RELIABILITY ISSUES AND FAILURE MECHANISMS-Simulating the real world in the test house

Defining the requirement

The real world contains many hazards for the poorly-designed circuit, and a range of tests has been devised to emulate the life experiences of a product. The key question which a designer has to face is which tests to use, and at what 'severities' – typically specifications describe how the test is to be carried out, and suggest a number of standard conditions (severities) which should be chosen. This standardisation helps control the proliferation of different standards.

First define the requirement! Traditional specifications described the worst case 'envelope' of conditions which embraced all the possible conditions under which a product might be expected either to be stored or work. The designer was then left to determine an appropriate test regime. An attempt has, however, been made to classify environmental conditions, and communicate these in ways that are meaningful to the designer, and also to generate guidance documents which relate the environmental requirements to standard environmental tests.

One classification of environmental conditions is given in BS EN 60721. This identifies many classes of application that are given a three-character code (Table 1), with a digit defining the application, a letter indicating the environmental challenge, and a final digit indicating the 'severity', where a higher value normally indicates more stringent conditions. For example, class 7K3 is for portable and non-stationary use under Climatic Conditions, Severity 3. The various parts of the publication contain tables with the severity of each environmental parameter for each class.

1st (digit) – Application		2nd (letter) – Environment	
1	Storage	K	climatic conditions
2	Transportation	B	biological conditions
3	Stationary use, weather-protected	C	chemically active substances
4	Stationary use, not weather-protected	S	mechanically active substances
5	Ground vehicle installations	M	mechanically active conditions
6	Ship environment		
7	Portable and non-stationary use		

The severities given are those which are exceeded either for an insignificant part of the continuous exposure time (for example, temperature conditions), or for an insignificant fraction of the total number of events (for example, shocks). Thus the classes define the maximum short term environmental stresses, but do not give information on the long term stress for a component. This is, however, illustrated in

Figure 1. The severities given in the classification are represented by the one value x1, whilst the totality of environmental stresses during the product lifetime includes the integral of the curve for all values of x.

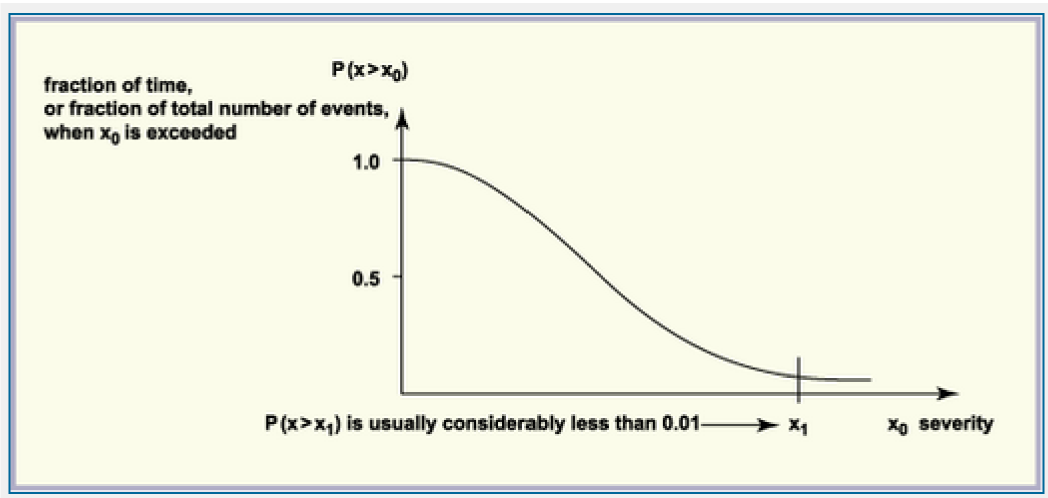


Figure 1: Illustration of the fraction of time (or events) when an environmental severity is exceeded

The probability of exceeding the classification severity is low, and the probability of exceeding both maxima simultaneously, correspondingly lower. However, parameters such as sun radiation and high temperature are statistically dependent, unlike vibration and temperature.

BS EN 60721 points out that these extreme environmental conditions may occur at any time in the product life, and a product which survives when new may fail when subjected to the same conditions after it has undergone slow degradation with life.

The standard also explains that the conditions may affect the product when it is either operating or non-operating, or perhaps both. It is important therefore to define whether the product needs to be capable of operating under the extreme conditions, or is only required to survive without permanent damage.

