Easy-to-read "Features of Environmental Testing" (Part 2)

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Even the field of reliability has its own examples of short-term cyclical fashions. The latest trendy topic is "lead-free soldering technology". Naturally, the field of environmental testing has not escaped this vogue, and has been drawn into the discussion. The consensus has come to regard the topic as a familiar topic taken up for human coexistence with technology. However, we should not be convinced too easily. Past experience is replete with examples of hoped-for improvements turning out to make matters worse. Merely because something has been initiated by quality control technology, or by reliability technology, does not automatically produce reliability. I believe that the constant topics of reliability should be pursued to the utmost by bold and careful actions to eradicate the lack of understanding.

4. Environmental test application

4-1 General points

Environmental tests can be divided into the following categories based on how the tests are applied. Please take note of these concepts, as they form the points of divergence for how the tests are utilized.

1) Tests run within the upper and lower limits of the product's rated range of use
2) Tests run under harsh conditions exceeding the product's rated range of use

Tests run within the pre-established rated range of the product are in category 1). These tests can generally be assumed to be applied using existing standard test methods with no changes, and so we will not go into this category here.

For the tests in category 2), we must also consider the purpose of the test. Tests can be separated into two groups, both of which result in harsh environments. The two test groups are:

(a) Tests run from a reliability standpoint using harsh environments to create accelerated tests capable of reproducing the failure modes occurring in the field, and
(b) Tests run from a true technological standpoint producing failure modes not found in the field.

These tests are run to ferret out inherent weaknesses in the product. Accelerated tests in group (a) focus on failure modes found in the field, and so use for methods or results that can convince society in general. Accelerated tests in group (b) are used to seek out weaknesses, and there is an increasingly strong tendency to run these tests at specific stress level ranges for specific purposes. However, those tests results cannot be universally applied to society in general. Most of the various in-house tests run during product research and development fall within this category.

By the way, when test results are provided elsewhere as information, tests conditions should be stated clearly, and while publicly providing results should be done prudently, it should be accompanied by the disclosure of as much incidental information as permissible. When a limited amount of information is provided, persons receiving the information can form misunderstandings based on their own presumptions about the incomplete areas. Furthermore, ignoring or deviating from the range of established levels and pre-planned logic in these tests should not be done lightly, as such a test approach generally results in little more than merely destroying the specimens.

Based on the above premises, I would like to summarize the key points for test application.

(1) In the case of category 1) above, does the approach simply confirm specimen failure or verify that the specimen can withstand test conditions set according to test standards (either in-house standards or public standards)? In the case of category 2) above, is it not necessary to clarify in advance whether the approach will attempt to investigate the inherent weaknesses of the product? The answers to these questions will affect software selection in regard to such factors as the test procedures and the combination of test environment conditions, and will also affect hardware selection in regard to the functions and performance of the required test equipment and measuring devices. These decisions will also greatly affect test costs and time requirements.

(2) The test environment conditions could be constructed through diligent reference to sources such as information from other companies and articles presented at the latest symposiums, but surely the best approach is to construct test environment conditions based on referring to prior in-house test results and creating in-house test plans and test specifications based on the experiences and results culled from

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environmental conditions of past tests. The number of persons who have built up such a wealth of experience is quite limited. As a result, testers often must rely on various publicized data. Relying on such data requires the ability to discern whether information from another person’s example is reliable data.

(3) Just as in other types of reliability testing, one major problem with environmental testing is the amount of time required to run the tests. Although accelerated testing is an attractive solution to this dilemma, accelerated testing introduces its own problem of whether a single test with a single test condition can determine all failure modes. Also, merely using expensive testing with a high level of complexity is no guarantee of being able to obtain sufficient required data, and the use of a simple, inexpensive test does not preclude obtaining satisfactory results. In such situations, the deciding factors will be knowledge backed by interdisciplinary judgement and the amount of past data that has been accumulated (e.g., through the creation of a data bank).

