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Foreword

This ETSI Technical Report (ETR) has been produced by the Equipment Engineering (EE) Technical Committee of the European Telecommunications Standards Institute (ETSI). ETRs are informative documents containing material which is not suitable for adoption as a formal standard.

The present ETR forms a general introduction to a multi-part European Telecommunications Standard (ETS), concerned with environmental conditions and environmental tests for telecommunications equipment. The Report gives the user the background to the main concepts of environmental engineering, the purpose and use of environmental classes and the corresponding tests philosophy. The document is based on IEC's philosophy, but unifies and extends IEC's concepts.

The complementary standard is divided into two main parts, each with a number of sub-parts:

ETS 300 019-1 [4]: "Classification of environmental conditions".

This part of the standard specifies different standardised environmental classes covering climatic and biological conditions, chemically and mechanically active substances and mechanical conditions during storage and transportation, and in use. There will be eight sub-parts: ETS 300 019-1-0 giving a general introduction will be issued for Public Enquiry during 1992, and ETS 300 019-1-1 to 300 019-1-7 inclusive, covering the different classes, have been adopted and published.

ETS 300 019-2 [5]: "Specification of environmental tests".

This part of the standard will specify the test requirements for the environmental classes. It will be divided into eight sub-parts corresponding with those in Part 1 of the standard. The drafts have been issued for Public Enquiry No 29, which ends on 2 October 1992.

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1 Scope

The aim of this document is to give the user the following information:

- an explanation of the main environmental concepts and terminology with examples;
- the purpose and use of environmental classes;
- the testing philosophy relating to environmental classes and equipment characteristics;
- the principles underlying environmental specifications.

2 References

The following references are used in this ETR.

[1] IEC Publication 721: "Classification of environmental conditions".

[2] IEC Publication 68: "Basic environmental testing procedures".

[3] IEC Publication 605: "Equipment reliability testing: Part 1: General requirements; Part 3: Preferred test conditions for equipment reliability testing".

[4] ETS 300 019-1: "Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Classification of environmental conditions" (Parts 1-0 to 1-7).

[5] ETS 300 019-2: "Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Specification of environmental tests" (Parts 2-0 to 2-7).

3 Environmental engineering

3.1 Purpose

The purpose of environmental engineering is to make the equipment and the environment mutually compatible.

This means that in some instances the equipment has to be modified and/or protected to resist a given environment or, alternatively, the environment itself shall be conditioned to match the equipment. The matching of the equipment to its environment and its effect on the environment need to be carefully evaluated. Finally, testing reveals whether the equipment and the environment successfully match.

3.2 Economic and technical aspects

Environmental requirements have a number of economic and technical consequences. These include:

- the equipment specification;
- the equipment design;
- the choice of materials;
- the testing procedure and protection, where applicable;
- the operational conditions and application.

The environmental requirements relating to equipment specification and design must be considered and stated in an early phase of a project. If this is not done, significant economic and technical difficulties may occur during the later phases of the project. An "overspecification", which results in "overdesign", is costly, complex and may not lead necessarily to a more reliable product.

To make the requirements for the environmental conditions at the equipment location too stringent may also be costly and complex.

The introduction of protection, whether in the equipment or on the environment, always requires an economic evaluation. This protection shall always be taken into account in any test specification.

Thorough testing is both costly and time consuming. Hence selecting the relevant and cheapest test procedures for the equipment is most important.

Good environmental engineering practice seeks to balance the above costs against the costs of environmentally-induced failures. Such costs arise from:

- elimination of the failure;
- possible redesign;
- operational losses;
- possible compensations.

The process involves both technical and economic optimisation in relation to the selected environment.

3.3 Outline of the test requirements

Figure 1 shows a total, but simplified, procedure for preparing an environmental resistibility test based on environmental data. Some main elements of the procedure are described in the following Clauses with the emphasis on environmental classes, transformation and the resulting test specification, whilst taking into account the performance requirements of the equipment.

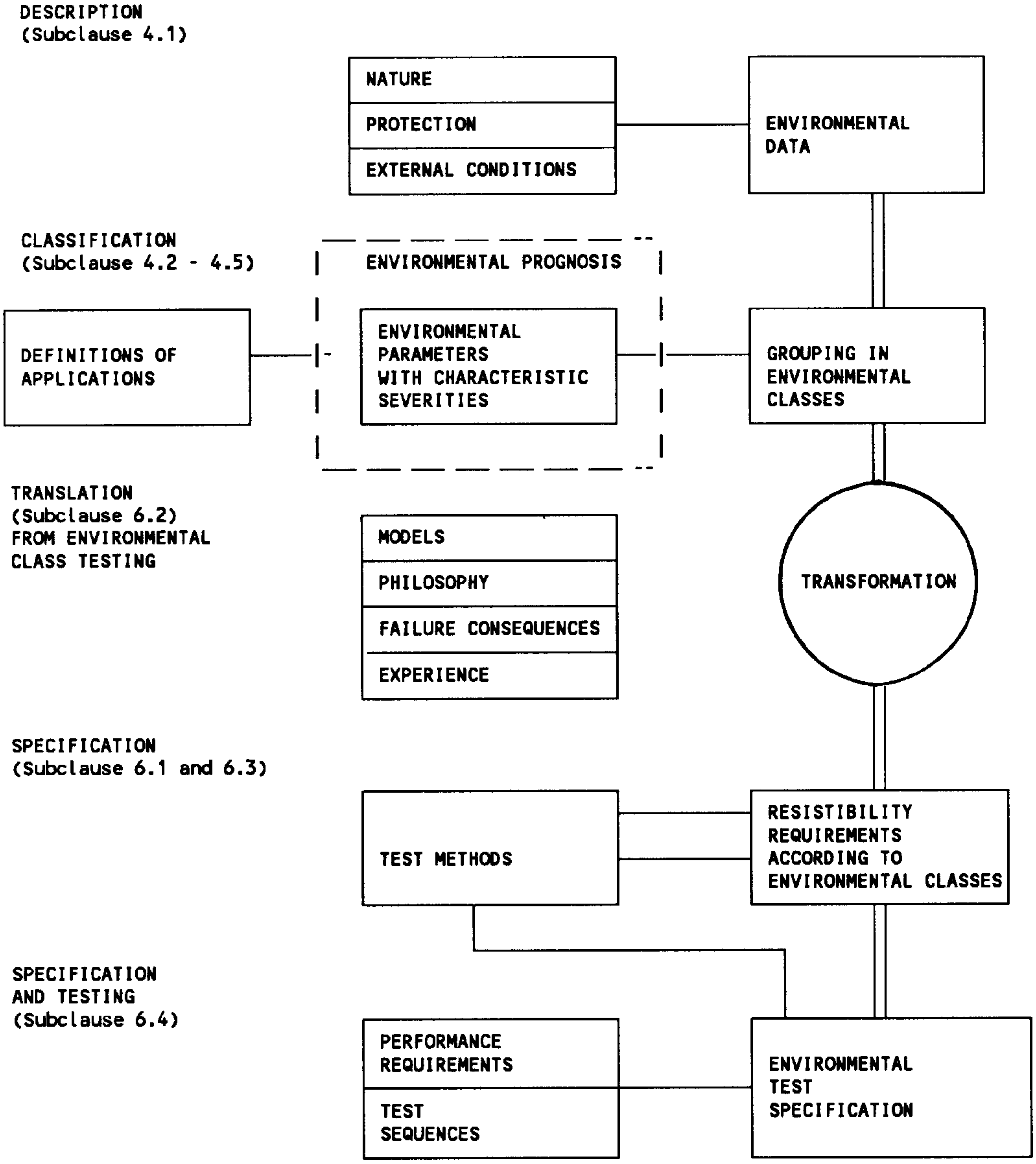


Figure 1: Outline for the preparation of the test specification

4 Environmental description

4.1 General

In this context environmental conditions are limited to the physical and chemical conditions to which equipment is subjected at a certain time for (more or less) well-defined locations and applications. Physical and chemical conditions should be considered in a very broad sense. They cover not only the two main areas - climatic and mechanical conditions - but also borderline and transitional areas, e.g. biological and chemical conditions as well.

