Technical information for our customers

ESPEC

TECHNOLOGY REPORT

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Special issue: Evaluating Reliability and Measurement System

CONTENTS

TABAI ESPEC CORP.

Our Philosophy

We at TABAI ESPEC are continually pursuing perfection. In our ongoing struggle to realize this ideal, we have established our Corporate Mind, which we proudly use as the basis for all our efforts. This Corporate Mind defines for us our present and future goals, directions and actions. At TABAI ESPEC, where “Environment” is our business, we offer aid for new technological developments and a more certain and improved living environment. With “Progress to Perfection” as our corporate policy, we aim to become the company, firstly “with public recognition by having our original line of business, and our own original product sphere by virtue of our original technology”, and secondly “with intellectual raison d’être of such that as specialists can, assist our clients and industry in setting up various issues and in finding answers to them”. This total concept we call ESPEC. From our internationally minded product development, to our thorough after-service, all our activities originate in this concept of ESPEC. ESPEC is the foundation upon which we manufacture products with superb performance, functional design and excellent cost-performance — our ESPEC.

ESPEC — our philosophy, our goal.

Corporate Data

TABAI ESPEC CORP.

Company Name:	TABAI ESPEC CORP.
Date founded:	July 25, 1947
Date incorporated:	January 13, 1954
Paid-up Capital:	6,778 million Yen (As of March, 1999)
Chairman:	Eiichi Koyama
President:	Kiyoshi Shimazaki
Senior Managing Director:	Yoshinobu Yamada
Managing Directors:	Susumu Nojii Toshikazu Adachi Nobuyoshi Shin
Directors:	Eishiro Hizukuri Yoshio Nakai Osamu Nakamatsu Hiromichi Fukumoto
Regular Auditor:	Katsuharu Nakano
Auditors:	Shoichiro Yoshioka Takuichi Omura Katsuyuki Kakihara
Employees:	601 (plus 58 temporary employees)

Product Guide

Environmental Test Chambers
- Temperature (& Humidity) Chamber
- Temperature (Humidity) & Vibration Combined Environmental Test Chamber
- Walk-in Type Temperature (& Humidity) Chamber
- HAST System (Highly Accelerated Stress Test System)
- Thermal Shock Chamber
- Temperature Chamber (Industrial Ovens)
- Environmental Test Chamber Network, E-Bus

Measurement Evaluation Systems
- Ion Migration Evaluation System
- PWB conductor Resistance Evaluation System

Burn-in Test Systems
- ECL Testing Burn-in System
- Flash Memory E/W Cycle Test System
- Automatic Burn-in System

LCD Production Equipments
- Automatic Clean Cure System
- Single Loading Plate Clean Oven

Laboratory Chambers

Biomedical Chambers

Agribusiness
- Plant Factory
- Phyto-tron (Environmental Control Chamber for Plant)
- Growth Chamber

NOTE:
Some models are available only in the limited countries.

Guidance for accelerated testing and reliability —For electrical and electronic parts and equipment—

Toshio Yamamoto*

Resources are continually being poured into efforts to improve the reliability of electrical and electronic parts and equipment. This has lead to the production of a large number of highly reliable products, and brought about a sharp decline in failure rates. Concretely evaluating product reliability requires extremely long periods of time of environmental testing, specifically in the area of reliability testing. These time constraints have created a need for accelerated testing that can produce effective results in shorter periods of time. However, accelerated testing cannot be achieved by merely ratcheting up the stress to shorten testing times, and this type of testing is not applicable to every situation. Accelerated testing, just like other forms of reliability testing, is a reliable test method supported by scientific logic.

In this report, we would like to present the logic behind accelerated testing in an easily understandable way, from the standpoint of environmental testing used in the fields of electricity and electronics.

Contents

*Technical Planning Department

1. Introduction

The details of environmental testing differ according to the type of product, and no one test method can serve for all products. We could go so far as to say that each individual product requires its own test procedure. Within the category of reliability testing, environmental testing normally focuses on determining whether a product can fully display and maintain its established functions within the marketplace environment of actual use after the product has been shipped from the factory. This testing is done from the standpoint of technology directly related to the product. However, even the same types of products face a variety of environments in the marketplace, including how the individual product may be used. Because products meet such conditions, each type of environmental test has its own significance. However, accelerated testing is not created by merely increasing the stress in a rush for results. Such methods will simply create destruction testing. Because of this, we must thoroughly understand the principles of accelerated testing, carefully construct the logic involved, and create a method in which no contradictions arise in the testing procedure.

2. Definitions, prerequisites, and fundamentals

According to "JIS (Japanese Industrial Standard) Z 8115 Glossary of terms used in reliability", accelerated testing refers to "a test in which the applied stress level is chosen to exceed that stated in the reference conditions in order to shorten the time required to observe the stress response of the item." In general, the more severe the conditions in relation to standard conditions, the more quickly it is possible to complete the test. However, it would be premature to conclude that we have proven the excellence of a product simply because it has endured an accelerated test. A product that has successfully endured extremely severe conditions may fail in a relatively short time under the same type of stress conditions that are considered extremely mild. We must create a test plan for all methods of use and surrounding environments that can be imagined, and we must carry out complete pre-test studies and check for misconceptions in logic, and make sure we haven't missed anything.

To start with, there is always a cause for each type of product failure. Unless there has been severe misuse, such failures do not merely appear out of the blue. Seen from a qualitative standpoint, the failure of electrical and electronic products, and electronic equipment in particular, begins when changes are experienced in the physical and chemical characteristics of the materials used in their production. Such changes can be caused by an intrusion from the external environment, or from internal factors, or from a combination of both internal and external factors. These physical and chemical reactions are affected by the surrounding environment (heat, in particular), speeding the reaction, and the product functions are weakened are weakened or completely stopped in the course of achieving equilibrium in that reaction. Therefore, accelerated testing consists of speeding up this physical and chemical process with suitable ambient environments, causing malfunctions to appear.

Accelerated testing characteristically entails knowing in advance the results of testing when deciding to run the tests, because one must establish what is being accelerated in relation to what, and clearly establish the items that serve as the basis for acceleration. Essentially, accelerated testing is not a means for ferreting out new modes of failure, but rather serves as a time-saving means of confirming phenomena that have already been identified. Therefore, major premises have already been proposed concerning the factors involved in failure and the mechanism leading to failure. Only when expected results are obtained do the conclusions form accelerated testing. Then, by recording the test preparations and accumulating the data, it finally becomes possible to apply the procedures to similar products. However, there are no accelerated tests that can be applied indiscriminately to all products and failure modes. For example, if the relation between the failure mode and the acceleration mechanism is not known and we just expose a new product to severe conditions and cause the product to fail, the only result will be that we have destroyed the product. We will not be able to obtain any scientifically valid data at all from such testing. We must remember that accelerated testing, as one form of reliability testing, is a very specific technical method.

To sum up, accelerated testing consists of, "accelerating the mechanisms causing product failure by using conditions that are more severe than standard conditions, and saving testing time by utilizing the systematic nature existing between the standard conditions and the accelerated conditions in the identical mode of failure." In other words, the absolute prerequisites to accelerated testing are:

(1) Having the same product failure mode, and
(2) Having a systematic relationship between standard conditions and accelerated conditions.

Care must also be taken in the following matters when performing accelerated testing.

(1) The test must be based on the main points whose results have been predicted by thoroughly examining the problems.
(2) The test conditions must be constructed on the basis of thoroughly grasping the usage conditions and the ambient environment of the product.
(3) When special prerequisites exist, they must be dealt with, but one should always try to gather universal data that can be applied in the future.

The most important condition of all is to clarify exactly the purpose for running the test. In other words:

(1) The test presumes a correlation with conditions in the field. (Conditions are within the product ratings, and the test aims at forecasting or reproducing failures that occur in the field.)
(2) The test attempts to detect the characteristic weaknesses of the product. (With the aim of collecting data to discover and improve product weaknesses)

(3) The test simply attempts to confirm product durability. (Durability is confirmed outside the product rating.)

Details and procedures will vary, depending on the purpose of the test, and different types of test and measurement equipment will be used.