(4) The environment consists of such factors as temperature, humidity, vibration, and wind velocity, while the specimens being tested always have such individual factors as size, shape, surface conditions, characteristics of structural materials, and thermal characteristics such as heat capacity. In testing, one should not get carried away with immediate performance changes. It is more important to constantly monitor the conformance between the environmental conditions and the individual characteristics of the specimen.
The principle that all test specimens be exposed to a uniform environment is fundamental to environmental testing. (In some cases, though, test aims require non-uniform conditions.) The principle of a uniform environment is reflected in IEC environmental standards which have adopted the requirement of a 1:5 ratio of specimens to test space as a basis for creating all types of test methods to secure a homogenized environment in the test chamber.

(5) Once we have entered a special area such as the test room, we can easily be overwhelmed by the test results to the point of forgetting about the phenomena produced by the tests. Focussing too narrowly on the specimens can cause us to overlook the effects of proper layout of the jigs and fittings that form the interface between the test equipment and the specimens. Some test conditions can cause dew condensation to be generated by the jigs and furnishings. Such moisture can form water droplets that follow the lead wires and reach the electrodes of the specimens. Dew condensation can also drip from the ceiling of defective test equipment onto the specimens. Test preparations must always be done with an eye on the long-term reproducibility of test results.

4-2 Special considerations for environmental testing and environmental stress

When attempting to perform environmental testing, it is paramount that only the targeted environmental conditions affect the specimens. They must not be subjected to any other type of stress. These prerequisites must be strictly controlled, especially when running accelerated tests. Prior investigation and preparation are critical since stress level targets may not be suitable due to problems in measurement technology or due to technological misunderstandings.

4-2-1 Excess stress in temperature and humidity environments

(1) Wind velocity in test space

Most actual environmental test equipment uses fans to provide forced air circulation through the test space. In this type of circulation, wind velocity is not uniform among the equipment manufacturers, and in some cases is not even uniform for all types of equipment from a single manufacturer. This lack of uniformity presents a problem when acquiring new test equipment or using different equipment to run subsequent tests with conditions identical to those used before changing the equipment. Preliminary tests must be run using dummy specimens during the new equipment preparation period to determine whether differences in stress occur at the same settings. One must not be confused by the looks of the temperature and humidity indicators and conditions. Even test environments required for simple temperature and humidity tests do not simply consist of temperature and humidity indicators. The environments also include absolute quantities of energy and moisture as conditions, and those conditions can be seen as stress-producing environments for the specimens. The heat transfer coefficient of the specimens depends on the surface shape and conditions of the specimen, but basically the coefficient is determined by air characteristics and wind velocity. Thus, wind velocity within the test equipment has an extremely important effect as a parameter.

(2) Airborne water droplets during humidifying

General purpose temperature and humidity test equipment has a humidifying pan installed in the chamber. Water vapor is led from this pan to the air conditioning chamber. Excess water vapor is then condensed in the dehumidifier and returned to the humidifying pan, and the required amount of water vapor is mixed into the circulating air. Specimens are generally tested while exposed to this fresh, moist air, but one must be careful when using this type of test equipment for humidity testing. The moist air blowing into the test chamber can carry relatively large water droplets, and strong air currents can catch droplets splashing from the boiling water surface of the humidifying pan. Those large droplets can be blown into the test chamber. The stronger the air currents, the more likely this is to occur. Especially during the ramping up of the temperature and humidity from the ambient chamber environment to setting values, there is a danger that quite a large amount of these droplets can be mixed in with the circulating air. These droplets then fall onto the surface of the test specimens and the amount of moisture placed on the specimens in the form of water droplets exceeds the original requirements. This in turn provides excess moisture, and for example, with parts such as surface-mounted multi-pin ICs, the moisture condenses and the droplets fall between the terminals, causing drastic weakening of the insulation resistance. Bridging results and the insulation is destroyed. This type of phenomenon affects test reproducibility, and can lead to incorrect test results.

(3) Test specimens and dew condensation

To avoid dew condensation on specimens during testing, most current test equipment uses temperature and humidity level control programs that employ such controls as delaying the humidity rise until after the temperature rise, but older model equipment and equipment that doesn't have temperature and humidity programming features are not well-equipped to deal with this problem. Therefore, testers must employ practical techniques to reduce the opportunity for moisture adherence, including taking such measures as pre-heating the test chamber specimens, keeping the specimen surfaces above dew-point temperature, and aligning the specimens with the air currents (especially surface-mounted parts with terminals exposed).

