) failure number

\( J_1 \) reference current density in amperes per square centimetre (A/cm\(^2\))

\( J_2 \) screen current density in amperes per square centimetre (A/cm\(^2\))

\( K^* \) constant of proportionality

\( k_B \) Boltzmann constant, \( k_B = 8.617 \times 10^{-5} \text{ eV/K} \)

\( M \) material constant (slope of Wöhler curve of the relevant material)

\( N_1 \) number of cycles to failure at use conditions

\( N_2 \) number of cycles to failure at screen conditions

\( n \) sample size

\( n_1 \) constant, specific to the voltage action

\( n_2 \) constant, specific to the humidity action

\( p \) proportion of weak components

\( P \) probability of failure

\( t \) operating time

\( t_1 \) time to failure at reference conditions

\( t_2 \) time to failure at screen conditions

\( T \) absolute temperature in kelvins (K)

\( T_1 \) reference temperature in kelvins (K)

\( T_2 \) screen temperature in kelvins (K)

\( T_{\text{max},1} \) maximum temperature reached during the cycle at use conditions in kelvins (K)

\( T_{\text{max},2} \) maximum temperature reached during the cycle at screen conditions in kelvins (K)

\( \Delta T_1 \) temperature range in kelvins (K) at use conditions

\( \Delta T_2 \) temperature range in kelvins (K) at screen conditions

\( V_1 \) reference voltage in volts (V)

\( V_2 \) screen voltage in volts (V)

\( W_1 \) acceleration density (ASD or PSD)\(^3\) r.m.s. value for random vibration under operating conditions

\( W_2 \) acceleration density (ASD or PSD)\(^3\) r.m.s. value for random vibration under screen conditions

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3) ASD: acceleration spectral density; PSD: power spectral density.
B.2 Design of a reliability stress screening test

Firstly the required number of components to be used in reliability stress screening is computed. For example, if the proportion of weak components is 5%, in order to draw a reasonable S-curve as shown in figure B.2 at least four failures are required. Assuming 90% probability of having at least four failures and using the nomograph of figure B.1, a line is drawn from the scale to the left $P = 5\%$ to $P = 1 - 0,9 = 0,1$ on the right-hand scale.

Since the probability $P = 0,1$ is for three or fewer failures, the point at which the line crosses the failure line $c = 3$ in the centre curves should be noted. From this point the sample size line is followed and $n = 130$ is read as a sample size.
This means there should be at least 130 components in the reliability stress screening in order to get at least four failures with 90% probability provided that the level of weak components is 5%. If the level of weak components is lower, a higher sample size is required. If the percentage of weak components is larger than 5%, then a smaller sample can be used.

B.3 Weibull analysis

When reliability stress screening has been performed, the data can be plotted on a distribution probability paper. The nature of this paper will depend on the type of failure distribution observed. The aim is to be able to draw a straight line through the points when plotted on the paper. If a straight line cannot be drawn, then the selected paper is not appropriate for the failure distribution and should be changed. There are a number of standard papers available including Normal, Weibull, Lognormal, etc. Application of any other probability paper is possible given a consideration of the underlying distribution. Software is available to make this task easier.

The following text describes the Weibull distribution since it is the most often used in reliability work.

Weibull probability paper is based on the two parameter Weibull distribution function:

\[ F(t) = 1 - \exp \left(-\left(\frac{t}{\eta}\right)^\beta\right), \quad \eta > 0, \quad \beta > 0 \]

where
- \( t \) is the operating time
- \( \beta \) is a parameter which determines the shape of the distribution
- \( \eta \) is a parameter, called the characteristic lifetime

The axes of the paper are transformed in such a way that the true Weibull distribution function plots as a straight line. Therefore, if data can be plotted in a straight line, they will fit a Weibull distribution.

In order to estimate the distribution function, the number of components in the test \( n \), the number of failures observed and the operating time to each failure \( t_i (0 < i \leq n) \) are required.

First, the failures are written in sequence after the time or number of reliability stress screening cycles from the earliest failure to the last failure. These operating times, or cycles to each failure are the \( x \) co-ordinate for the plot.

For the \( y \) co-ordinate, it is necessary to compute the cumulative frequency distribution.

