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Environmental Testing of DANETV Products

Overview and Code of Practice

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DANETV

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The Danish Centre for Verification of Climate and Environmental Technologies, DANETV, offers independent tests of technologies and products for the reduction of climate and environmental changes and of monitoring equipment detecting environmental changes. The focus is on technologies that are of great importance to the progress of climate and environmental strategy and also on the positioning of Danish suppliers of innovative technologies. DANETV is a co-operation between five technological service institutes: DHI, Danish Technological Institute, FORCE Technology, DELTA and AgroTech. DANETV has been established with financial support from the Danish Ministry of Science, Technology and Innovation.

Abstract

This report has been made in order to give an overview and a code of practice of environmental testing relevant for products in the DANETV system.

The following aspects are included in the report:

Test purpose, such as:

- Performance verification (performance in reference conditions)
- Environmental verification (performance in relevant environments)
- Reliability verification (performance in relevant environments over time)

Test strategies, such as:

- Preliminary prototype testing
- Weak-point testing
- Type testing
- Production testing

Project plan focusing on type testing issues, such as:

- Overall requirement specification
- Detailed test specification
- Test plan (including quality issues)
- Test execution
- Test reporting
- Certification

A catalogue of international recognised test standards.

A list of other relevant test issues.

References for deeper studies.

A number of case studies with environmental tests.

Preface

Background

This is one of the documents in the DANETV set of documents used to describe how it can be verified that “Environmental technology works as promised”.

Other DANETV documents are focussing on the overall DANETV scope or, on how to verify the functional performance of a product under the DANETV scope. This document has its focus on how it can be verified that a product can work as promised in the different environmental conditions it will face.

The document is a mix of overview of testing methods and strategies used in other product and application areas of Environmental Verification tasks and “Code of Practice” as they could be implemented in DANETV tasks.

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Readers

This report is intended for the non-specialists seeking background information, overview and examples of Code of Practice relevant for DANETV areas. As the overall area of environmental testing is a very huge area, all the details necessary to have present before performing an actual environmental testing task, can not be described in one single document. Therefore it is necessary to cooperate with an environmental test lab with a suitable level of capabilities and experience before the actual test task can be specified, planned and executed in a professional way.

Table of contents

1. General

What is the best way to test a product?

This report gives an introduction to relevant tests, and the background why to use them. An overview is given on the purpose of testing, which is often to see if a given requirement of the product is met. These requirements can be based on different things such as end user expectations, legal terms, large customer requirements etc. This leads to three main areas that can be specified:

- What a given product must be able to do (Performance verification)
- Under which conditions it must be able to do it (Environmental verification)
- How long it must be able to do it (Reliability verification)

Different test strategies can be used to accomplish the different verifications. This report focuses on

- Weak-point testing, where the test is tailored to find weak points in the product, the weak-points are then eliminated, and the product should be improved.
- Type testing, when it has to be verified that a given product for a given application is fulfilling the relevant set of requirements.
- Production testing, which is used to verify that the production of a product is continuously at a given quality level.

When a project is planned there are different aspects to take into consideration. A requirement specification can be made stating different requirements for the product e.g Function as specified up to xx °C, Can withstand dust/water, Used in harsh environment, Working for the next 10 years. Based on these requirements different tests can be specified along with a plan for the testing. When the tests are performed, the results are reported and a certificate can be issued, where relevant.

This report also gives an extensive catalogue of different test standards. The catalogue is divided into generic test standards and application specific test standards.

The generic test standards describes how to make a correct temperature, vibration etc. test and gives different severities regarding test level and duration of test, that can be chosen.

Application specific test standards could be a test standard for Railway application stating which tests to use if the product is placed in a train.

2 case studies are presented. The cases represent a new product, and an existing product with a new application. The different steps in the process of getting the product tested are reviewed.

1.1 Scope

The scope of this report is to give DANETV members a background for testing, and thereby giving them a tool to design a good test to evaluate their product. Following the case studies and applying them to new products, DANETV members should be able to get better and more robust products after reading this report.

2. Test purpose

2.1 General

Test can be defined as activities used to verify that a given set of requirements are fulfilled.

Requirements may be of different kind, but they are almost always coming from a set of needs.

The needs can come from many sources, e.g.:

- End user expectations
- Intended use situations
- Legal terms
- Market expectations
- Authorities
- Large customer requirements

Depending on the source of need, the form of the needs may be very different. This is why it is always a very good idea with a Requirement Specification stating all the relevant needs for at given product or application.

The following terms are often used in connection with requirements and testing and can be defined as follows:

- The term quantitative refers to a type of information based in quantities or else quantifiable data (objective properties).
- The term qualitative refers to a type of information which deals with apparent qualities (subjective properties).
- Verification is a quantitative test activity.
- Validation is a qualitative test activity.

Another way to show the difference between validation and verification can be seen on the figure below (example taken from Grundfos Management A/S, ref. Lars Rimestad).

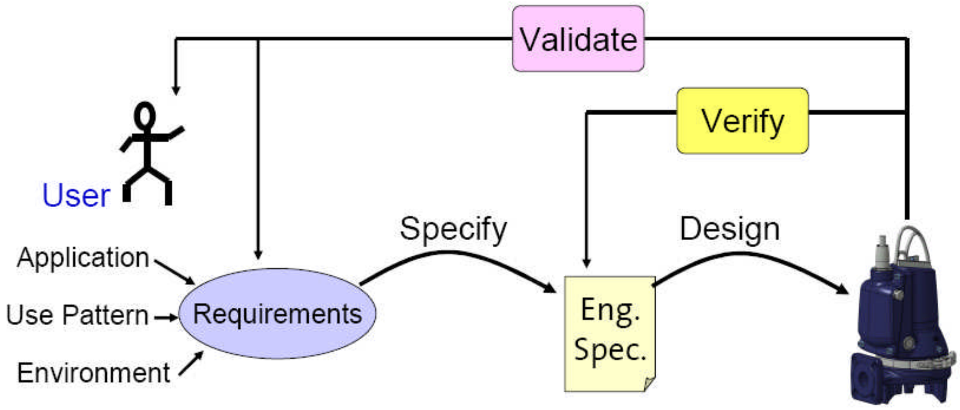

FIG 2.1.1 Validation and verification

The end users will typically have an expectation of full functionality throughout the product's lifetime. And almost any product will show a so-called “graceful degradation” over time. This means that the product must be stronger than the end user's expectations when the product is leaving the manufacturer. One could say that there must be suitable margins between the “zero-time” design specification (as given in the engineering specification) and actual end user's expectations (as stated in the requirement specification).

The inputs for the requirements are coming from:

“User”

“Application”

“Use Pattern”

“Environments”

And in order to find data for this input it is a good idea to start with a verbal description of the so-called “Intended Use” and “Intended Users”.

Let us illustrate this with a small example, where a simple electrical power supply is to be used in one of the 3 following examples:

- The intended use for the power supply is together with the xx waste water pollution analyser to be used stationary indoor on laboratories worldwide by trained personnel.

- The intended use for the power supply is together with a docking station for a portable air pollution data logger. The docking station will be used indoor in offices by more or less all employees in a community (practically all kinds of persons). The docking station (including power supply) will occasionally be transported between different locations and even though a storage box is supplied with the docking station, this box can not be expected to be used during all transportations.

- The intended use for the power supply is together with the xx traffic pollution system to be used when measuring cars in Europe. The system will be installed by trained personnel in a fixed position behind the dashboard, or in the luggage compartment, and the normal user (driver) will not operate the power supply directly.

In order to avoid “re-inventing the wheel”, it is a good idea to look for suitable standards that can more or less cover a given product and use.

Some major international standardisation organisations are:

- ISO, International Organization for Standardizations (www.iso.org)
- IEC, International Electrotechnical Commission (www.iec.ch)
- CEN (EN), European Committee for Standardization (www.cen.eu)
- ETSI, European Telecommunications Standards Institute (www.etsi.org)
- ASTM International (formerly known as the American Society for Testing and Materials) (www.astm.org)

For the sake of clarity, the different parts of a requirement specification can be divided into the 3 areas shown in the model below:

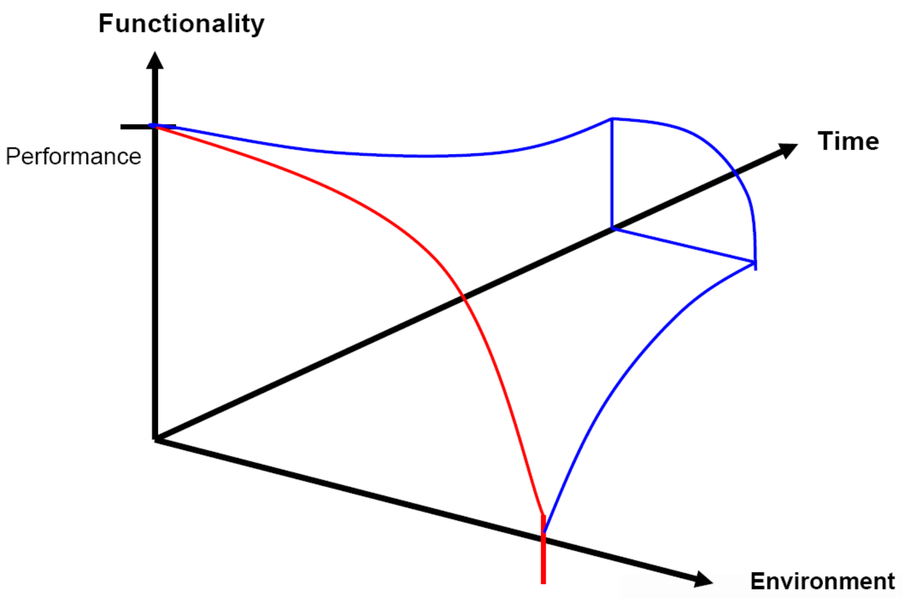

FIG 2.1.2: Model of requirements divided in 3 areas.

One could also say that we need to specify at least:

- What a given product must be able to do (Functionality)
- Under which conditions is must be able to do it (Environment)
- And how long it must be able to do it (Time)

Verification of these 3 requirement specification areas is often named as follows:

- Performance verification
- Environmental verification
- Reliability verification

2.2 Performance verification

Performance verification is basically to verify that the functionality or performance of a given product is according to the requirements for the product.

Examples of performance points to be verified for a small power supply could be:

- Input voltage and frequency range
- Output voltage (and frequency)
- Output stability
- Mechanical interface (plugs, connectors……)
- Size
- Mass
- Surface

And examples of performance points to be verified for a waste water pollution analyser could be:

- List of pollutants to be measured
- Measuring ranges for each pollutant to be measured
- Accuracy of each pollutant measurement
- Allowable temperature range of the waste water to measured on

Each product and / or each set of applications may have their own set of performance points to be verified.