The environmental conditions comprise those conditions appearing in nature as well as "artificial" conditions. The "artificial" conditions may be of a favourable nature, e.g. a house being heated during the winter, but they may also be of an unfavourable nature, e.g. thermal influence from the equipment itself or from other equipment.

Typical environmental conditions usually have simple names, such as "outdoors", "in a car". However, such "typical" conditions involve numerous environmental factors (parameters) apparently varying at random in strength (severity) and having complex interactions. These factors determine the actual influence of the environment on the relevant equipment.

As a result, only those parameters having a significant effect on the equipment are considered.

4.2 Purpose of classification

The main purpose of environmental classes is to establish a number of "standardised" and operational frames of reference for a wide range of applications of (telecommunications) equipment. These classes cover use, transportation, etc. in typical environmental conditions.

The classification system arose out of the difficulty of describing environmental conditions in detail and the even greater difficulty of applying the results in practice. Until recently the only tools were some specific tests covering a few environmental effects. The introduction of the concept of environmental classes provides a more powerful approach.

The environmental classes cover:

- environmental requirements prescribed for the equipment;

- resistibility requirements imposed on the equipment (important for the designer and for forming a basis for testing);

- emission requirements imposed on the equipment which, in certain situations (e.g. heat dissipation) may need restricting , such that the effect on the original environment is "negligible" ("negligible" in this context means that conditions defined by the environmental class still remain valid).

4.3 Classes

An environmental class is a systematic representation of the environment for a family of locations with "similar properties". This means that the detailed description of the class may be envisaged as an envelope around a group of related environmental conditions. The class itself may not be considered directly as a typical example.

A class is composed of the most significant single factors, termed environmental parameters, selected from those factors which may be assumed to influence equipment performance.

Severities and other characteristics are appended to the parameters to specify the class (c.f. subclauses 4.4 and 4.5).

4.4 Parameters

Environmental parameters represent those physical or chemical properties of an environment which can be distinguished and specified in relatively simple terms. In many instances additional detail parameters should be stated in order to make the specification unambiguous. Table 1 shows typical examples of parameters with their related detail parameters covering both climatic and mechanical conditions.

Most detail parameters are quantified by their characteristic severity (c.f. subclause 4.5).

In a few instances the parameter itself may be qualitatively expressed (e.g. "conditions of condensation"), with the "value" "yes" or "no" and without further details (considered as a characteristic). However, the fact that these conditions may occur should be reflected in both the design phase and the test procedure.

Table 1: Examples of environmental parameters and related detail parameters with corresponding characteristics marked with a * or characteristic severities for a class.

A: Climatic conditions: Humidity

Environmental parameter		Characteristics * or characteristic severity for a class	Unit
Parameter	Detail parameter		
Relative humidity	High	100	%RH
	Low	10	%RH
	condensation *	yes *	

B: Mechanical conditions: Vibration

Environmental parameter		Characteristics or characteristic severity for a class		Unit
Parameter	Detail parameter			
Vibration, sinusoidal	Displacement	3.5		mm
	Acceleration		10	m/s^2
	Frequency	2-9	9-150	Hz

4.5 Severities

The severity of a parameter, or detail parameter, is generally the quantitative measure of the stress introduced by the parameter involved. It may be stated as magnitude, rate or duration.

A practical example shows some fundamental aspects concerning the concept of severity. The example considers the climatic parameter "outdoor air temperature" for a defined geographical area.

The statistical distribution of the observed temperatures is shown as a histogram in figure 2, where the dashed curve is an approximation to a continuous distribution. The distribution appears to have two peaks and has extremes of about - 15° C and + 30° C.

Considering the definition of severity as a measure of the stress, the parameter "outdoor air temperature" is split into two parameters:

- low air temperature; and
- high air temperature.

This is because either may induce its own stress with its own consequential failure mechanisms on the equipment.

The parameters "low air temperature" and "high air temperature" are shown in figure 3. Both show increasing stress and correct fractiles to the right. The values to the left are not defined because they are not relevant. The characteristic severity can thereby comply with the definition that this severity (i.e. the stress) is rarely exceeded.