- For sample sizes of 30 components or more, the cumulative frequency distribution can be computed in percentage terms as

\[ H_i = \frac{i}{n} \times 100\% \]

where
- \( i \) is the failure number
- \( n \) the sample size (\( n \geq 30 \))
If the sample size is less than 30, it is necessary to compensate for the small sample size. For this purpose, the median rank is used as the y co-ordinate. The median ranks can be found in textbooks or can be computed using the following approximation:

\[ H_i = \frac{i - 0.3}{n + 0.4} \times 100\% \]

The failures can then be plotted on a Weibull probability paper. Each failure will result in one point on the paper. A smooth curve can then be drawn through the points using best engineering estimates. If the data is weibullly distributed, a straight line will appear. If not, or if the data is bimodal, a curve will appear. If the curve is S-shaped, a bimodal distribution probably exists, as shown in figure B.2.

![Figure B.2 - Estimation of \( \eta \) and \( \beta \)](image)

When the best smooth curve has been drawn and the knee of the curve found, the percentage of weak components \( p \) can be found as the y co-ordinate of the knee, the point where the curve levels off and becomes more or less horizontal.

Estimate the Weibull parameters of the weak population by multiplying \( p \) by 0.632 and then examining the curve to see where this percentage intersects, go vertically down to the x axis, to find the characteristic lifetime of the weak components \( \eta \).

In order to find the shape parameter \( \beta \) for the weak components, draw a line that represents the slope of the first part of the S-curve up to the knee.

Plot the weak failures separately and read the number of reliability stress screening hours or reliability stress screening cycles needed to remove any percentage of the weak components. 90 %, 95 % or 99 % of the weak components can be removed. Using this line a more precise estimate of \( \beta \) and \( \eta \) can be obtained.

Following the failure analysis, it can be useful to plot each failure mode separately using the method of suspended items.

In some cases, it is desirable to estimate the percentage of failures caused by the reliability stress screening process on the strong components. In this case, it is necessary to find the parameters for the strong population. This can only be done if there are at least two failures from the strong population.
Plot the weak failures in one plot and the strong failures in another plot. In this case, the sample size \( n \) for the weak components is equal to the number of weak failures, and the sample size for the strong components is the rest of the original sample. For this plot, it may be necessary to use the Bayes method to distinguish between the weak and the strong failures.

If the curve does not have an S-shape, the reason may be that

- the reliability stress screening was too short. Not all weak components in the sample have failed during the test
- the stress level chosen for the reliability stress screening was too low. All the weak components in the sample have not failed in the test
- the reliability stress screening-stress level was too high, all components failed with a test related failure mechanism
- there may be some failure-free time before the first weak components fail (in this case, the shape of the curve will be more like a U than an S)
- there may be no weak components.

When in doubt, the Bayes method can be used.

**Example**

Assuming that a reliability stress screening test with \( n = 23 \) components has been carried out, and five failures have been observed. The median ranks for the Weibull plot can then be computed (see table B.1).

<table>
<thead>
<tr>
<th>Failure No.</th>
<th>Time to failure</th>
<th>Median rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>( i )</td>
<td>( t_i )</td>
<td>( H_i = \frac{i - 0.3}{n + 0.4} \times 100% )</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>3.0</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>7.3</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>11.5</td>
</tr>
<tr>
<td>4</td>
<td>42</td>
<td>15.8</td>
</tr>
<tr>
<td>5</td>
<td>98</td>
<td>20.1</td>
</tr>
</tbody>
</table>

*Table B.1 – Screening test results*
A smooth line drawn through the points shows that the knee of the curve is at approximately 18% and this indicates that 18% weak components are present in the population. $\beta$ is estimated at 1.

The characteristic life, $\eta$, is found by computing $18\% \times 0.632 = 11.3\%$ and then reading the $x$-value from the smooth curve at this ordinate. In this example it is found to be 23 h.
In order to calculate the parameters of the weak population, the first four failures are plotted separately using the original x co-ordinates, however the y co-ordinates are given in Table B.2.

Table B.2 – Screening test results for weak populations

<table>
<thead>
<tr>
<th>Failure No.</th>
<th>Time to failure ( t_i )</th>
<th>Median rank %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>39</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>61</td>
</tr>
<tr>
<td>4</td>
<td>42</td>
<td>84</td>
</tr>
</tbody>
</table>

The straight line drawn through the first four failures shows that the slope of this line is \( \beta_1 = 1.2 \). The Weibull parameters for the weak distribution are therefore \( \beta_1 = 1.2 \) and \( \eta_1 = 25 \text{ h} \).