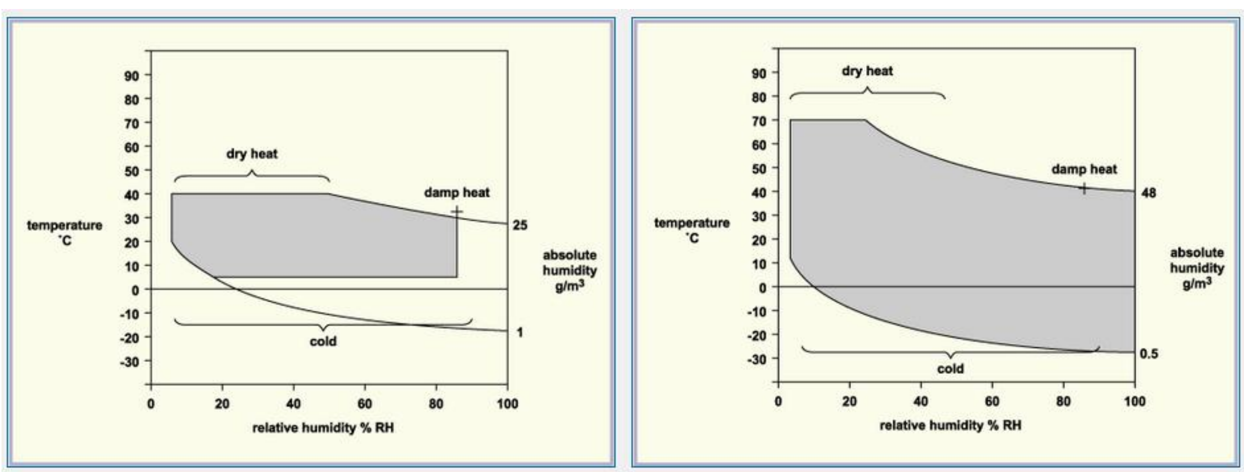
These environmental classes are used as a basis for the choice of design and test levels, but that does not mean that the limits should be used for test or design, or that zero failure should be required or expected at the limits. Care must be taken to choose appropriate conditions having regard to the acceptable risk of failure – a higher or lower severity may be chosen depending on the expected consequences of failure.

Related to the severity classifications in BS EN 60721 is a set of guidance documents with titles of the form "IEC TR 60721: Guidance for the correlation and transformation of environmental condition classes of IEC 60721 to the environmental tests of IEC 60068".

While the documents make it clear that they have no mandatory status, and are intended only for guidance, in practice they are extremely helpful in suggesting levels of test that are appropriate for assessing products for conformance. They also contain the useful idea of a 'climatogram'. This shows temperature against relative humidity and plots the area under which a product may be expected to operate.

Two examples for different environmental classifications are given in Figure 2. Note that the second of these (Class 7K3) has a very complete definition of the locations at which it applies, and be aware that, if you use these documents, you will need to familiarise yourselves with its detail and jargon.

Figure 2:Climatograms for Classes 1K2 and 7K3



For testing products against the conditions of the climatogram, only three tests are normally used:

dry heat test, where the relative humidity may not exceed 50 % but is not specifically controlled

cold test, where humidity is not controlled

damp heat test, steady state, where both temperature and humidity are controlled.

These tests are indicated on the climatogram. Other boundary conditions of the climatogram are not required to be tested and there are no IEC 60068 tests available.

Obviously more than just these three tests may be needed, and the tables in the guidance document indicate suitable tests. More helpfully, they suggest whether or not tests are required, and whether different severities might be appropriate.

It is clear from the information that, whilst guidance is available, the responsibility lies with the designer to ensure that the selection of test severities is appropriate for the application, critically depending on the effects of failure.

Testing the product

The tests themselves have a long history within the British Standards systems as BS2011, and as IEC Publication 68. Over the years they have been adapted, extended and harmonised, and contain a battery of environmental test procedures and appropriate test severities that make available to the specifier standard tests covering most eventualities.

The generic document is now called “BS EN 60068-1:1995, IEC 60068-1:1988 Environmental testing. General and guidance”. This document is an introduction, which explains how the system works. The detailed tests themselves comprise Part 2 of what has become a large, loose-leaf publication. The contents of this are indicated in Figure 3 – for each of the families of tests, there are one or more detailed specifications and guidance documents.