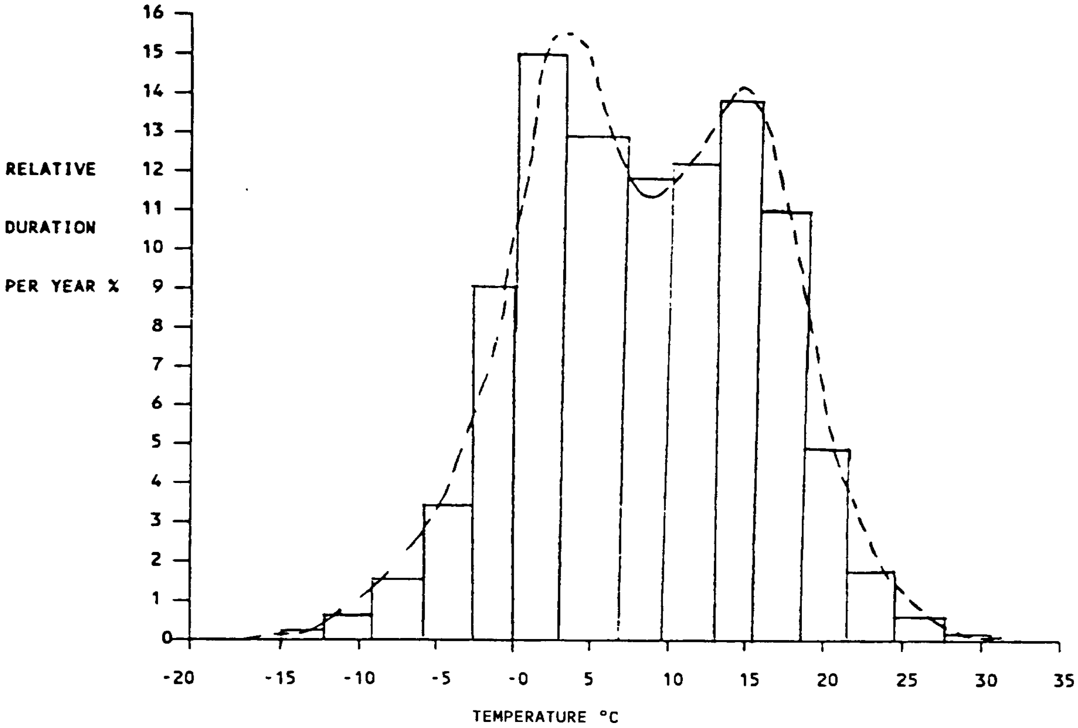


Figure 2: Distribution of outdoor temperature

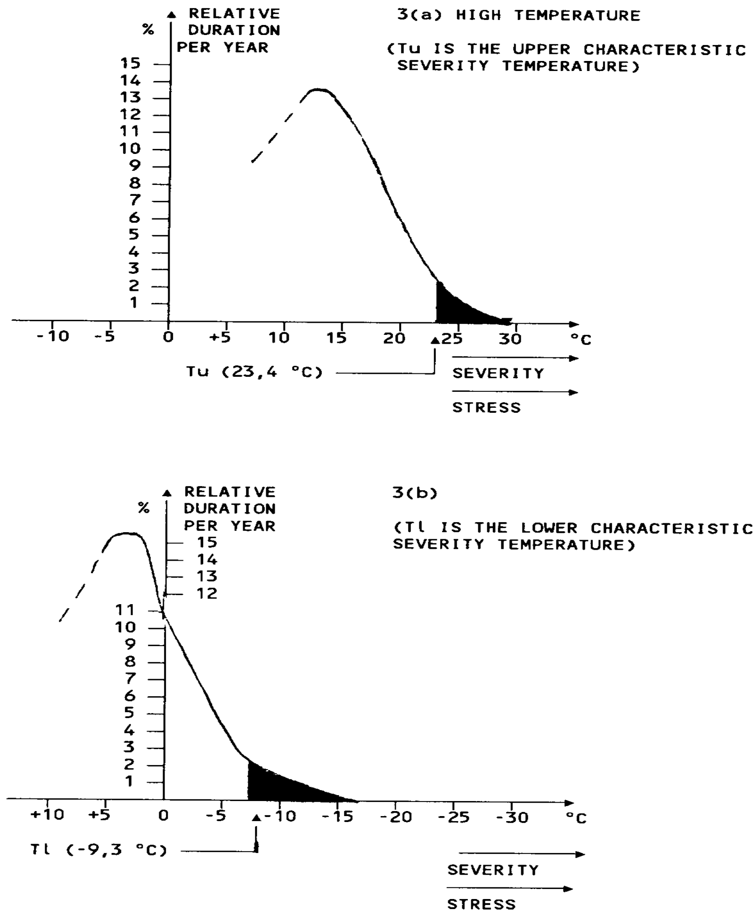


Figure 3: Separated distributions of outdoor air temperature showing the boundary value of the upper (Tu) and the lower (Tl) characteristic temperature.

Figure 3(a) shows the right-hand - i.e. high temperature - side of the distribution shown in figure 2. The shaded portion of figure 3(a) represents 1% of the total area under the curve of figure 2 and has been calculated by numerical integration. The left-hand vertical edge of the shaded portion intersects the temperature axis at some temperature Tu. The temperature Tu represents the boundary value, for a given distribution, which is acceptable as an upper characteristic severity (in the example shown in figure 3(a), Tu = 23,4°C. Depending upon circumstances a higher severity temperature value may be appropriate, see also figure 8).

Figure 3(b) is a mirror-image of the left-hand - i.e. low temperature - side of the distribution shown in figure 2 (the mirror-image allows severity to be shown increasing in value to the right as in figure 3(a)). In figure 3(b) the left-hand vertical edge of the 1% shaded portion intersects the temperature axis at some temperature Tl. The temperature Tl represents the boundary value for a given distribution, which is acceptable as a lower characteristic severity (in the example shown in figure 3(b) Tl = -9,3°C. Depending upon circumstances a lower severity temperature value may be appropriate, see also figure 8).

Most other climatic parameters (with the exception of humidity), and all mechanical parameters, induce low stress at low levels. Hence one distribution defines both high and low extremes as shown below.

The severity stated for the relevant detail parameters in a class is designated the characteristic severity. This is (in principle) to be considered as an extreme point of the statistical severity distribution for each parameter. The probability of exceeding the characteristic severity is normally (very) low. This is illustrated in figure 4.

The above principles of statistical distribution shall be applied when interpreting the climatograms of prETS 300 019-1. The type of distribution curves to be applied is under discussion.

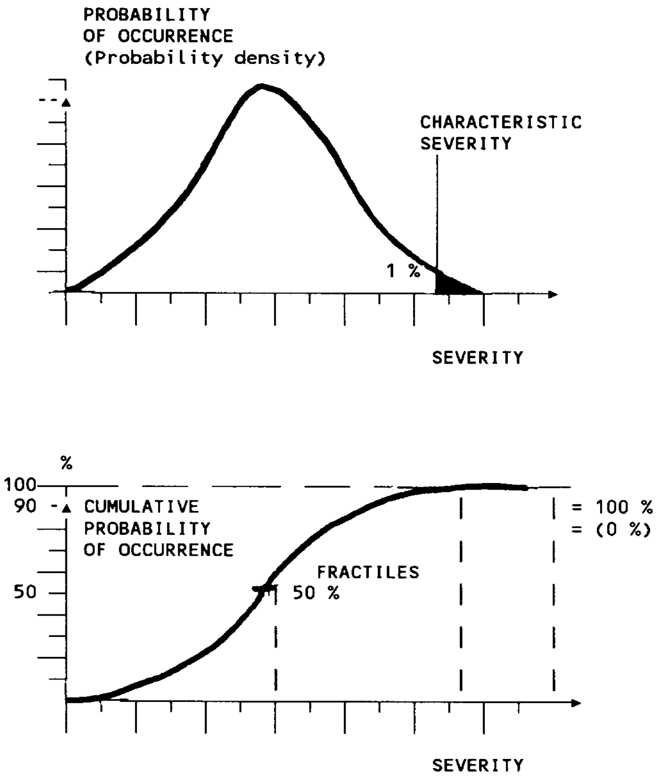


Figure 4: Schematic example showing the occurrence of the severity of a parameter (e.g. level of aggressive pollutant)

The characteristic severity represents a degree of severity which is rarely exceeded (often with a probability of less than 1%). Occurrence refers to time or relevant (geographical) locations. It is important to note that the characteristic severity, although an extreme, may be exceeded from time to time or from place to place. Depending on the equipment this fact should be considered in the test procedure.

Thus the characteristic severity determines the resistibility requirements on the equipment and forms the basis for the test specification. The characteristic severity also applies to the requirement on the environment according to the class. Furthermore, the characteristic severity forms the basis for the requirement on the maximum permissible emission.

4.6 Limitations and considerations

It must be emphasised that the description of environmental conditions by means of environmental classes provides only simplified models of reality. This affects primarily:

- the application of classes and severities; and
- the simultaneous occurrence of parameters.

4.6.1 Application

The stated classes apply only to a limited number of "standard" environments and hence "special" conditions are not directly covered. For such conditions new classes may be established - preferably by the modification, or combination, of existing classes. The temptation to apply a very severe standard class should be avoided as it risks overspecifying some of the parameters.

The characteristic severities stated for a class define the "maximum" short term stresses on the equipment. However, the severities do not give any information about the long term (total) stresses on the equipment. These are important for reliability and life/endurance assessments. If these total stresses are to be considered then a better knowledge of the complete distribution is needed. This aspect is covered in more detail in subclause 6.5 of this document.

4.6.2 Simultaneous occurrence

The parameters of a class are stated individually. But in practice the equipment will be exposed simultaneously to a large number of parameters of varying severities.

Some of the parameters are statistically independent, e.g. (normally) vibration and temperature. In such instances the probability that both parameters simultaneously exhibit their extreme severities is very low.