4-2-2 Special considerations for HAST

A more recent method of temperature and humidity testing called HAST (Highly Accelerated Stress Test) is able to attain greater acceleration than conventional tests. The HAST test method was developed to speed the evaluation of humidity resistance of plastic sealed electronic parts. These highly accelerated stress tests are performed under extremely harsh conditions that greatly exceed the specimen's environmental resistance rating. Therefore, any stress applied outside the targeted stress can greatly skew test results, creating the need for the utmost care to be taken at all times in these temperature and humidity tests. In other words, if the occurrence of stress outside the targeted stress is not strictly controlled, the test is in danger of not having stable reproducibility.

A test environment that is this harsh creates an especially inappropriate method for the materials, construction and type of some specimens. In addition, the failure modes that appear may differ greatly from those found in the field, and the test method cannot be applied to just any type of specimen. The tester must perform careful advance studies to determine whether this method suits the test objectives. For reference, I will include the test conditions in "IEC60068-2-66 Part 2: Test methods—Test Cx: Damp heat, steady state (unsaturated pressurized vapor)". (IEC standards do not list this test method as HAST.)

Temperature*1 (°C)	Humidity*2 (%)	Exposure time*3 (h)		
		I	II	III
110	85	96	192	408
120	85	48	96	192
130	85	24	48	96

Notes:
*1. ±2°C in the test space
*2. ±5%
*3. 0, +2 h

When selecting test equipment, we would do well to choose equipment with superior temperature and humidity control performance that achieve test stability. Although not listed in the standard severity, let's look at a case requiring environment control at humidity levels approaching 100 percent. In these conditions a mere ±0.1°C is the difference between a saturated environment and an unsaturated environment, or at times successive supersaturated environments, and so water adsorption will result at the test specimen surface.

Notes: This is a rather broad statement, but the characteristics of many products are such that pursuit of high temperature resistance often produces a corresponding drop in humidity resistance. For individual test specimens, care must be taken to confirm such special characteristics. When performing these tests, we must make every effort to carry out careful studies in advance on the properties of specimen structure and materials.

4-2-3 Temperature cycle tests and thermal shock tests

When reading collections of articles presented at reliability symposiums, we often notice that a clear distinction is not made between temperature cycle tests and thermal shock tests. This is often due to the definitions of both tests not being clearly distinguished, but normally tests using a gas (e.g., air) as a thermal medium are called temperature cycle tests, while tests using a liquid thermal medium are called thermal shock tests.

The difference between using a gas or a liquid as a thermal medium represents a striking difference timewise in the thermal stress placed on the specimen. The thermal shock test is far more severe from the standpoint of the thermal conductivity coefficient as well. The problem is, as noted in section 4-1, that it is not clear whether this is an accelerated life test or a test to search for weaknesses. In any case, there is a strong tendency to use the thermal shock test as a test to find weaknesses.

Let's first look at the temperature cycle test as a reliability test.

In its everyday usage environment, a product is exposed to the daily atmospheric temperature variations as well as temperature changes from being turned on and off. These temperature fluctuations produce fatigue (mostly mechanical) in the product, and this fatigue may accumulate. In parts that are not heat-generating, temperature fluctuations usually occur gradually, and in energy-saving electronic parts in particular, there is comparatively little difference between the internal temperature and the surface temperature. The source of mechanical defects can be traced to differences in structural materials, and differences in assembly and shape. Temperature cycle tests focus on these phenomena, and the conditions for acceleration can be understood as performing multiple repetitions in a short period of time, and increasing the temperature differential in order to increase the level of stress. Therefore, we can take this to be a thorough acceleration test, but increasing the temperature gradient too much in an excessive attempt to reduce test time will produce too great a temperature differential between the surface and the internal parts of the specimen, introducing the danger that the temperature test will not reflect the original field environment. The limits of the temperature gradient will depend on such factors as the purpose and type of use of the product as well as its size. However, one should be aware that merely increasing the temperature gradient does not necessarily result in an accelerated test.

