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ISO Environmental testing and reliability standards for optics

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Introduction

In this paper, we give a little background into the work of ISO/TC172/SC1/WG1, the ISO subcommittee that is writing standards for the environmental testing of optics and optical instruments. By environmental test standards, we mean standards that outline what sort of climatic variations and conditions of use optical instruments must survive and still operate within given performance specifications.

The scope of the standards this subcommittee is writing is then described followed by a thorough description of the general content of the 2 standards that are nearing completion. Finally we discuss the applicability of these standards and how they may affect optics and optical systems that are intended for sale in international markets. We also discuss briefly the relationship of these ISO standards to MIL-STD-810E, *Environmental Test Methods and Engineering Guidelines*, the US Military standard governing the environmental rigors military optics and other devices must survive to be approved for sale to the military.

Background

ISO Technical Committee 172 (ISO/TC172) - Optics and optical instruments, was founded in 1979 under the sponsorship of the German National Institute for Standardization, DIN. There are 9 subcommittees (SC's) within TC172. SC1 - Fundamental Standards, is responsible for optical testing (Working Group 1), optical drawings (WG2) and environmental testing (WG3). For the past 10 years, this group has been working on 2 standards, each with many parts, that in the first instance define various environmental tests and in the second, define the applicability of these tests to various types of optical instruments. Under the leadership of Mr. H. Zulehner of Carl Zeiss, both of these standards are in the process of being adopted as international standards.

Most parts of the first standard have already been adopted while some parts of the instrument specific standard are lagging behind as experts on the particular types of instruments negotiate reasonable levels for the application of the standard tests. The actual conditions of test in the first standard were adopted from the IEC standards written for the environmental testing of electrical products. Since the IEC has been in the international standards writing business for about 100 years and most of the environmental standards they have written have been in use for some time, it was felt the these standards made a good basis for the similar ISO standards. These standards were, however, suitably modified to be applicable to optical products.

Before getting into the specifics of the standards, there are a few words of explanation needed to set the stage. The reason for having environmental standards is that it is recognized the performance of an optical instrument depends on the environment in which it is operated. For example, the film winding mechanism in a camera may not work until it warms up if the camera has been left in a car over a very cold night.

For any particular optical instrument, the type and severity of environmental test parameters depend on the global location and conditions of use. Clearly, an instrument intended for laboratory use will not function up to expectation in the Sahara Desert or on a polar expedition. On the other hand, a customer should not have to pay extra for environmental hardening when the instrument will never be used outside a laboratory.

These 2 ISO environmental standards are designed to insure an optical instrument will meet customer expectations of performance when the instrument is used in the manner and in the climatic conditions for which it was designed, built and sold. These standards establish objective criteria to help see that these expectations are met. They also imply a dual responsibility; the manufacturer will deliver a quality instrument that will perform to specification as long as it is not abused by improper operation or use in a climate for which it was not intended.

Scope of the Environmental Standards

The first standard is ISO 9022 - *Environmental test methods*, and it defines terms relating to environmental tests for optical instruments and for instruments that contain optical assemblies and components. In addition, it specifies the essential steps for conducting an environmental test and defines some 20 basic types of tests along with various subcategories of these tests.

The other standard, ISO 10109 - *Environmental requirements*, specifies the environmental requirements to be met regarding the reliability of a particular optical instrument when exposed to various applicable environmental influences. It also defines the geographical and technological areas of applicability of the instruments. This standard does <u>not</u> apply to specifications for <u>packaging</u> for transportation and storage.

ISO 9022 - Environmental test methods

The 20 Parts of ISO 9022 are listed in Table 1 along with an indication of how many subdivisions there are of the basic test. While we will not list all the subdivisions, it is instructive to see an

ISO 9022 - Environmental Test Methods

Part 1 : Definitions, extent of testing

Part 2 : Cold, heat, humidity - 7

Part 3 : Mechanical stresses - 8

Part 4 : Salt mist - 1

Part 5 : Combined cold, low air pressure - 2

Part 6 : Dust - 1

Part 7 : Drip, rain - 3

Part 8 : High pressure, low pressure, immersion - 3

Part 9 : Solar radiation - 1

Part 10 : Combined sinusoidal vibration, dry heat or cold - 2

Part 11 : Mould growth - 1

Part 12 : Contamination - 4

Part 13 : Combined shock, bump or free fall, dry heat or cold - 6

Part 14 : Dew, hoarfrost and ice - 3

Part 15 : Combined random vibration wide band - 2

Part 16 : Combined bounce or steady state - 4 acceleration, in dry heat or cold

Part 17 : Combined contamination, solar radiation - 2

Part 18 : Combined damp heat and low internal - 3 pressure

Part 19 : Temperature cycles combined with sinusoidal or random vibration - 3

Part 20 : Humid atmosphere containing sulphur dioxide or hydrogen sulphide - 2

Table 1 Parts of ISO 9022

example in Table 2 where the subdivisions of Parts 2 and 3 are listed. Before looking at any of these tests in detail, we will discuss the definitions in Part 1 to get some background material needed to understand the tests.