If, for example, the probability of exceeding the characteristic severity is 1% for both parameters, then the probability is only 0.01% that both severities occur simultaneously. In the case of independent parameters it is reasonable to test individually the effect of each parameter at high severity.

Although two parameters might be statistically independent, another aspect occurs if their physical effects on the equipment are dependent. This means that their effects cannot just be superimposed if the parameters are occurring simultaneously. A typical example is the correlation between vibration and temperature where most materials exhibit a low fatigue strength during conditions of simultaneous vibration and low temperature. Such phenomena shall be considered during design and, if necessary, shall be reflected in the test procedure.

Some pairs of parameters, e.g. temperature and relative humidity, solar radiation and high temperature, are (strongly) dependent. This means that in such instances extremes may (often) occur simultaneously. Such conditions cannot be deduced directly from the specification for the class. However, the corresponding test specification shall reflect the mechanism, e.g. by stating higher test severities than the characteristic ones.

Generally the physical influences of environmental conditions on an equipment may be the result of a number of parameters. This shall be considered during design. An important example is the surface temperature of an equipment which results from a combination of:

- surrounding air temperature;
- solar radiation; and
- heat radiation from other nearby equipment, heating elements and possibly spotlights.

5 Equipment properties

So far the environments have been treated without too much reference to the equipment which is located in the relevant environment. In order to make an approach to the test philosophy some properties of the equipment need defining.

5.1 Resistibility and performance

Environmental resistibility is the capability of an equipment to endure, or resist, a relevant environment for a short period of time. This means that the equipment shall be able to fulfil certain performance requirements when or after it is exposed to one or more specific environmental influences. The influence is determined by the severities and the duration of the test.

Performance requirements should be understood in a very broad sense. It may, for example, be a requirement for a surface just to "look nice". Another requirement may be that the equipment should fulfil all specified technical functions. A third requirement may be that the equipment should be capable of surviving.

To systematise the relationship between performance requirements and environmental stresses, it may be appropriate to grade the performance requirements against increasing severity of the environmental test conditions in the following way:

- Normal performance: all specified performance and functional requirements shall be fulfilled, including given tolerances;

- Reduced performance: all specified primary function requirements shall be fulfilled, possibly with wider margins (primary functions are essential properties which are significant during the use of the equipment)

- Specified secondary functions are not required to be fulfilled (secondary functions are properties which facilitate/improve the use of the equipment);

- Intermittent function, which is considered as a functional failure often of short duration. Normal performance is required after recovery from the severe environmental exposure;

- Cessation of function, which is considered as an irreversible failure, is acceptable under very severe environmental exposure. The equipment is required not to cause any damage to its surroundings, including to other equipment. There is no requirement for the equipment to resume normal performance.

The proper use of the four different performance requirements is discussed in subclause 6.2.2.

Sometimes it may be difficult for the specification writer to distinguish between primary and secondary functions. A general rule is that the user cannot dispense with the primary functions without the equipment, or the whole system, being jeopardised. All other functions are secondary.

Generally the purpose of introducing "reduced performance" is to see what happens when the environmental conditions occasionally become very severe (e.g. exceeding the characteristic severity). Hence an expensive overspecification requiring normal performance may be avoided.

Table 2 shows, as an example, some primary and secondary functions of a telephone set, including some normal performance requirements.

Table 2: Example of specification of some suggested primary and secondary functions of a telephone set

Function category	Equipment characteristic	Performance	
		Normal	Reduced
Primary	Send reference equivalent tolerance	±2,5dB	±5dB
	Multi frequency tone signalling tolerance	±5 dB	
Secondary	dialled number	yes	
	Loudspeaker distortion	<5%	

5.2 Failure consequences

Obviously different kinds of telecommunications equipment are not all equally important and hence the significance of proper function and the failure consequences may vary considerably. Within the field of environmental engineering, just as within reliability, failure consequences may range from negligible to catastrophic depending upon the nature and application of the equipment. Important failure consequences may be:

- loss of life and limb and other catastrophic situations (all beyond the present scope);
- loss of service, e.g. failing alarms;
- loss of equipment, e.g. destruction;
- loss of revenue, e.g. charges for calls;
- loss of reputation, e.g. public criticism; and
- expenses, e.g. for repair and modifications.

In order to make failure consequences an operational concept of testing, three degrees of failure consequences are introduced:

- moderate failure consequences, which apply to common subscriber installations and equipment, e.g. telephone sets;
- severe failure consequences, which apply to essential centralised equipment and to equipment of a system security nature, e.g. central processors and alarm equipment; and
- minor failure consequences, which apply to equipment having the characteristic of auxiliary facilities, or where alternative equipment is available, e.g. automatic diallers.

Failure consequences shall be taken into account when selecting test severities.

The proper use of the three grades of "failure consequences" in relation to the different "performance" requirements is discussed in subclause 6.2.2.

5.3 Emission

An equipment is influenced by the ambient environment, as discussed under environmental resistibility. However, in many instances the equipment will also influence the environment by producing emissions. This means that (in principle) the environmental conditions are changed from what they were before the equipment was brought into service at the location. Emission from the equipment may be:

- acoustic noise;
- dissipated heat;
- mechanical vibration.

These emissions raise problems regarding both the specification of and the actual interference to the original environment.

The first step to solving these problems is to consider that the emission shall be so limited that the interference to the environment is negligible. This does not necessarily mean that the original conditions shall be unchanged, but that the conditions still remain within the original environmental class, as specified by the characteristic severity. Thus the emission requirements keep the environment within the class boundaries.

A second approach considers the problems when the emission is so large that it becomes impossible for the environment to remain within the original class boundaries. In this instance a solution may be to introduce:

- separate protection, e.g. shields, filters, or shock absorbers at the location;

  or

- elimination, e.g. a cooling or ventilation system, at the location.

In such instances co-operation between manufacturer and end-user is usually needed.

5.4 Protection

Protection of the equipment environment is an important measure acting in two directions:

- it protects the equipment from the surrounding environment by tempering the inside environment (e.g. cover, lightning arrester, filter, shock absorber);

  and

- it protects the environment from emissions from the equipment by suppressing those emissions (e.g. electromagnetic shield, filter, acoustic damping).

It is important to notice that all protection defines an interface between two environments with differing conditions. This shall be considered when specifying the equipment requirements and the test conditions by stating to which class the equipment belongs both with and without protection.

6 Environmental testing

6.1 Purpose and philosophy

As mentioned in Clause 4, environmental classes are one "tool" relating to the specification of resistibility requirements. It must be realised, however, that this "tool" is not particularly useful as far as the verification of resistibility is concerned.

Thus another "tool" is needed to prove - or more precisely to render it possible - that the equipment can meet the requirements. Environmental testing is such a "tool". The purpose of testing is to demonstrate that an equipment, under defined environmental conditions, can:

- survive without irreversible failure; and

- perform according to requirements.

This means in fact that the test shall demonstrate the potential failure mechanism of an equipment. Or more clearly expressed, the test shall attempt to produce the effects of the environment, which is generally far from reproducing the real environment itself. This philosophy is fundamental to the design of most of the testing methods. Examples 1 to 3 below illustrate this philosophy.

Generally environmental tests are carried out as laboratory tests. In certain instances the tests may also utilise defined field conditions. However, an approach of trying to let a laboratory test reproduce the real environmental conditions is generally not feasible.

Example 1: High temperature

A high temperature test on a heat dissipating item of equipment is designed to produce the thermal effect of subjecting it to:

- high air temperature;

- solar radiation;

- heat radiation from nearby sources, etc.