This more exact \( \eta_1 \) is found on the plot of the weak population alone. It is not possible to draw the curve for the strong population since there is only one strong failure. It is possible to estimate the percentage of strong components that have failed at 98 h to be 1 out of 23 – 4 = 19 strong components, i.e. 5.3%.

It is desirable to remove 99% of the weak components in the test and, therefore to, plot the weak components alone. The optimum duration of the reliability stress screening process will be 90 h. Since this time is lower than 98 h, the probability of a strong component failing is much less than 5.3%. A good conservative estimate assuming constant failure intensity will be \((90/98) \times 5.3\% = 4.9\%\).

**B.4 Equations for computing acceleration factors**

It is difficult to compute the acceleration factors for a reliability stress screening process. Therefore, statistical methods are used that are independent of the acceleration factor. To estimate the acceleration factor of the reliability stress screening process in order to choose the duration of the initial stress screening optimization, the following equations can be used.

The proposed acceleration formulae should be used carefully. The constants in the equations depend on the technological characteristics of the components and can vary by a large amount.

Before using these equations, careful checks to ensure that the equations are applicable to the situation under scrutiny are required. The constants used in the equations can be found in some data books or can be obtained empirically from experiment. The component manufacturers will often know the constants values for the components they manufacture and these values should be used whenever possible.

In most cases more than one failure mechanism will be present and unfortunately the mixture of these mechanisms will vary with the absolute temperature. This means that any average activation energy will be temperature dependent and using an average value may lead to incorrect results. Therefore it is necessary to perform any calculations for each failure mechanism in turn.
B.4.1 Temperature acceleration factor

The Arrhenius equation allows the acceleration factor caused by an increased temperature to be estimated. Due to the higher rate of chemical reactions at higher temperature a small number of hours at a high temperature is equivalent to a larger number of hours at low temperature.

The equation for the acceleration factor \( t_1/t_2 \) (proportion between the time at reference temperature \( T_1 \) and the time at screen temperature \( T_2 \)) reads:

\[
\frac{t_1}{t_2} = \exp \left( \frac{E_A}{k_B} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \right)
\]

where
- \( T_1 \) is the reference temperature, in kelvins (K)
- \( T_2 \) is the screen temperature, in kelvins (K)
- \( E_A \) is the activation energy, in electron-volts (eV)
- \( k_B \) is Boltzmann constant, \( k_B = 8.617 \times 10^{-5} \) eV/K

B.4.2 Vibration acceleration factor

For computing the acceleration factor for an acceleration spectral density (ASD) or power spectral density (PSD) specified random vibration, the following equation is used:

\[
\frac{\tau_1}{\tau_2} = \left( \frac{W_2}{W_1} \right)^M
\]

where
- \( \tau_1 \) is the duration of vibration under operating or transport conditions
- \( \tau_2 \) is the duration of random vibration under screen conditions
- \( W_1 \) is the acceleration density (ASD or PSD) for random vibration under operating conditions
- \( W_2 \) is the acceleration density (ASD or PSD) for random vibration under screen conditions
- \( M \) is the material constant (slope of Wöhler curve of the relevant material); the typical value is 4 for metal, which also can be used in general for electronic equipment

If this equation is used for calculations for sinusoidal vibration, \( W \) represents peak \( g \) values and \( M = 6 \) in the general case for electronics and \( M = 2.5 \) in the case of electronic boards.

If the vibration levels are specified using root mean square (r.m.s.) values, the following equation is used:

\[
\frac{\tau_1}{\tau_2} = \left( \frac{W_{12}}{W_{11}} \right)^{2M}
\]

where
- \( W_{11} \) is the r.m.s. value for random vibration under operating conditions
- \( W_{12} \) is the r.m.s. value for random vibration under screen conditions
B.4.3 Voltage acceleration factor

Specially for MOS components, where the oxide defects are preponderant, the acceleration is described by:

\[ \frac{t_1}{t_2} = \exp \left( \frac{C}{d_{ox}} (V_2 - V_1) \right) \]

where
- \( C \) is the voltage acceleration factor, in Ångströms per volt (Å/V)
- \( d_{ox} \) is the thickness of oxide, in Ångströms (Å)
- \( V_1 \) is the reference voltage, in volts (V)
- \( V_2 \) is the screen voltage, in volts (V)