Performance verification is often performed at normal laboratory conditions, i.e. without applying more or less severe environmental conditions.

Examples of data for “normal laboratory conditions can be found in EN/IEC 60068-1, section 5 as follows:

5.2 *Standard atmospheres for referee measurements and tests*

If the parameters to be measured depend on temperature, pressure and humidity and the law of dependence is unknown, the atmospheres to be specified shall be selected from the following:

Temperature (°C)			Relative humidity[1] (%)		Air pressure[1]	
Nominal value	Close tolerance	Wide tolerance	Close range	Wide range	kPa	mbar
20	± 1	± 2	63 to 67	60 to 70	86 to 106	(860 to 1 060)
23	± 1	± 2	48 to 52	45 to 55	86 to 106	(860 to 1 060)
25	± 1	± 2	48 to 52	45 to 55	86 to 106	(860 to 1 060)
27	± 1	± 2	63 to 67	60 to 70	86 to 106	(860 to 1 060)

[1] Inclusive values.

Notes 1. — The above values include those previously published in IEC Publications 160 and 68-1 (fifth edition) and those given in ISO Standards 554 and 3205.

2. — The value of 25 °C is included primarily because of its interest for the testing of semiconductor devices and integrated circuits. (It does not appear in ISO Standards 554 and 3205.)

3. — The close tolerances may be used for the referee measurements. The wider tolerances may be used only when allowed by the relevant specification.

4. — The relative humidity may be disregarded when it has no influence on the test results.

5.3 *Standard atmospheric conditions for measurement and tests*

5.3.1 The standard range of atmospheric conditions for carrying out measurements and tests is as follows:

Temperature [1]	Relative humidity [1) 2)]	Air pressure [1]
15 °C to 35 °C	25 % to 75 %	86 kPa to 106 kPa (860 mbar to 1 060 mbar)

[1] Inclusive extreme values   [2] Absolute humidity ≤ 22 g/m³

Notes 1. — Variations in temperature and humidity should be kept to a minimum during a series of measurements carried out as a part of one test on one specimen.

2. — For large specimens or in test chambers where it is difficult to maintain the temperature within the limits specified above, the range may be extended beyond these limits either down to 10 °C or up to 40 °C when allowed by the relevant specification.

FIG 2.2.1 Normal laboratory conditions - EN/IEC 60068-1, section 5.

where 5.2 is often used for measurements and tests requiring very high accuracy (e.g. calibration activities) and 5.3 is often used for practical measurements and tests.

Note that many requirements regarding electrical safety are described in the Low Voltage Directive published by EU (Directive 2006/95/EC). The conformity mark for EU directives is the “CE-mark” and the “CE-mark” on a product is basically telling that the given product fulfils all relevant EU directives.

Performance verification is not further discussed in this “Environmental Testing document”, as it is described in details in other parts of the DANETV documentation.

2.3 Environmental verification

Environmental verification is basically to verify that the functionality, or performance, of a given product is according to the requirements for the product when the product is subjected to ambient conditions other than normal laboratory conditions. Note that a certain degree of decreased performance may be allowed in more severe environments. This is indicated on the red curve showing the performance as function of environments on FIG 2.1.2.

Environmental conditions are often divided into the following areas:

- EMC: Emission & immunity, radiated & conducted, ESD……
- Climatic: Temperature, humidity, water, air pressure, sun…...
- Mechanical: Vibration, shock, drop, twist, bending, impact……
- Chemical: Sweat, salt mist, cleaning fluids……
- Others: Fungus, animals…..

where EMC stands for ElectroMagnetic Compatibility. The wikipedia definition of EMC is:

Electromagnetic compatibility (EMC) is the branch of electrical sciences which studies the unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects (Electromagnetic interference, or EMI) that such energy may induce. The goal of EMC is the correct operation, in the same electromagnetic environment, of different equipment which uses electromagnetic phenomena, and the avoidance of any interference effects.

EMC requirements are more or less completely covered by the EMC requirement called out in the EMC directive published by EU (Directive 2004/108/EC). See also the note on the “CE” conformity mark for EU directives in Section 2.2.

Data for different environments can be found in miscellaneous international standards.

When one is searching for data relevant for different environments, one should be very aware of, if the data are representative for the environments or if they are data for more or less accelerated environmental tests.

Some useful data sources for **environmental data** are:

- ECR-137 "Vibration Environments" (Issued by DELTA)
- ETSI 300 019 - 1 - xx (Issued by ETS)
- IEC 60721-2-xx ".. conditions appearing in nature…"
- IEC 60721-3-xx ".. classification of environmental conditions…."

Some useful data sources for **environmental test levels** can be seen in Section 5.

2.4 Reliability verification

Reliability verification is basically to verify how long the functionality or performance of a given product is according to the requirements for the product when the product is subjected to what we can call "Real life conditions". Environmental conditions other than normal laboratory conditions are a part of the "Real life conditions" for most equipment. Note that a certain degree of decreased performance may be allowed as a function of combination of environments and time. This is indicated on the blue curve showing the performance as function of environments and time on FIG 2.1.2.

The wikipedia definition of Reliability is:

Reliability engineering is an engineering field that deals with the study of reliability: the ability of a system or component to perform its required functions under stated conditions for a specified period of time.

i.e. the reliability could be defined as a probability (a figure between 0 and 1 or 0% and 100%).

The above given definition of reliability indicates that a figure for reliability for a specific product can be found by analysis and / or testing, if the "Real life conditions" can be stated. So for a product that will face "Real life conditions" that can be described with a suitable degree of confidence on the data for the environmental stress and the user-scenario, a reliability figure can be found. The confidence on the reliability figure is of course completely depending on the confidence on the input data (environment stress and user-scenario).

The reliability can also be given in form of an expected lifetime.

The environmental stress for real life conditions are often given as a kind of distribution, showing how many percentages of a population that will experience a given stress level.

The following 3 levels can be used in order to describe the distribution in a very simple way:

- “Average user (sometimes also called “Normal user)”
- “Normal severe user”
- “Extreme user”

where “user” can not only be a person, but also a stress level.

In order to give an example of this, one could consider the drop height that a handheld, portable instrument (looking like a Mobil phone) could experience during real life conditions when it is accidentally dropped from time to time.

Many of the instruments would only experience low values for drop height and some instruments would practically never experience a drop. As the “average user” is defined as the sum of the drop heights divided by the overall number of instruments, the value for the “average user” could be quite low, perhaps just a couple of centimeters.

But some instruments may be used more often or by more “careless” persons dropping the instrument from a typical height of the hand of a standing person. This could be represented by the “normal severe user” and the value for the drop height could be - let’s say - 120 cm.

A very small number of instruments could experience to be dropped by a person standing on a ladder. This could represent the “extreme user” and the value for the drop height could be up to several meters.

Another value sometimes used to describe a certain stress distribution is the so called “foolish extreme level” or “foolish stress level”. This is a stress level, where one is almost certain that the product will fail if this stress level is reached just once.

The “average user”, or “normal user”, was earlier used to find reliability figures in form of Mean Time Between Failure (MTBF) analysis and figures. But the more modern approach is to find reliability figures using the “severe user”, “extreme user” and “foolish extreme level” as basis for the reliability analysis or testing.

Another issue to consider when trying finding reliability, or useful lifetime, is accelerated testing. The wikipedia definition of Accelerated testing is:

Accelerated life testing is the process of testing a product by subjecting it to conditions (stress, strain, temperatures etc.) in excess of its normal service parameters in an effort to uncover faults and potential modes of failure in a short amount of time. By analyzing the product's response to such tests, engineers can make prediction about the service life and maintenance intervals of a product. To accelerate a test, engineers use several techniques. Commonly, the rate of loading is increased. For example, an automotive suspension spring may be tested at several hundred compression–rebound cycles per minute. In service, the spring may experience one hundred or fewer cycles per minute. As a result, *the spring fails sooner, but at the same number of cycles, so good data is collected, but in a much shorter time than it could be gathered in the actual application.*

CALT (Calibrated Accelerated Life Testing) is a single stress analysis and test strategy used to find a product's lifetime. The highest stress level is defined as slightly below the “Foolish stress level”, which is where the device instantly breaks down. A device is tested to failure at the highest possible stress level and the time to failure is recorded. The actual failure mode is identified. Test another device to failure at a lower stress level, and record again. Perform an analysis of the results and test a third device at a stress level corresponding to the time available for reliability testing. Finally, the expected life at normal stress level is calculated on the basis of all the test results. The figure below (taken from GMW8758) is showing this in a graphical way:

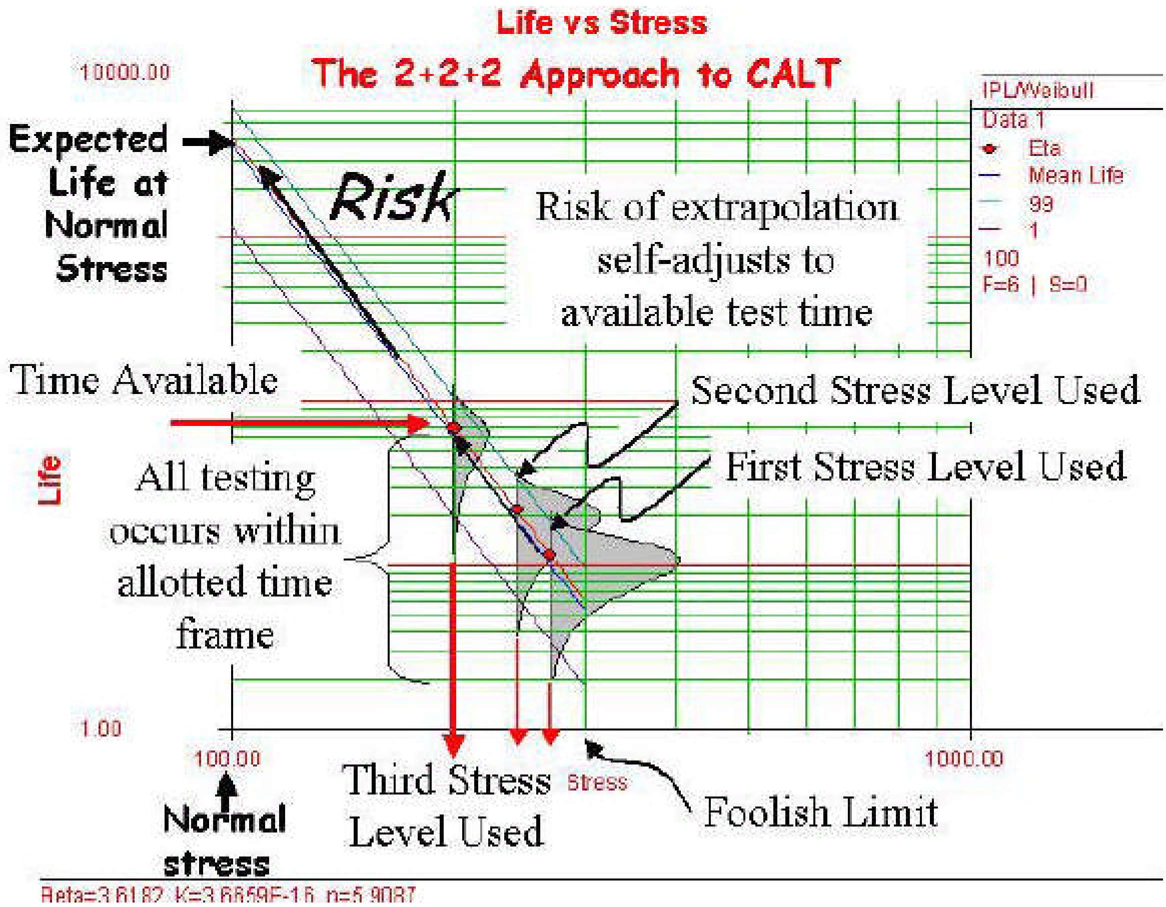

FIG 2.4.1 Calibrated Accelerated Life Testing (CALT) graphically.

More information about accelerated testing and CALT can be found in:

- SPM-178 “Acceleration factors and accelerated life testing”
- GM Test Procedure, GMW8758 “Calibrated Accelerated Life Testing (CALT)

Another technique is the so-called Multiple Environment Over Stress Testing (MEOST). This is basically a CALT with several stressors acting simultaneously. The range between “Extreme user” and “Normal severe user” is divided in 10 equal linear steps for each stressor.

First activity:	Test at highest step and find time-to-failure
Second activity:	Test at next-highest step and find time-to-failure
Third activity:	Analyse results and decide final test step from available test time slot (as long as possible in order to be closest to “Normal severe user”)
Final activity:	Analyse results and calculate life at “Normal severe user”

All the above mentioned terms and techniques are valid for products where the “Real life conditions” can be stated. This is, however, not the case for many products. An example of this could be a water circulation pump to be used worldwide in many - and very different - use scenarios.

This implies that the reliability or expected lifetime for this kind of product can not be found as a simple figure, neither from analysis nor testing.

Instead one could use a strategy where weak points in the design are identified and removed from the design of a given product.

“Robustness” is a general term often used to describe a product that are both durable with reference to stressful environmental conditions including mis-use and with a high reliability.

And “Robustness testing” is often used to characterise test activities used to verify a high degree of robustness to many environmental conditions and / or testing activities used to increase the reliability of a given product.

3. Test strategies

3.1 General

Based on the purpose of the testing, many different test strategies can be used.

Several of the test strategies are relevant in connection with development of new products.

The focus in this DANETV reign is on environmental type testing as described in Section 3.4.

3.2 Preliminary prototype testing

Preliminary prototype testing can be used early in the product development phase in order to investigate whether or not it is likely that the product can pass the type testing to be performed at a later state. It can also be used to investigate whether a given design has a sufficient robustness or not.

For the DANETV testing, preliminary prototype testing can be used to test on a limited number of the most critical parameters in order to render probable whether the product can pass the type testing to performed later without having to start the complete type testing sequence.

3.3 Weak-point testing

Testing for weak points is a common way to achieve knowledge about the product in an early state of the development phase.

A weak point test can be designed to “quantify” one or two identified weak points in a product. The test can be tailored to find exactly were the weak point is. Or it can be performed with a broader horizon in order to identify any possible weak point in the product.

Usually when weak-point testing is discussed, people think of a classical thermo mechanical HALT test.

The acronym stands for Highly Accelerated Life Test It is a test technique that evolved around 1970 at Hewlett-Packard under the names “Design Ruggedization” and STRIFE (STRess plus lIFE).

The idea is simple: Apply stresses to a product in excess of its design specification to generate failures, find the root cause of each failure and eliminate them by design improvements. When this is done during the original design of the product, it will result in a much more reliable product, reduced warranty and service costs, shorter time-to-market and more satisfied customers.

The background philosophy for this kind of test is entirely different from the traditional test philosophy.

Traditionally, test is seen as a measurement instrument to verify some quality parameters of a product (either a value or go / no-go). In order to optimise this measuring instrument, the focus has been on the ability of test methods to detect the intended quality parameter and obtain a measure for it with reasonable accuracy and reproducibility without spending too much time and money.

HALT, however, is a tool to improve the quality of a product by finding and eliminating weak points, both in the design and in the production processes. This process of improving is iterative. It stops when margins between breakdown limits and operating conditions are the largest reasonably possible. In order to optimise this tool, the focus is on finding the weak points relevant for real use and introduce redesign or process change to eliminate them without spending too much time and money.

The benefits of HALT are:

- Huge savings in warranty and service costs
- Shorter time-to-market
- Confidence and insight when introducing new products
- Large and known strength margins to operational stress
- Possibility of investigating field failures
- Product is mature and free from teething troubles when entering production
- Failures practically never occur when product is in use
- Customer requirements satisfied

HALT testing is often performed with early prototypes.

A HALT test can not replace the type testing.

For more information on HALT testing, please refer to:

- SPM 169 “HALT & HASS - when and how is it relevant?”
- SPM 174 “Advanced HALT”
- GM Test Procedure GMW8287 “Highly Accelerated Life Testing”

3.4 Type testing

Type testing is used when verification of a type has to be done, i.e. when it has to be verified that a given product for a given application is fulfilling the relevant set of requirements.

Type testing is also known as “Conformance testing”.

Ideally, the type testing should be performed with a product taken from the final production. But if one wants to perform the type testing at an early state of bringing new products on the market, one can be forced to use prototypes for the type testing. The prototypes should be as close to the final product as possible. If this is not the case, it may be necessary to repeat some parts of the type testing with final products.

Some type test programmes specify that a new test specimen can be used to each test or each group of tests. Other type test programmes specify that the same test specimen shall be used for more or less all tests to be performed. Quite often, only one or very few test specimens are present for the type testing, so the test specimen must be used for any different tests.

Type testing is almost always specified to be a “go / no-go” test, i.e. all tests must be passed.

Type testing can include Performance verification, Environmental verification and Reliability verification as described in Sections 2.2 to 2.4.

For this specific DANETV document “Environmental Testing of DANETV Products”, focus has been made on Environmental verification as described in Section 2.3.

If possible, it is a good idea to base the type testing on international and recognised standards. Some useful standards relevant for typical DANETV products can be found in Section 5.

One way to group different types of standards in 3 main groups are as shown below:

Product category standards: Standards relevant for a given category / type of product (for a given application/use).

Example: IEC 60118-1: Hearing aids - Part 1: Hearing aids with induction pick-up coil input.

Generic product standards: Standards relevant for any category / type of product for a given application/use.

Example: IEC 60704-1: Household and similar electrica appliance- Test code for the determination of airborn acoustical noise - Part 1: General requirements.

Generic standards: Standards relevant for a non-specific product or a broad definition of application/use.

Example: IEC 61000-6-2: Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments.

3.5 Production testing

Production testing is used to verify that the production of a given product is continuously at a given quality level.

Traditional production testing has been made by using burn-in testing or Environmental Stress Screening (ESS). Both these techniques are performed with testing **within the specification limits** for the given product.

Burn-in testing is typically performed with the equipment situated at an elevated temperature and with continuous operation, except for a given number of power OFF/ON cycles.

ESS is typical performed with the equipment exposed to some kind of temperature cycling with continuous operation, except for a given number of power OFF/ON cycles. Mechanical vibration may be included in the ESS testing, sometimes even in combination with the temperature cycling.

Modern production testing is made after the so called Highly Accelerated Stress Screening (HASS) strategy. This is typically a rather short exposure (< 30 minutes) with a combination of very fast temperature cycling and 6-axis random vibration and with continuous operation, except for a given number of power OFF/ON cycles. The temperature range and the vibration level are normally **outside the specification limits** for the given product. A HASS test can not be performed unless a HALT test has been performed and all the weak points have been removed from the design.

Both Burn-in/ESS and HASS testing can be made as 100 % production testing, i.e. with testing of all samples which leave the production facility, or as an audit based screen process (sample testing). HASS testing without 100 % testing is called Highly Accelerated Stress Audit (HASA).

For more information on HASS testing, please refer to:

- SPM 169 “HALT & HASS - when and how is it relevant?”
- GM Test Procedure GMW8287 “Highly Accelerated Life Testing”

4. Project planning focussing on type testing

4.1 General

This section is describing the process going from knowledge of the requirement specification for a given product / application over a detailed test specification, a detailed test plan to test execution. When the test execution is done, the results must be reported and for some test areas, a certificate can be issued.

4.2 Requirements specification

The basis for all testing is the Requirement specification. This document should summarise the requirements for the actual product for the given application(s).

An example for a list of content for a Requirements specification could be:

1. Introduction

2. Description and application
   - Short product description
   - Short application description
     - Intended use
     - Intended users
     - Operating conditions
     - Profile of operation

3. General product requirements
   - Relevant legal requirements
   - Relevant EU directives

4. Technical requirements
   - Functional
   - Electrical
   - Mechanical
   - Interface

5. Environmental requirements
   - Mechanical
   - Climatic
   - EMC
   - Other

6. Reliability requirements
   - Reliability Targets
   - Expected Lifetime

- Conditions (maintenance, service…)
- User expectations

7. Regulatory requirements
   - CE marking

8. Safety requirements
   - CE marking
   - Occupational Safety and Health (OSH)

9. EMC requirements
   - From CE requirements
   - Special product/application requirements

10. Type approvals and markings

11. References

12. Change history

The content of the Requirements specification could be shown to external connections, like customers, authorities, and other stakeholders.

The so-called Engineering specification is a document with more ore less the same list of content as the Requirements specification, but as the Engineering specification should be used internally for the product development phase, the level of the requirements may be increased in order to incorporate suitable design margins.

For many DANETV tasks, the Requirements and Engineering specifications could be out of the DANETV focus, as it is expected that the product development is more or less finalised when the products are ready for DANETV verification.