An obvious first definition says that an environmental test is a laboratory simulation of (usually severe) climatic, mechanical and chemical influences likely to occur during transport, storage and operation on a test specimen in order to quickly determine changes in the behavior of the specimen due to the influences. The act of subjecting the specimen to these influences is called conditioning.

Conditioning is considered to be the sum of external influences acting on the specimen during the test including the conditioning method (or particular environmental test), the degree of severity of the test and internal influences due to the state of operation such as motion and/or temperature change. Also defined are 3 states of operation; State 0 - In a storage or transportation container, State 1 - Unprotected, ready for use but not turned on, and State 2 - Unprotected, turned on and operating.

In order to evaluate what has happened during a test or conditioning, there are 3 types of tests or examinations. The first is simply a visual examination to see if, for example, some part of the specimen became loose during conditioning. The second is a functional test to see if the device still functions after conditioning. Finally there is measurement, an objective determination of a physical quantity by comparison with a specified quantity.

This Part also defines a test sequence and this given in Table 3. While in some respects this Table looks trivial, it does define precisely what is meant by a test sequence and that there are some important matters that must be noted before applying the conditioning so that changes may be recognized after the conditioning. In order to specify what test(s) are to be performed on a particular instrument, an Environmental test code is defined as shown in Fig. 1.

As an example, using material from Table 4 where Conditioning method 86, one of the subdivisions of Contamination, is illus-trated, we could specify an Environmental test code of "Environmental test ISO 9022 -86 - 03 -2". This means that the 6 test agents listed in Table 4 are applied as outlined in Part 12 of the Standard to the test specimen for 30 days while the specimen is sitting unprotected on a workbench, but is not turned on. At the end of the 30 days, the test agents are cleaned off the specimen and it is examined to see if there have been any changes to the finish of the specimen.

ISO 10109 - Environmental requirements

Whereas ISO 9022 outlines the details and degrees of severity of nearly 100 conditioning methods, ISO 10109 is concerned with which of these methods and with what degree of severity they should be applied to a particular optical instrument designed for a particular type of use or

Part 2 : Cold, heat, humidity

10 : Cold
11 : Dry heat
12 : Damp heat
13 : Condensed water
14 : Slow temperature change
15 : Rapid temperature change
16 : Damp heat, cyclic

Part 3 : Mechanical stresses

30 : Shock
31 : Bump
32 : Drop and topple
33 : Free fall
34 : Bounce
35 : Steady state acceleration
36 : Sinusoidal vibration
37 : Random vibration (wide band)

Table 2 Subdivisions of Parts 2 and 3

Definitions - Test sequence

* Preconditioning - Prepare specimen for testing
* Initial test - State of device prior to testing
* Conditioning - Apply conditioning method at degree of severity and state of operation
* Intermediate test - does it function in state 2
* Recovery - Bring back to ambient conditions
* Final test - State of device after testing
* Evaluation - Determination if specifications met

Table 3 Definition of a Test Sequence

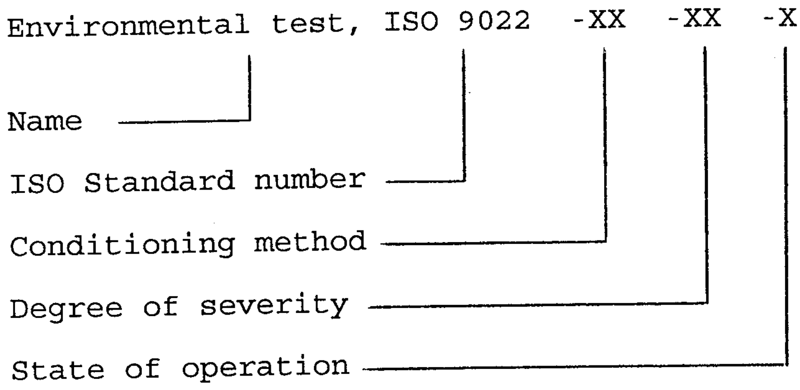

Figure 1 Example of an Environmental Test Code

Degrees of severity for conditioning method 86 : Basic cosmetic substances and artificial hand sweat

Degree of severity	01	02	03
Test agents	Paraffin oil, high purity Glycerine, high purity Vaseline, white*) Lanolin (unguentum molle)*) Cold cream (unguentum leniens)*) Artificial hand sweat**)		
Exposure time d	1	7	30
State of operation	1 or 2		

*) Felt pat drenched in melted test agent.