3. Accelerated testing and the physical chemistry of product failure

The physical chemistry of product failure in electrical and electronic equipment can be broadly grouped into approximately 30 categories, or more specifically classified into about 70 categories. The mechanisms leading to failure have mostly been elucidated. Therefore, the method of planning accelerated testing or analyzing product failure quite often consists of selecting the appropriate mechanism leading to predicted failure from among these categories, and then verifying the pre-selected or pre-constructed failure model.

First of all, to capture the general concept of failure occurrence, the stress-strength model is briefly checked, and then great emphasis is placed on the chemical kinetics model, which is extremely easy to understand for accelerated testing.

3-1 Stress-strength model

This model explains the process leading to failure through the relationship between the characteristic durability of the product and the stress from the ambient environment. (Failure occurs in the areas in which deterioration of durability and distribution of stress overlap.)

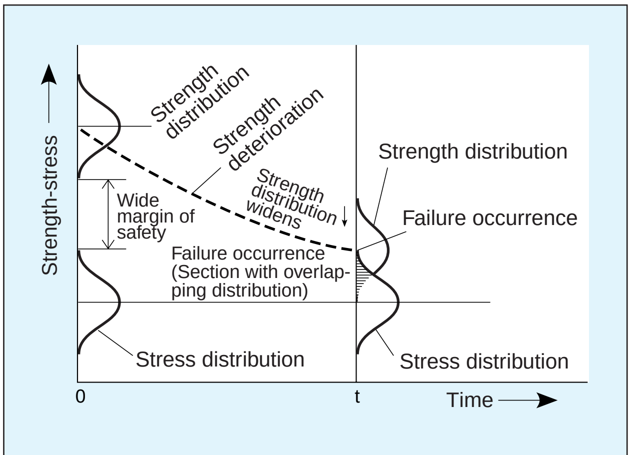

Fig. 1 Stress-strength model

3-2 Chemical kinetics model

This model is based on the chemical reactions between the molecules of matter within a solid, and utilizes the principle that the existence of background heat strongly influences the initiation and the progress of the reaction. For example, when hydrogen and oxygen react to form water, the higher the temperature, the greater the speed of the chemical reaction.

The Arrhenius model is the model that most directly expresses the thermal transition. In 1899, S.T. Arrhenius proposed the formula

$$K = \Lambda\,[\exp(-B/T)] \tag{3.1}$$

Where T represents temperature (absolute temperature) and K represents the speed of the chemical reaction. This formula shows strong conformity to test results.

Formula (3.1) can also be written in the following way.

$$K = \Lambda\,[\exp(-E/RT)] \tag{3.2}$$

Here, Λ and E represent individual constants for the reaction conditions. Λ is called the frequency factor, and E is called the apparent activation energy. R is the Boltzmann constant, and by writing this another way, it can be done in the same manner as the Maxwell-Boltzmann distribution, which specifies the energy distribution of the gas molecules. When the chemical reaction is primary, Λ contains the $[\text{time}]^{-1}$ dimension, so it is called the frequency factor. The fact that E is positive in this formula means that rising temperature increases the speed of the chemical reaction, and the greater the value of E, the greater the speed of the chemical reaction.

As the temperature of a gas rises, the motion velocity increases in the molecules that make up the gas. However, the gas contains a mixture of fast-moving and slow-moving molecules, and if we posit that the velocity distribution conforms to the negative exponential distribution in relation to ($1/T$), then in particular the activated molecules abounding in energy are what is actually contributing to the reaction, and the proportion of activated molecules increases markedly along with rising temperature. It has been proposed that the chemical reaction between two gases can only be contributed to by molecules with relative motion energy that exceeds activation energy level E. Therefore, in isothermal reactions in this type of molecular collision between two gases, the explanation of formula (3.1) applies to the proportion of $\exp(-E/RT)$, which is the proportion of activated molecules with energy above a certain energy limit value. However, because this theory cannot be properly applied to more complex reactions in which numerous molecules participate, in 1935 H. Eyring and E.H. Eyring proposed the absolute reaction theory that was developed from this approach.

This approach holds that activation energy is the main factor in reaction velocity, and that this can be separated into activation energy and activation entropy. When T represents temperature stress and S represents other stress, reaction velocity K becomes

$$K = \Lambda\,[\exp(-B/T)]S^{\alpha} \tag{3.3}$$

This is known as the Eyring formula. This formula is frequently used in the field of electrical and electronic equipment. However, no theory has yet been established that can account for all chemical reactions. Here, α becomes the constant.

3-3 Applying chemical kinetics

Let's try to adapt these formulas to the field of electrical and electronic equipment reliability. Using the aforementioned stress-strength model, we can conceptually grasp the process in which physical changes resulting from stress such as temperature and voltage reduce durability and lead to failure. Can chemical kinetics be applied to explain this type of phenomenon?

If we express the level of stress applied to a product as x and the level of resulting deterioration as y, and if we regard y as a function of x, then we can express the following relationship.

$$y = \phi(x)$$

When there are multiple sources of stress, we must regard x as a vector, but to simplify matters, we can make it scalar.

Deterioration with age dy/dt signify reaction velocity, so we can express this as

$$\frac{dy}{dt} = K \qquad (3.4)$$

Here, when K is a constant, if we integrate formula (3.4), we get $y = Kt$. Now, if we set L as the time in which deterioration level y reaches product proof stress limit r, then the $y = Kt$ relationship yields the relationship

$$L = r/K \qquad (3.5)$$

Next, if we substitute formula (3.3) for this formula, we get

$$L = [(r/\Lambda)\exp(B/T)]S^{-\alpha} \qquad (3.6)$$

At this point, we can think of the product being operated. If we have the following two instances,

(1) Stress voltage is V_1, operating temperature is T_1 and the corresponding life is L_1, and the failure rate is λ_1

(2) Stress voltage is V_2, operating temperature is T_2 and the corresponding life is L_2, and the failure rate is λ_2

Using formula (3.6), we can show both relationships as

$$L_2 = L_1 \exp[B(1/T_2 - 1/T_1)] \cdot \left(\frac{V_2}{V_1}\right)^{-\alpha} \qquad (3.7)$$

If we attempt to express this as a failure rate, the mean life L and the failure rate λ of the electrical and electronic equipment have an inverse function relationship, and so the above formula becomes

$$\lambda_2 = \lambda_1 \exp[-B(1/T_2 - 1/T_1)] \cdot \left(\frac{V_2}{V_1}\right)^{\alpha} \qquad (3.8)$$

In the above formula, $V_2/V_1 = S$ is called the stress ratio.

When $\alpha = 0$ in formula (3.7), this becomes the Arrhenius formula, and is often adapted to temperature-dependent deterioration phenomena, and is useful for establishing the acceleration factor when performing accelerated testing.

In other words, formula (3.7) can be rewritten in the following way.

$$\begin{aligned} L_2 &= L_1 \exp[B(1/T_2 - 1/T_1)] \\ &= L_1 \exp[E/R(1/T_2 - 1/T_1)] \end{aligned} \qquad (3.9)$$

In other words, the rate of acceleration (the acceleration factor) can be found with the following formula.

$$Ac = \frac{L_2}{L_1} = \exp\left[\frac{E}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right]$$

$$\text{or} \quad \ln\frac{L_2}{L_1} = \left[\frac{E}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right] \qquad (3.10)$$

The Arrehnius model is widely applied to reliability testing and failure analysis of electrical and electronic equipment, especially to semiconductor devices. That is to say, semiconductor devices are manufactured using physical and chemical changes in the surface layers of material, and rather than having a structure of complete crystallization or solidification, they are combined in an amorphous state. Because of this, the changes that appear tend to be chemical rather than physical changes, and so chemical theory is considered easier to apply.

4. The relationship between accelerated testing and predicting product life

At this point, we would like to take up a very simple example and examine it using numerical values.

From the standpoint of environmental conditions, we shall set the following theme. "What levels of acceleration are possible if instead of using a TH (Temperature and Humidity) test with test conditions of 85°C and 85 percent RH, we substitute a HAST (Highly Accelerated Temperature and Humidity Stress Test) with test conditions of 120 to 140°C and 85 percent RH? Also, using those results, to what level of reliability can we predict product life in the field?"

