Easy-to-read "Features of environmental testing" (Part 1)

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This report is the first of a two-part series that, as the title indicates, is meant to cover the main features of environmental testing without getting bogged down in overly difficult aspects of the subject. Although intended to be easily read, we must be wary of simplifying the subject to the point of making it meaningless. Perhaps we could say that the level of this overview is "easy to read, with some difficulties", and presented as a column. The discussion may seem at times to jump from topic to topic.

1. Introduction

Environmental testing is one type of reliability testing that has been developed as a method of predicting how the ambient usage environment will affect product functions and performance. In other words, environmental testing is used before the product is marketed to check the degree that the environment will affect the product. When product functions are affected, environmental testing is used to pinpoint the cause and to maintain proper reliability by creating measures to protect the product from such environmental effects. These tests have evolved well beyond their original aims, now being used to cover a wide variety of purposes, including research and development of materials and products, various checks in production processes, pre-shipping inspections, and post-shipping quality control. The tests may also be used for analyzing defects occurring in the field, as well as for a wide variety of applications focusing on the improvement of pre-existing products. The tests are very effective for improving methods of checking and maintaining reliability.

At first glance, it may seem logical to say, "Well, the test equipment happens to be free right now, so we'll just slip some products in for testing," but a wise engineer will never take this approach. Modern environmental testing must be done with logical measures in specific sequences capable of satisfying an independent observer. Proper testing does not consist of vaguely applying the label of "environmental testing", but first requires clearly determining the purpose of the test from the outset. Next, the tester must be able to predict the results and estimate the required costs, and finally must draw up a complete test plan (written) of test requirements. Ideally, the tester will also be able to coordinate all of this.

To accomplish all of the above, the tester must be familiar with everything from product materials to production process details, and must consider both the product and the environmental features that the product will be exposed to in the field. The tester must predict what defects will occur under what circumstances, and create a test profile that can reproduce the failure mechanism. These preparations result in the ability to grasp when tests can be handled simply and effortlessly, when large-scale testing projects are required, when relatively simple equipment can be used, and when high-level equipment is necessary for testing and measuring. Sometimes merely drawing up the plans and making the clarification studies obviate the need for testing. While not limited to environmental testing, the approach consists of first drawing up the plans, then making thorough studies, then constructing hypotheses, and finally carrying out the tests. Rushing into the test is simply not called for. The test should be seen as a means of verifying hypotheses.

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2. Test preparations

Since the subject of the test is a manufactured product, the first step in making preparations must be to thoroughly clarify every aspect of the product in advance. While you may feel that you have a wealth of information related to the test product when approaching the test, this information is always from the standpoint of what you have already been able to find out. The main players in this drama are you and the product being tested. All tests begin from this point.

Now, let's look at some points that will serve as references in the process starting from creating a test plan and going up to the point of actually carrying out the test.

2-1 Preparations

2-1-1 Gathering all information possible related to the product

The basic approach consists of obtaining in advance all technical data related to items such as the structure, functions, and capabilities of the product to be tested. Specifically, we need to obtain all information related to the materials used in the product, regardless of whether the product that we are looking at is electrical, electronic, mechanical, or a hybrid that combines any of these types. We must then investigate the specific physical properties of those materials. For example, these days, resins, which are chemical products, are being applied to a wide variety of mechanical products as well as electrical and electronic products too numerous to name. We must first collect information on such aspects in advance (including past in-house test reports). We must then investigate these aspects down to the atomic level, and that goes for conventional metal materials as well, and we must reconfirm their physical properties. (When materials are purchased from a new supplier, the composition may vary slightly due to differences in manufacturing processes even when the standards seem to be the same.)

2-1-2 Creating a "Life-Cycle Environmental Profile" of the product

At this point, we shall draw up a life-cycle profile that predicts all events the product will encounter from its manufacture to its use in the field until it is discarded. This profile will associate every aspect of these predicted events with the ambient environment that the product is expected to encounter. In other words, we must hypothesize the various environments to which the product will be exposed at every stage of its life. At the manufacturing stage in particular, we must get a firm grasp of conditions, including the environment for storage of materials and products as well as their handling and transfer. We must then investigate all possible details of each environment that the product will encounter at every stage after the product's completion, and draw up a hypothetical profile (outline) of these environments. This profile should include packing methods and materials, shipping conditions and environments, pre-use storage, methods of handling from one operation until the next, local environments within the installation area as well as the overall geographical environments to which it will be exposed, and the environment of the main unit into which the product is placed. When creating this profile, obtaining the following information will increase the accuracy of environmental tests.

(1) Conditions of the installation location and connections between the product and the main unit into which the product is placed
(2) Conditions of the boundaries between the product and neighboring products
(3) Details of the environment the product encounters and the absolute time period and the relative time period that these aspects are encountered
(4) Probability that the intended environment will occur

Although some areas will overlap with previously mentioned items, the following items should also be grasped.

1) Carry out detailed examinations of the main structural parts and materials starting from the final acceptance inspection and continuing through storage period and conditions and every condition encountered in the manufacturing and assembly processes.
2) The environmental and stress conditions predicted to occur during the product life need to be put in time series, quantified numerically, and estimated statistically (if possible, displayed as a standard deviation).
3) When product defects appear, they are often generated by events occurring outside the technological domain of the product itself, such as in handling during shipping. These items should be thoroughly investigated and grasped, and it is important that the items of investigation be unified.