Thus the test temperature will be substantially higher than just the ordinary room temperature (c.f. subclause 4.6.2).

Example 2: Shocks

In a shock test an item of equipment is subjected to a simple, half-sine shaped pulse, although the actual conditions are not that simple. To attempt to produce the same mechanical stresses requires a comparison of the two shock spectra.

Example 3: Moisture

In practice the relative humidity varies within such wide limits and in a manner so complicated that to attempt to reproduce the actual humidity conditions is unrealistic. Instead the preference is to produce - by means of different damp heat test methods - a number of failure mechanisms that may be caused by humidity, e.g.:

- Humidity absorption by testing at constant high temperature and high humidity (damp heat, steady state);

- Chemical and galvanic corrosion and moisture accumulation by testing in cyclically varying humidity where condensation occurs (damp heat, cyclic).

None of the damp heat exposures mentioned above resemble realistic environmental conditions, although their effects try to reflect real conditions.

Very often the environmental tests required, for instance by the customer, can be considered as a part of a type qualification approval which is normally a "go, no-go" test. Environmental testing, however, is not confined to this application. During the development phase particularly, environmental testing is a powerful tool both in evaluation and analytical programmes considering for example, safety margins and comparison between designs and materials. In particular, testing with increasing severity ("step stress"), produces very useful information. Figure 5 shows a general outline of the different purposes, applications, test methods and evaluation principles for environmental testing.

In this recommendation only resistibility tests undertaken as a part of qualification approval have been considered. These aspects have been marked with X.

Endurability and reliability tests are discussed in subclause 6.5.

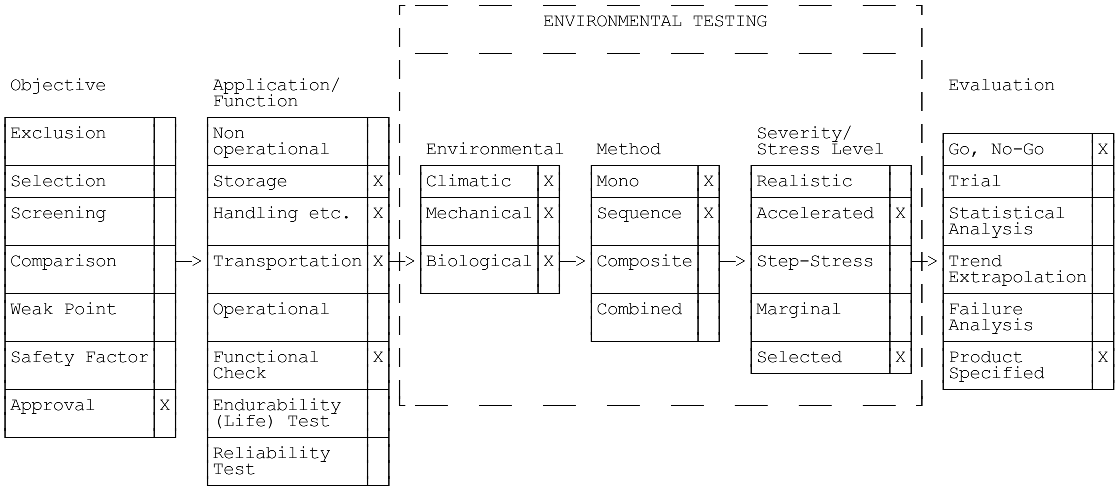


Figure 5: Outline of environmental testing applications

6.2 Transformation from class to test

International and national standards for environmental testing procedures were established long ago. Recently, proposed standards for environmental classifications have been prepared. However, despite great demand, the transformation from class to test has not yet been defined internationally. The principle reason is that the transformation can never operate universally. This is because the transformation largely depends on:

- the type of equipment;
- the mode of operation;
- the significance of proper operation (failure consequences).

Some of these aspects have already been considered and will be used together with the "stress-strength" model as elements in the following ETSI transformation proposal.

6.2.1 Stress - strength

For equipment used in applications where failures have severe consequences tests are often carried out with severities which are a little greater than those stated in the environmental class. The reason for this may be briefly described with reference to the so-called stress-strength model.

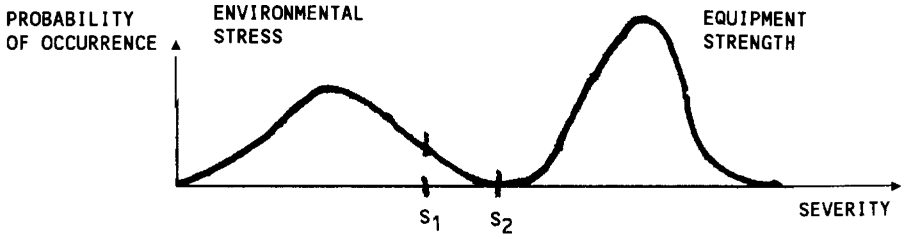


Figure 6: Stress-strength curves for an equipment with a reasonable safety margin

It appears that there is no influence on the test result whether the test is carried out at the characteristic severity S_1 or at the maximum severity S_2.

In figure 6 the curve on the left shows the probability (probability density) of occurrence (rate or relative duration) for an environmental parameter versus the severity. Point S_1 indicates the characteristic value usually about the 1% (99%) fractile for the environmental class.

The curve on the right shows - for a certain type of equipment - the distribution curve for environmental resistibility. Imagine that this latter curve (normally unknown) has been produced by testing a large sample of the equipment, and that for each result the exact value of the severity has been plotted - e.g. the temperature at which the equipment fails - i.e. the functional requirements are not met.

If the test severity is stated as S_2 (maximum severity for the environment) it can be seen that the equipment can safely resist even the worst occurring environment within the environmental class and hence a safety margin is obtained. This means that the lower strength limit of the equipment is not close to the severities predicted for the application. This last statement should be viewed in the light of the fact that type testing is normally carried out on very few samples.

This may be seen by comparing figure 6 with figure 7, but with the significant difference that figure 7 deals with a less robust equipment.

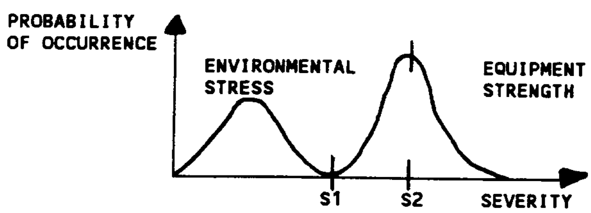


Figure 7: Stress-strength curves for an equipment with a lower strength limit which is too low.

If the test is carried out at the characteristic severity S_1, then apparently the exposure of weak points does not necessarily follow. However, if the test is carried out at the maximum severity S_2, there would appear to be a reasonable chance of demonstrating the lack of environmental resistibility of the equipment.

By testing with the severity S_2 (figure 7) there is a probability that either real failures, or merely tendencies for malfunction (i.e. weak design points) will appear.

The demonstration of such weak points is of great importance. This is partly because a better knowledge of the product and its application is obtained and partly because - with a small effort - improvements to exposed weaknesses are often possible.

6.2.2 Failure consequences and performance

Besides what has already been mentioned about the stress-strength model, two more elements must be considered in order to state the test severity, namely:

- failure consequences; and

- performance requirements.

