Electro-Optical Environmental Considerations

Parameters and Testing Analysis

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Introduction

In the requirement development, design, and system development the majority of attention is paid to the mechanical, electrical and optical components and assemblies of Electro-Optical systems. In many cases the intended operating environment is overlooked or the requirement implication misunderstood. This paper will look at a few of the more common environmental parameters and unlike most documents this paper will pose questions for the reader to consider when develop a system or system requirements. Unfortunately the answers to these questions will be extremely dependent on the systems intended application. In addition some test methodologies and testing limitation will be discussed. The intent of this paper is provide new hire engineers/scientist a

Environmental Considerations

Temperature

When developing system requirements or the design for a system one of the more vital operational conditions to understand is the temperature and there are two area to in which to understand; 1.) At what temperature range is the system intended to operate and 2.) At what temperature range will the system be submitted to during storage or transit?

To understand these two items the operational environment of the system really needs to be understood. Is this a lab system, or something that will sit outside in the artic? Is this system going to see fast temperature changes, such as being mounted externally on an aircraft and what is the operational altitude of the aircraft? Is the system going to experience long duration exposure to sunlight? Once this is understood MIL-HDBK-310 can assist in bounding the problem by providing highs and lows and well as frequency of events related to worldwide climate data. Are there going to be liquids internal to the system, e.g. Liquid Nitrogen? Are there internal source of heat or cooling that need to be accounted for, e.g. flash lamp?

The temperature range at which the system is going to by required to operate is very important in the material selection stage of the design. Equations 1 – 7 show that temperature differences, which can be cause by the natural heating and cooling of the diurnal cycle, altitude changes, or heat transfer (optics on a weapon). The equations show that not only does temperature affect the stress and strain of the metal material but also optical properties such as focal length.

Thermal Expansion Equation

$$\Delta \mathrm{L} = \alpha * \mathrm{L} * \Delta \mathrm{T} \tag{1}$$

$$\Delta L = (\alpha_1 * L_1 + \alpha_2 * L_2) * \Delta T \tag{2}$$

ΔL – Change in material length
α – Coefficient of Thermal Expansion
ΔT – Temperature Difference
L – Original material length

Thermal Stress Equations

$$\mathrm{F} = E * A * \alpha * \Delta T \tag{3}$$

$$\sigma = \frac{F}{A} \tag{4}$$

$$\sigma = E * \alpha * \Delta T \tag{5}$$

F – Force
E – Young's Modulus
A – Cross sectional area of the material
ΔT – Temperature Difference
σ – Stress

Thermal Expansion of Optics

$$\Delta \mathrm{f} = \beta * f * \Delta T \tag{6}$$

$$\beta = \alpha - \frac{1}{(n_r - 1)} * \frac{dn_r}{dT} \tag{7}$$

Δf – Change in focal length
f – Original focal length
ΔT – Temperature Difference
$\frac{dn_r}{dT}$ – Thermal-Optic Coefficient
n_r – Effective Index of Refraction

For testing of any environmental requirement MIL-STD-810G Ch. 1 is a really good place to start. However, it is very important to understand that when using MIL-STD-

810G Ch. 1 the test methodology must be read and specified to the correct detail. There are many times when a requirement calls out, for example,

MIL-STD-810G Ch. 1 Section 501.6 High Temperature +55°C, and this is insufficient to perform a valid test.

This may be the operational requirement, but to test using MIL-STD-810G Ch. 1 additional things need to be answered. Is this the Storage condition (Procedure I), the Operational condition (Procedure II), or the Operational Standby mode (Procedure III)? Is this constant temperature requirement, or does the system have to operate for a temperature cycle and if so how many cycles? At what humidity is the test required to be run at?

Below is a listing of temperature related test within MIL-STD-810G Ch. 1

MIL-STD-810G Ch. 1 Section 501.6 High Temperature

Limitations: This section is limited to evaluating the short-term effects even distributions of heat. This section is not generally used for evaluating: time-dependent aging effects, effects of solar radiation producing thermal gradients, photochemical effects, or effects of aerodynamic heating.