2-1-3 Understanding the limits of environmental testing

Environmental testing done in the test chamber cannot possibly reproduce the exact conditions of the field environment and employ all of the environment factors encountered in the field. Therefore, when creating the test conditions, the tester must select the appropriate environmental factors thought to have the greatest affect on the product. As a result, the test environment can only be an artificial environment far removed from equivalency to the actual environment.

In general, product defects are caused by (1) the concentrations and variations of materials, friction, wear, stress, heat, current, and electric field strength as these factors affect specific areas of the product, (2) factors due to product characteristics (materials, processing methods, and structural parts and materials and their manufacture) that are built into the product in design and production processes, and (3) stress from the peripheral environment of use. Therefore, test conditions must be set according to a specific product group test profile that is unique to that product group. When the product group being investigated is changed, naturally the test profile must also be revised.

2-2 Test sequence

The test sequence is crucial in environmental testing. Even in a single series of tests, changing the sequence can change the results. As noted above, we absolutely must not simply decide to change the test sequence for such reasons as "the test equipment was not being used".

For testing in general, validity is assumed to be provided by following the same order of environments that the usage profile predicts will be actually encountered by the product at each stage, but this approach requires a large investment of time. In such cases, it seems more logical to follow the sequences considered to have the greatest affect on the product. This approach uses the technique of intentionally producing defects in the product within specific targeted boundaries. The following test methods can be useful for such cases.

(1) An attempt is made to deliberately create a "trigger" in the initial test to produce the subsequent defect phenomenon. Then, the defects are promoted and expanded in the following tests.
(2) When the number of test samples is extremely small, tests with the least amount of stress are run first to obtain a large amount of relevant data before the test items receive lethal damage.
(3) To determine whether the product can withstand the most severe environment from the outset, priority is given to the most severe environment related to the actual environment.

For example, method (3) is appropriate when the samples are parts, the number of test samples is large, and the samples can be grouped according to test items. When there are a limited number of samples, method (2) is often used. Method (1) is used for a series of tests involving both parts and devices.

However, in that case, there are some points for which special care must be taken. Depending on the test sequence, items that show signs of defects in a previous test may appear to be restored in subsequent tests, and so one must be careful especially when making a series of tests with the same samples. Furthermore, items showing functionally normal values may actually have physical defects revealed upon closer observation, and so multifaceted analysis and confirmation must be carried out. This means that the number of samples must be as large as possible, and samples thought to be free of defects must first be analyzed (non-defective item analysis), then after each subsequent test sequence, a small number of samples must be analyzed and taken apart, and finally a detailed analysis must be made of data and observations. Test planning and test item preparation with this type of margin is especially encouraged in environmental testing.

To supplement the above explanation, let's look at some specific hints using text examples involving parts.

For parts testing, the initial approach basically involves a series of tests using thermal shock. With parts, the functional part being tested is often sealed inside a mold or a case. When the sealing material for the functional part turns out to be unable to completely withstand the thermal stress (low or high temperature conditions), continuing testing beyond that point becomes meaningless.

(1) Further emphasizing defects

When specific purpose tests produce defects due to thermal shock, mechanical tests such as shock and vibration tests are then carried out to further emphasize these defects. These tests produce further expansion of cracking and sealing defects. Quite often the expansion of these defects leads to the appearance of some sort of internal functional variance caused by subsequent temperature and humidity testing, making it easier to detect incomplete functioning.

(2) Temperature and humidity cycle tests

During temperature and humidity cycle tests in particular, moisture often enters through the defective part, and it becomes possible to further emphasize defects using follow-up low-temperature endurance tests and depressurization tests. In other words, continuous temperature and humidity cycle tests cause a large amount of moisture to invade the defective part due to the breathing effect, enabling the tester to detect changes in functional characteristics.

(3) Constant humidity tests

Constant humidity tests are appropriate for investigating conditions of products left in moist air for long periods of time. These tests require a suitably long period of time, and so it is logical to leave these until after all other environmental test have been completed.

(4) Other tests

As a rule, tests for special items (e.g., solder characteristics tests, terminal strength tests, fire resistance tests, corrosion tests, falling and toppling tests, and sun exposure tests) are not a part of the test sequence, and instead are generally tested separately using separate test items.

Fig. 1 shows a general environmental test sequence for testing parts. This sequence is not presented as a standard recommended sequence, but should rather be understood as a sequence that can be varied depending on the purpose, such as moving individual items up or back or eliminating individual items. Variations become even more likely when testing devices rather than parts.