4.3 Test specification

In order to have a detailed description of the actual test to be performed, it is necessary to extract the test requirements from the Requirements specification and supplement this with test details. The document with this info is the so-called Test specification. As a matter of fact, a Test specification ought to be issued before any testing activities are started.

The Test specification should contain at least the following information:

- What to test? (Device Under Test, auxiliary equipment, cabling …)
- How to test the DUT? (Operational state, running mode, special inspections...)
- Which tests to perform? (Performance, Environmental, Relibaility)

- How to perform each test? (Reference standards, severities, procedures...)

As the focus of this part of the DANETV project is on type testing with environmental parameters, the Test specification to be issued under coming DANETV projects will also focus on environmental testing.

An example of the content of one section of an environmental Test specification could be:

3.2.5 High air pressure

The purpose of this test is to verify the ability of the test specimen to operate and perform measurements according to specifications at the highest expected atmospheric air pressure of the use environment.

Reference specification

IEC/EN 60068-2-13, Test M: Low air pressure.

Severity

Temperature	:	Ambient
Atmospheric pressure	:	106 kPa (corresponding to 800 mmHg)
Duration	:	≥ 1 hour

Procedure

1. The test specimen is placed in a test chamber were the air pressure can be increased to 106 kPa.
2. The test specimen is switched ON and remains operating as specified by "Company" for the remaining part of the test.
3. A functional test is performed.
4. The pressure of the test chamber is then adjusted to the specified level.
5. The pressure of the test chamber is maintained for the specified duration.
6. A functional test is performed.
7. The pressure of the test chamber is adjusted to ambient conditions.
8. A functional test and a visual inspection are performed at ambient conditions after 1 - 2 hours of recovery.

4.4 Test plan

The Test plan is based on the detailed test specification and should contain at least the following information in order to ensure a proper test execution:

- Where to test? (In-house, external lab, on-site…)
- Quality level of testing (preliminary, accredited…)
- Resources needed (DUT, function test setup, test equipment, personnel…)
- Level of reporting (simple test record, accredited report…)
- Time planning (remember pre- and post-test activities)

For the environmental type testing to be performed in the typical DANETV environmental verification task, it is recommend that as much testing as possible is performed as accredited testing in an accredited test lab.

The combination of the Test specification and the Test plan is a natural basis for establishing an overview of the actual costs for the environmental verification activities.

4.5 Test execution

When the Test specification and the Test plan are present in an adequate quality level, any professional test lab, with capabilities to perform accredited testing in the relevant environmental test areas, should be able to perform the type testing.

A suitable accreditation scheme to use with Europe could be “European co-operation for Accreditation” or just EA. EA states the following as their mission on the EA webpage:

Consumers demand confidence in the safety and quality of the products they use, the environment they live in, the reliability of health care services, etc.

It is also important for businesses and regulators to have confidence in the integrity and quality of the services supplied by laboratories, inspection and certification bodies.

It is the independence, competence and impartiality of EA member accreditation bodies that guarantee this confidence.

EA, European co-operation for Accreditation, is a non profit association which was set up in November 1997 and registered as an association in the Netherlands in June 2000 (Articles of Association).

EA is the European network of nationally recognised accreditation bodies located in the European geographical area.

In Denmark, the nationally recognised accreditation body is “Danish Accreditation and Metrology Fund” or just DANAK.

A list of accredited test labs within different test areas can be found on DANAK’s web, www.danak.dk

DELTA’s accreditation to perform environmental testing is listed as no. 19 in the DANAK system and it is based on the ISO/IEC 17025 standard.

4.6 Test reporting

When an accredited testing has been performed at an accredited test lab, the results are typical presented in a so-called Accredited test report.

The content of an Accredited test report will typically follow the requirements from ISO/IEC 17025. The following text is taken directly from ISO/IEC 17025:

5.10.2 Test reports and calibration certificates

Each test report or calibration certificate shall include at least the following information, unless the laboratory has valid reasons for not doing so:

a) a title (e.g. "Test Report" or "Calibration Certificate");

b) the name and address of the laboratory, and the location where the tests and/or calibrations were carried out, if different from the address of the laboratory;

c) unique identification of the test report or calibration certificate (such as the serial number), and on each page an identification in order to ensure that the page is recognized as a part of the test report or calibration certificate, and a clear identification of the end of the test report or calibration certificate;

d) the name and address of the customer;

e) identification of the method used;

f) a description of, the condition of, and unambiguous identification of the item(s) tested or calibrated;

g) the date of receipt of the test or calibration item(s) where this is critical to the validity and application of the results, and the date(s) of performance of the test or calibration;

h) reference to the sampling plan and procedures used by the laboratory or other bodies where these are relevant to the validity or application of the results;

i) the test or calibration results with, where appropriate, the units of measurement;

j) the name(s), function(s) and signature(s) or equivalent identification of person(s) authorizing the test report or calibration certificate;

k) where relevant, a statement to the effect that the results relate only to the items tested or calibrated.

NOTE 1 Hard copies of test reports and calibration certificates should also include the page number and total number of pages.

NOTE 2 It is recommended that laboratories include a statement specifying that the test report or calibration certificate shall not be reproduced except in full, without written approval of the laboratory.

5.10.3 Test reports

5.10.3.1 In addition to the requirements listed in 5.10.2, test reports shall, where necessary for the interpretation of the test results, include the following:

a) deviations from, additions to, or exclusions from the test method, and information on specific test conditions, such as environmental conditions;

b) where relevant, a statement of compliance/non-compliance with requirements and/or specifications;

c) where applicable, a statement on the estimated uncertainty of measurement; information on uncertainty is needed in test reports when it is relevant to the validity or application of the test results, when a customer's instruction so requires, or when the uncertainty affects compliance to a specification limit;

d) where appropriate and needed, opinions and interpretations (see 5.10.5);

e) additional information which may be required by specific methods, customers or groups of customers.

One should note, that possible statements from the manufacturer or results from non-accredited testing can be included in an accredited test report, as long as it is clearly marked that these not are a part of the accredited test work.

4.7 Certification

In some areas, it may be relevant to summarise the results from accredited testing or other kind of assessments in a short form document called a certificate. A certificate can be seen in many different shapes, but in the DANETV Environmental Verification area, they will typical be in the form of a so-called “Attestation of Conformity” document.

This kind of document typically contains information that a given product (or range of products) from a given manufacturer is fulfilling the requirements from a specific standard.

An example of an Attestation of Conformity is given below (for a specific flow transmitter):

Attestation of Conformity

EMC test - Certificate no. 729

Since 1992 DELTA has been appointed Competent Body by the notified authority National Telecom Agency, Denmark. The attestation of conformity with the below mentioned standards and/or normative documents is based on accredited EMC test carried out at DELTA.

DELTA client
Proces-Data A/S
Navervej 8
8600 Silkeborg
Denmark

Product identification (type(s), serial no(s).)
PD 340 flow transmitter

Manufacturer
Proces-Data A/S

Technical report(s)
DELTA Test Report, project no. A53047, DANAK-199767
DELTA Test Report, project no. A530047-1, DANAK-198014

Standards/Normative documents
EN 55022:1998+A1+A2
CISPR 22:1997+A1+A2
OIML R117 2CD
EMC Directive 89/336/EEC

DELTA
Danish Electronics,
Light & Acoustics

Venlighedsvej 4
2970 Hørsholm
Denmark

Tel. (+45) 72 19 40 00
Fax (+45) 72 19 40 01
www.delta.dk

The product identified above has been assessed and complies with the specified standards/normative documents. The attestation does not include any market surveillance. It is the responsibility of the manufacturer that mass-produced apparatus have the same EMC quality. The attestation does not contain any statements pertaining to the EMC protection requirements pursuant to other laws and/or directives other than the above mentioned if any.

Hørsholm, 08 July 2005

Per Thåstrup Jensen
M.Sc.E.E.

DELTA

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5. Test standards

5.1 General

Depending on the DANETV product, relevant environmental requirements could exist in the targeted branch of industry. Cataloques of requirements for their specific area of use have been set up in many branches: Examples are the maritime classification societies, automobile manufacturers, railway, agriculture etc.

In such cases, the requirements are assembled in a document, often called an application standard, which, in a matrix of generalised, branch-specific, typical applications and -products, states requirements in terms of tests.

In most cases a collection of single tests, to be compared to “exams” (typetests) to be passed by a product. In other cases specific sequences or combinations of tests are given (reliability test), corresponding to a “trainee period” in the human education analogy.

In any case, the application standards build on well-known international standard **environmental test methods**, which are used to define the requirements.

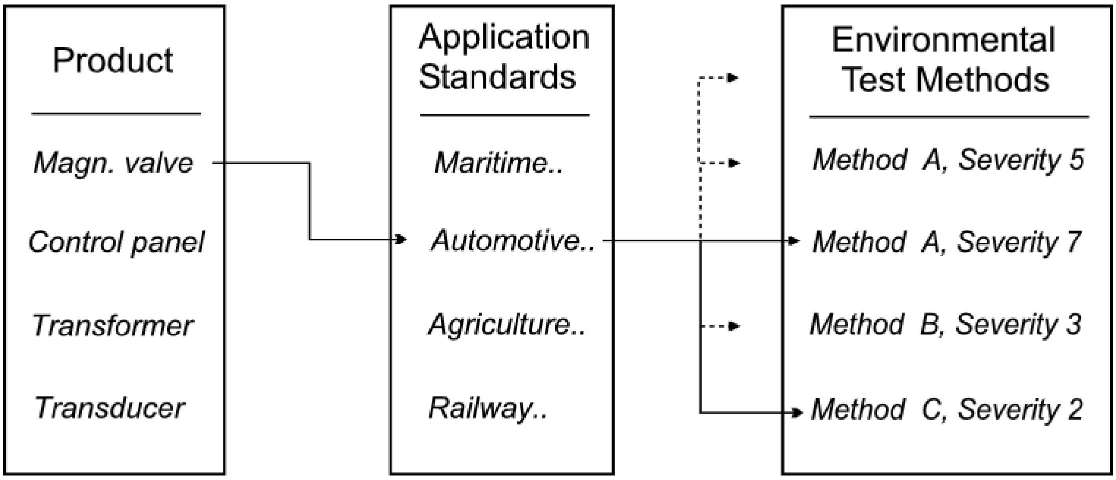

FIG 5.1.1 Choosing relevant application standard.

In the illustration above, “Method A” could mean Dry heat, “Method B” could mean Random vibration” etc.

It should be mentioned, that the terminology used here is not universally agreed upon. Application standards are sometimes called product standards.