B.4.4 Current acceleration factor

The effect of the current is described by the following formula:

\[ \frac{t_1}{t_2} = \left( \frac{J_2}{J_1} \right)^n \exp \left( \frac{E_A}{k_B} \frac{1}{T_1} - \frac{1}{T_2} \right) \]

where
- \( J_1 \) is the reference current density, in amperes per square centimetre (A/cm²)
- \( J_2 \) is the screen current density, in amperes per square centimetre (A/cm²)
- \( n \) is a parameter, \( 1 \leq n \leq 3 \)
- \( E_A \) is the activation energy, in electron-volts (eV)
- \( k_B \) is the Boltzmann constant, \( k_B = 8.617 \times 10^{-5} \text{ eV/K} \)
- \( T_1 \) is the reference temperature, in kelvins (K)
- \( T_2 \) is the screen temperature, in kelvins (K)

This formula is based on the characteristics of electromigration.

B.4.5 Fatigue acceleration factor

The acceleration factor for fatigue is given as

\[ \frac{N_1}{N_2} = \left( \frac{f_1}{f_2} \right)^{\Delta T_2 / \Delta T_1} G_1 \left( \frac{T_{max,1}}{T_{max,2}} \right) \]

where
- \( N_1 \) is the number of cycles to failure at use conditions
- \( N_2 \) is the number of cycles to failure at screen conditions
- \( f_1 \) is the cycling frequency at use conditions
- \( f_2 \) is the cycling frequency at screen conditions
- \( \alpha \) is a constant
- \( \beta \) is a constant
- \( \Delta T_1 \) is the temperature range at use conditions, in kelvins (K)
- \( \Delta T_2 \) is the temperature range at screen conditions, in kelvins (K)
- \( G_1 \) is a factor, dependent on the maximum temperature \( T_{max,1} \) (use conditions)
- \( G_2 \) is a factor, dependent on the maximum temperature \( T_{max,2} \) (screen conditions)
- \( T_{max,1} \) is the maximum temperature reached during the cycle at use conditions
- \( T_{max,2} \) is the maximum temperature reached during the cycle at screen conditions
B.4.6 Multiple stresses acceleration factor

The Arrhenius model is dedicated to temperature. To take into account other stresses simultaneously, it is necessary to use the Eyring model. The Eyring model equation can be used in the following form:

\[
\frac{t_1}{t_2} = \exp \left[ \frac{E_A}{k_B \left( \frac{1}{T_1} - \frac{1}{T_2} \right)} \right] \left( \frac{V_2}{V_1} \right)^{n_1} \left( \frac{H_2}{H_1} \right)^{n_2}
\]

where

- \( T_1 \) is the reference temperature, in kelvins (K)
- \( T_2 \) is the screen temperature, in kelvins (K)
- \( E_A \) is the activation energy, in electron-volts (eV)
- \( k_B \) is the Boltzmann constant, \( k_B = 8.617 \times 10^{-5} \text{ eV/K} \)
- \( V_1 \) is the reference voltage, in volts (V)
- \( V_2 \) is the screen voltage, in volts (V)
- \( n_1 \) is a constant, specific to the voltage action
- \( H_1 \) is the reference level of humidity
- \( H_2 \) is the screen level of humidity
- \( n_2 \) is a constant, specific to the humidity action
Examples of applications of reliability stress screening processes

Examples given in this annex represent different reliability stress screening cases and component families. They are all fictional.

C.1 Power semiconductors

Typical properties for this component family are a high dissipation, a high junction temperature, a large temperature range, high currents, requirements on low and stable saturation forward voltage and large chips. This means that there are high demands on the thermal design.

Types of components covered are thyristors, power MOSFETs, power bipolar transistors, SCRs, triacs, etc. Some of the component types in this category are very sensitive to electrical overstress (ESD or EOS) and this should be taken into consideration as one parameter for the decision whether or not to perform reliability stress screening.

The reliability stress screening should be designed according to information given in this method individually for each component type which is to be subjected to reliability stress screening and also taking the application and the aim of the reliability stress screening into consideration.