On the other hand, the thermal shock test subjects the specimen to abrupt surface temperature changes, producing a temperature fluctuation gradient between the surface and the internal parts of the specimen in a very short time. This test can be taken as an attempt to evaluate resistance to thermal shock, but it is often seen as a test for products with unusual applications (e.g., electronic parts used in airplanes that repeatedly undergo rapid changes in altitude), or as a test with specific aims for finding weaknesses in products during the manufacturing process. We must be aware that this test will require individual conditions depending upon specimen characteristics such as the size and shape of the specimen, and especially its thermal capacity.

In either of these tests, the factors producing the temperature fluctuations in the test specimen itself can be listed as the air or liquid temperature around the specimens, the wind or current velocity, the thermal capacity and thermal conductivity coefficient of the specimen, and the shape and surface conditions of the specimen.

4-3 Key points for running environmental tests

Naturally, different environmental test aims call for different procedures. For example, measures used for failure analysis of test specimens will depend on such factors as whether the test aims are somewhat academic, or whether the test is simply run for routine business purposes such as inspecting production lots or checking customized products and purchased parts.

In the above-mentioned academic cases in particular, running effective tests requires taking a somewhat cautious attitude. For example, one should not simultaneously test products from different companies, nor should one introduce changes and abnormalities unrelated to test results. Otherwise, the tester may often find he is left with conjectures about other companies' problems, or that post-test investigation reveals failure precursor phenomena, or that the test equipment and test methods were not suited to the abnormal failure modes. Post-test analysis may even reveal that even though there were no electrical abnormalities, the specimen was on the verge of physical failure.

Persons directly and indirectly involved in running this type of testing will affect the tests differently depending on

1) how much interest the tester himself has in the test,
2) whether the person in charge of development is seriously concerned about the reliability of the product to be tested, and
3) whether the tester has experience with reliability tests.

All of such conditions affecting the human factor taken together add up to specific test know-how. In other words, we can see that environmental testing, just like other reliability testing, has many of its own unique technical aspects. (While this situation is unavoidable, the essential point is whether this know-how is passed on to successors.)

On the other hand, routine business tests in general, whether public or private, are usually handled as standard tests with responsibilities divided among different workers. This allocation of responsibility has led to a situation in which testers decide to run tests without understanding the original purpose of the tests, merely applying standard tests automatically. If we hazard a guess as to why this situation has occurred, it seems that along with the popularization of quality control activity, standard test characteristics have also become entrenched so that people are now able to carry out tests (as part of their jobs) without understanding the field of reliability.

Viewpoints on how the various tests methods should be applied differ between manufacturers and users (e.g., delivery testing vs. acceptance testing).

Even when identical test names and terms are used for a product subjected to testing, the meanings associated with such terms often differ widely in specific fields of technology (e.g., electrical, electronic, mechanical, and chemical). Therefore, especially when there is some disparity between the individual fields of technology, meanings of terms must be mutually agreed upon during the pre-contract negotiations, and these definitions should be written into the contract. By taking full advantage of this cost-effective time to solve problems before the test contract takes effect, these extremely important conditions should be revised and understood so that they do not interfere with the work at some later stage.

4-4 Using standard tests

We have already seen that it is impossible to prescribe a single environmental test that can be comprehensively applied to every different type of product. However, it is possible to suggest multi-purpose test methods that can logically be applied to all products. Obviously, the IEC test standards exist for this purpose. As I have said before, when suitable conditions cannot be found in the prescribed test conditions (test severity), individual test specifications may be created and required test conditions may be employed and given priority. When the test conditions need to be modified, the modified conditions should be clearly written down and attached to the existing standards when writing the test plan.

When the endurance of a product is already known through prior use of environments exceeding the conditions prescribed in the standards, subsequent tests based on those established conditions can of course be omitted. For example, if the conditions for storage tests have already been covered by transportation tests, we need not go to the trouble of running tests using those storage conditions. Now, let's summarize the key points for the individual items of test use.