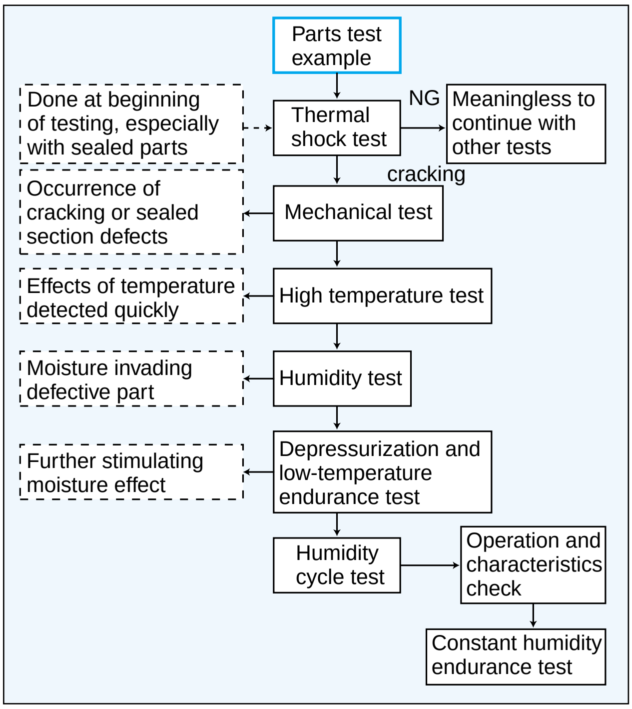


Fig. 1 General environmental test sequence for parts

2-3 Defining specific defects

Reliability (i.e., defects) must be defined for events encountered during the product life cycle. In other words, we must clarify what produces the determination that an item has a defect (or failure) , and what are the "standard points" that serve as milestones of functional degradation.

Furthermore, we must assume that unpredicted situations will occur during the test (e.g., power outage, water shut-off, and test equipment failure), and we must determine in advance what our response will be to such emergencies (e.g., judgement standard of whether to continue or terminate the test). We must draft in advance a PERT (Program Evaluation & Review Technique) for test processes and not be left wondering what to do should such situations arise.

3. Effective method of creating field environments

Within environmental testing, some tests such as the paint coating exposure test, are carried out completely in a natural environment. However, at present most tests are carried out based on completely artificially-created environments using environmental test equipment completely removed from the natural environment, in a space that has been partially or completely sealed off. Therefore, making a mistake in selecting or combining environmental factors introduces the danger of creating an environment that greatly differs from the original purpose. At this point, let's look more closely at how to create an appropriate artificial environment.

3-1 Constructing an artificial environment and reviewing factors

Let’s say we are testing electrical and electronic products. The environmental tests will be as shown in Fig. 2. In this example, test items are grouped as systems or parts, and a group in charge of each is set up, with another group established for the mechanical tests common to both systems and parts, and the test items are performed for the respective groups. This figure was downloaded from the NASA homepage, and processed and posted, and as you might expect it seems well-organized.

Naturally, these test constructions can also be considered appropriate for application to mechanical systems products as well. In fact, sometimes the same test name is used. However, one must be careful with these names, because the same name might be used in a specific field with quite different test contents, depending upon the industry to which the product belongs. (One example, while not of a test name, is the problem of the extent of corrosion [e.g., rust] in the field of electrical and electronic parts. In the field of shipbuilding, for some reason this is not referred to as corrosion.)

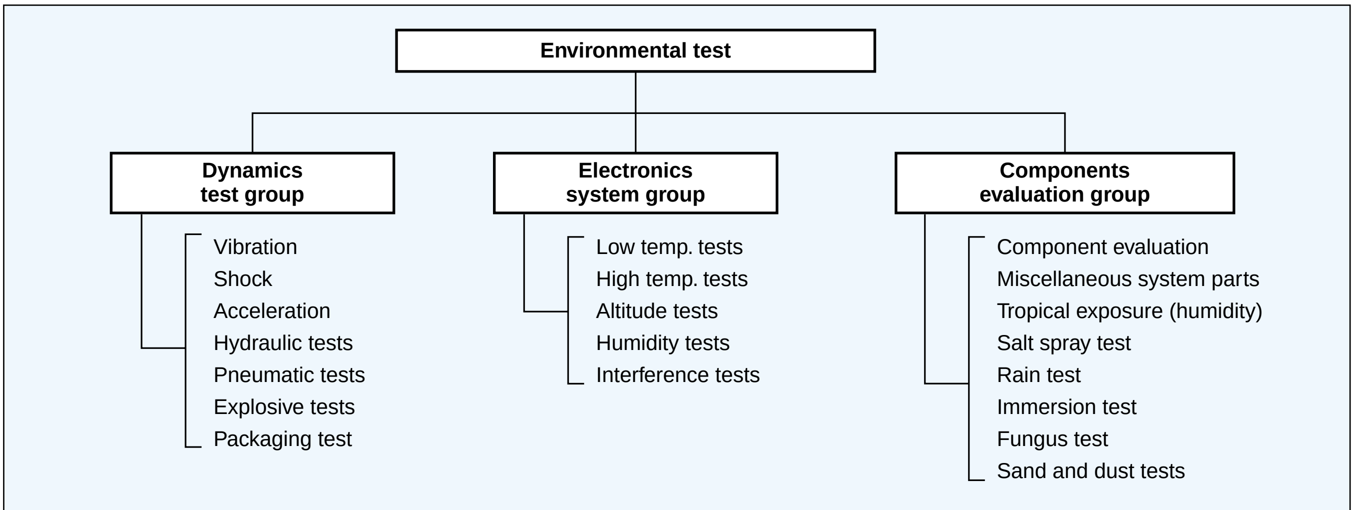
In any case, the test contents must be determined on their own. Because of this, the details of these individual test conditions are created by combining test factors as in Table 1. Then, the tester must decide whether to expose the specimens (for reference: in the field of environmental testing, items subject to testing are generally called specimens) to various levels of environmental conditions for specific periods of time, or whether to operate the products that are specimens at that time, or whether to simply let them set.