As a precondition, these are temperature and humidity tests, and in detailed analysis the water vapor pressure differential is required as an environmental condition. However, to simplify the explanation, let's say the relative humidity is proportional to the temperature, and utilize the common value and just do away with the humidity parameters. (There has yet to be a theory established proving the humidity relationship. Perhaps water vapor pressure corresponds to the amount of intruding water vapor. Water vapor and water are physical matter, and so this activity level is thought to correspond to the temperature.)

First of all, let's look at the first of the two formulas in formula (3.10).

$$Ac = \frac{L_2}{L_1} = \exp\left[\frac{E}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right]$$

If we say that $R = 8.615 \times 10^{-5}$ (eV/K), the above formula becomes the following.

$$Ac = \exp\left\{1.16 \times 10^4 \times E \times \left(\frac{1}{273 + T_{85}} - \frac{1}{273 + T_{HAST}}\right)\right\} \quad (3.11)$$

If we insert the various temperatures into this formula and do the calculations, we obtain the acceleration factors in Table 1 depending on the different values for E.

Table 1 Acceleration factors for TH tests in HAST

E (eV)		0.6	0.8	1.0	1.2	1.5
HAST	110°C	3.56	5.43	8.29	12.7	23.9
	120°C	5.65	10.1	17.9	31.9	75.8
	130°C	8.77	18.1	37.3	76.6	228
	140°C	13.3	31.6	74.8	177	647

Note: The values of E, the activation energy, are values obtained from typical failure modes of semiconductor devices, but please regard these numerical values as strictly hypothetical.

Next, from the results of HAST (130°C and 85 percent RH), let's try to predict the corresponding product life for a product submitted to the test, and let's say that the product will be used in Japan in a typical Japanese summer environment of 35°C and 85 percent RH. Let's take the lower limit for the value of E as 0.8 and the upper limit as 1.0.

Predicted life when E = 0.8

$$L_{E=0.8} = \exp\left\{1.16 \times 10^4 \times 0.8 \times \left(\frac{1}{273 + 35} - \frac{1}{273 + 130}\right)\right\}$$

=1268.512 ⟶ approximately 1200 times

Predicted life when E = 1.0

$$L_{E=1.0} = \exp\left\{1.16 \times 10^4 \times 1.0 \times \left(\frac{1}{273 + 35} - \frac{1}{273 + 130}\right)\right\}$$

=7570.39 ⟶ approximately 7500 times

Therefore, if we perform a 48-hour test using the above test conditions, and we say that failure did not occur, the product life in the field would be:

For E = 0.8: 48 × 1200 = 57,600 hours = 6.5 equivalent years

For E = 1.0: 48 × 7500 = 360,000 hours = 41.0 equivalent years

5. *Constructing accelerated tests*

5-1 The acceleration factor

When we discuss accelerated testing, our immediate greatest concern is the acceleration factor.

By the way, we are often told, "We would like to perform humidity endurance testing for a certain product, but at what level should we estimate the acceleration factor, and what test conditions should we use?" Well, there is no acceleration test that corresponds unconditionally even to any one product, and moreover, there is no acceleration factor that can be applied unconditionally with no preconditions at all. The related references and research papers contain notations of acceleration factors as test results for specific products, and for those of you who are considering testing this may look like something you just "gotta have", but wait just a minute. Previously, we introduced the matter of "preconditions". Do those references and research papers include the details of those "preconditions"? Unfortunately, in most cases those preconditions simply don't exist, and the details of the course and conditions of the test have been omitted. As these are not completely hypothetical discussions, they should serve as a reference, but they are, after all, other people's data, and you'll have to decide for yourself whether you can rely on them in your own circumstances.

There are three variables (E, T_1, and T_2) in formula (3.10), given earlier for finding the extremely simple acceleration factor. We have nothing to say at this point about T_1 and T_2, but E is crucial. It is the value for activation energy, and as we saw in the previous example, even a slight change in this value can yield a prediction for product life that is about six times longer. Therefore, the actual value of E must be found at all costs from the experimental data itself.

Well, how should we go about finding the value of E?

5-2 Constructing conditions for an acceleration test (1)

First of all, rather than indulge in excessive explanations, let's try to solve the following example.

Question

Preliminary testing of a certain product found that the MTTF (mean time to failure) was 310 hours at 150°C, 1000 hours at 125°C, and 4000 hours at 100°C. Let's hypothesize that the failure mechanism for this product does not change at temperatures between 75 and 150°C, and answer the following questions.

(1) Find the activation energy, then find the MTTF at 75°C.

(2) Indicate whether a test should be run to find how many hours MTTF will be at 125°C to prove that MTTF is 5000 hours at 75°C.

Answers

(1)

a) First of all, arrange the preconditions as follows.

L_{150} = 310-hour life at 150°C

L_{125} = 1000-hour life at 125°C

L_{100} = 4000-hour life at 100°C

b) Next, using the second of the two formulas in (3.10), change the formula to find *E*.

$$\ln\frac{L_2}{L_1} = \left[\frac{E}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right]$$

$$\rightarrow E = \frac{R(\ln L_{100} / L_{150})}{\left[\frac{1}{T_{100}} - \frac{1}{T_{150}}\right]} \quad (3.11)$$

If we substitute the actual values in formula (3.11), we get

$$E = \frac{8.615 \times 10^{-5}(1n\ 4000/310)}{\frac{1}{273+100} - \frac{1}{273+150}}$$

$$= 0.68(eV) \text{ ... the activation energy}$$

c) Since we have found the activation energy, let's see what sort of ratio exists between L_{100} (T = 100°C) and L_{75} (T = 75°C).

$$\ln\frac{L_{75}}{L_{100}} = \frac{0.68}{8.615 \times 10^{-5}}\left(\frac{1}{273+75} - \frac{1}{273+100}\right)$$

$$= 1.523$$

$\therefore L_{75}/L_{100}$ = exp 1.523=4.59 (the acceleration level between L_{75} and L_{100})

Since the MTTF is 4000 hours when T = 100°C, we can find the MTTF when T = 75°C by calculating 4000(hr) × 4.59 = 18,360(hr).

(2)

Using the MTTF for T = 75°C found above in part (1), find the acceleration factor between L_{75} and L_{125}.

Ac = L_{75}/L_{125} = 18,360hr/1,000hr = 18.36

Therefore, to prove that MTTF is 5000 hours at temperature conditions of 75°C, the conditions at 125°C would be 5000(hr)/18.36 = 272.33(hr). In other words, a test of approximately 272 hours would be required.

(When solving this sort of problem, in addition to methods such as the above relying entirely upon using formulas to calculate the answers, one can also use the Arrehnius plot using semi-logarithmic paper. Due to space limitations we cannot deal with that method in this report.)

5-3 Constructing an acceleration test (2)

From the example in section 5-2, we have seen an overview of how to construct an acceleration test. Namely,

(1) Since product tolerances for the ambient environment are set in the product planning and design stage, pretesting should be done, and just as in this example, test conditions should be separated into several stages to find the MTTF.

(2) In an attempt to shorten testing time, these pretests are begun from temperatures thought to be at the upper limits of product heat endurance. However, you have a small number of specimens and you are collecting a wide variety of technical data in the course leading up to product failure, then you should start from low temperatures. In the example, acceleration testing was constructed for tests at low temperatures, but if the product has a high temperature tolerance, then high temperatures can be used to find test times.

(3) Perform failure analysis for products that fail at each stage, and analyze the mechanism leading to failure. Since obtaining identical failure modes is a precondition for accelerated testing conditions, it is extremely important to check analysis work and results. (At this time, it is also important to analyze products that did not lead to failure. A comparison of good products with failed products can be a conclusive factor in determining product quality, and can also be a basis for improvement measures.)

(4) As you can see, the conditions for accelerated testing are determined at the stage of pretesting and analyzing the pretest results. More time is required for constructing an accelerated test than for carrying out the test. When there are no systematic relations, there can be no accelerated testing.

(5) The following two methods are used to reveal acceleration. In the example, we used method number 1 below to calculate acceleration.