**) Composition :

4,0 g sodium chloride (NaCl)
1,0 g urea [$CO(NH_2)_2$]
3,5 g ammonium chloride (NH_4Cl)
3,0 ml lactic acid [$CH_3CH(OH)COOH$]
0,5 ml acetic acid (CH_3COOH)
0,5 ml pyruvic acid ($CH_3COCOOH$)
1,0 ml butyric acid (C_3H_7COOH)
} high purity

add sufficient distilled water to make 1 000 ml of solution.

Table 4 Conditioning Method 86 from Part 12

for use in a particular climatic region. It is this standard that tells the manufacturer of, say, binoculars that they will be expected to survive the application of 6 conditioning methods without a loss in imaging performance if they are to be sold as Grade "A" binoculars. It may not make any difference in a domestic market how well the binoculars perform, but there is a high likelihood that products that do not meet certain minimum standards will not meet import criteria in the EC and other countries. While these exact requirements have not been finalized in this case, the day is close at hand.

ISO 10109 is an 11 Part standard that specifies the types of testing needed to establish the suitability of an optical instrument for its intended conditions of use. The first Part deals with definitions while the remaining 10 Parts are instrument type specific sets of environmental requirements. The subject of these Parts is shown in Table 5.

ISO 10109 Part 1:	General information, definitions, climatic zones and their parameters
ISO 10109 Part 2:	Test requirements for ophthalmic optics
ISO 10109 Part 3:	Test requirements for photographic instruments
ISO 10109 Part 4:	Test requirements for telescopes
ISO 10109 Part 5:	Test requirements for microscopes
ISO 10109 Part 6:	Test requirements for medical optical devices
ISO 10109 Part 7:	Test requirements for optical measuring instr.
ISO 10109 Part 8:	Test requirements for extreme conditions of use
ISO 10109 Part 9:	Test requirements for geodetic instruments
ISO 10109 Part 10:	Test requirements for photogrammetric instr.
ISO 10109 Part 11:	Test requirements for electro-optical systems

Table 5 Parts of ISO 10109

Part 1 starts by defining 5 Climatic zones listed in Table 6. Zone 5 is a normal, protected environment in which most analytical instruments would be expected to operate. On the other hand, many types of optical instruments must survive rather severe climates and virtually all instruments must be unaffected by air shipment, much of the reason for Zone 4, High altitudes. The severe climates can be thought of as Arctic (Zone 1), Maritime (Zone 3) and all other outdoor regions (Zone 2). Table 7 shows the definition of Zone 2 - Global locations, in terms of ranges of 6 climatic parameters and certain modifiers.

Next a Suitability index is defined as shown in Table 8. This Table gives 5 degrees or indices of suitability and explanations as a function of State of operation. The standard then goes on to define 3 instrument types; field instruments, instruments used in weather protected locations and these same instruments with the additional proviso that they must sterilizable. Also defined are 10 groups of instruments along with subclasses as shown in Table 9. These begin with ophthalmic optics and cover the field to electro-optical systems.

Definitions - Climatic zones
Zone 1 - Not weather protected, cold & extremely cold
Zone 2 - Not weather protested, global locations
Zone 3 - Not weather protested, maritime locations
Zone 4 - High altitudes to 30,000 m
Zone 5 - Weather protested, laboratory environment

Table 6 Definitions of Climatic Zones

Environmental influence	Value	Comments
Temperature	-33 to 55 °C	In extreme geographical conditions temperatures of as low as -45 °C and over 60 °C may be experienced in the location of use. With temporary or permanent storage in enclosed vehicles, sheds, hangars or attics temperatures of over 55 °C may occur in strong sunshine, and over 85 °C in extreme conditions.
Relative humidity	up to 100 %	At a relative humidity of ≥ 95 % the highest temperature occurring is 33 °C, and 37° in extreme conditions.
Air pressure	700 to 1060 mbar	500 to 1100 mbar in unfavourable conditions.
Solar radiation	up to 1,1 kW/m^2	Intensity of global radiation on the earth's surface.
Amount of precipitation (rain, snow or hail)	≤ 15 mm/min	
Dew or ice build-up	yes	

Table 7 Climatic Zone 2 - Global Locations

State of operation / Index	0 and 1	2
A	suitable	specifications met in full
B	generally suitable	Instrument fully operable; in extreme climatic conditions, the specifications may not be met in full (e.g. at temperatures below -25 °C)
C	suitable to a limited extent	Reduced function; specifications not fully met.
D	generally unsuitable	Pronounced reduction in function; specifications not met.
E	unsuitable; damage is possible.	Instrument may become inoperable. Damage is also possible