Example: Bipolar silicon power transistor (standard, catalogue component)

- Necessity for the component screen

The application of the component requires that the turn-on time be 0.5 µs and turn-off time be 1.0 µs at $I_C = 2$ A. According to the component data sheet the times are specified as typical data at $I_C = 5$ A. The use of this component type, with the special performance regarding the switching (pulse response) data, gives the equipment top performance and it will be competitive on the market.

- Establish contact between the two parties involved

The component manufacturer cannot give any advice regarding the expected outcome of a screening operation and is not aware of anyone else who performs this kind of selection. He is not willing to perform the screening as the requested quantity is too low and any special arrangement during manufacturing to increase the ratio of good components is not possible for technical reasons.

The time decreases with increasing temperature. The temperature coefficient is not well defined. As the parameter is not measured at the outgoing control and has not been measured during type tests, nothing can be predicted about the stability over time with certainty.

No reject is accepted by the component manufacturer regarding components with parameters outside the user's criteria. Rejects are accepted only if the specified data are outside the manufacturer's specified limit.

- Identify the possible flaws and failure modes for each component

This step is not applicable for this reliability stress screening case.
Select stress types, stress levels and stress sequence to be used in order to precipitate failures

From the contact with the component manufacturer it is obvious that the screening should be performed by measuring the pulse response times at a low temperature and also after some time at the high temperature operation screening. The measurement will be performed with \( I_C = 2 \text{ A} \) and \( V_{CC} \) and other data as in the current application. The high temperature screening will be performed with specified power applied.

The highest ambient temperature at the devices location in the equipment is measured in prototypes and calculated to be 70 °C, this is lower than the specification value of 125 °C. The specified maximum power should be applied during screening to raise the junction temperature and increase the acceleration. The specified lowest ambient temperature is 0 °C and the measurement should therefore be performed at this temperature.

It is of interest to know the temperature coefficient of the parameters and also the stability over time. Therefore the following sequence is initially performed as a baseline:
- measurement and logging of the parameters at 0 °C ambient temperature,
- measurement and logging of the parameters at room temperature,
- high temperature operation screening at 125 °C,
- measurement and logging of the parameters at room temperature.

It should however, be kept in mind that, if the temperature coefficient and the stability could be assured, the sequence could be reduced to measurement at room temperature only. It is therefore decided not to obtain a full set of screening and test equipment before a test screening is performed.

Determine the duration of the reliability stress screening process

The duration should be long enough to assure the stability of the parameter during the required life of the equipment. For the current application, it is calculated, using the expected operation profile for the equipment and acceleration formulae given in annex B, so that the required life corresponds to 1 000 h at 125 °C ambient temperature. It is then decided to perform an initial test screening according to the baseline sequence to possibly find the stability and the influence of the temperature. Intermediate measurement at room temperature will be performed at 100 h, 200 h and 500 h.

Mathematically analyze initial test results

The results of the reliability stress screening test show that:
- the stability of the parameters is generally good (within ±10 % as 3 \( \sigma \) values), but one batch had a large drift, higher than 100 % after 100 h for 50 % of the population. The drift after 1 000 h was higher than 100 % for 90 % of the population,
- the temperature coefficient is generally very low, the individual spread is also very low. It can be taken care of by a further small reduction of the acceptance criteria, to 0.4 µs and 0.9 µs respectively.

Perform failure analysis

Failure analysis was performed and contamination problems were found.
Perform stress sequence on the components

Taking the results from the test screening into account it was decided to perform the screening according to the following sequence:

- measurement of the parameters at room temperature; logging of data; components outside the (reduced) acceptance criteria are rejected;
- high temperature operation screening at 125 °C ambient temperature for 96 h;
- measurement of the parameters at room temperature; logging of data.

All measured data for the parameter is logged and the drift is calculated. Also the reject rate for the batch is calculated.

Determine approval or rejection criteria

Components with a drift of more than 50% or that are outside the acceptance criteria are rejected. All batches with a reject rate higher than 10% are rejected.

Develop closed-loop corrective action process

The results of the test screening made it possible to reduce the time for the high temperature screening and measurement at 0 °C could be deleted.

If experience from equipment manufacturing or from field use of the equipment shows that the parameters increase more with time than is experienced during the test screening, the time for the screening should be increased or possibly the criteria for batch reject should be changed. An evaluation should be performed before a decision is taken.