In general, environmental tests composed of only a single factor (e.g., temperature, moisture, pressure, vibration, shock, or a special substance such as salt) are called simple environmental tests, but it is actually very difficult to create this type of completely simple environment, and it isn’t very realistic. On the other hand, single factors can be combined to create complex environments that are simultaneously reproducible. Most actual test environments consist of such complex environments, and the test name reflects the factor being emphasized within the compound test conditions. For example, even when moisture is introduced, if the test involves high temperature and the moisture is not considered to have much effect on the products being tested, the test is called a temperature test, or a high-temperature test. Furthermore, humidity tests do not merely have environments with moisture, but have rather complex environments involving functions of temperature and moisture quantity.

Table 1 Typical appropriate environmental factors

Natural factors	Induced factors
Planetary IR	Acceleration
Clouds	Chemicals
Electromagnetic Radiation	Corona
Electrostatic Discharge	Electromagnetic, Laser
Fog	Electromagnetic Radiation
Freezing Rain	Electrostatic Discharge
Frost	Explosion
Fungus	Icing
Gravity, Low, Hail	Magnetics
Humidity, High	Moisture
Humidity, Low	Nuclear Radiation
Ice	Shock, Pyro, Thermal
Ionized Gases	Space Debris
Lighting	Temperature, High, Aero.Heating, Fire
Magnetics, Geo	
Meteoroids	Temperature, Low, Aero.Cooling
Pollution, Air	Turbulence
Pressure, High	Vapor Trails
Pressure, Low, Vacuum	Vibration, Mechanical, Microphonics
Radiation, Cosmic, Solar	
Rain	Vibration, Acoustic
Salt Spray	
Sand and Dust	
Sleet	
Snow	
Temperature, High	
Temperature, Low	
Wind	

Source: NASA Preferred Reliability Practices No.PD-EC-1101



Source: NASA Preferred Reliability Practices No.PD-EC-1101

Fig. 2 Groups in charge and individual test items for environmental testing

3-2 Points for consideration when composing test environments

The complex environments that result from combining a large number of environmental factors (refer to Table 1) have a higher probability of complex effects on product reliability than environments with fewer factors. However, we must be careful when introducing mechanical factors, because it is quite possible to end up with a combination that is neither logical nor realistic. Therefore, when composing the test environment, we must fully analyze and study the individual factors and the results of their combinations from a realistic and scientific viewpoint, and we must make very sure that the environmental conditions concur with the test purposes. Fig. 3 shows an example of a matrix check diagram that serves as a tool for studying the validity of compound environments when constructing an environment with representative factors. Table 2 presents effects of combining environmental factors of various types. These tables and figures can be used to roughly determine the validity of the effect.