MIL-STD-810G Ch. 1 Section 502.6 Low Temperature

Limitations: This section is not intended to simulate an unpressurized aircraft at altitude.

MIL-STD-810G Ch. 1 Section 503.6 Temperature Shock

Limitations: This section does not specifically address the following: sudden extreme temperature changes, lengthy exposure to extreme temperatures, transition between air and liquid or two liquids, rapid transient warmup by engine compressor bleed air, or aerodynamic loading, fire to cooled with water transition, or safety or hazard assessment of munitions.

MIL-STD-810G Ch. 1 Section 505.6 Solar Radiation

Limitations: This section does not consider all of the effects related to the natural environment, environment for an item is within an enclosure, or space applications due to the change in irradiance.

Pressure

Pressure requirements are usually much more straight forward that most of the other environmental requirements. Primary this consideration deals with at what altitude or depth the system with be operated and/or stored. The only other time pressure is really considered is during gunfire or explosive shock. However, these two cases are tested in conjunction with other effects, such as mechanical gunfire shock, and therefore are not discussed here. Many of the same consideration listed above are also relevant, such as temperature, climb/dive rate, humidity, and exposure duration. While these test ultimately tell you if the system works or not, one area to really understand is how are the seals holding up. When pressure is lowered will air seep in and condense on the ground leading to moisture issues? Does liquid nitrogen escape at altitude leading to shorter operational life expectancy?

MIL-STD-810G Ch. 1 Section 500.6 Low Pressure

Limitations: This section is not intended to be used to evaluated; materiel operated vehicles that fly at altitudes above 21,300m, Procedure IV is not intended to be used for materiel transported in a cargo bay.

MIL-STD-810G Ch. 1 Section 512.6 Immersion

Limitations: This section is not intended to be used for buoyant items unless the life cycle profile identifies specific applications such as restraints that could hold the materiel under water.

Humidity

While MIL-HDBK-310 is a great reference for a consideration such as humidity, this one in particular is very important to understand when specifying MIL-STD-810G Ch.1. This test is one that is very commonly specified at too low a detail. There are three primary procedure for this test; 1.) Operational or natural, 2.) Storage or induced, and 3.) Aggravated. The first two tests are self-explanatory, but it requires the selection of the proper cycle. Cycles may be tailored to meet specific requirements, however it is important to discuss changes with the lab that will be preforming the test to ensure that their equipment can support any tailoring.

The other factor that comes along with the humidity cycle testing is cost. Some test cycles only require 15 days of chamber time, but others require up to 180 days of chamber time. This test can become very costly very fast. While the tests are costly for items that will be used outside this is a very important test. Poor performance in this test may require redesign of seals and/or addition or desiccant cartages to reduce the internal humidity that may damage electrical components or degrade optical performance. These will add weight and cost to a system.

MIL-STD-810G Ch. 1 Section 5074.6 Humidity

Limitations: This section may not evaluated; long term effects or with low humidity situations, temperature/humidity environment but, provides a generally stressful situation that is intended to reveal potential problem areas in materiel. Testing in the natural environment, whenever practical, may provide more valuable results,

Abrasion

This requirement really goes back to understand the operational environment the system is intended to operate in. For ground and near shore applications abrasion is of high concern. There are three big tests that one should consider; Dust, Sand, and Optics. The two MIL-STD-810G Ch. 1 are really intended to test the system enclosure and seals. These tests are extremely hard on optical material to the point where options will be either very expensive or possible even unable to past the test while still providing any kind of image performance. For optical material abrasion specifications MIL-PRF-13830B is a more common standard. This standard calls for two different abrasion tests depending on the Knoop's hardness of the material, but also an adhesion geared more toward the coatings.

Conclusions

Environmental parameters are extremely important considerations when developing system requirements. Designs that work for a lab environment will not work for military application, however military application requirements would cause lab equipment to be very unaffordable. When developing requirements remember to do a cost benefit analysis for requirements that are not necessary inherent to the environment, but more importantly understand the operational environment of the system. The second takeaway should be that MIL-STD-810G Ch 1. is a really good source for testing requirements, however it is not complete, nor are most test intended to predict survivability over the life of the system, but really intended to find design flaws.

References

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