It is very important to realise that any statement of requirements starts with a verbal description of the product and its application. For useful general requirements, these descriptions include a group of present or future products and applications.

5.2 Generic test standards

Standard type test methods are the basic building blocks for the “world of testing”. Each describes testing (mainly) using one particular test parameter, like temperature, humidity, or vibration.

The by far most relevant environmental test methods have been published by the International Electrotechnical Commission, IEC, with the series of standards numbered **IEC 60068-2-xx.** This standard series have been published and revised since the 1960’s by the technical committee TC50 of the IEC, and have actually been the main criteria for design of climatic chambers, vibrators and other test facilities.

FIG 5.2.1 IEC 60068-2-xx standards.

A complete list of the IEC 60068-2-xx series can be obtained via the web page www.iec.ch, under / Standards Development / Publications and work in progress / <search>. They can be acquired in pdf-format from Dansk Standard, for a nominal fee.

Other IEC standards apply to electrotechnical applications, but the 60068-2-xx environmental test methods apply to any kind of products. The US military standard MIL-STD-810 is sometimes referred to instead of IEC, but the basic philosophy is the same, probably because the US participitates in the IEC work, like most nations of the world.

Environmental test laboratories need to know the test methods in every detail. Specification writers need to know mainly the discrete set of standardised severities of the tests.

We mention the most commonly used IEC test methods below, with the most relevant severity parameters listed.

5.2.1 Climatic test methods

FIG 5.2.1.1 A temperature and humidity chamber.

FIG 5.2.1.2 The inside of a larger climatic chamber.

Temperature

IEC 60068-2-1, Test A: Cold

IEC 60068-2-2, Test B: Dry heat

These two standard methods are quite similar in many ways. The “Cold” standard is actually used up to +5 ºC. They deal with constant temperature tests.

Both standards give slightly different procedures depending on the heat dissipation of the test specimens, and introduce a subscript “b” or “d” to reflect this:

Test Ab Cold and Test Bb Dry heat: “for non-heat-dissipating specimens”.

Test Ad Cold and Test Bd Dry heat: “for heat-dissipating specimens”.

These tests are typically used to verify function, “Operating” temperatures, but also survival of extremes (shipping).

The most used standard severities are:

Test A: -55, -40, -25, -10, -5, +5 ºC , and

Test B: +40, +55, +70, +85 ºC

- combined with any of the following standard durations:

2, 16, 72 or 96 hours.

IEC 60068-2-14, Test N: Change of temperature

This test is used to verify the effects of differential thermal expansion coefficients of different materials in a construction, e.g. simulation of quick transfer from indoor to outdoor.

The tests consist in cycling between a low and a high temperature, chosen from the previously mentioned cold and dry heat tests. The number of cycles can be (2), 5 or 10. Each cycle spends the same time t1 at the low and at the high temperature. Duration per cycle: 2 x t1 + 2 x transfertime. t1 = 10 min, 30 min, 1h, 2h or 3h. (In practice t1 needs not to be longer than what required for temperature equillibrium).

There are three subtests:

Test Na: Rapid change of air temperature. This is the most commonly used test reference. It requires the use of two sub-chambers, one at each temperature, and each transfer can be <30s or 2 - 3 min for non-automatic facilities (large specimens).

Test Nb: Gradual change of temperature, 1, 2 oir 5 ºC per minute.

Test Nc: Temperature shock, using alternating immersion in two fluid bath.

Air humidity

IEC 60068-2-30, Test Db: Damp heat, cyclic (12 h + 12 h cycle)

Keeping the relative air humidity at approx 97%RH, the temperature is cycled between 25 ºC and then either 40 or 55 ºC, in a number of 24 h cycles. Number of cycles are 2, 6 or 12. An example profile is given in the figure below.

This test intends to produce condensation on the surface of the test specimen, and it can produce accumulating (fluid) water in cavities due to the repeated condensing conditions.

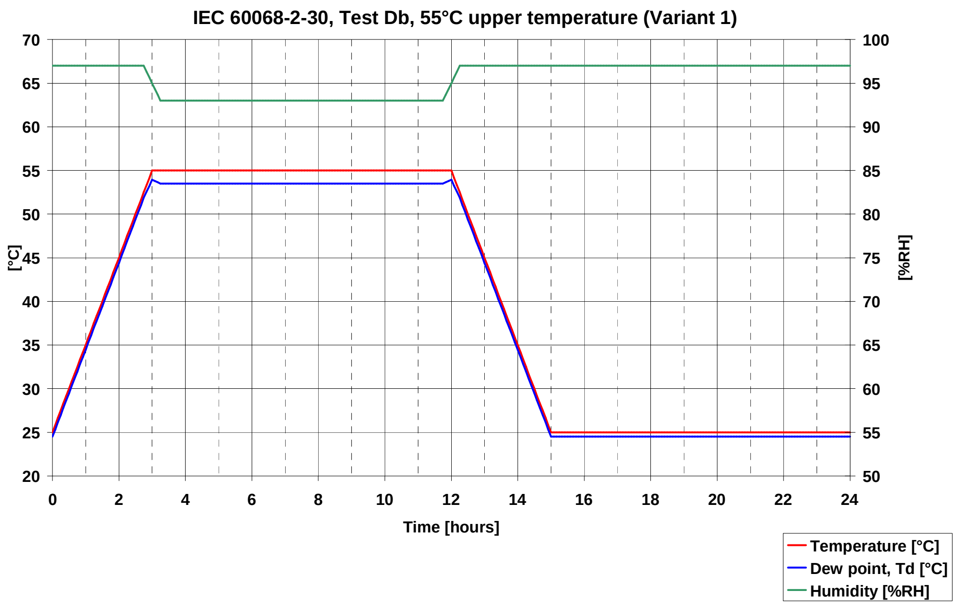

FIG 5.2.1.3 Example profile, Damp Heat cycling.

IEC 60068-2-38, Test Z/AD: Composite temperature/humidity cyclic test

This test consists of ten 24 h-cycles 25 - 65 ºC, but every second cycle an excursion to -10 ºC is included. Used extensively by e.g. the automobile industry.

IEC 60068-2-78, Test Cab: Damp heat, steady state

A steady water vapour partial pressure can produce water uptake in materials by diffusion. This test does not intend to produce condensation on the test specimen.

The single most used condition is 40 ºC at 93 %RH for either 4, 10, 21 or 56 days.

The temperature 30 ºC can also be chosen, as well as the humidity of 85 %RH.

For more information about humidity tests, see:

- SPM-174: "Advanced HALT, Investigation of non thermo-mechanical exposures".

Corrosion

IEC 60068-2-52 Test Kb: Salt mist, cyclic (sodium, chloride solution)

This is the commonly used test for corrosion in automotive or maritime applications and many other applications.

It is performed as either 3 one day cycles or 4 one week cycles. Each cycle includes two hours salt-spraying followed by storage at 40 ºC the remaining cycle time.

IEC 60068-2-11 Test Ka: Salt mist

This older standard is sometimes referred to. It includes constant spraying with salt mist for days.

IEC 60068-2-42 Test Kc: Sulphur dioxide test for contacts and connections

IEC 60068-2-43 Test Kd: Hydrogen sulphide test for contacts and connections

These two standards have been used over the years, especially to verify electrical contact interfaces with gold plating and similar.

Water, dust

IEC 60068-2-18 Test R and guidance: Water

IEC 60068-2-68 Test L: Dust and sand

These test standards are actually not widely used. Instead, it is the practice to specify the tightness of enclosures using IP-code, as measured according to the IEC 60529 standard.

Other climatic methods

IEC 60068-2-05 Test Sa: Simulated solar radiation at ground level

Effects of chemical degradation of exposed surfaces or localised thermal heating under influence of the sun.

IEC 60068-2-13 (1983-01) Ed. 4.0 Test M: Low air pressure

This is used for equipment which may be influenced thermally or otherwise functionally due to low air pressure at high altitudes. Also used for equipment, transported by air, which could be damaged mechanically by low external air pressure.

5.2.2 Vibration and shock test methods

FIG 5.2.2.1 A dedicated shockmachine.

FIG 5.2.2.2 Vibrator with slip-table.

General

IEC 60068-2-47, Mounting of specimens for vibration, impact and similar dynamic tests

This is a guideline for a very important aspect of vibration and shock tests.

Vibration

Vibration is performed sequentilly in three axes, one axis at a time. The axes are mutually perpendicular specimen axes.

IEC 60068-2-06, Test Fc: Vibration (sinusoidal)

Defines what is meant by sine vibration, one frequency at a time, sweeping or dwelling. Sine vibration is used extensively for measurements in addition to regular tests for some close-to-rotating-machine applications.

Standard frequency ranges and levels are defined. Levels are invariably given as amplitudes in unit of acceleration, g or m/s^2, 1 g = 9.81 m/s^2 .

Durations typically are from 30 min to 8 (32) hours per axis.

IEC 60068-2-64 Test Fh: Vibration, broadband random

A spectrum of "simultaneously" present frequencies, of a magnitude called "PSD" for Power Spectral Density, in units of g^2/Hz, is applied for a specified duration sequentially in each of three axes. The squareroot of the area under the PSD spectrum is the rms value of the controlled "noise".

Shock

Shock acceleration pulses have a direction: Two per axis. Three axes are referred to, as for the symmetrical vibration tests which "have three axes" only. Shocks have six directions.

IEC 60068-2-27 Test Ea and guidance: Shock

Ultimate strength, verified by three repetitions of the shock, for each of the 6 directions. Some typical shock severitis are half-sine pulses of amplitude / duration: 10 g - 6 ms, 50 g - 11 ms and 100 g - 6 ms. Severities correspond to drop in a cushioned shipping package, for instance.

Repetitive shock were historically called "Bump", and are repeated many hundred or thousand time per direction, but not always in all six directions. This is a reproducible way of testing for many small jumps and jerks acting onesidedly.

Transient vibration

IEC 60068-2-57 Test Ff: Vibration - Time-history method

IEC 60068-2-81 Test Ei: Shock - Shock response spectrum synthesis

These standards deal with an intermediate between vibration and pulse-shocks. The exposures are defined with a special kind of frequency analysis of the oscillatory acceleration transients, called the "Shock Response Spectrum".

Other mechanical methods

IEC 60068-2-31 Test Ec: Rough handling shocks, primarily for equipment-type specimens

IEC 60068-2-75 Test Eh: Hammer tests

IEC 60068-2-07 Test Ga: Acceleration, steady state

5.3 Application specific test standards

In any area of application, be it on ships, in cars or in wind turbines, a product is presumably mostly known by a name relating to its function. From this name, the specialist in the business will immediately know most aspects, like construction, size, weight, locations etc.