1. One method is to use proportionate time and attain an equivalent cumulative failure rate to compare accelerated testing and tests run at standard conditions.

$$\textbf{Degree of acceleration} = \frac{\textbf{Time required at standard conditions}}{\textbf{Time required at accelerated conditions}}$$

2. Another method is to use proportionate time for the failure rate at a specific time to compare accelerated testing and tests run at standard conditions.

$$\textbf{Degree of acceleration} = \frac{\textbf{Failure rate at accelerated conditions}}{\textbf{Failure rate at standard conditions}}$$

In general, the first method is more widely used.

6. Conclusion

When considering accelerated testing from the standpoint of the reliability of an individual product, the preceding examples show that it can be relatively dangerous to assume that you can just use the same test conditions that another company has used. In particular, when applying the chemical kinetics model, the key to success is the value of *E*, the activation energy, and this value can be assumed to vary with different products. Even among products with the same types of functions, there will be slight variance among different manufacturers in raw materials, design details, and manufacturing methods. This “slight variance” can have a considerable impact on the value of *E*.

If you should feel that, “It’s the same type of product, and seen from the current level of technology, there should be very little difference from our company in materials, design details, and manufacturing methods,” we must concede the possibility of opening reference literature or other research papers and utilizing the values of *E* given there. However, it will not be possible to ascertain whether these values are actually applicable to your company’s product. You should keep in mind that the reliability testing results and the predicted life calculated using these values may be lacking in accuracy.

Up to this point we have been discussing individual accelerated tests, but actually it is possible to predict the failure rate without relying on testing, though this is limited to electronic parts. This can be done by using such procedures as MIL-HDBK-217F Reliability prediction of electronic equipment, and the Bellcore TR332 ISS05 Reliability prediction procedure. The former, being “MIL” naturally is used by the US military for electronic parts, but since it is based on field data, it has a high level of precision, and is very useful as a reference. However, it requires some modification for application to civilian parts. The latter is based on MIL-HDBK-217, and consists of purchasing specifications establishing an independent evaluation method.

[Bibliography]

1) Hisashi Mine, “Reliability Technology to Make Troubles Zero”, Union of Japanese Scientists and Engineers Publication, (1990)
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Report 1

Evaluation validity in systems with continuous, automatic measurement

Kunikazu Ishii*

Rapid strides are being made in miniaturizing electronic equipment while simultaneously offering improved functions and performance. Companies are under pressure to reduce product development time, while equal pressures demand that product safety and reliability be maintained. To handle these opposing demands, both the effectiveness and the accuracy of environmental testing require further improvement. To meet such requirements, we at Tabai Espec are incorporating measurement of electrical characteristics in our environmental test equipment. This arrangement enables us to continually measure specimen characteristics under environmental conditions, and thus grasp real time characteristics when determining malfunction modes. We are currently developing a full line of automatic measuring systems. This report will introduce some aspects of evaluation systems and discuss the effectiveness of automatic measurement systems.

1. Introduction

To produce ever-more-compact electronic equipment, companies are striving to miniaturize chip sizes, especially for chips used in semiconductor IC packages and electronic parts. Complicating the problem has been rapid pace of the development of build-up circuit boards*1, which make high-density mounting possible. Studies of new methods and materials for connecting IC packages are also proceeding at a fever pitch. To further complicate matters, developers are not only working under the constraints of market competitiveness with regard to cost and functions, but they are also working under the constraints of global environmental protection and societal regulations, such as using Pb-free solder*2, meeting VOCs regulations*3 for flux, and developing environmentally friendly printed circuit boards. While handling such a wide variety of requirements, developers must also shorten the development time while maintaining product reliability. To meet these conditions, developers must have a means of accurately and more effectively assessing safety and reliability.

At Tabai Espec, in addition to checking functions and evaluating reliability, we are combining our widely used environmental equipment, and while running environmental tests we are continuously measuring electrical characteristics of specimens. By extracting real time data, we are developing automatic measuring systems that are able to detect malfunctions and failures. In this report, I would like to present some real world examples of evaluations involving continuous measurement of electrical characteristics of specimens in the environments used for these tests. I would also like to discuss the effectiveness of these measurement systems.

2. How evaluation needs to be done

To guarantee reliability of products with complicated advanced functions while covering a wide variety of development requirements in less time than ever before, developers must be able to improve the effectiveness and accuracy of product evaluation. Fig. 1 presents some suggestions for methods to improve the effectiveness and the accuracy of evaluation.

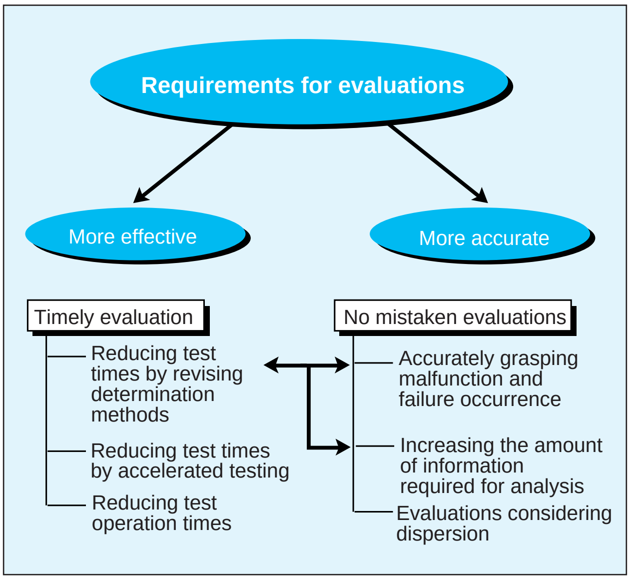


Fig. 1 Requirements for evaluation

*Measurement system integrated group

2-1 Evaluating more effectively

To evaluate more effectively, first of all, the time required to make evaluations must be shortened. Next, test times must be reduced by cutting down the time taken for the test operation itself as well as by revising the determination methods for evaluation. For example, when running a product life test, in the most general evaluation method, failure and relative advantages of different specimens is extrapolated from data measured at specific intervals. In this case, if evaluation could be made with data from shorter measurement intervals, it would be possible to assess product life and malfunctions more quickly and shorten test times. Also, applying accelerated life testing would be very effective in reducing test times. At this point, I would like to discuss reducing test times, and making more efficient evaluations based on data from continuous measurements and more efficient test operations.

2-2 Evaluating more accurately

Current products boasting advanced functions with high-density mounting are experiencing failure modes that did not occur in previous products. These advances mean that even slight changes in characteristics can lead to failure, and so current evaluation practices must be much more strict. To improve evaluation accuracy, there is greater need to be more precise in capturing failure phenomena, and a concurrent need to increase the amount of data used for analysis.

In other words, it is difficult to determine whether failures only occur in specific environments and whether failure will occur unless the product is in such a specific environment. Reproducibility (the ability to predict test results) is also difficult to obtain. For example, continuously measuring specimen characteristics as well as selecting measurement methods that are appropriate to the characteristics of failure modes occurring in the test environment used both are indispensable for detecting insulation deterioration due to ion migration, defective contact due to differences in coefficients of thermal expansion, and fluctuations in resistance values due to cracking.

To clarify failure modes and to more accurately predict product life, we must be able to accurately detect not only the fact of failure occurrence but also the time of occurrence. We must also be able to make our analyses based on data that can contrast fluctuation in specimen characteristics with such environmental conditions as temperature and humidity. We must further maintain a large enough quantity of data to enable us to make statistical determinations that consider dispersion. Since the time of running the test does not change, if we can even slightly increase the amount of data used for analysis, we will be able to obtain more accurate evaluation results.

3. Automatic measurement systems

Fig. 2 shows the basic approach to developing automatic measurement systems that we use at Tabai Espec. Automatic measurement systems combine environmental tests with electrical measuring equipment, making it possible to measure the electrical characteristics of electronic parts and devices in real time under environmental test conditions, and process the resulting data. System hardware and software are designed so that while operating under environmental test conditions, they are able to accurately grasp the data required for evaluation and to capture changes in characteristics that are peculiar to specific modes of failure. Computers are used to fully automate test management, data processing, and control of the environmental test equipment.