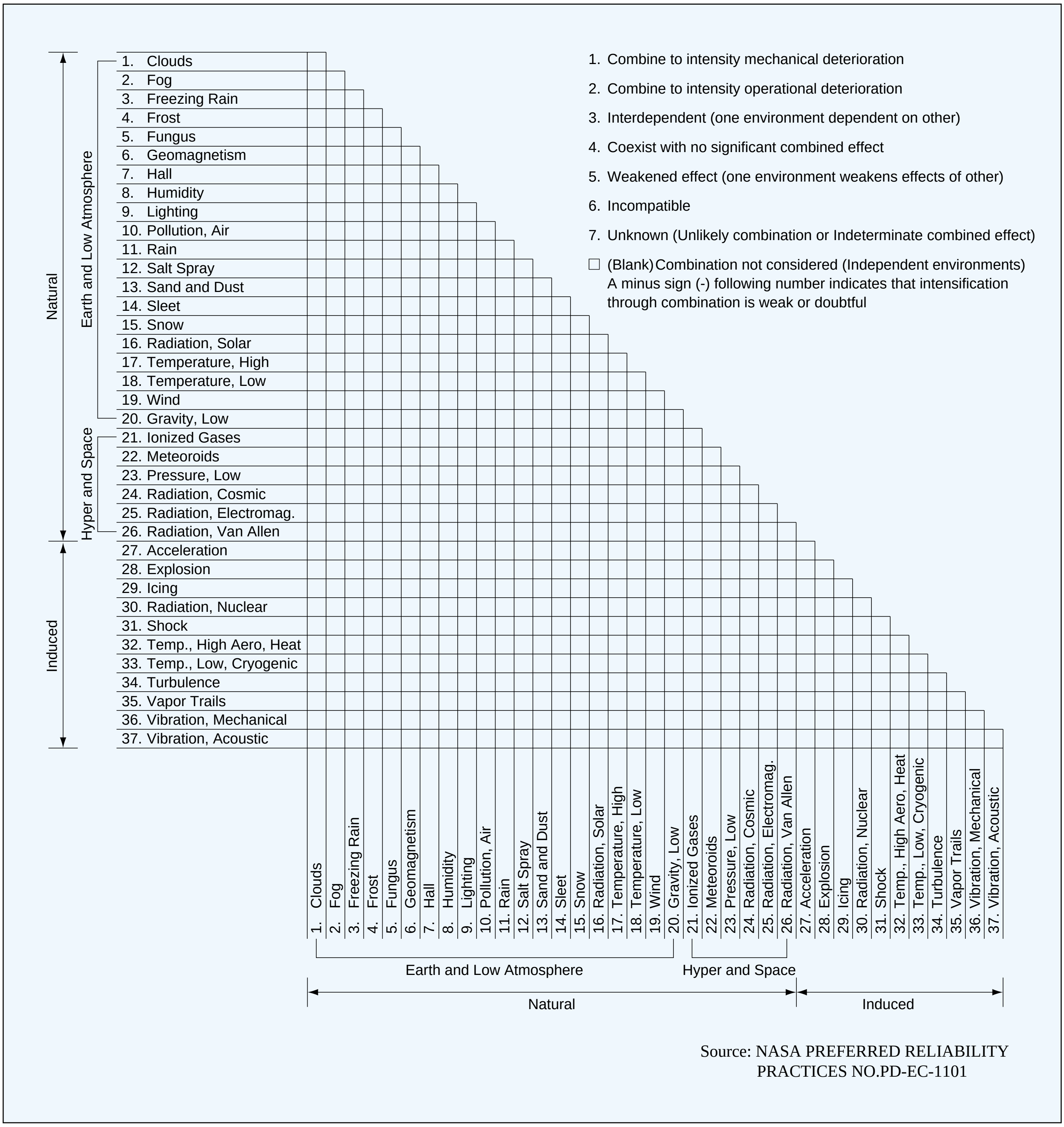


Fig. 3 Example of a matrix graph to study the creation of combined environments

Table 2 Combining various environmental factors

Classification	Combined environmental factors	Effects of combining
High temperature	High temperature + humidity	High temperature tends to foster invasion by humidity. Normally, the humidity degradation effect is promoted by high temperature.
	High temperature + low pressure	The various factors of these environments display a synergistic effect. For example, a drop in pressure promotes the discharge of gas from the materials. Also, a rise in temperature fosters the discharge of gas.
	High temperature + saltwater mist	High temperature tends to foster corrosion due to the saltwater mist.
	High temperature + exposure to sunlight	When organic substances are mixed in, the effect is heightened.
	High temperature + bacteria	The growth of bacteria and minute organisms exists at favorable temperatures. Bacteria and minute organisms cannot multiply above 71°C.
	High temperature + dust	The level of corrosion promoted by dust is accelerated by high temperature. On the other hand, high temperature reduces invasion by dust.
	High temperature + (shock or vibration)	Environments in which both of these coexist affect the properties of most materials. They cause synergistic effects, and the level of effects changes depending of the strength of each factor. Except in the range that they don't coexist with extremely high temperatures, plastics and polymers are more sensitive to this environment than metals.
	High temperature + acceleration	This combination produces the same effects as high temperature + (shock or vibration).
	High temperature + explosive atmosphere	As merely a trigger for explosion, the temperature has a minimal effect. However, it does affect the air-gas component ratio. This problem merits serious consideration.
	High temperature + ozone	At above approximately 150°C, ozone reduction begins. At above approximately 270°C, ozone cannot exist at normally encountered pressure.
Low temperature	Low temperature + humidity	Humidity rises concurrent to the temperature drop. Low temperature induces water vapor to condense. If the temperature drops sufficiently, frost and ice form.
	Low temperature + exposure to sunlight	Low temperature tends to attenuate effects of exposure to sunlight.
	Low temperature + low pressure	This combination accelerates leakage of seals.
	Low temperature + saltwater mist	Low temperature reduces the degree of corrosion caused by saltwater mist.
	Low temperature + dust	Low temperature fosters the invasion of dust.
	Low temperature + bacteria	Low temperature slows the rate at which bacteria multiply. At sub-zero temperatures, bacteria hibernate.
	Low temperature + (shock or vibration)	Low temperature tends to aggravate the effects of (shock or vibration). However, this only becomes a problem at extremely low temperatures.
	Low temperature + acceleration	This combination produces the same results as the effects of low temperature and (shock or vibration).
	Low temperature + explosive atmosphere	As merely a trigger for explosion, the temperature has a minimal effect. However, it does affect the air-gas component ratio. This problem merits serious consideration.
	Low temperature + ozone	Low temperature attenuates the effects of ozone. However the ozone concentration increases as the temperature drops.
	Low temperature + saltwater mist	This combination is not expected to produce additional effects.
Humidity	Humidity + low pressure	Humidity promotes the effects of low temperature. In particular, this effect is striking with electrical and electronic appliances.
	Humidity + saltwater mist	High humidity reduces the salt concentration, and as a result widens the effective range of the salt, expanding the corrosion reaction. This causes an increase in conductivity.
	Humidity + bacteria	Humidity aids the growth of bacteria and minute organisms, but has no other effect.
	Humidity + dust	Dust has a natural affinity for water. This combination promotes degradation.
	Humidity + exposure to sunlight	Humidity strengthens the degradation effect due to exposure of organic substances to sunlight.
	Humidity + vibration	This combination increases the chances for destruction of electrical and electronic materials.
	Humidity + (shock or acceleration)	In general, the length of time of shock and vibration is too short to promote the effects of humidity.
	Humidity + explosive atmosphere	Humidity is not an effective trigger for explosion. However, high humidity reduces the pressure of an explosion.
High humidity	High humidity + ozone	In the presence of water vapor, ozone creates hydrogen peroxide. The effects of this combination are more severe than the sum of the individual effects on the degradation of plastics and elastomers.

(Cont.)