In application standards you use this function-name, but you have to use other criteria for assigning products into classes:

- Location, degree of shelter or heating,
- Mass, size, mounting, use, transportation

And a given product may belong to more than one application class, like a climatic class and a mechanical class.

To each class (sometimes called category) the application standard assigns a set of test methods-with-severity.

Some products, such as critical products, may need special considerations related to the specific function. In such cases, application standards serve as starting points for assigning tests and severities.

FIG 5.3.1 Application standards.

The following chapters are summaries of some aspects of the mentioned papers, and the original versions must be consulted for any actual use of the documents.

5.3.1 Maritime applications

IACS, International Association of Classification Societies, E10, Test Specification for Type Approval

This is a document made by the maritime classification societies, summarising their main requirements. The classification societies are Det Norske Veritas, Germanischer Lloyd, Lloyds Register of Shipping, Bureau Veritas, etc. Some of them have slightly different / more elaborate requirements.

Application categories are only used for vibration in E10: General, mounting on engines or mounting on exhaust manifolds.

Temperature:

IEC 60068-2-1, Cold, +5 °C or -25 °C. 2h at equillibrium.

IEC 60068-2-2, Dry Heat, +55 °C, 16 h or +70 °C, 2 h.

Humidity:

IEC 60068-2-30, two 24 h-cycles, 93%RH, between 25 °C and 55 °C.

Corrosion:

IEC 60068-2-52, Salt mist, 28 days: Four cycles of: 2h-spraying plus 7 days storage.

Vibration:

IEC 60068-2-6, Sinusoidal,
0.7g (1 mm) 2 - 100 Hz, or 4 g (1.6 mm) 2 - 100Hz for mounting on engines etc.
Dwell 1½ h per resonance with Q>2, or at 30 Hz, in each of three axes.
For mounting on exhaust manifolds the frequency range and level is significantly increasd.

Det Norske Veritas, DNV, Standard for Certification No. 2.4

This paper has an extensive classification of tests / severities according to “location classes”:

- Control room, accomodation
- Machinery spaces
- Bridge
- Pump rooms, Holds, without heating

- Open deck

These apply to severities for the parameters temperature, humidity, vibration and enclosure protection.

IEC 60945, Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required results

This is the practical implementation of the requirements of the International Maritime Organization and is used by government administrations for approval of equipment on ships concerning safety at sea.

For allocating different severities to some of the specified environmental tests, equipment is classified into application classes: Portable, protected, exposed and submerged.

For portable equipment the most severe tests are stated:

Temperature:	+55 °C / -20 °C operating, and +70 °C / -30 °C
Thermal shock:	From 70 °C, immersed into 25 °C water.
Drop:	6 drops: 1 m onto hard surface. 3 drops: 20 m onto water
Solar radiation:	1120 W/m2, 80 hours
Oil resistance:	ISO oil no. 1, 24 h, 19 °C.

This is in addition to the requirements for other applications / locations, protected or exposed:

Damp heat:	One 24 h-cycle, 93%RH, between 25 °C and 40 °C.
Corrosion:	Salt mist, 4 cycles of: 2 h-spraying plus 7 days storage.
Vibration:	Sine, 0.7g, 2 h dwell/resonance, 2 - 100 Hz.

All tests (except oil) are according to the relevant IEC 60068-2-xx methods.

Low temperature for protected equipment is -15 °C and it is -25° C for exposed equipment.

Rain and spray for exposed equipment is based on IPx6 defined by IEC 60529.

The corrosion and solar radiation tests can be waived where evidence can be produced that the components, materials and finishes employed in the equipment would satisfy the test.

5.3.2 Automobile industry

ISO 16750, Road vehicles - Environmental conditions

The ISO 16750-x series of application standards represent a common set of requirements relevant for electrical and electronic equipment for automotive use.

ISO 16750	Road vehicles - Environmental conditions and testing for electrical and electronic equipment.
ISO 16750-1	General
ISO 16750-2	Electrical loads
ISO 16750-3	Mechanical loads
ISO 16750-4	Climatic loads
ISO 16750-5	Chemical loads

The following aspects have to be defined in order to establish the detailed test requirements from ISO 16750:

Classification by mounting location

- Engine compartment
- Passenger compartment
- Luggage compartment / load compartment
- Mounting on the exterior / in cavities
- Other mounting locations

Operating modes

- Operating mode 1 (no voltage applied…)
- Operating mode 2 (operated with battery voltage….)
- Operating mode 3 (operated with alternator operating…)

Functional status classification

- Class A (All function during and after test …)
- Class B (…may be out of tolerance during test, but OK after test…)
- Class C (… not OK during test, but automatically OK after test…)
- Class D (… not OK during test, needs manual reset after test…)
- Class E (… not OK during test, needs repair after test…)

The "Classification by mounting location" defines the actual test severities, after a further classification, which is summarised here for mechanical loads / vibration. Two main categories: Passenger cars and commercial vehicles. For each of these:

- Mounting on vehicle sprung body
- Wheel / suspension
- Plenum chamber
- Gear box
- On engine

5.3.3 Agricultural machines

ISO / FDIS 15003, Agricultural engineering - Electrical and electronic equipment - Testing resistance to environmental conditions

This standard aims at all kinds of mobile and hand-held agricultural machinery, forestry machinery, landscaping and gardening machinery.

It is recommended to use the same sample of equipment in all tests unless specified otherwise for a particular test, and functionality should be monitored during tests when practical.

The following tests are given:

Change of temperature:

IEC 60068-2-14, Test Nb, Change of temperature
3 cycles of 24 h.

Steady state time at both low and high temperature is 3 h. Transition times adjusted to give total of 24 h /cycle.

Low / high temperature examples are given:

0 / 70 ºC	Protected, gardening and harvesting machinery
20 / 70 ºC	Unprotected, also forestry machinery
-40 / 85 ºC	Unprotected, forestry machinery, tractors and attachments
-40 / 105 ºC	In an engine compartment
-40 / 125 ºC	On engine / transmission

Temperature shock:

IEC 60068-2-14, Test Na, Change of temperature
10 cycles of approx. 1 h, steady state time at both low and high temperature is 0,5 h. Transition times less than 1 min.

Low / high temperature examples given are the same as above.

Damp heat, steady state

IEC 60068-2-78, Test Cab, Damp heat, steady state
40 ºC / 93% RH for 4, 10 or 21 days.

Examples given:

4 days	Protected from weather
10 days	Unprotected, on engine, transmission
21 days	Engine compartment

Damp heat, cyclic

IEC 60068-2-30, Test Db, Damp heat, cyclic (12h+12h cycle)

Two or six 24 h cycles as defined in the standard, with constant high humidity, approx. 95%RH, and temperature cycling between 25 ºC and upper temperature either 40 or 55 ºC.

The following examples are given:

2 cycles, to 40 ºC	Protected from weather
2 cycles, to 55 ºC	Unprotected from weather
6 cycles, to 55 ºC	Engine compratment or on engine / transmission

Particle impact

A test is defined in detail, as no standard can be given.

In summary: 0.5 liter gravel of a defined stone size is blown onto the test specimen using equipment for producing air blast, devices for measuring air blast pressure and equipment for injecting gravel into the air blast. Tubes and nozzles and distances are defined. Test is carried out 10 times, each time for about 5 - 10 secs.

Mechanical shock

IEC 60068-2-27, Test Ea, Shock

Halfsine shocks, 3 per direction, all six directions.

Examples of severities:

15 g 11 ms	Protected, (internal), in cab
30 g 18 ms	Unprotected, (externally)
50 g 11 ms	In engine compartment, on engine

Random vibration

IEC 60068-2-64, Test Fh, Vibration, broadband random.

In all cases, test duration is 24 h, with 8 h /axis in each of the three orthogonal axes, with a PSD from 10 Hz to 350 Hz. Three PSD curves are given by straight-line segments on lin-log plots (unconventional: slopes in dB/Hz instead of dB/octave).

The three corresponding rms values and examples of severities are as follows:

1.4 grms	Protected, (internal), in cab
1.9 grms	Unprotected, (externally)
3.9 grms	In engine compartment, on engine.

Sinusoidal resonance/dwell test

IEC 60068-2-6, Test Fc, Vibration, sinusoidal

In each of three axes:

Response investigation by sweeping at 1 oct/min from 10 - 2000 - 10 Hz, with an amplitude of 2 g. Locations / frequencies with amplification >2 are noted as resonances. Resonance dwell at 2 g is then performed for 10 min, 30 min or 90 min per resonance. (Severity level 1, 2 or 3, p.t. no further application examples).

Corrosive atmosphere

IEC 60068-2-11, Test Ka, Salt mist

The test is performed by spraying a 5 % aqueous NaCl solution at 35 °C and a pH 6.5 to 7.2, for either 16 h or 48 h.

Inspection / check immediately after test, and again 100 h after test (100 h at 25 ºC, <50%RH) without rinsing.

Examples of severity levels:

16 h spray	Protected locations
48 h spray	Unprotected, engine compartment.

Protection by enclosures (IP code)

IEC 60529

Examples related to location are given:

IP 54	Protected
IP 67	Unprotected
IP 66	Engine compartments
IP 68	On engine, transmission

Air pressure (altitude)

IEC 60068-2-13

Two 12 h cycles between 80 kPa (1700 m above sea level) and 100 kPa (sea level).
7 - 8 h at 80 kPa and 3 - 4 h at 100 kPa. Transition times adjusted to give 12 h /cycle.
Lower pressure should be applied to higher altitudes of operation.

Chemicals

The following list of chemicals is given. When more than one is to be used, a new sample shall be used for each. The sample is brushed once a day for three days. When spraying is necessary, it shall be done for 2 min a day, for 5 days.

List of chemicals:

- Urea nitrogen, saturated solution
- Liquid lime, 10%
- NPK fertiliser (7.5 % N, 7.5 % P, 7.5 % K compound), saturated solution
- Ammonium hydroxide, 20 % aqueous solution
- Diesel fuel, 100%
- Petrol, 100%
- Hydraulic oil, 100%
- Ethylene glycol, 50 % aqueous solution
- Agro-chemicals, strongest solution recommended by manufacturer.

Solar UV radiation

A procedure is given, based on IEC 60068-2-5 and IEC 60068-2-9.

The test specimen is subjected to cycles of alternating exposure to UV and to humidity.

UV exposure time is 8 h followed by 4 h with condensing humidity at 50°C.