As mentioned, the failure consequences may vary considerably, depending upon the kind of equipment and its application. Quite often two types of equipment may be placed at locations covered by the same environmental class. However, one type of equipment may be tested under significantly more severe conditions than the other one because of its different failure consequences. Hence two or more different test severities may apply to a certain environmental class. In most cases only "moderate" failure consequences are considered.

The grading of performance requirements allows the specification of different test severities for the same type of equipment in the same class. In this way more information from the resistibility test on the equipment can be obtained as well as avoiding an expensive "worst case" test with full normal performance.

Based on a schematic (and simplified) model shown in figure 8, the use of the concepts of failure consequences and performance requirements will be explained together with their interrelations.

Figure 8 (upper) shows the distribution of an environmental parameter in a class (e.g. temperature) with some fractiles indicated.

Figure 8 (lower) shows the different test severities on the x-axis corresponding to the class and with the three grades of failure consequences on the y-axis.

For each of the three grades of performance the corresponding test severities are plotted against the failure consequences. The corresponding points are connected with symbolic lines to show the relevant performance.

If figure 8 were really valid (unfortunately it is not that simple), the procedure for stating the test severities for a specific type of equipment assigned to a class would be as follows:

- select the failure consequence on the y-axis;

- read the corresponding test severities on the x-axis for the three grades of performance - if they are all needed.

Generally only moderate failure consequences are considered with a stated test severity for normal performance. In certain instances, however, two or more test severities are stated for moderate and for minor and severe failure consequences as well. Figure 8, as a model, may nevertheless show the use of the different concepts.

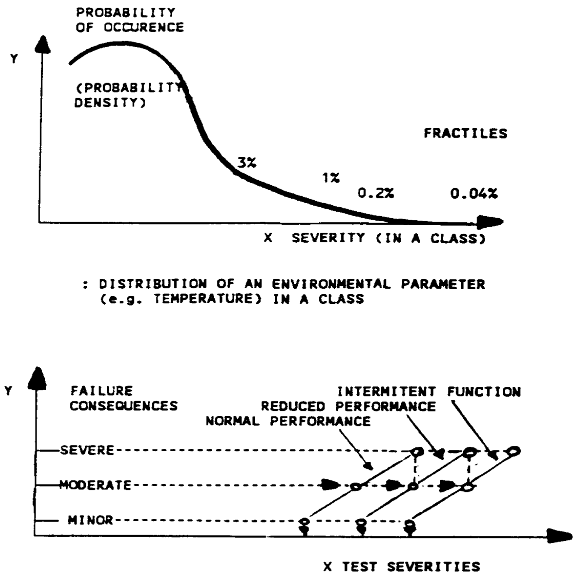


Figure 8: Schematic outline of test severities (x) corresponding to different failure consequences (y) and different grades of performances

6.3 Test methods

First and foremost, test methods shall, of course, be reproducible. Additionally they should also be realistic with regard to failure effect, be relatively simple and be reasonably rapid to perform. Internationally accepted methods, such as those in IEC Publication 68 [2], usually meet these requirements. In ETS 300 019, reference has been given as far as possible to IEC Publications.

Significant changes in characteristics or performance due to environmental conditions are often brought about slowly. Thus in order to make a test within a reasonable time these changes need acceleration either by increasing the test severity or by "compressing" the time, etc.. Many test methods are implicit accelerated tests, such as humidity and mechanical tests, although generally, and unfortunately, these have an unknown "acceleration factor". However these aspects are important when specifying the test procedure.

6.4 Environmental resistibility test

6.4.1 Purpose and limitations

An environmental resistibility test is generally considered as being a part of a type test. The environmental resistibility test demonstrates characteristic properties of an equipment regarding its capability of withstanding certain environmental conditions. These conditions are typically specified as different applications and environmental classes with specified performance requirements. The resistibility requirements shall be a part of the basic equipment specification covering all normal applications.

Thus the purpose of an environmental resistibility test is to verify - or render it possible - that an equipment will survive and perform as intended when it is used, stored and/or transported.

An environmental resistibility test has some inherent limitations. The most important one is that the test only covers the equipment type (e.g. the design) and not the complete population. This is because a resistibility test is generally carried out on only a few specimens hence the test cannot be a "guarantee" for production lots. The test can, however, assure that the equipment, considered as a type, is capable of resisting the expected environment.

Some other limitation aspects concern the operational life of the equipment. In general a resistibility test is not able to give evidence either about the reliability or the endurability of the equipment. These aspects are discussed in subclause 6.5.

Finally the information obtained from a resistibility test is limited, partly because of limited evaluation after exposure and partly because of the fixed test severities (e.g. no step-stress), cf. figure 5, subclause 6.1.

6.4.2 Test sequence

In order to cover the many different influences of several environmental parameters (concerning operational and non-operational conditions), a resistibility test must comprise a number of different tests.

Most tests are performed in either one, or a few sequences. This means that each specific test, after a recovery period, is succeeded by the next, specific test in a relevant sequence. Such a test procedure is truly not realistic, but practical.

If required two tests can be carried out immediately after each other (a composite test) or two tests can be carried out simultaneously (a combined test).

The sequence of tests is important because a conclusive result to the resistibility test may depend on the test sequence. For example the result of a final insulation test may change significantly depending on whether the test sequence is a dry heat test followed by a damp heat test or vice versa. The general rule is to choose the most severe sequence - if it is reasonably relevant - because the purpose of testing is to demonstrate the potential failure mechanisms. This rule is valid for resistibility testing.

Furthermore another rule shall be considered relating to the objective of obtaining early information about failure tendencies or major failures (in order to obtain the most significant information as early as possible). In this case severe - and preferably short and cheap tests - are conducted at the beginning, while the less severe, prolonged and expensive tests are placed later in the sequence. Naturally some of these considerations and rules may be contradictory and not always applicable. If this is so then the test sequence can be based on what is most likely to occur in practice.

Any test sequences suggested in this standard aim to utilise the rules mentioned.

If the testing concerns investigation of a prototype during development only one or a few specimens may be available. In this situation the objective of the test sequence is to keep the specimen "alive" as long as possible in order to obtain as much information as possible before damage occurs. Hence the sequence shall start with the least severe test.

6.4.3 Environmental test programme

Complete environmental testing for a specific equipment type typically employs three environmental test specifications:

- storage;
- transportation;
- in use.

Each specification comprises several "individual" tests which can be performed in a stated order, i.e. sequence. In order to realise all the testing activities it is necessary to construct a complete environmental test programme.