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Low pressure	Low pressure + saltwater mist	This combination does not occur.
	Low pressure + exposure to sunlight	This combination is not expected to produce additional effects.
	Low pressure + dust	This combination only occurs when small dust particles are carried at a high altitude by a pungent storm.
	Low pressure + vibration	This combination affects all kinds of equipment, including most electrical and electronic devices.
	Low pressure + (shock or acceleration)	These combinations are only important in environments linked to high temperature.
	Low pressure + explosive atmosphere	At low pressure, electrical discharge is more likely to occur. However, it cannot easily serve as a trigger for explosions.
Saltwater mist	Saltwater mist + bacteria	This combination is unlikely to occur.
	Saltwater mist + dust	This combination produces the same effects as the combination of humidity and dust.
	Saltwater mist + vibration	This combination produces the same combined effects as humidity + vibration.
	Saltwater mist + (shock or acceleration)	These combinations are not expected to produce additional effects.
	Saltwater mist + explosive atmosphere	This combination is thought to be incompatible.
	Saltwater mist + ozone	This combination is similar to humidity + ozone, but is even more corrosive.
Exposure to sunlight	Exposure to sunlight + acceleration	The result of exposure to sunlight, this combination probably produces the same effects as the combined effects of high temperature and bacteria. Furthermore, direct exposure to ultraviolet rays acts as a bactericide.
	Exposure to sunlight + dust	This combination probably produces high temperature.
	Exposure to sunlight + ozone	This combination fosters oxidation of materials.
	Exposure to sunlight + (shock or acceleration)	These combinations are not expected to produce additional effects.
	Exposure to sunlight + vibration	Under conditions of vibration, exposure to sunlight has a high ratio of causing degradation of materials such as plastics, elastomers, and oils.
	Exposure to sunlight + explosive atmosphere	This combination is not expected to produce additional effects.
Bacteria	Bacteria + ozone	Ozone destroys bacteria.
Vibration	Vibration + acceleration	The effects of this combination are promoted with the coexistence of high temperature and low pressure.
Dust	Dust + vibration	Vibration can promote the wear effects of dust.
Shock	Shock + vibration	This combination is not expected to produce additional effects.

While this is related to drafting to the life cycle profile of the product, the environment and its variations must be thoroughly examined from the assembly process of the parts used, through the preliminary operation of the completed product, to the environment after the product is in the field and through every stage of use while the product lasts.

1) The stress on the product in the various processes such as parts assembly, inspection, testing, transportation (or transfer) has a marked impact on the reliability of the completed product. Because of this, the tester needs to thoroughly confirm every type of experience the main structural parts and materials encounter in the parts manufacturing and parts assembly processes from the final acceptance inspection through the assembly process, and including storage time and control conditions.
2) Many items are often overlooked, especially the stress pertaining to test operation of the completed parts and the load during inspection periods. In these processes, it is possible that from the intention to confirm the functional limits of the product that the product can be forced to an unnecessarily severe level of operations that in reality it would rarely ever meet.
3) In addition, the actual product could be exposed to environments more complex than it would actually encounter during transportation or during normal operation (e.g., combined environments such as non-stable temperature, humidity, stress fluctuations, and shock and vibration). In particular, the probability of occurrence, the sequence, time, and severity of stress in the environment require thorough study before making a careful composition of the test profile. To give a realistic problem as an example, if there is no margin of error in the delivery period, a short-term transportation company may be used that handles the product roughly during transportation, but if there is enough margin of error in the delivery period, the manufacturer will actually select a company that handles the product carefully even though it takes more time.

We can see that the environments and stress predicted to occur during the product life need to be put in time series, quantified numerically, and estimated statistically (if possible, displayed as a standard deviation). The estimation data at this stage can be verified later at the various stages when the actual values are confirmed, and the results of that analysis will become valuable technical material for product design in the future. In particular, shipping and handling cannot be simply disposed of as not being directly related to product design. These areas must be thoroughly investigated and grasped and are essential to test planning and composition.

3-3 Test environment construction

The treatise on constructing test methods "For busy people in a hurry" presents various "Meals with fixed menu" style environmental test methods set up according to public test standards. Typical standards include IEC standards (60068 Series) and the JIS standards (C0010 Series) that are basically a Japanese translation of the IEC standards. Industrial standards include the EIA (Electronic Industries Alliance) standards and the EIAJ (Electronic Industries Association of Japan) standards. These test methods clearly establish test conditions, and so if the test objectives of your product coincide with these, you can use them just as they are. However, these standard tests cannot be expected to produce long-term warranty data for actual usage conditions in the field environment.

On the other hand, if the individual test conditions of the product are clearly established in the individual specifications of the product, you can then substitute those individual test conditions for the test conditions (severity) in the standards. (The IEC standards permit prioritizing the individual test conditions, and when it is possible to clearly establish the necessary test items, the IEC standards number may be used as is. However, such use is based on the condition that the details of the substitution be clearly displayed in the test report.)

On the other hand, when there is a strong need of creating individual test conditions, you can select an appropriate standard test method from among the above-named standards. At present, making such revisions and combinations is more logical on every account than creating a test entirely from scratch.

3-4 Supplements to test environment construction

At this point, we will supplement material about three tests to item 3-3.

3-4-1 Climate tests

As previously noted, it is basically impossible to recreate the various phenomena of the real natural world within a limited space, that is to say within the confines of the test chamber and the test equipment. To overcome these limitations and develop a realistic approach, environmental factors such as temperature and humidity are combined to create the individual test environments. The 60721 Series of the IEC standards present standards classifying environmental factors by individual product category. This is an invaluable aid in creating appropriate complex environmental conditions corresponding to product applications.