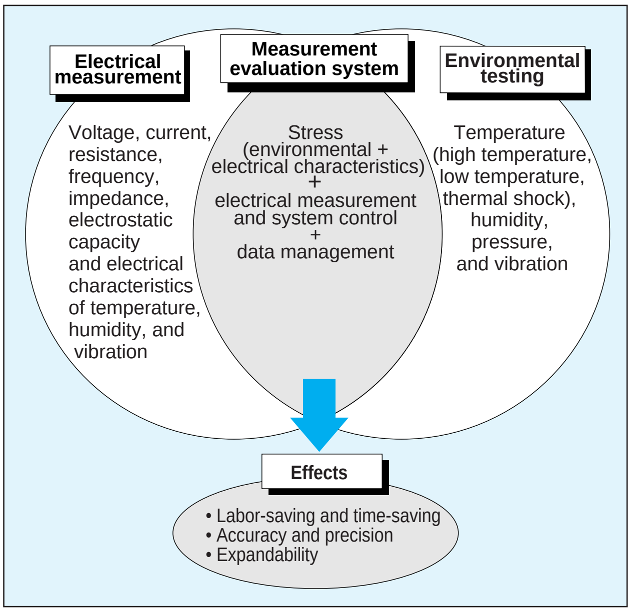


Fig. 2 Basic approach of automatic measuring systems

Our line-up of automatic measurement systems includes such equipment as ion migration evaluation systems, insulation resistance evaluation systems, leakage current measurement systems, and short interruption measurement evaluation systems. (Fig. 3)

Automatic measurement systems

- Conductor resistance evaluation systems
- Ion migration evaluation systems
- Insulation resistance evaluation systems
- Leakage current measurement systems
- Capacitor temperature characteristics of capacitance evaluation systems
- Optic device detection systems
- Electromigration evaluation systems
- Short interruption measurement evaluation systems
- TDDB (Time Dependent Dielectric Breakdown) evaluation systems
- Automated semiconductor parameter evaluation systems

Fig. 3 Main automatic measurement system products

4. *Validity of continuous, automatic measurement*

Now, let's look at the validity of continuous measurements in test environments using examples from evaluating ion migration, solder connection reliability, and short interruptions, and let's consider the possibility of using automatic measurement systems.

4-1 Evaluating ion migration

4-1-1 Necessity of evaluating ion migration

Ion migration is the phenomenon of precipitate growth in the gap between facing or adjacent electrodes on a printed circuit board. This growth results from metal ions from one electrode being reduced as metal at the base of the other electrode.

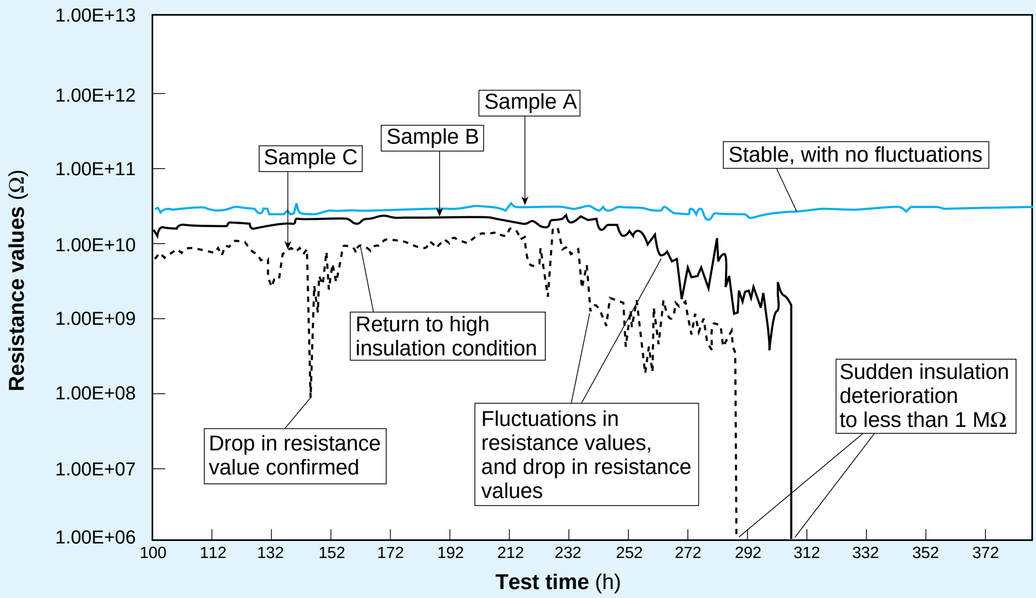
Ion migration can only occur when there is moisture in the presence of an electrical field between the electrodes. In reality, occurrence is usually linked to the effect of impurities on the circuit board that precipitate out on the positive side. Photo 1 shows a picture of a ion migration occurrence in a test using the water drop method. Because it is extremely fragile, the ion migration substance fuses and disappears in a very short instant due to current occurring in the instant of a short circuit.

The ion migration phenomenon has been well known for years. Recently, though, ion migration has been occurring more frequently due to such factors as finer pitches being incorporated in the printed patterns in wiring in IC packages such as BGA*5 in build-up circuit boards. Other factors include stronger electrical fields between the patterns, smaller insulation gaps, impurities in flux residue and new materials, and the impact of humidity absorption due to the portability of the electronic equipment. The fact that ion migration leads quickly to failure places a high priority on evaluation of the phenomenon.

Photo 1 Ion migration

4-1-2 Validity of continuous, automatic measurement in evaluating ion migration

Ion migration is generally evaluated using comb-patterned printed circuit boards as specimens, and applying voltage between the comb-patterned electrodes in a high-temperature, high-humidity environment. The insulation resistance between the electrodes is measured by removing the specimens from the temperature and humidity chamber at specified intervals and measuring them at room temperature. However, using this evaluation method that I have just described, it is possible for the specimen to recover high insulation characteristics at the time of measurement. Therefore, there is a danger that



Measurement period for measuring insulation resistance	30 minutes
Leak-touch detection level	50μA (1MΩ)
Applied stress voltage	50 V DC
Measurement voltage	50 V DC
Environmental conditions	40°C, 90%RH

* In this example, leak-touch detection was confirmed at 291.2 hours and 311.8 hours.
* This data has been converted from data measured by an ion migration evaluation system to text data and has been processed with spreadsheet software.

Fig. 4 Insulation deterioration characteristics under high-temperature, high-humidity conditions

the specimen will be mistakenly determined to have no malfunction, even though a malfunction has occurred. In addition, manually measuring the insulation resistance of each specimen and processing that data is time-consuming and inefficient. To resolve these issues, it would be possible to continuously and automatically measure insulation deterioration and changes in insulation resistance occurring in an extremely short time due to ion migration while applying stress voltage between the electrodes under conditions of high temperature and high humidity. Fig. 4 shows an example of deterioration characteristics obtained by continuously measuring flux insulation resistance in a high-temperature, high-humidity environment.

As you can see from these measurement examples, by measuring insulation resistance under conditions of high temperature and high humidity, we can accurately capture the insulation deterioration characteristics caused by ion migration, as well as the time at which the failure level was attained. From fluctuations in the resistance values, we were able to confirm that a gap exists between specimens at the initial stage when the test started. We were also able to obtain information confirming the major fluctuation in resistance values leading up to failure.

4-1-3 Ion migration evaluation systems

Ion migration evaluation systems require the ability to detect insulation deterioration at high speed under environmental test conditions, as well as the ability to accurately measure changes in insulation resistance. A truly convenient system should have linked control with the environmental test equipment, and be able to perform simultaneous graphing of insulation resistance values and the test environment (such as temperature and humidity). It should also process data on a LAN and be able to confirm operating conditions.

Let's look at a real world example of an ion migration evaluation system. (Photo 2)

This system can accurately measure insulation resistance on the order of 10^{13} Ω, and by detecting leak-touch can detect changes in insulation resistance in an extremely short time when ion migration occurs.