(1) Storage tests

Storage tests are based on the environmental conditions to which a product is exposed during storage. However, when the term "storage" is used in the standards, it refers to the period from product manufacture up to initial use, excluding the transportation period.

The product is tested for normal conditions, but for example, when a product is packaged during storage, the basic approach is to have it packaged in the tests. If some products are packaged and some are not during storage, tests must be run for both conditions.

For some types of products and test conditions, we must be careful to note that packaging results in harsher test conditions. For example, moisture remaining inside the package in products in airtight packaging may experience dew condensation from changes in ambient temperature. Also, package leaking can generate the breathing effect due to changes in the external atmospheric temperature, sucking in more and more moisture from the ambient atmosphere.

(2) Transportation tests

Transportation tests are based on the environmental conditions to which a product is exposed during storage. This can be on land, on sea, or in the air (e.g., in an airplane), but in this article we are using the word "transportation" to indicate the transportation period involved when a product is transported from one place to another after being shipped from the production site.

Products can be tested under a wide range of individual transportation conditions, but if they are packaged during shipping, they should be packaged during testing, and if they are not always packaged during shipping, both packaged and unpackaged conditions should be used during testing, just as in part (1) on storage tests above.

(3) Usage condition tests

Usage condition tests are based on all conditions found during the life cycle of the product, including product use time, down time, time hooked up to peripheral equipment, and maintenance and repair time. At this point we shall ignore the environments of individual products inside equipment, leaving that matter for a later discussion.

Individual specifications are established for product operation during the environmental tests and for the measurements required before, during, and after testing. The sequence of these tests is prescribed in individual specifications. A variety of test combinations can be conceived of before and after the targeted test, but creating too specialized a sequence requires extreme caution, and may be linked to excessive test costs.

(4) Test (exposure) time

Test time is prescribed in the standards, but considering when the standards were established, we can take "time" to mean "time enough to confirm the affects on the product". A lot of time has elapsed since the standards were enacted, and if the standards no longer fit the current level of technology, or if we are running the test with different aims, these new settings should be written down in individual specifications and given priority.

(5) Compound tests

Compound tests (test loads with multiple environmental factors) are supposed to produce results that are closer to those found in the actual environment than the results of simple tests run in sequence.

We should only acknowledge that the tests are effective after we have clearly determined the effects of the individual factors that make up the multiple conditions within the environments to which the specimen is exposed in compound tests.

5. *Pitfalls of test conditions*

Despite the advances of the current information age, the geographical conditions and meteorological environments in which individual persons actually use the products, and especially with regard to consumer products, the individual products are placed in local environments, and so we realize that the supplier of the product absolutely cannot confirm all these actual usage conditions. We can conjecture a wide variety of environments in various locales in different countries, including both artificial and natural environments. To use an extreme example, even the north and south polar regions do not always have cold winds and blizzards. Because of this, even equipment and instruments used in those regions are not necessarily always exposed to their symbolic environment. For example, inside places such as well-managed rooms for air conditioning facilities and inside unexpectedly humid living quarters, products are operated in local environments entirely unrelated to the polar environment.

First of all, I would like to discuss a few occasions of failure that we have experienced. These factors illustrate occurrences that were caused by a total lack of grasping the situation in countries where our products were sold. (The examples are somewhat dated, but please be patient.)

5-1 Fungus occurrence caused by lack of clearly understanding the transportation situation

A little more than ten years ago, many circumstances were probably a good bit different than now. At that time, products for overseas markets were basically packed in semi-hermetically sealed packing. Before shipping products from the factory, residual moisture was removed from such sources as test chambers inside test equipment and water distribution pipes. First, products were dried by ventilation with dry air, and then moisture absorbents were placed at various sites and the products were wrapped in plastic bags and finally placed in wooden crates.

Products were shipped by air in urgent cases, but when delivery time permitted, products were sent by sea. The case we shall consider here involved air delivery to Stockholm, Sweden during summer to autumn. (The products cannot be considered to be isolated from the outside world. Basically the plastic is permeable to air, and we also cannot say that cracks did not exist. Therefore, the packing method cannot be considered appropriate to shipping involving long periods of time.)