Provide feedback to the component manufacturers

Information about the outcome of the test screening is given to the component manufacturer. He is also informed about the design of the screening sequence, about the reject criteria and about the results of the continued screening. The component manufacturer has no obligation to react but the information could be valuable as it is of a common interest to supply components to a tighter specification and the user would expect higher rates of good components in the deliveries.

Discontinue the reliability stress screening process

As soon as confidence is reached that no batches with bad stability are delivered, the high temperature operation screening can be discontinued.

Only if a very high degree of confidence is reached, so that no components are delivered with parameters outside the acceptance criteria, can the measurement of the parameters be discontinued as the values of the parameters are not guaranteed by the component manufacturer.

C.2 Transformers

Necessity for the component screen

It is assumed in this example that the transformer is custom made for a specific product by a small manufacturer. Since the production volume is low it is decided to use component reliability stress screening.

Establish contact between the two parties involved

In this case, the reliability stress screening is performed by the equipment manufacturer or by a submanufacturer.
• Identify the possible flaws and failure modes for the component

The transformer core is made of thin sheets of metal. There is a possibility that a wrong type of metal is used, or that the magnetic properties of the metal are damaged by the winding process or the heat treatment. This will, however, be found when measuring the no load current. The major problem, however, is known to be acoustical noise from the C-core. After the production, the core is cut, polished and reassembled around the windings. This can produce acoustical noise if there are flaws in the polishing and reassembly process.

For the windings the use of the wrong type of wire (primarily wrong diameter) is a possibility. But this failure will normally be found when the electrical resistance of the winding is measured. The number of windings may be wrong, but this will be found when measuring the voltage/transformer ratio. The most dangerous flaw in the windings is damage to the insulation, wrong insulation lacquer (wrong temperature characteristics), and nicks and damages to the wires.

• Select stress types, stress levels and stress sequence to be used in order to precipitate failures

In order to check for the acoustical noise one can use either mechanical vibration or bump/shock to check if the two parts can become loose. This test should be followed by a noise test in cold and in hot condition. Alternatively one could use thermal cycling for the transformer with continuous noise monitoring. For noise monitoring direct listening could be used, but this requires each transformer to be checked individually in an anechoic chamber. An alternative can be to listen to each transformer with the aid of a stethoscope. Another possibility is a microphone or accelerometer combined with a frequency analyzer.

For the windings it is usual to put the finished transformer into a hot chamber, load it electrically to its maximum rating, and measure the temperature of the windings. This will find the flaws from damaged lacquer and wrong type of lacquer. It will also find any nicks in the wire. Alternatively a thermovision picture of the wire can be used to indicate local hot spots caused by short circuits or nicks in the wire. Some damage to the lacquer and insulation will be found during the high voltage test that is required for safety reasons.

For the vibration and bump/shock very large values can be chosen due to the mechanical robustness of the transformer. Care should however be taken with plastic parts and terminals. A level of 40 m/s² up to 70 m/s² can usually be used without problems. The temperature level also has to take the maximum operating temperature into account. The chosen level should be the maximum operating temperature of the lacquer minus the expected temperature rise in the transformer at full load.

The transformer must be operated at full load in the hot chamber. The sequence is selected to be 1 000 bumps at 70 m/s² followed by a noise measurement. Subsequently the transformer is placed in a climatic chamber heated to the maximum operating temperature of the wire minus the expected temperature rise at full load. In this example 80 °C lacquer is used. The expected temperature increase is computed as 18 °C. The test is therefore made at 60 °C in the climate chamber with full electrical load. The temperature soak lasts for 2 h after the temperature stabilization. After the temperature test, the acceptance test is performed including high voltage test of the insulation.

• Determine the duration of the reliability stress screening process

The reliability stress screening test of 100 transformers is performed and the number of failures noted as a function of the duration of the temperature soak and the number of bumps. It is decided to keep the duration of the temperature soak as 2 h. The number of bumps can, however, be reduced to 500 since a Weibull plot shows that 90 % of the failures occur during the first 300 bumps.
• **Perform failure analysis**

The failures found are analyzed. It turns out that nicks in the wire and damage to the insulation are caused by burrs on the C-core. A better process solves this problem. Noise is caused by the assembly of the C-core. A more precise torque is specified and a new tool implemented. This solves the problem to a degree that the bump test and the noise measurement can be reduced to a sample. The temperature soak is, however, kept for safety reasons.