Figure 3: BS EN 60068 test designations

A Cold	L Dust and sand
B Dry heat	M Air pressure (high or low)
C Damp heat (steady state)	N Change of temperature
D Damp heat (cyclic)	Q Sealing (including panel sealing, container sealing and protection against ingress and leakage of fluid)
E Impact (for example shock and bump)	
F Vibration	R Water (for example rain, dripping water)
G Acceleration (steady state)	S Radiation (for example solar, but excluding electromagnetic)
J Mould growth	T Soldering (including resistance to heat from soldering)
K Corrosive atmospheres (for example salt mist)	U Robustness of terminations (of components)

The basic document itself deals with some important concepts:

Pre-conditioning: this is treating the specimen to counteract the effects of previous history, and includes ‘recovery’ after certain tests. For example, you would not want to apply high voltage to a product which is still wringing wet from its humidity experience!

Sequence of tests, defining both the order in which a specimen is exposed successively to two or more test environments, including pre-conditioning/recovery, and the acceptable intervals between tests.

Conditioning: this subjecting the specimen to specified conditions (for example, temperature and humidity) before measurement, to allow equilibrium to be attained.

Standard conditions: the reference condition is 20°C and 1013 mbar at 60–70% RH. For measurement and test, this is replaced by a standard range of 15–35°C, 25–75% RH, and 860–1060 mbar.

The specification also suggests a standard sequence of climatic tests, where the test components are independent. This ‘climatic sequence’ is carried out in a defined order:

Dry heat.

Damp heat (cyclic), first cycle with upper temperature of 55°C.

Cold.

Low air pressure (if required).

Damp heat (cyclic), remaining cycles.

This sequence is just one of the ways in which attempts have been made to reduce the very large number of possible combinations of tests and severities. Another is the use of a ‘component climatic category’ which indicates generally the conditions for which components1 are suitable. The category is indicated by a series of three groups of digits separated by strokes, corresponding respectively to the temperatures of the cold test and the dry heat test, and the number of days of exposure to steady state damp heat that the components will withstand. As an example, a component classified 25/085/04 would meet the requirements after at least a –25°C cold storage test, a +85°C dry heat test, and 4 days damp heat (steady state) storage.

1 The climatic categories referred to are used primarily for components, but BS EN 60068 applies to the complete range of what it calls 'electrotechnical products', and suggests it can also be applied in other fields.

But does BS EN 60068 cover everything you need to test a product? You will already be familiar with the UL test for flammability of materials, but BS EN 60068 specifically excludes fire hazards. The guidance document referred to in BS 6221-3, the guide for design and use of printed wiring boards, actually makes reference to guidance in BS EN 60695. However, this guidance is expressed in very general terms, although supported by test methods2.

2 Interestingly, the IEC standard includes a 'glowing wire' test as well as the familiar needle flame test, and in many ways this covers more fully the possible causes of ignition within a system. However, technically superior though it may be, the fact is that UL are the main drivers in this area.

Another omission from the specification is that of ingress protection, assessing the ability of an electronic enclosure to resist people, dust and water. This is covered later in this document.

You also may have noticed that the damp heat test suggested for Class 7K3 is less severe than the maximum relative humidity to which the assembly may be exposed. This is because the tests have not only been standardised, they have been aimed at what is achievable rather than fully attempting to simulate the real world. With moisture, this is due to the fact that real-life climatic changes include temperature fluctuations, and these will result in precipitation of moisture unless the humidity is maintained slightly below 100% RH.

Be aware that not all the tests which you will come across are intentionally realistic; many of them have extreme severities in order to impart stresses to the component that will accelerate failure. Two examples are with constant acceleration, where often semiconductor packages tested at values of g which are impracticable for equipment – if you apply 20,000g, the aim is to try to pull off the wire bonds without having to resort to pull test. Similar, but less dramatic, is the replacement of slow natural cycling by the temperature rapid change test, where a product is transferred between cold and hot chambers, and sometimes even plunged alternatively into hot and cold liquid.

Probably the key criticisms of any approach involving standard tests is that:

They depend for their effect on establishing a relationship between early failures occurring at high stress and long term survival at low stress

Combination tests would be more realistic, but it is difficult to select the best combination.

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Source: http://www.ami.ac.uk/courses/topics/0195_strw/index.html