While products were uneventfully arriving at the destination and we imagined everything to be all right, suddenly complaints began to fly. We were told that the products “smelled moldy”. At first, we didn’t understand how inorganic products could be “moldy”. Perhaps the Scandinavian fastidiousness for cleanliness was to blame.

Setting aside such speculations, I flew over empty handed. When I arrived to see for myself, I found that some products had become damp — especially those wrapped with glass wool for thermal insulation — and “smelled moldy” and had a “green mold” adhering to the packing material. (I no longer remember the name of the mold.) Of course it “smelled moldy”. Setting aside the investigation into the cause, since I had arrived empty handed, I went with the local staff for a tour of the Stockholm tool shops, purchased some tools, found an air-conditioning materials shop and purchased some insulation materials. Then, I disassembled the equipment at the customer’s location and carried out the required procedures. Some smell still remained, but it was at a bearable level. Naturally, we also had to pay a penalty.

After returning to Japan, I investigated the processes from packing up to shipping. The results showed:

1) When shipped from the factory, the product was determined to be dry and to have ample moisture absorbent.
2) There was no problem with the combination of the plastic packing and the moisture absorbent.
3) The wooden crate packing was not done in house, instead relying on another company to provide that service. Accordingly, that company’s service was also subject to the investigation, and we determined that they were following procedures more or less as outlined.

That left us with the question as to what could be the cause of the defect. In fact, the source of the problem was found to lie in the wooden crate material and the transportation conditions.

1) First, let’s look at the wooden crate material. Naturally, the crates were made of wood, but this wood was a product imported from Southeast Asia. (Indeed, by that time, there were probably already no domestic wood products suitable for use in packing materials.) The required management processing had been done, but that the results had come from less-than-thorough processing was made abundantly clear by the discovery of mold and nematodes inhabiting the packing materials of other products during the same time period. In short, the processing standards for imported materials at that time were very weak in regard to materials for Southeast Asia. The living organism that had slipped through this process gateway was able to multiply under a certain combination of conditions. Therefore, we can assume that the presence of nematodes indicates that the adhering mold spores were able to breed and multiply.
2) On the other hand, the transportation conditions were those of air freight, and so we had assumed (without checking) that the product would be traveling directly to the destination in a short period of time. However, while the product had been transported directly to the Amsterdam airport, it had had to stay in Amsterdam until enough freight had accumulated to fill a large cargo flight to Stockholm, Sweden. In other words, the product had spent days exposed to airport storage conditions. Naturally, the weather had become hot, it had rained and been foggy, and so moisture penetration inside the wooden crates was not at all strange. (In other words, for the function of the moisture absorbents, the somewhat low pressure inside the plastic may have been doing more harm than good.) At any rate, we could presume that this had produced just the right environment for the mold to breed.

The source of the problem given above in section 1) combined with the factors in section 2) to produce a situation in which the mold was able to breed and spread to the thermal insulation material of the product.

To summarize what this example illustrates:

(1) The cause should be weeded out in the beginning.
(2) Data and current conditions for the required local environments should be checked.
(3) Incomplete management processing can do more harm than good.

5-2 Metal rust occurrence caused by not learning about the local environment

Here is another example of problems caused by not learning about the local environment.

The product in question is an incubator with a water jacket that doubles as an inner chamber wall and a thermal barrier. The product was constructed with a double inner tank wall, and the space between the walls was filled with water. Either distilled water or ion exchange water could be used, and this was written in the instruction manual. This product was delivered to a research laboratory in Switzerland. Before long, we received a complaint that water was leaking from the inner wall.

When we retrieved the item for observation at the warehouse of the local sales company, we did find traces of water leakage. Since the walls were entirely of stainless steel, the shelf supports had also been made of stainless steel and installed with electrical spot welding. And yet, wasn’t there a rough, dry white powder adhering to the welding sites?

The next day, I requested our Swiss agents to obtain a laboratory analysis of the powder and the residual water. When I received the reports to take back to Japan for analysis, they revealed that the main component was salt.