Table 8 Definition of a Suitability Index

Definitions - Groups of instruments

Group 1 : Ophthalmic optics - 3 types
Group 2 ; Photographic insts - 3 types
Group 3 : Telescopes - 4 types
Group 4 : Microscopes - 5 types
Group 5 : Medical devices - 3 type
Group 6 : Metrology insts - 4 types
Group 7 : Military insts - 3 types
Group 8 : Geodetic insts - 3 types
Group 9 : Photogrammetric insts - 3 types
Group 10: Electrooptical systems - 3 types

Table 9 Definition of Instrument Groups

In the various instrument specific Parts, the standard outlines the requirements for particular optical systems. In Table 10 we have shown a portion of the proposed requirements for photographic systems. These requirements can be written down in a condensed fashion as shown in Table 11, a part of the requirements for medical instruments that incorporate optical elements. It does not make sense at this point to go into all the details of these requirements as they have not been finalized, but this does give a picture of what type of specifications will be placed on the function of optical instruments when exposed to various environmental conditions.

Serial no.	ISO 9022 Part	ISO 9022 Conditioning method	Instrument type		Camera systems			Instruments in weather protected locations			Waterproof camera systems		
			Type no.		01			02			03		
			State of operation acc. to ISO 9022 Part 1		0	1	2	0	1	2	0	1	2
16	14	76 Hoarfrost followed by the process of thawing	Technical requirement		Thawing								
			Degree of severity acc. to ISO 9022 Part 14		-	01	-	-	-	-	-	01 1)	-
			Suitability		The instrument is only suitable for the technical requirement if it is operative without restriction after conditioning.								
			Comment		1) The test is not required for underwater camera systems.								
17	16	57 Combined bounce, dry heat	Technical requirements	During mechanical stresses, temperature °C	60	-	-	60	-	-	60	-	-
			Degree of severity acc. to ISO 9022 Part 16		01	-	-	01	-	-	01	-	-
			Suitability index for standard climate	1	A	-	-	A	-	-	A	-	-
				2	A	-	-	A	-	-	A	-	-
				3	A	-	-	A	-	-	A	-	-
				4	A	-	-	A	-	-	A	-	-
				5	A	-	-	A	-	-	A	-	-
				6	A	-	-	A	-	-	A	-	-
			Comment										
18	16	58 Combined bounce, cold	Technical requirements	During mechanical stresses, temperature °C	-30	-	-	-30	-	-	-30	-	-
			Degree of severity acc. to ISO 9022 Part 16		01	-	-	01	-	-	01	-	-
			Suitability index for standard climate	1	E	-	-	E	-	-	E	-	-
				2	B	-	-	B	-	-	B	-	-
				3	A	-	-	A	-	-	A	-	-
				4	E	-	-	E	-	-	E	-	-
				5	A	-	-	A	-	-	A	-	-
				6	A	-	-	A	-	-	A	-	-
			Comment										

Table 10 Portion of the Requirements for Photographic Systems

Conclusions

We conclude by saying that the writing of international environmental standards is moving toward finalization. It would make sense at this point to become involved with the writing of the final versions of the actual requirements so that manufacturers are aware of what types of tests their instruments will be expected to pass before selling them in an international market.

Those manufacturers who are already following MIL-STD-810E and/or the NASA equivalent will be much better prepared for ISO 9022 and ISO 10109 than those companies that have not had to worry about formal environmental standards to date. However, even those using the MIL-STD will have to "translate" it into ISO 10109 terms so that the requirements can be interpreted on an "apples versus apples" basis. Once this is done, it will be relatively easy for these companies to do business in ISO terms rather than the MIL-STD-810E terms.

Environmental requirement ISO 10109-05-1-T	Environmental requirement ISO 10109-05-02-T	Part of ISO 9022
Environmental test ISO 9022 –		
10-08-0 10-07-1 11-06-0 11-04-1 11-01-2 11-03-2 12-01-2 14-05-1 16-02-1	10-08-0 10-02-1 11-05-0 11-03-1 11-01-2 11-02-2 12-01-2 16-01-0	2
30-03-0 30-04-1 30-05-2 31-01-0 36-04-0	30-03-0 30-01-1 30-05-2 31-01-0 36-01-0	3
66-14-0	66-14-0	13
85-02-1	85-02-1	11
86-02-1 87-02-1	86-02-1 87-02-1	12

Table 11 Example of the Condensed Form of Instrument Requirements

Finally, it makes good marketing sense to be able to say, whether there is a legal requirement or not, "My product meets or exceeds the requirements of ISO 10109", or whatever the appropriate standard. Of course the product must really meet the standard, but if it does, it is like having an official blessing on the product. Particularly in optics where only an expert with access to fairly sophisticated laboratory test instruments can really determine the optical quality of many instruments, being able to say yours meets certain standards has got to give customers a warm feeling.