Photo 2 Ion Migration Evaluation System AMI-025-P (left), and Temperature and Humidity Chamber (right)

Table 1 Main specifications

Item	Specifications
Model	AMI-025-P
Measurement range	1×10^6 Ω to 3×10^{13} Ω (measurement cable tip)
Measurement interval	Min.0.1 hour (in 0.1 hour steps)
Leak-touch detection range	1 to 100 μA
Leak-touch detection speed	μ seconds order
Measurement voltage	3V to 100V DC
Applied stress voltage	3V to 100V DC (Can be set independent of measurement voltage)
Number of measurement channels	Standard: 25 channels Maximum: 1 rack, 150 channels
Power requirement	100V AC, single phase 15A

* Measurement voltage and applied stress voltage can be up to 500 V.

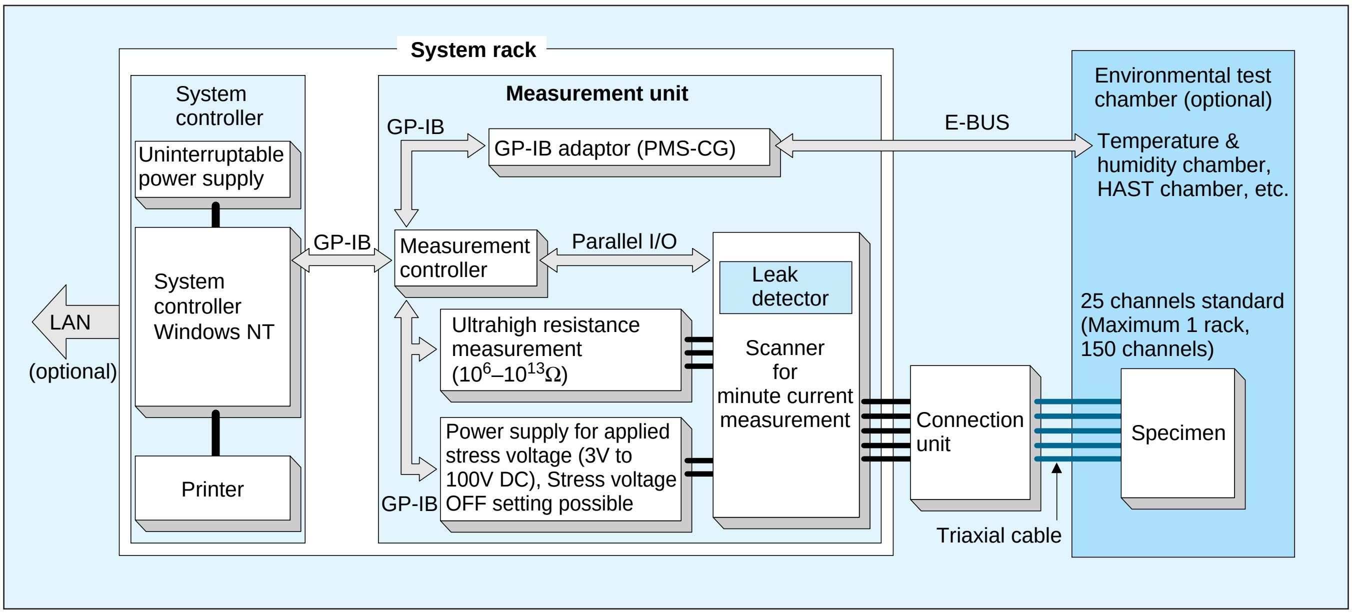


Fig. 5 System Block Diagram

The standard unit also uses a scanner to switch among measuring up to 25 specimens. The scanner uses specially developed high resistance measurement to achieve stable measurement in the high resistance range. Other features include a converter for linking environmental test equipment to the power source for applying stress voltage, a special cable for measuring high insulation resistance, a relay unit, and a control computer. All units required for tests can be placed on a single rack. Fig. 5 shows the system layout, while Table 1 shows the main specifications.

4-2 Evaluating reliability of solder connections

4-2-1 The need for evaluating reliability of connections

The appearance of build-up circuit boards and array type IC packages such as BGA and CSP*6 has dramatically increased mounting density, bringing about a great leap forward in product miniaturization.

However, since BGA and CSP are directly connected to the printed circuit board pattern using balls of solder covering the bottom surface of the package, the difference between the coefficient of thermal expansion of the package and that of the circuit board results in stress that cannot be dispersed or alleviated, with the result that this stress becomes focused on the solder. As a result, the stress is known to appear as cracking in the solder connection, and this factor causes the loss of connection reliability. The miniaturization of electronic parts has also had the effect of making the equipment tend to be more strongly affected by internal heat, and to increase stress due to the greater differences in coefficient of thermal expansion resulting from the greater temperature gap between the operating temperature and idle temperature. On the other hand, because of package miniaturization, the connections are also miniaturized and thus have less connection strength, increasing the necessity of evaluating connection reliability.

4-2-2 Validity of continuous, automatic measurement in evaluating connection reliability

When evaluating connection reliability, temperature cycle testing is used for environmental conditions to evaluate the impact of stress generated by the differences in coefficients of thermal expansion among each component material. To evaluate the connection condition, at each specified cycle (e.g., when running a 1,000-cycle test, at cycles 100, 250, 500, and 750) the specimens are removed from the test chamber, and the resistance of the connections is measured at room temperature, and the values are compared to the initial values and the specimens are inspected visually. However, in this method, even when cracking occurs in connections under environmental conditions (especially when exposed to high temperatures) of temperature cycle tests, the cracked surfaces become electrically connected at room temperatures, and no changes show up in resistance values. Therefore, it is difficult to accurately capture the occurrence of cracking in resistance measurements at room temperatures. With BGA and CSP, the connections are on the package bottom surfaces and so are difficult to evaluate through observation. Visual inspection is also difficult in other cases such as when the connections are covered with resin.

These problems could be resolved in an extremely effective manner if we could continuously capture changes in connection resistance values under temperature cycle test conditions and evaluate the increase in those resistance values as substitute characteristics for the occurrence of cracking. Compared to the conventional method, this approach would make it possible to evaluate more accurately (detecting failure) and more efficiently (determining malfunctions within the optimum test time).

Fig. 6 shows an example of characteristics when continuously measuring changes in resistance values of solder connections (BGA) under temperature cycle test conditions. After 320 cycles, the resistance of sample A and sample B were measured at room temperature, and showed no major changes compared with initial values. However, the continuous measurement data revealed that sample B had major changes in resistance on the order of kΩ changes in the high-temperature region of around 307 cycles. Evaluating with this method, we are able to determine that failure has indeed occurred and we are able to accurately capture the time of failure (the cycle number). By observing the progress during the test, we are able to instantly determine malfunction occurrence and the relative merits of the various samples from changes in characteristics leading to the failure level, and this is connected to reducing the test time.

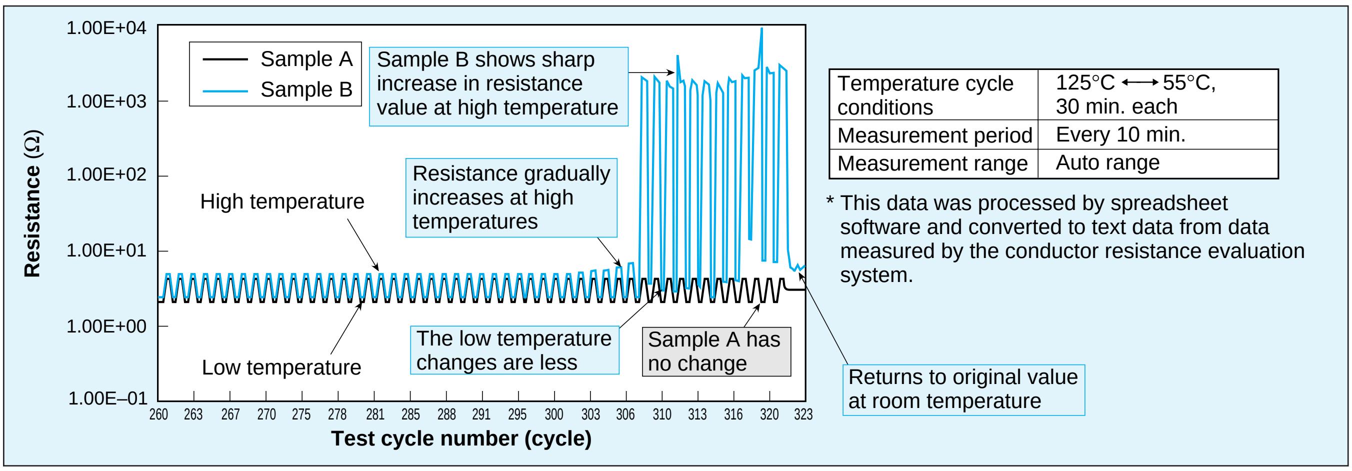


Fig. 6 Conductor resistance change characteristics under temperature cycle test conditions

4-2-3 Evaluation system for printed circuit board and solder conductor resistance

Next, let's consider real world examples of evaluation systems for printed circuit board and solder conductor resistance. (Photo 3) This system is used with environmental test equipment such as thermal shock chambers, and so the equipment provides such functions as automatically measuring specimen resistance under test environment conditions, processing data of resistance value changes that can cause cracking, and determining malfunctions. Fig.7 presents a layout diagram, and Table 2 gives the main specifications.