This programme shall be based on the relevant test specifications, and take into account other considerations and detailed information, such as:

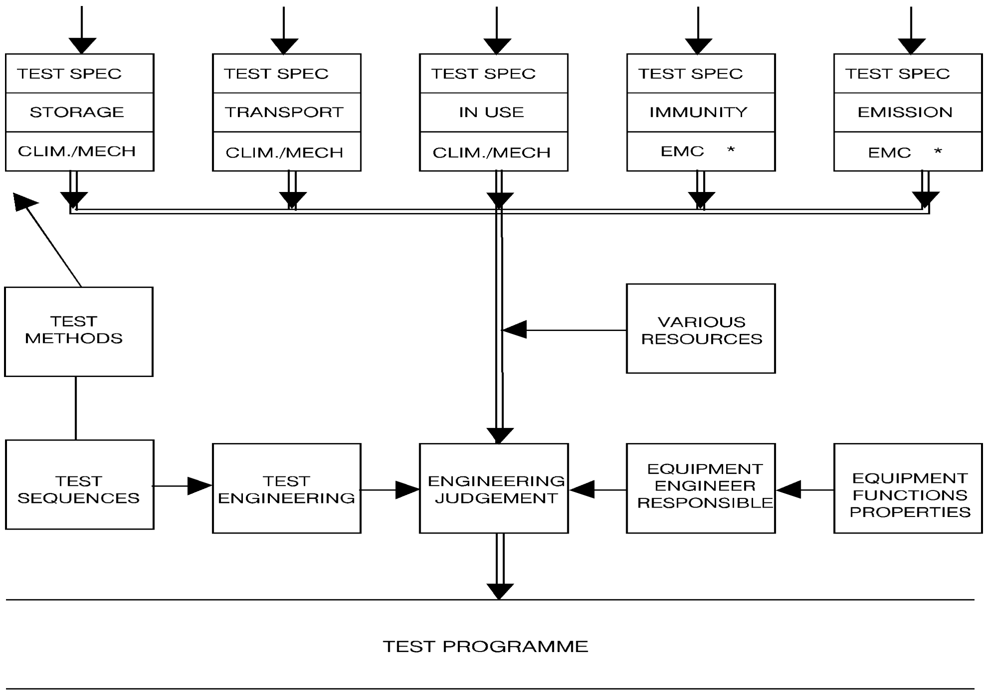
- equipment functions, properties and technologies;
- available resources, time, test facilities, funds, etc.;
- engineering experience and judgement;
- common sense.

The overall objective is to perform the complete programme in an efficient way e.g. by:

- utilising results from previous tests;
- deleting needless tests;

- avoiding thorough functional testing, if possible.

Thus the environmental test programme requires careful and specific consideration. This means that the programme shall be prepared by the test engineer in co-operation with the engineer responsible for the equipment. Figure 9 shows the procedure and the elements for preparing a complete environmental test programme.



*) EMC has been included for completeness although not within the scope of this document.

Figure 9: Outline for the preparation of a complete environmental test programme

6.5 Testing related to operational life

6.5.1 General

So far most of the emphasis has been directed towards the performance of the equipment under extremes of environmental conditions. These cover the environmental classes as well as the tests. A natural consideration is how this emphasis is reflected in the "behaviour" of the equipment during its normal operational life (assuming that all environmental requirements are fulfilled).

The conclusion is that such equipment is "debugged" in so far as environmentally induced design failures are concerned, thus avoiding problems from these possible failure effects.

Thus the behaviour of the equipment has certainly been improved compared with equipment having poor environmental resistibility. In this special context this might be called improved reliability. However, it must be strongly emphasised that an environmental resistibility test - as part of a type test - must never be confused with a reliability test (c.f. subclause 6.5.2).

Summarising, it may be concluded that although an environmental resistibility test is very important, it cannot "stand alone". It is a necessary - but not a sufficient - basis to ensure that the user obtains a reliable performance from the equipment.

6.5.2 Reliability

The environmental conditions have a significant effect on the reliability performance of an equipment. A typical example is the component failure rate. This normally increases with increasing temperature, where the average temperature is the determining parameter.

A proper reliability test is performed under defined environmental conditions. The following typical test conditions differ from a resistibility test in the following way:

- many specimens are under test;
- prolonged test time;
- reasonably mild environmental conditions;
- environmental conditions often varying in a cyclic manner;
- simulation of typical use is intended;
- field tests often used;
- random failures are provoked.

Thus there is a visibly significant difference between a resistibility test and a reliability test (see IEC Publication 605 [3]).

6.5.3 Endurability

Similar considerations relating to reliability are also relevant for endurability, i.e. the environmental conditions have a significant effect on the endurability of an equipment (endurability concerns lifetime, ageing, wear etc.).

A typical endurance test may be performed under the following conditions:

- few specimens under test;
- prolonged test time;
- often relatively severe environmental conditions due to acceleration;
- time dependent failures are provoked;
- systematic failures (e.g. design, manufacturing, wear out, failures etc.) are provoked.

Thus some, but not all, of the conditions are significantly different from a resistibility test. Some examples will illustrate these aspects.

Example 1: High temperature

Exposure to high temperature is a typical example of how the same test method can be utilised in two completely different ways. Only the duration and the test severity are changed.

Resistibility test: Short test time with the objective of assessing the functional performance under extreme temperature operation (e.g. 45°C, 16 hours).

Endurability test: Long test time with the objective of assessing degradation (e.g. thermal ageing, cracking etc.) at room temperature by means of an accelerated test (e.g. 100°C, 56 days).

Example 2: Cyclic damp heat

Exposure to damp heat is an example of a single test where the duration of the exposure is usually so significant for the equipment that the test conditions, as well as the objective of the test, are very similar for both a resistibility test and an endurability test.

Example 3: Vibration

Generally vibration tests for mobile equipment (e.g. sinusoidal sweep at several g's over several hours) may be considered as a resistibility test as well as a (mild) endurability test. A true endurability test, however, shall consist of a sinusoidal resonance search followed by an exposure with constant acceleration at the resonance frequency. Usually the duration is extended to the order of magnitude of 10^6 cycles to ensure that any possible fatigue strength failure is proved.

In short, the conclusion is that even though the endurability tests have their own specific objectives, some of the resistibility tests may have a tendency to approach the endurability test. However, referring to subclause 6.1 and figure 5 it is always important to realise what the objective of the test is, and to which potential failure mechanisms it may apply.

7 Terminology

7.1 Environmental description

7.1.1 Environment, environmental conditions

Environment is the physical and chemical conditions external to the equipment and to which it is subjected at a certain time. The **environmental conditions** comprise a combination of single **environmental parameters** and their **severities.**

NOTE: The environmental conditions generally comprise environmental conditions appearing in nature and environmental conditions generated by artificial sources including the equipment itself.

7.1.2 Environmental parameters

An **environmental parameter** represents one or more properties of the physical or chemical **environment.**

Example: Some **environmental parameters:**

air temperature;

humidity;

vibration, sinusoidal or random.

7.1.2.1 Detail parameters

In order to define the **environmental parameter** unambiguously, it may be necessary to state one or more **detail parameters.**

Example 1: Some **detail parameters** for sinusoidal vibration:

displacement or acceleration;

frequency range.

Quantitative measures for **detail parameters** are **severities** (particularly **characteristic severities**) and other characteristics.

Example 2: **Environmental parameter:** vibration, sinusoidal;

Detail parameter: acceleration;

Severity: acceleration value;

Characteristic: frequency range.

7.1.3 Severity

The **severity** indicates a quantitative measure for each **detail parameter** characterising an **environmental parameter** - i.e. magnitude, rate and duration. Specified severity values are used to:

- characterise **environmental classes** (by the **characteristic severity)**
- determine test values corresponding to performance requirements

7.1.3.1 Characteristic severity

The **characteristic severity** for a certain **detail parameter** in an **environmental class** states a **severity** which has a low probability of being exceeded (generally less than 1%) and which refers to duration, rate of occurrence or location.

The **characteristic severity** applies to **requirements on the environment** and to **resistibility requirements.**

7.1.4 Environmental class

An **environmental class** is a representation of the **environment** at locations having similar properties.

The **environmental classes** are specified and "standardised" to provide an operational frame of reference for

- **requirements on the environment;**
- **resistibility requirements;**
- **emission requirements.**

The **environmental class** is described in terms of an envelope of the **environmental conditions** by a number of **environmental parameters** and the corresponding **characteristic severities** of the **detail parameters** or other characteristics.