Since the instruction manual clearly stated that ion exchange water should be used, naturally the user had done so, and so we surmised that the cause could be that somehow the chlorine had not been completely cleaned out of the ion exchanger. This led to the conclusion that the high temperatures at the sites of spot welding during assembly had caused severe compositional change to the materials, leading to relatively rapid corrosion around the welded areas.

To summarize the cause of water leakage from these circumstances, we find that the following types of conditions are overlapping.

1) First of all, although I had learned from a textbook or somewhere in my school days that from long ago in Europe, rock salt was used from the mountainous regions, I had never thought much about it. Therefore, I lacked the concept that drinking water was basically came from mineral water sources that included salt. (In fact, you will see many seniors in Europe who need canes to walk because they have bad knees. I have heard that this is a result of drinking water with a high mineral content over many years.)
2) Even though the maintenance of water purification equipment is not that bad, after the equipment has been in use for a while, even water that has passed through an ion exchange device may have residual salt.
3) The equipment was manufactured for specifications that presumed the mostly soft water conditions of Japan.

If we observe carefully, we find that products equipped with water jackets are rarely seen in Europe. Seeing the lack of such products as a marketing opportunity, we had marketed the product without fully considering the surrounding environment. It goes without saying that sales of products of that type were immediately halted.

5-3 A case of equipment malfunction caused by failure to consider the high altitude environment

Ordinarily, we rarely pay attention to the details of the atmospheric pressure unless we're listening to hurricane warnings or we're reaching the summit of a high mountain. We never thought about our environmental test equipment being brought to a research laboratory over 1,000 meters above sea level. We realized that for some reason the environmental test equipment was reproducing that sort of high-altitude environment at ground level.

The product that caused the problem was HAST equipment used for running highly accelerated humidity tests, meaning that the water vapor and pressure constituted the whole of the test. At the start of the test, the equipment had atmospheric air in the chamber and humidifying water. When the door was closed, the chamber had only one port open to atmospheric pressure: a single electromagnetic exhaust valve with a small orifice. When this valve was closed, the inside of the chamber that formed the test space was totally isolated from the outside world, completely sealed off. The temperature normally used was over 110°C, and as the temperature would rise, the initial residual atmosphere would be removed along with the water vapor during the process of reaching the set conditions. When the test temperature and humidity were reached, no air remained inside the chamber, and the environment was over 100°C composed of water vapor only.

Inside the chamber, the pressure is somewhat higher than the surrounding atmospheric pressure while the exhaust valve is open, and so while this valve is open the water temperature will only rise to about 100°C. This means that the valve is closed at around 100°C, creating a completely sealed space. At this point the residual air has almost all been discharged. Then, as the humidifying water is heated further, water vapor of over 100°C is generated, also causing the pressure to rise. This ventilation valve was controlled by a sensor mechanism that detects the humidifying water temperature (some models use a vapor temperature sensor). However, at altitudes of above 1,000 meters the boiling point is reached before the humidifying water temperature reaches 100°C. Thus, the humidifying water in the chamber all evaporates and is discharged outside the chamber through the exhaust valve before the ventilation valve can close. The heater for the humidifying water then runs with an empty pan and overheats, and finally the safety device activates to stop the equipment.

In this example, the environmental test equipment was originally intended for use at ground level. Reproducing environments in the test equipment whose functions are based on a ground-level environment that cannot be obtained within the ambient environment can cause your subconscious assumptions to become your enemy. This case was concluded by resetting the opening and closing point of the valve to a somewhat lower temperature (at a setting below 100°C).

5-4 Failures caused by differences in environmental substances

These examples demonstrate a lack of feedback. Here, we shall consider only the salient points.

During the time of the Gulf War, the multi-national forces went to the deserts of the Middle East to carry out military operations using tanks. The American military caterpillar tanks are said to have become inoperable within just four days.

Quite some time ago, because MIL-prescribed Arizona desert sand could not be obtained, sand was used from the Suma Beach in Kobe, Japan to test the construction process of the sandstorm test equipment under certain conditions. Very quickly holes appeared in the plate fin coolers of the equipment. I have also heard that the bulldozers of a certain heavy equipment manufacturer experienced similar problems in the Arabian region. Even simple desert sand can differ greatly from place to place.