Photo 3 AMR-040-P Evaluation system for printed circuit board and solder conductor resistance (left), and TSA-70L Thermal shock chamber (right)

Table 2 Main specifications

Item	Specifications
Model	AMR-040-P
Measurement ranges	1×10^{-3} Ω to 3×10^{4} Ω (measurement cable tip)
Measurement interval	Min. 6 seconds (10 channels), (in 0.1 hour steps)
Measurement ranges	10mΩ, 100mΩ, 1Ω, 100Ω, 1kΩ, 10kΩ and automatic range
Measurement frequency	1kHz
Maximum voltage applied	20mV
Measurement method	4-terminal measurement method (end of measurement cable)
Number of measurement channels	40channels standard, Max. 280 channels
Power requirement	100V AC, single phase 15A

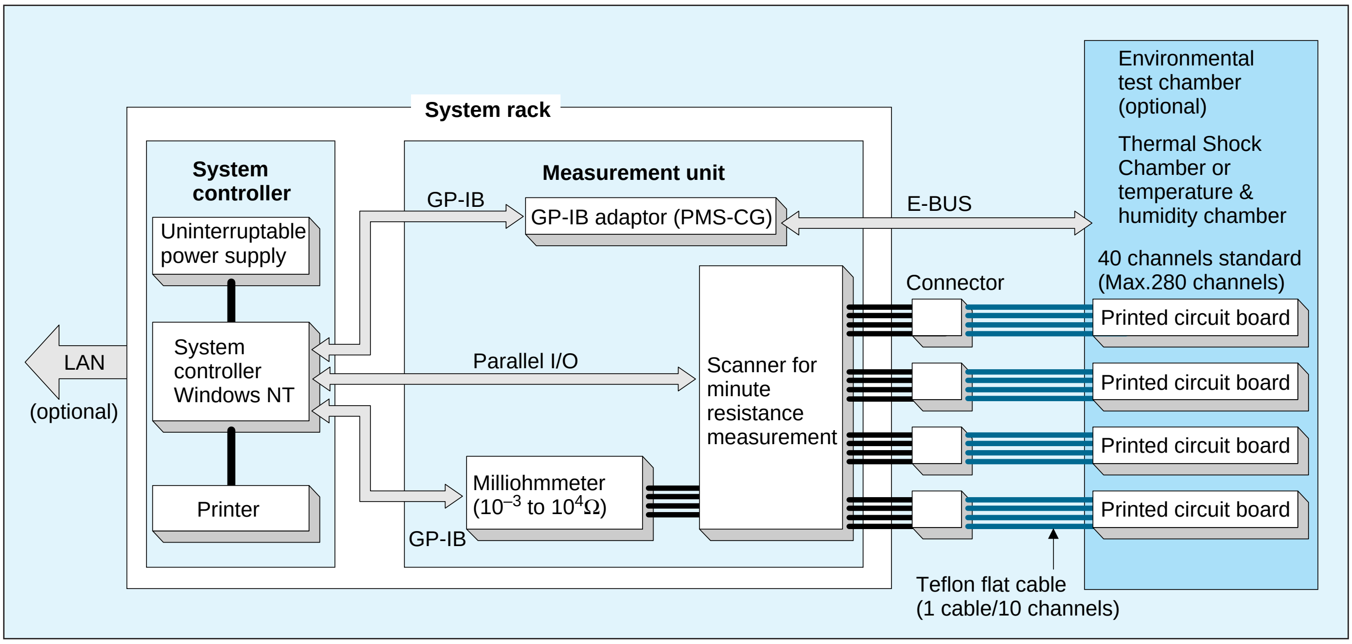


Fig. 7 System Block Diagram

4-3 Evaluating short interruption

4-3-1 The need for evaluating short interruption

Electronic equipment with advanced functions suffers problems from conditions that did not cause trouble for previous equipment, and so we must be aware that even slight changes in characteristics can lead to failure. One such factor that can cause failure is short interruption (circuit connection is cut off for an instant).

Conventionally, short interruption has been evaluated using connection equipment such as connectors and relays used in electronic equipment mounted in automobiles under test environment conditions with severe vibration. However, more recently, the portability of general electronic equipment has led to a higher probability of its being subjected to vibration. As a result, there is now an even greater need to evaluate this phenomenon to prevent the resultant instantaneous signal cut-off from causing mistaken operation with serious repercussions to product life.

4-3-2 Problems in evaluating short interruption

The general approach to evaluating short interruption is to apply vibration to the specimen and take measurements to determine whether short interruption occurs at points of contact and connections.

The guideline for determining failure in the test is usually, "short interruption did not occur for a minimum of 1µsec." The method of measuring short interruption, as shown in Fig.8 using a connector as an example, is to apply steady current to the point of connection with the connector engaged, and use the trigger function of an oscilloscope or memory recorder to detect a voltage surge for an extremely short instant at the point of contact.

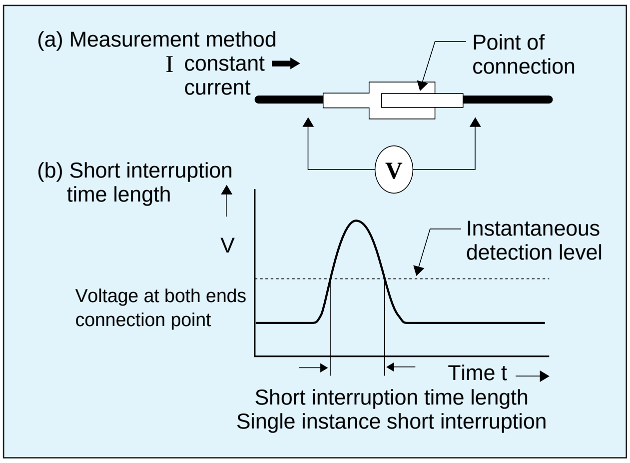


Fig. 8 Method of measuring short interruption

However, testing multiple specimens with this method would require as many measuring instruments as specimens. From the standpoint of cost, the limited number of specimens that can be tested simultaneously becomes a problem. Furthermore, this method cannot be used to continuously measure occurrences of short interruption, nor can it connect the occurrence of the phenomenon to the vibration at that point in time. These limitation mean that this approach cannot provide the amount of useful information we would like to have.

4-3-3 Short interruption evaluation systems

Short interruption evaluation systems are able to collect and record data under conditions of vibration test and thermal shock environments. These systems can measure the number of multiple occurrences of continuous short interruption of multiple specimens, the time length of each occurrence, the vibration frequency and acceleration, and the temperature. (Photo 4) Fig.9 shows the system layout, and Table 3 presents the main specifications.