It is extremely difficult to recreate the variety of factors within various environments, and sometimes the recreation is unrealistic because of the complexity. As noted above, a large variety of test construction data appears elsewhere, and so the tester must carefully study and grasp in advance the degree that each factor affects the product when creating test conditions.

3-4-2 Sunlight exposure test

The IEC60068 Series does not deal with specific environmental test methods for general sunlight exposure. In most cases, a simulated sunlight spectrum is used in tests for sunlight exposure. However, as an actual problem, within the various restrictions (e.g., tests costs, equipment, required personnel, and preparation time) it is extremely difficult to simulate sunlight inside a common test chamber or inside test equipment. Because of this difficulty, one simple method requires creating a small-scale spectrum test separated into the three separate regions of infrared, visible light, and ultraviolet light. Then, the products are sorted according to their sensitivity to these individual conditions, and the appropriate test is carried out according to the purpose.

The following is presented as a reference for the three major phenomena caused by exposure to sunlight.

1) **Chemical action and sunlight degradation**

In most cases these effects are produced in the ultraviolet range of the spectrum. However, the same sort of effects are known to occur in the visible range, and so we must be careful. Typical of these effects is the fading of product surfaces and fogging of semi-transparent plastic. Usually tests to evaluate these effects can be performed on materials and parts, but it is also possible to perform the tests on completed products. For example, discoloration of color paint results from increased heat absorption that raises the temperature of the product itself.

2) **Heat effect**

To determine the induction capacity and failure mechanisms related to temperature, the following method can be used to evaluate individual products.

- Temperature rise

  The sunlight load produces a markedly higher temperature at the surface of the product and in the nearby air temperature than in the ambient temperature. There are two methods of simulating this temperature rise. The first, for example, involves using the 15°C rule (the predetermined temperature rise value calculated through experience).

  The second method involves using a calorescent lamp to raise the temperature at the required surface of the test product and nearby.

- Heat gradient

  The characteristics of sunlight exposure are related to the single direction from which the rays come, and so thermal effects in the natural environment are not equal overall, but are related to the direction of exposure. Therefore, exposed products suffer different thermal effects in different areas. This localized heat rise expands the common differences within the product and causes localized swelling of materials, causing defects in sealed functions and creating such problems as variations in performance of miniature parts in specific locations. To handle the problems of simulating the directional radiation heat source in a small test chamber, the tester must take measures to avoid causing an unrealistic heat rise in other sections of the product by maintaining appropriate air circulation.

3-4-3 Mechanical environment tests

In most cases, mechanical environments are more often induced or artificial environments rather than natural environments. In other words, these environments occur due to artificial transportation and equipment operation. Therefore, the tester must create and carefully analyze a life cycle profile for each element of which the product is composed. This profile should combine the phenomena resulting from exposure to the surrounding natural environment with the environment generated by the product itself, such as noise, shock, and vibration.

1) **Vibration tests**

The sine wave sweep vibration test is restricted by the measurement results and the test limits, but it is comparatively easy to control the test equipment and analyze the results. This test has historically been applied to most products. The test can be applied, for example, to a product that involves rotation while operating in a comparatively fixed position such as an airplane propeller or a rotor. At present, the test is limited to investigating sine wave resonance.

On the other hand, random vibration involves determining the gravity force according to power spectrum density and vibration time, providing a more realistic phenomenon. Nowadays, when we talk about vibration tests, we are generally referring to random vibration tests.

2) **Shock tests**

Shock tests are applied to products exposed to comparatively rare conditions encountered in non-repetitive situations encountered during product operation, transportation, and use. (All product packages are used to handle product fragility in these environments, and so there are various ways of using these tests.)

Typical effects of shock include:

a) Permanent damage caused by excessive load
b) Sudden damage or fatigue to materials
c) Failure caused by friction or variations in impedance between the products.

3-5 Specifications of environment test equipment

Test contents for individual products are determined by developers, designers, and testers. Rather than presume to understand these individual contents, at this point we will create a format of required specifications for environmental test equipment based on the standpoint of supplying test equipment corresponding to your tests, assuming you are performing general environmental tests involving temperature and humidity. From the standpoint of supplying test equipment, this format will enter somewhat into the individual tests contents of all of you who are users, but by using the format we can create a framework for test equipment that will create the required test environment conditions.

Test equipment suppliers propose specific forms of test equipment based on this framework.

Every type of test equipment that actually creates the test environments currently includes measurement systems. Therefore, compared to 20 to 30 years ago, using pre-existing equipment and procuring new equipment is amazingly easy. (However, the high cost of environmental test equipment compared to its functions still presents a problem.)

On the other hand, the simpler types of test equipment could be created using do-it-yourself methods. You should be aware, though, that recently in some cases self-manufacture actually raises the overall cost. Because of that, from the aspect of reliability of test results, sometimes the test environment cannot be precisely controlled, and concerns for safety arise during continuous operation and automatic operation, and so we must be very careful on these points. If you are still determined to go ahead with the do-it-yourself approach, the above details must be carefully studied before attempting to design and manufacture the equipment.

The most important thing is to take sufficient care at the beginning of any endeavor. The same holds true for environmental testing. This report has taken up the issue of reliability testing (ignored perhaps because its importance is taken for granted), but we have attempted to address a variety of fundamental issues. For newcomers to the field, the report probably contains many new concepts, but the discussion may have been old hat for experienced technicians. In either case, we will be happy if reviewing the background for handling the daily duties of carrying out environmental tests has been of service.