Readability of displays

Display is monitored for readability as defined by “the user”, while subjected to solar light as defined in IEC 60068-2-5. Three levels of light can be chosen: 108, 36 or 0 candela.

5.3.4 Railway application

EN 50155, Railway applications, Electronic equipment used on rolling stock.

Enclosure protection:

Assumed to be normally covered by an enclosure external to the equipment.

Temperature:

IEC 60068-2-1, Cold, -25 °C or -40 °C. >2 h at equillibrium. If storage: 16 h.

IEC 60068-2-2, Dry Heat, +55 °C or +70 °C, 6 h. additional 15 °C for 10 min, in cubicles.

Humidity:

IEC 60068-2-30, two 24h-cycles, 93%RH, between 25°C and 55°C.

Corrosion:

IEC 60068-2-11, Salt mist, NaCl, 4 h, 16 h, 48 h or 96 h duration.

Vibration and shock:

Concerning all aspects of vibration and shock, EN 50155 points to the application standard: IEC 61373, Rolling stock equipment, Vibration and shock.:

Test methods: IEC 60068-2-64, Random vibration, IEC 60068-2-27, Shock

General:

Vibration 5 h/axis at 0.8 grms, 5 - 150 Hz, operation at -18 dB if any.

Shock, half-sine, 5 g 30 ms, 18 shocks, 3/direction.

Mounting on bogie:

Vibration 5 h/axis at 4.3 grms, 5 - 250 Hz, operation at -18 dB if any.

Shock half-sine, 30 g 18 ms, 18 shocks, 3/direction.

Mounting on wheel/axle:

Vibration 5 h/axis at 30 grms, 10 - 500 Hz, operation at -18 dB if any.

Shock halfsine, 100 g 6 ms, 18 shocks, 3/direction.

Lower levels than stated here are actually required for horizontal train axes. For heavy equipment, both level and frequency ranges are decreased.

EN 50125, Railway applications

EN 50125-1, - Equipment on board rolling stock
Similar to the railway specification mentioned above, in many respects.

EN 50125-3, - Equipment for signalling and telecommunication.
Climatic data for different locations, vibration level on rail, in ballast etc.

5.3.5 Aircraft applications

RTCA/DO-160, Environmental Conditions and Test Procedures for Airborne Equipment.

This is the main application standard for civil aviation. It is a document with 22 test methods, with each method described on 5- 25 pages. The following photo is of the table of contents.

The tests include methods for:

- Temperature/-variation/-with low pressure
- Humidity / cyclic
- Mechanical shock
- Vibration
- Water, fluids, sand, dust, fungus
- Salt spray
- Electic / magnetic / lightning

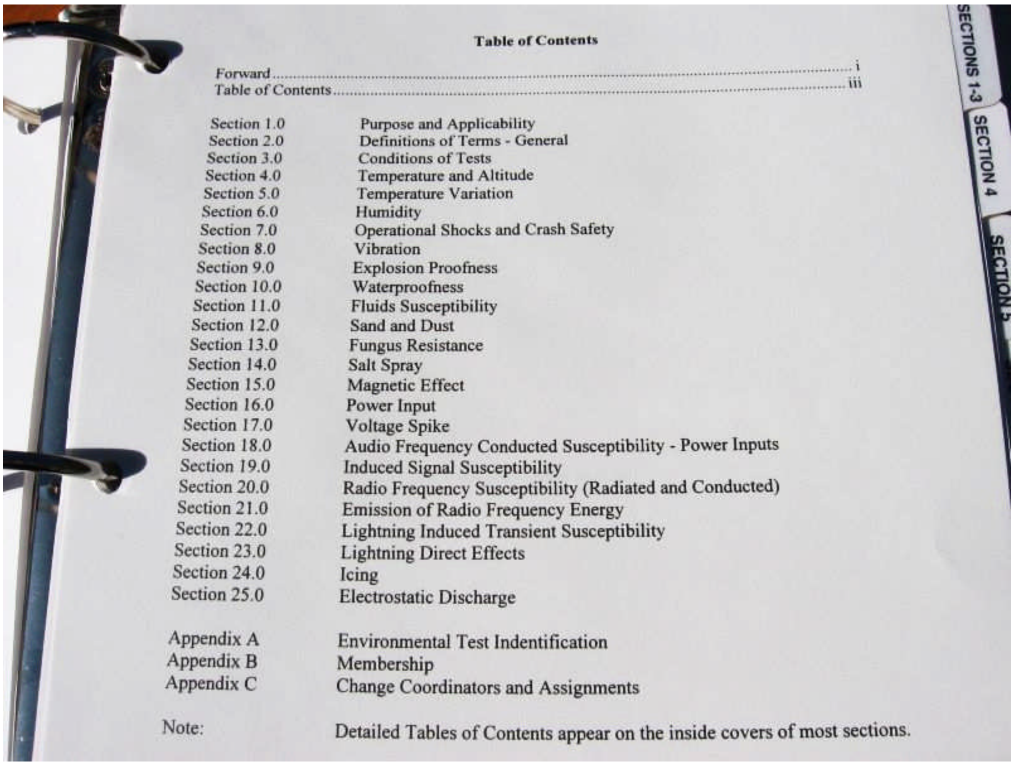

Table of Contents

Forward i
Table of Contents iii

Section 1.0	Purpose and Applicability
Section 2.0	Definitions of Terms - General
Section 3.0	Conditions of Tests
Section 4.0	Temperature and Altitude
Section 5.0	Temperature Variation
Section 6.0	Humidity
Section 7.0	Operational Shocks and Crash Safety
Section 8.0	Vibration
Section 9.0	Explosion Proofness
Section 10.0	Waterproofness
Section 11.0	Fluids Susceptibility
Section 12.0	Sand and Dust
Section 13.0	Fungus Resistance
Section 14.0	Salt Spray
Section 15.0	Magnetic Effect
Section 16.0	Power Input
Section 17.0	Voltage Spike
Section 18.0	Audio Frequency Conducted Susceptibility - Power Inputs
Section 19.0	Induced Signal Susceptibility
Section 20.0	Radio Frequency Susceptibility (Radiated and Conducted)
Section 21.0	Emission of Radio Frequency Energy
Section 22.0	Lightning Induced Transient Susceptibility
Section 23.0	Lightning Direct Effects
Section 24.0	Icing
Section 25.0	Electrostatic Discharge
Appendix A	Environmental Test Indentification
Appendix B	Membership
Appendix C	Change Coordinators and Assignments

Note: Detailed Tables of Contents appear on the inside covers of most sections.

FIG 5.3.5.1 RTCA/DO-160 Table of Contents

Each method devises a subset of severities for various subcategories. Each method has its own terminology for defining categories.

As an example, the following figure is from Section 8, Vibration. The table gives “Categorization and Tests by Aircraft Types and Equipment Locations”.

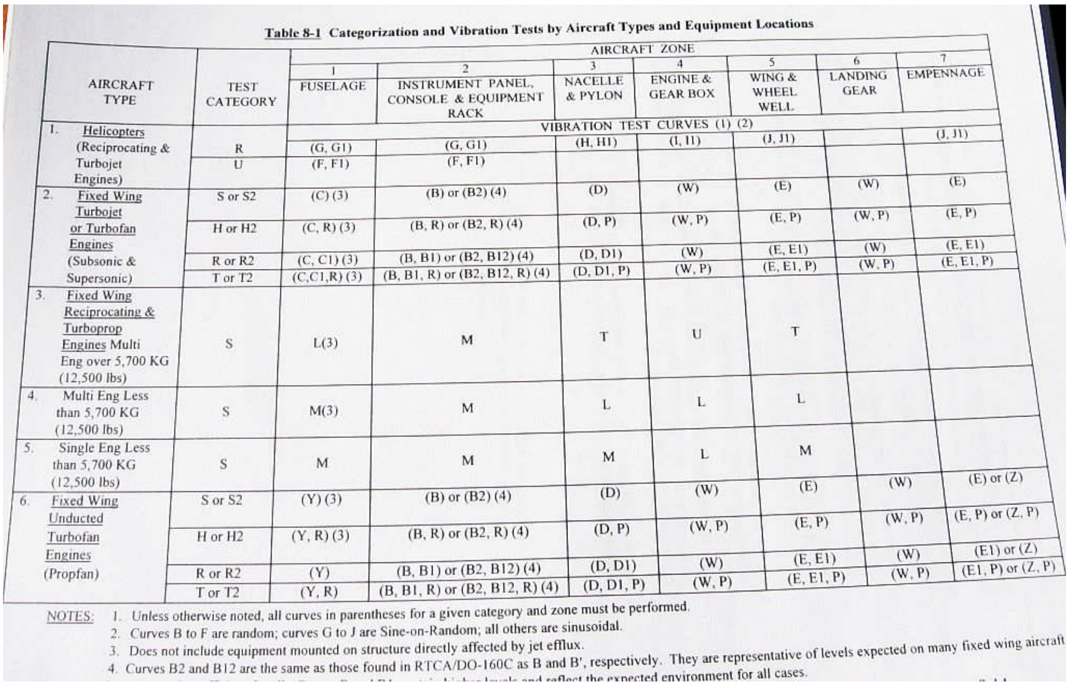

Table 8-1 Categorization and Vibration Tests by Aircraft Types and Equipment Locations

AIRCRAFT TYPE	TEST CATEGORY	AIRCRAFT ZONE 1 FUSELAGE	2 INSTRUMENT PANEL, CONSOLE & EQUIPMENT RACK	3 NACELLE & PYLON	4 ENGINE & GEAR BOX	5 WING & WHEEL WELL	6 LANDING GEAR	7 EMPENNAGE
		VIBRATION TEST CURVES (1) (2)						
1. Helicopters (Reciprocating & Turbojet Engines)	R	(G, G1)	(G, G1)	(H, H1)	(I, I1)	(J, J1)		(J, J1)
	U	(F, F1)	(F, F1)					
2. Fixed Wing Turbojet or Turbofan Engines (Subsonic & Supersonic)	S or S2	(C) (3)	(B) or (B2) (4)	(D)	(W)	(E)	(W)	(E)
	H or H2	(C, R) (3)	(B, R) or (B2, R) (4)	(D, P)	(W, P)	(E, P)	(W, P)	(E, P)
	R or R2	(C, C1) (3)	(B, B1) or (B2, B12) (4)	(D, D1)	(W)	(E, E1)	(W)	(E, E1)
	T or T2	(C,C1,R) (3)	(B, B1, R) or (B2, B12, R) (4)	(D, D1, P)	(W, P)	(E, E1, P)	(W, P)	(E, E1, P)
3. Fixed Wing Reciprocating & Turboprop Engines Multi Eng over 5,700 KG (12,500 lbs)	S	L(3)	M	T	U	T		
4. Multi Eng Less than 5,700 KG (12,500 lbs)	S	M(3)	M	L	L	L		
5. Single Eng Less than 5,700 KG (12,500 lbs)	S	M	M	M	L	M		
6. Fixed Wing Unducted Turbofan Engines (Propfan)	S or S2	(Y) (3)	(B) or (B2) (4)	(D)	(W)	(E)	(W)	(E) or (Z)
	H or H2	(Y, R) (3)	(B, R) or (B2, R) (4)	(D, P)	(W, P)	(E, P)	(W, P)	(E, P) or (Z, P)
	R or R2	(Y)	(B, B1) or (B2, B12) (4)	(D, D1)	(W)	(E, E1)	(W)	(E1) or (Z)
	T or T2	(Y, R)	(B, B1, R) or (B2, B12, R) (4)	(D, D1, P)	(W, P)	(E, E1, P)	(W, P)	(E1, P) or (Z, P)

NOTES:
1. Unless otherwise noted, all curves in parentheses for a given category and zone must be performed.
2. Curves B to F are random; curves G to J are Sine-on-Random; all others are sinusoidal.
3. Does not include equipment mounted on structure directly affected by jet efflux.
4. Curves B2 and B12 are the same as those found in RTCA/DO-160C as B and B', respectively. They are representative of levels expected on many fixed wing aircraft … reflect the expected environment for all cases.