To digress somewhat, with products for export and with products that are brought to other locales, lack of thorough knowledge about the various environments of the region can cause absurd failures. Sometimes the conditions of the local environment must be seen to be understood. For example, even with the various international standards, we cannot always feel confident simply because a product has cleared the test standards as they are written. (Indeed, it is not written anywhere in these standards that "running tests using these test methods provides a total guarantee of the product".) Confidence can only be acquired by accumulating experiences of failure.

We now live in an age that is going digital and visual. A little effort goes a long way toward obtaining a wealth of information on environments all over the globe. Acquiring such information is becoming easier every day. For example, international information can be found using such sources as newspapers, magazines, travel brochures, and TV news and documentaries. In such cases, judgement is not merely based on personal observation. I believe that to avoid overlooking environmental substances, one must develop the habit of looking at the details for oneself, grasping them, thinking about them, and forming images.

6. Conclusion

This article has discussed a wide variety of factors involved in environmental testing. As far as possible, I have tried to take up matters that you will not find in general references on reliability. Perhaps the focus has been on psychological factors, but as a writer, this is as far as I can go. Filling in the details is your job.

We have taken up all the test methods found in the IEC 60068 Series that consists of representative environmental test standards, and currently no specific proposals have been put forth for test methods with new standards. Furthermore, manufacturers are not very fond of presenting failure analysis based on examples of failure, and so you will not often find published references or lectures and symposiums based on such examples. The only way to accumulate such information is to do it on your own.

We can no longer say that looking at cost and resources will suffice to determine whether to run all of the tests affecting the product. During the research and development stages as well, many questions remain as to whether all hypothetical test items must be run.

Now, let's summarize the key points of environmental testing

(1) Knowing just when to 1) avoid work is crucial. Surely this constitutes part of modern job know-how, and is a key point. (A basic sense of logic is required, and an overly subordinate attitude of following the rule book is not really very bright.) You have to put on your thinking cap. A little intelligence is needed. Being able to carry this off requires 2) a background of basic knowledge and education. Using how-to methods for people in a hurry cannot give you that background.

(2) However, if you have routine duties for running clear-cut environmental tests, you need only follow the existing manual. The job is not improved by considering unnecessary items. (Nowadays, if the subdivision of duties has advanced to the point of making a cut-and-dried process, that is sufficient.) Sometimes, what is unnecessary is clearly unnecessary.

(3) Running into difficulties can take a lot of time, but basic education and 3) accumulated experience can round out environmental test technology. However, we must not forget that this technology, along with developing peripheral technology, is in constant transition (including becoming out-of-date).

(4) While this may go without saying, the what this article means by "basic education" concerns linguistics, mathematics, physics and chemistry. If possible, a background in technology is also helpful. (This represents my own personal opinion.)

I hope that this article will give you a fuller knowledge of environmental testing technology and prepare you for handling the basic methods.

Although these are not key points, let's also consider urgent problems in environmental test technology.

(1) It is of vital importance to pass on to the next generation environmental test technology that has been accumulated as varied technological experience. Somehow, we must recognize the importance of converting the hidden information known as know-how and individual technological aspects to concrete information and passing this information on to our successors.

(2) At present, software has not yet been developed that can include all environmental test items, but in the near future when simulation technology for analytical evaluation is established that can use details of past data and construct theories, we should be able to run "virtual tests". All of the roles played by current test methods directly using all types of environmental test equipment will slowly but surely disappear.

As we enter the age of low birth rates, it will become more and more difficult to solve problems with labor-intensive methods. Even now, policies are being boldly carried out to improve human education, and we must consider nurturing human abilities that can achieve the maximum state of the art.

Finally, living, breathing humans are the real focus of activities to plan and run environmental tests that maintain the reliability of products, even when the subject of those activities are inorganic industrial products, so don't forget that you play an important role.

[Bibliography]

1) NASA Preferred Reliability Practices Environmental Factors Practice No.PD-EC-1101