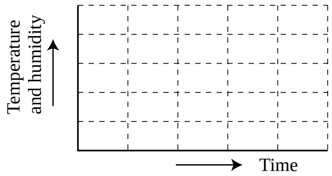
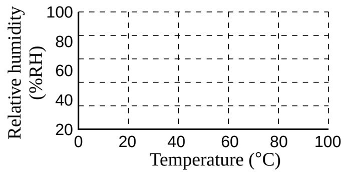
In our next issue, we shall take a closer look at some key points of environmental testing taken from the aspect of applications.

Table 3 Checklist of required specifications for environmental test equipment

Check item	Required specifications
1. Check of main contents of test	
1.1 Test purpose (Which of the following apply to the test being planned?)	☐ Testing within the range of upper limits and lower limits of the application environment established for the product (testing within rating) ☐ Testing at harsh conditions outside the range of upper limits and lower limits of the application environment established for the product (testing outside rating) * The test contents will be explained in the next issue.
1.2 Specimens (confirming the pieces to be tested) a. List of specimens by type and test contents b. Model type, dimensions, and rating c. Quantity and weight	Type ________ Contents ________ ________ Number of items ______ ______ kg
1.3 Test conditions (corresponding to main test contents) a. Standards on which test is based (e.g., public standards, in-house standards) b. Temperature and humidity range and distribution of permissible fluctuation range c. Required wind velocity (The wind velocity determines the stress on the specimens. In particular, the wind velocity is related to the humidity control method of the test equipment.) d. The load that the specimens generate on the test equipment (e.g., applied bias, whether operating, amount of heat generated) e. Test time (with cycle tests, time and number of cycles) f. Whether to cause dew condensation on the specimens or not (related to controlling temperature and humidity)	________ _____ – _____°C ± _____°C _____ – _____%RH ± _____%RH ______ – ______ m/s ________ _______ Cycles _______ min. ☐ Caused or ☐Not caused
2. Checking installation site for test equipment (putting the required infrastructure in order)	
a. Space for facilities b. Load resistance of floor c. Test site height, temperature, and humidity (when air conditioned, confirming whether air conditioning operates at night and on holidays), whether in direct sunlight d. Whether combustible gas or corrosive gas is generated (avoiding unnecessary external disturbance) e. Power capacity and voltage fluctuations (avoiding unnecessary external disturbance) f. Water supply and drainage facilities (nowadays, from the standpoint of protecting the global environment) g. Whether there is an earth contact point (avoiding external disturbances on control and measurement) h. Route and loading entrance for equipment and specimens (related to size and construction of doors for test equipment)	W _______ mm × H _______ mm × D _______ mm Within _______ _______ kg Height ______ m _______–_______°C ______ – _______%RH Direct sunlight ☐ Yes ☐No ☐ Yes ☐No AC (or DC) _______ V ☐ 50 Hz ☐ 60 Hz ☐ Yes ☐No ☐ Yes ☐No
3. The main point in drawing up specifications for test equipment that must be stored	
3.1 Power (including whether power supply to the specimens is required)	☐ AC (or DC) ______ V ± ______ % ______ A ± ______ % ☐ Single phase ☐ 3 phase (3-line type or 4-line type?) ☐ 50 Hz ☐ 60 Hz
3.2 Ambient temperature (particularly when cooling equipment is used, maximum water temperature in summer) a. Range of equipment operation b. Range of performance maintained	Air temperature _______ – _______°C Water temperature _______ – _______°C ________ – _______°C
3.3 Temperature and humidity control method	PID control (at present, this method is almost always used)

(Cont.)

(Cont. from the previous page)

3.4 Details of test standards used (related to specimens) a. Public standards b. In-house standards or standards from user c. For programmed test, contents of each cycle and number of cycles	 ______ ______  ______ Cycles
3.5 Performance a. Confirming required performance b. Temperature and humidity range c. Humidity fluctuation range d. Temperature and humidity distribution e. Temperature heat-up range and pull-down range f. Setting precision of temperature and humidity controller g. Indication accuracy of temperature and humidity controller h. Permissible temperature load	 Ambient temperature ______ – ______°C (Maintain the following performance when setting the specimens in place.) ______ –______ °C ______ –______%RH  ± ______ °C at ± ______ %RH ± ______ °C at ± ______ %RH Heating from ______ to ______ °C for ______ min Cooling down from ______ to ______ °C for ______min. ______ ______ ______°C at ______ %RH, Max. ______ W
3.6 Internal and external dimensions, load resistance, weight a. Volume inside test chamber b. Load resistance of shelf for specimens c. External dimensions d. Overall weight	 W______ mm × H ______mm × D ______mm ______ Levels ______ kg × ______ (Number of shelves) W______ mm × H ______ mm × D Within ______ mm Within ______ kg
3.7 Other incidental items (directly related to how the test is performed) a. Has observation window? b. Has cable port? c. Has voltage impression terminals? d. Has timer? e. Signal connection terminals f. Computer connection terminals g. Other	 ☐ Yes ☐ No ☐ Yes ☐ No ______ ϕ × ______ ☐ Yes (withstand voltage ______ V × ______ (Number of pieces) ☐ No ☐ Yes ☐ No Specifications ______ Specifications ______ ______
3.8 Safety devices (in particular, contents determined by in-house standards) (When safety equipment is legally required, the requirement usually falls on the test equipment manufacturer.)	 ______