The **environmental parameters** specified for the class are limited to those which may affect equipment performance.

7.1.5 Requirements on the environment

The specified requirements are imposed on the environment at the location where an equipment, or parts of an equipment, are placed. **Requirements on the environment** may be given by an **environmental class.**

7.1.6 Environmental protection

Environmental protection is a measure for the purpose of either

- protecting the equipment from the surrounding **environment (**e.g. by lightning arrester, shelter); or
- protecting the **environment** from the influence of the equipment (e.g. by shock absorber).

7.2 Application

7.2.1 In-use

An equipment is **in-use** when it is directly operational.

7.2.1.1 Stationary use

An equipment is mounted firmly on the structure, or on mounting devices, or it is permanently placed at a certain site. It is not intended for **portable use,** but short periods of handling during erection work, down time, maintenance and repair at the location are included.

7.2.1.2 Portable and non-stationary use

The equipment is frequently moved from place to place. During transfer there is no special packaging for the equipment. The total transfer time may amount to a significant portion of the product's lifetime. The product is not permanently mounted on any structure or placed at a fixed site. The product may be operated while being either in a non-stationary or in a transfer state.

7.2.1.3 Mobile use

An equipment is in **mobile use** when it is primarily intended to be operated in, or on, a vehicle or a ship.

7.2.2 Not-in-use

An equipment is **not-in-use** when it is non-operational. **Not-in-use** principally covers **transport conditions** and **storage conditions.**

7.2.2.1 Transport conditions

Transport conditions are the **environmental conditions** to which equipment will be exposed during transportation, including loading, unloading and temporary storage. The equipment is **not in use** under these conditions.

7.2.2.2 Storage conditions

Storage conditions are the **environmental conditions** to which equipment will be **exposed during warehousing.**

7.2.2.3 Storage

The equipment is placed at a certain site for long periods but is not intended for **use** during these periods.

7.2.2.4 Weather-protected location

A location at which the equipment is protected from weather influences:

- **totally weather-protected location**: direct weather influences are totally excluded;

- **partially weather-protected location**: direct weather influences are not completely excluded.

7.2.2.5 Non weather-protected location

A location at which the equipment is not protected from direct weather influences.

7.3 Performance requirements

The **performance requirements** shall be specified under defined **environmental conditions.**

7.3.1 Normal performance

All specified **performance requirements** shall be fulfilled.

7.3.2 Reduced performance

All specified, **primary function** requirements shall be fulfilled, possibly with wider margins.

7.3.2.1 Primary functions

The **primary functions** of an equipment are those properties essential for the use of the equipment.

Example: Some **primary functions** of a telephone set:

- transmitting and receiving voice;
- transmitting dialling (or tones);
- receiving ringing.

7.3.2.2 Secondary functions

The **secondary functions** of an equipment are properties which facilitate/improve the use of the equipment.

Example: Some **secondary functions** of a telephone set:

- storing last called number;
- displaying "dialled" number.

7.3.2.3 Intermittent function

Intermittent function is a functional failure and often of a short duration and may occur occasionally under severe **environmental conditions**. Automatic recovery to **normal performance** is required when the **environmental conditions** (the exposure) return within the limits of the class, unless otherwise specified.

7.3.2.4 Cessation of function

Cessation of function is a functional failure that may occur under very severe **environmental conditions.** Any damage or permanent malfunction shall be confined to those parts of the equipment which were exposed to the **environment.**

7.3.3 Resistibility requirements

7.3.3.1 Environmental resistibility

Environmental resistibility is the capability of an equipment to endure or resist a relevant **environment** for a short or long period of time. This means that the equipment shall be able to fulfil certain **performance requirements** when - or after - being exposed to one or more specific environmental influences. The extent of the influence is determined by the severities and the duration of the test.

7.3.3.2 Performance requirements

Performance requirements should be interpreted in a very broad sense. It may for example be a requirement for a surface just to "look nice". Another requirement may be that the equipment should fulfil all specified technical functions. A third requirement may be that the equipment should be capable of surviving.

7.3.4 Failure consequences

Failure consequences denote all significant consequences of environmentally-caused failures, such as loss of service, equipment, revenue and reputation, and costs for repair and changes.

Failure consequences are graded as **minor failure consequences, moderate failure consequences** and **severe failure consequences** considering that various types of equipment - although placed at locations covered by the same **environmental class** - are not required to be tested at the same **severity.**

7.3.4.1 Minor failure consequences

An equipment has **minor failure consequences** when:

- its functions or facilities are dispensable for a limited period of time without significant inconvenience;
- repair (or replacement) can be made simply and cheaply; and
- alternative equipment is available.

7.3.4.2 Moderate failure consequences

An equipment has **moderate failure consequences** when:

- a failure causes limited inconvenience; and
- the failure may be repaired without compromising the contractual responsibilities.

This category is standard unless special circumstances are indicated.

7.3.4.3 Severe failure consequences

An equipment has **severe failure consequences** when:

- a failure compromises the function of vital, centralised systems or services of a security-related nature; and
- large costs are involved in restoration.

7.3.5 Emission requirements

Emission requirements are the required limitations of the emission (e.g. dissipated heat) from an equipment in a designated **environmental class.**

The objective of the **emission requirements** is to make the interference to the **environment** "negligible", such that the **environmental conditions** remain covered by the original **environmental class** (i.e. retained within the specified **characteristic severity).**

7.4 Testing

7.4.1 Environmental testing

Environmental testing is usually a well-defined and reproducible laboratory test exposure of an equipment to one or more **environmental parameters** having specified **severities** and in a specified sequence. In relevant cases **environmental testing** may also be carried out under defined field conditions.

Environmental testing normally consists of:

- pre-conditioning;
- initial examination and measurements;
- exposure (conditioning) according to the test method/procedure and including measurements;
- recovery;
- final examination and measurements (IEC Publication 68 [2] part 1).

Environmental testing is intended to demonstrate, with some measure of assurance, by reproducing the effects of the **environment** that an equipment (or component) will survive and perform under specified **environments.**

7.4.2 Environmental test programme

A complete **environmental test programme** for a specific kind of equipment consists of the relevant **environmental test specifications** (normally) supplemented by a stated **test sequence** and other detailed information (e.g. engineering judgements) considering that the **environmental test programme** can be performed in an efficient way.

Generally the **environmental test programme** is prepared by the test engineer in co-operation with the engineer responsible for the equipment.

7.4.3 Environmental test specification

The **environmental test specification** states, with reference to the test methods, the relevant **parameters** with their test **severities** in relation to the **performance requirements** and **failure consequences.**

7.4.4 Standard atmospheric conditions for testing

Standard atmospheric conditions for testing are the **environmental conditions** which have to be fulfilled during measurements and tests. The **standard atmospheric conditions for testing** are defined by IEC Publication 68 [2] Part 1 with the following values:

Temperature :	15°C to 35°C
Relative humidity :	25% to 75%
Air pressure :	86 kPa to 106 kPa

7.4.5 Type test

A **type test** is a representative test of the characteristics, including performance, of the equipment type (i.e. the design) of an equipment. The **type test** may lead to a type qualification approval.

7.5 Environmental specification

An **environmental specification** states:

- the **requirements on the environment**, given by an **environmental class**;
- the **environmental test specification** corresponding to the **environmental class** when the nature and application of the equipment are taken into consideration.

Annex A (informative): Alphabetic index

History

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