FIG 5.3.5.2 “Categorization and Tests by Aircraft Types and Equipment Locations”.

The codes inside the table point further to test procedures and severities. The aircraft zones are

- Fuselage
- Instrument panel, console, rack
- Nacelle & pylon
- Engine & gear
- Wing
- Landing gear
- Empennage

The aircraft types are:

- Helicopters: About 20 different levels,
  3 - 200 Hz (2000 Hz), 1.6g to 7.5 grms (28 grms), 4 hours per axis.

- Propeller aircraft: 5 different procedures/levels.
  5 - 150 Hz (500 Hz), 1.5g - 10 g (20 g), 1 hour per axis with sine-sweeps.

- Jet aircraft: About 12 different procedures/levels
  10 - 250 Hz (2000 Hz), 1.5 grms - 10 g (20 g), 3- 4 hours per axis.

5.3.6 Other application standards

ETSI, ETS 300 019-2-x, European Telecommunications Standards Institute, Specification of environmental tests.

Apart from transportation, this is mainly stationary installations in protected locations. A very elaborate system of tables of equipment categories, tests and test severities is presented.

EN/IEC 60721, Classification of environmental conditions.

As the title says, this is a description of conditions, in different classes of applications. By using codes for the different classes, it provides a short-hand notation to be used when stating requirements for sub-suppliers. The information can be very useful for an equipment designer, but the classes do not, however, define actual tests to be used for verification.

NT-ELEC 16G, Environmental Test Procedures.

This is a collection of about 80 environmental test procedure examples.

Each example, on two pages, defines a test for a given parameter, for a given application and object of testing. There are more examples for the same parameter, corresponding to different applications and test-purposes and correspondingly different severities.

The examples illustrate, how, in an ideal world, any test for a product, should be defined.

5.4 Non-standardised testing

Sometimes a new product is obviously subjected to significant influences for which no standard test method exists. Examples are:

- Exposure to chemically active substances, oil, cleaning fluid, gasoline, see e.g. ISO 15003 above

- Bending of credit cards, once an important topic
- Repeated stretching of (spiralised) cabling
- Bending of cables
- Pressing of buttons and levers
- Particle impact (gravel, stones), see ISO 15003 above
- Readability of displays, see ISO 15003 above

The fact that a suitable standard test method cannot be found, does not mean that some kind of testing is not relevant for a specific product.

In many cases it could be important to combine the special testing with exposure to temperature, humidity, vibration etc.

It is often possible to lean on existing standards in new combinations, to achieve a well-defined and reproducible test.

6. Case studies

6.1 General

In the following we construct hypothetical products.

6.2 Case 1: New product

We consider a new product which consists of a:

- GPS unit for mounting on top of bulldozer for landscaping purposes
- Control box as the human interface inside the cab of the bulldozer

Of course the GPS unit could be any kind of sensor-like unit, fertilizer spray magnetic valve etc, and the bulldozer could be some agricultural moving machinery.

We do not have a specific buyer, but consider selling the new product to harsh environments as in agriculture, forestry or road building.

If the product was intended for more military purposes, like vehicles, we should consider some requirements from MIL810G.

This is not the case, and we therefore set out to use the requirements from the previously, in Chapter 5.3, discussed ISO /FDIS 15003.

This gives the following resulting test specification, given in summary here:

ISO 15003 section:	ISO test level	Exposure, summary	GPS unit	Control box
5.2.1 Change of temperature	3	-40 ºC to/from 85 ºC, 8 cycles (24 h)	x	x
5.2.2 Temperature shock	2	-20 ºC to/from 70 ºC, 10 cycles (10 h).	x	-
5.3 Damp heat, steady state	2	40 ºC / 93%RH, 10 days	-	x
5.4 Damp heat, cyclic	2	55 ºC / 93%RH, 2 cycles (2 days)	x	x
5.7 Corrosive atmosphere, salt	2	48 h (+100 h drying).	x	-
5.5.2 Mechanical shock	1	18 applications of: 15 g 11 ms		x
	3	50 g 11 ms	x	
5.6.1 Random vibration	2	3 axes: 8 h at 1.9 grms to 350 Hz.		x
	3	3.9 grms to 350 Hz	x	
5.6.2 Sinusoidal (resonance) test	2	3 axes: 2 g to 2k Hz, dwell ½ h / resonance	x	x

The enclosures are from a supplier with documented tightness IP 67, which we need not document in a new test, since we also use military grade connectors.

Readability of the Control box display is very important, and should be verified.

Air pressure is not considered important.

If the “GPS unit” was some valve placed close to the ground, it could be relevant to add the “Particle Impact” test also, depending on the robustness of the unit enclosure.

6.3 Case 2: Existing product, new application

Some time after the successfully finished testing of the GPS unit and Control box, according to the plan above, the products are sold to railway operator.

The Control box is to be mounted in the driver compartment, and the “GPS unit” on the roof of the rail traction car.

The railway operator, however, says that the products should live up to his general specification EN 50155, discussed above in Chapter 5.3.

The question is now if the already performed tests (ISO 15003) are sufficient to cover the new requirements?

The new EN temperature requirements of -40 ºC / +70 ºC are indeed covered by the ISO tests Change of temperature, as they were performed switched ON with function at the high temperature and switching-on, cold-start, at the low temperature.

The cyclic humidity requirements are identical, so also OK. (ISO steady state humidity not required by the train specifications).

The performed Corrosion/ Salt mist test is more severe than the new requirements: OK.

Mechanical shock: The new requirements call for only 5 g 30 ms, which is significantly lower than the test already performed and documented. Method, directions and number of applications are the same.

Vibration:

The following figure shows the PSD for the performed ISO-agri-test, 1.9 grms, in red.

The green figure shows the PSD required by the new train operator customer.

As apparent, the new requirements require a new vibration test to be performed, using the green curve, 5 hours per axis, at 0.8 grms. This will be sufficient for both GPS and control box.

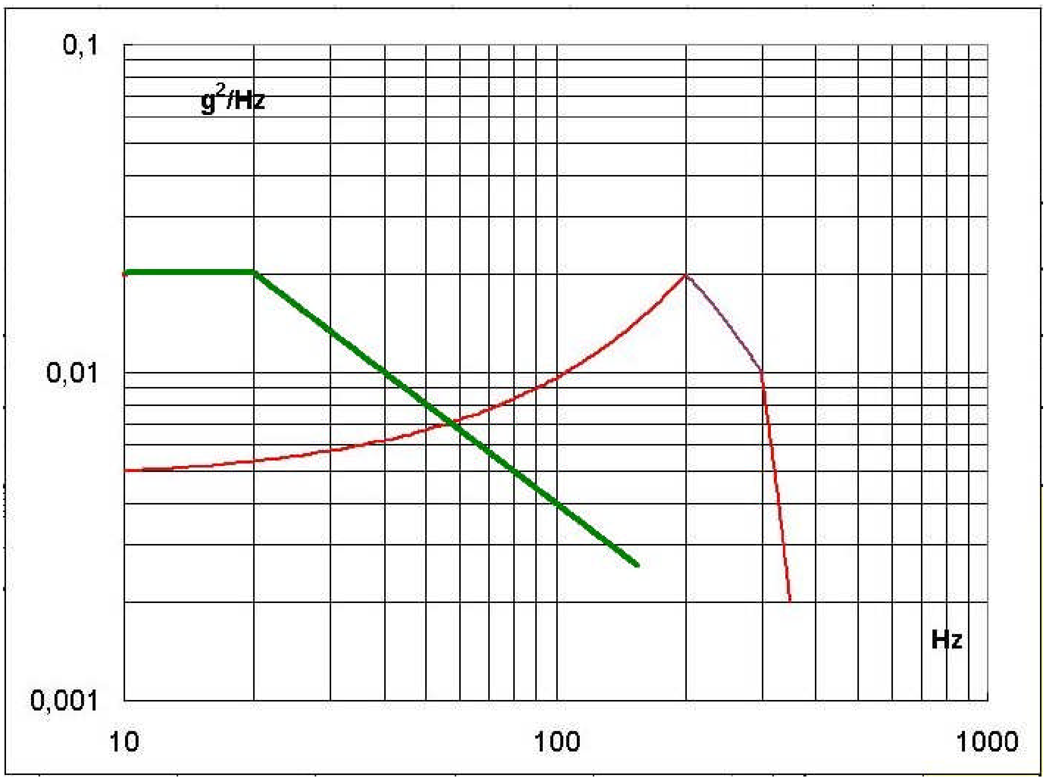

FIG 6.1 PSD curves.

7. Conclusion

This report has presented an introduction to environmental type testing of DANETV products. The following subjects were covered:

Test purpose - where different kinds of verification methods were described. Whether it is performance, environmental or reliability that is the purpose, this will lead to different tests.

Test strategies - here the difference between, and background of, weak-point testing, prototype testing, type testing and production testing were described.

Project planning - The different aspects of planning a project with focus on type testing is covered. Describing the project from the initial requirement specification, to the reporting and certification of the test.

Test standards - Is an extensive catalogue of different test standards, both generic and application specific standards are covered.

Case study - two cases are presented that covers the principles described in this report.