• **Mathematically analyze initial test results**

The Weibull plot of the bump test is shown in figure C.1.

• **Perform the stress sequence on the components**

The reliability stress screening sequence is performed 100 % on the transformers.

• **Determine approval or rejection criteria**

The noise measurement and test during and after the temperature soak are initially made 100 % and failed items are scrapped.

After the sample test, the rule is that one failure observed in the sample of 20 transformers results in re-implemention of 100 % bump and noise measurement on the lot where the failure was observed.

• **Develop closed-loop corrective action process**

The feedback resulted in the reduction of the number of bumps from 1 000 to 500. In this example, the feedback to the production was easy and appropriate changes to processes and tools were made.
Figure C.1 – Weibull plot of the bump test

- **Discontinue the reliability stress screening process**
  The bump process was reduced to a sample as soon as the production processes were improved. The heat test is kept for safety reasons.

**C.3 Connectors**

- **Necessity for the component screen**
  For this example it is assumed that a manufacturer has received a batch of crimp connectors where the pull test used in production to verify the adjustment of the crimping tool shows a small but significant percentage that does not fulfil the required pull test (80 % of the tensile strength of the wire).
• **Establish contact between the two parties involved**

Contact with the manufacturer confirms that the problem is caused by the connectors. Due to variations in a batch of raw material (rolled metal plate), the tolerances of the stamped and formed connector, and the yield strength of the material vary. The equipment manufacturer is not able to return the batch since this would stop his production.

• **Identify the possible flaws and failure modes for the component**

The flaw is known to be a deviation in the size of the connector and variations in the properties of the metal.

This causes variations in the crimping force resulting in risk of corrosion (oxidation and corrosive gases may penetrate the crimp) which causes a high resistance or intermittent connection.

This effect is known to happen with time, especially in a hot and corrosive environment. Vibrations accelerate the process. The connectors are used in electronic equipment for ships, so both vibration and a corrosive environment will be present.

• **Select stress types, stress levels and stress sequence to be used in order to precipitate failures**

Dry heat, corrosive gases and vibrations to accelerate the failures could be used, but this would take too long. Instead it has been decided to employ the pull test as a screening process. The equipment is already available and so the screening can start immediately. Since a good, i.e. gas tight crimp connection is able to withstand 80% of the tensile strength of the wire itself, this can be used as the stress level. For a good crimp connection the test is not destructive.

It is decided to perform the pull test immediately after the crimp process.

• **Determine the duration of the reliability stress screening process**

In this case, a sample of 50 connectors is taken and a pull test performed. The force at which the wire is pulled out of the connector crimp is noted. The force is limited to 80% of the tensile strength of the wire. It turns out that 18% of the connectors fail. They all fail at a force that is between 10% and 50% of the tensile strength. It is therefore decided to use the 80% as the reliability stress screening level. In this case, the duration is given (one pull per wire).

• **Mathematically analyze initial test result**

The pull out force of the sample is plotted on Weibull paper to find the strength parameters of the weak population (see figure C.2).

• **Perform failure analysis**

A failure analysis of the failed connectors confirms that the structure and strength of the base metal of the connector element is not as specified.

• **Perform stress sequence on the components**

The pull test is performed 100% on all the crimped connectors during two days. During this time, it turns out that the flawed connectors are found more or less in sequence in the packages.
Weibull probability paper

Distribution function $F(o)$ or cumulative frequency distribution $H(\%)$

Figure C.2 – Weibull plot of the pull test

- **Determine approval or rejection criteria**

It is therefore decided to reduce the pull test to one out of each 10 connectors. If a failure is observed, the next connectors are pull tested 100% until 20 connectors in sequence are faultless, after which sampling is continued.
● Develop closed-loop corrective action process

The percentage of failures is sent to the component manufacturer who is able to locate more closely the deficient connectors in the lot. Therefore it is possible to release part of the lot for normal production, with a pull test on the first and the last connectors in each box.

● Discontinue the reliability stress screening process

The connector manufacturer is soon able to send a new lot without any flawed connectors and the reliability stress screening process is discontinued. However, the pull test is used each day to check that adjustment of the crimping tool is maintained.
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