Photo 4 Weather-Proof Vibration Shaker (left), Connector short interruption evaluation system (center), and temperature and humidity chamber (right)

Table 3 Main specifications

Item	Specifications
Model	AES-005
Applied current	1 mA to 100 mA DC, in 1 mA steps
Short interruption detection level	0.5 V to 2.0 V DC
Short interruption time length	Min. 500 nsec. (Min. resolution, 100 nsec.)
Short interruption occurrence count	Max. 500 times
Measurement items	Number of occurrences of short interruption, shot interruption time length, vibration condition at time of detection of short interruption (optional)
Number of measurement channels	Standard, 5 channels Max. 75 channels
Power requirement	100V AC, single phase 15A

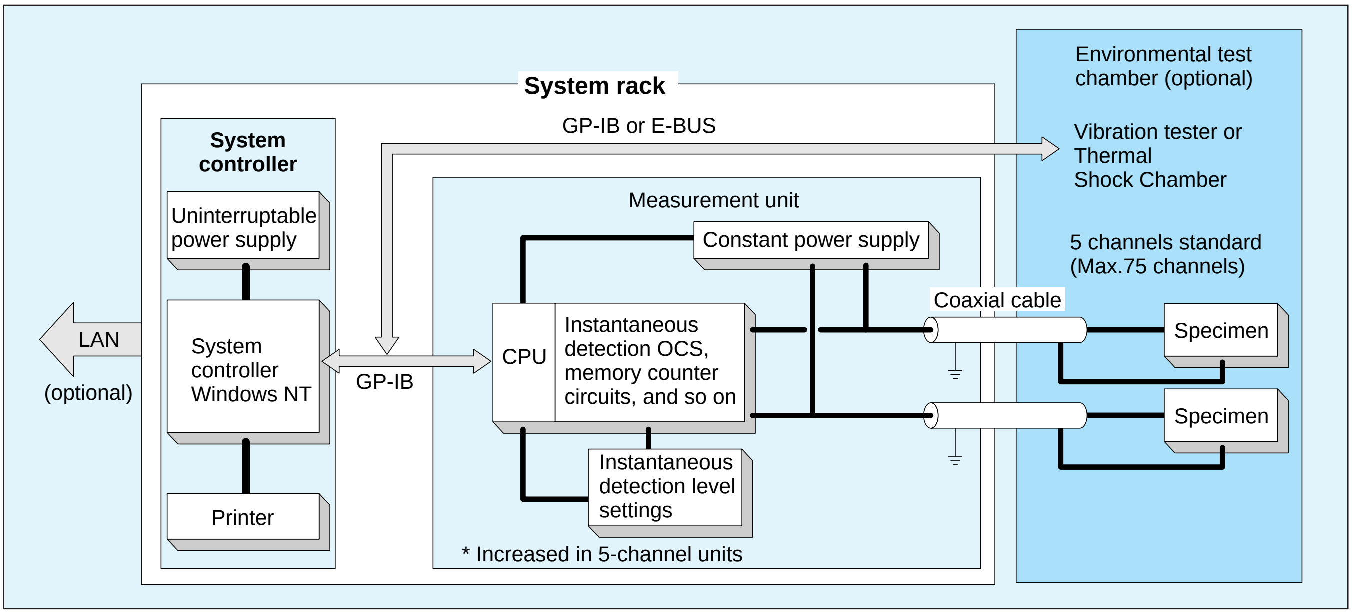


Fig. 9 System Block Diagram

4-3-4 Examples of continuous, automatic evaluation in short interruption evaluation systems

Next, I would like to present an example of using a short interruption evaluation system to continuously measure short interruption occurrence at a relay contact point.

To confirm the occurrence of short interruption due to vibration at a relay contact point, a measurement cable from the short interruption evaluation system is connected to the relay contact point and a vibration test is run. The results, as seen in Fig. 10, reveal 57 occurrences of short interruption in one sweep from 10 Hz to 100 Hz. The maximum length of time for short interruption is found to be 3.4µsec.

(Measurement conditions are:

(1) applied current, 1 mA,

(2) detection level for short interruption, 0.5 V,

(3) length of time for short interruption, detected over 500 nsec.,

(4) vibration conditions: Refer to Fig.11 for vibration test conditions.

Note: since the vibration conditions were used to generate short interruption, the conditions were much more severe than usual.)

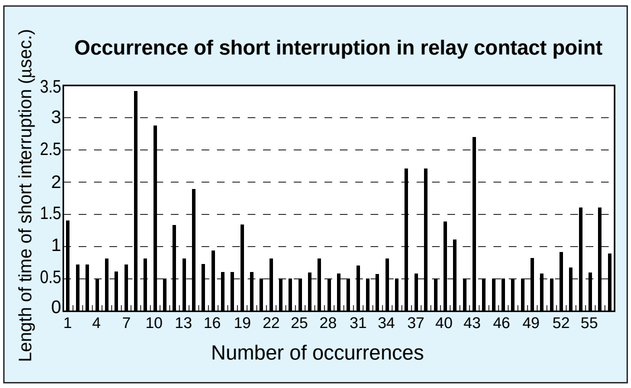


Fig. 10 Test results

Short interruption measurement conditions

Item	Condition
Test current	1mA
Filter value	0.5µsec
Determination voltage	0.5V
Test cycles completed	500 times

Vibration test conditions

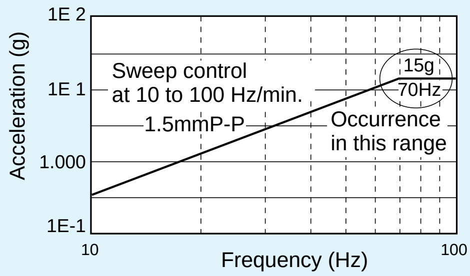


Fig. 11 Vibration test conditions

When the number of occurrences of short interruption and the length of each occurrence can be continuously measured in this way, we can much more easily grasp the characteristics in relation to elapsed time and test conditions. Furthermore, by simultaneously collecting and recording the data under conditions generating the short interruption (e.g., vibration frequency, sweep time, and temperature), we are able to obtain valid data for evaluation. Because we are also able to test multiple specimens simultaneously, we can compare specimen differences and see product dispersion. Testing not only becomes easier, evaluation becomes more accurate and more efficient.

This system can also be used with temperature cycle test conditions to evaluate whether defective contact is generated for extremely short times due to differences in thermal expansion coefficients of various connection materials and connection parts.

5. Conclusion

Combing automated systems with environmental tests and measurement and data processing enables us to attain exceptional improvement in evaluation efficiency. Using data from continuous measurements under test environment conditions, we can capture previously unknown phenomena and achieve more accurate evaluation results. We are very confident that this advanced testing method will prove to be an extremely effective tool for evaluation.

Terminology

* 1 Build-up circuit board
A high-density printed circuit board using a copper-clad laminate as a core, and having alternate conductive and insulating layers (optic-sensitive resin) build-up on top of the core.

* 2 Pb-free solder
The toxicity of lead in solder has come to be regarded as an environmental problem. When solder is exposed to rain, the lead leaches out of the solder and is thought to pollute the soil and the subterranean water supply, and so efforts are under way to regulate the use of lead. Because of this, developers are working to create Pb-free solder compounds.

* 3 VOCs (Volatile Organic Compounds) regulations
VOCs refer to chemical compounds such as PAN (Peroxyacetylnitrate) and optical oxidants formed in reaction to ultraviolet rays when both NOx and organic compounds with low boiling points are present. These substances may be harmful to humans and animals, and so legislation has been proposed to eliminate the use of VOCs in Europe and America.

* 4 Environmentally-friendly printed circuit boards
Fireproof electrical equipment is in high demand from the standpoint of safety. Halogen compounds are used on printed circuit boards for their fireproof quality, but these present dangers of creating organic toxins such as dioxin and benzofuran when incinerated. Environmentally-friendly printed circuit boards are those being developed that do not rely on the use of halogen-based fireproofing.

* 5 BGA (Ball Grid Array)
BGAs are IC packages capable of high-density mounting. The bottom surface of the package serves as the connecting end to the circuit board, and balls of solder are arranged in a grid pattern on the bottom surface for mounting.

* 6 CSP (Chip Size Package)
CSPs are also IC packages capable of high-density mounting. They are surface-mounted packages that are constructed the same size as semiconductor chips, or equivalent to BGA size.

Report 2

Investigating the effects of packaging materials on products

Hiroko Inoki*, Yuichi Aoki*, Hirokazu Tanaka*, Shigeharu Yamamoto*

Modern packaging materials emit naturally-occurring gas that can corrode the metal parts of the products. To investigate this problem, we developed methods for testing and evaluating the Outgas. Our investigation revealed the source of corrosion to be sulfuration due to hydrogen sulfide (H_2S) emitted by the packaging materials. Sulfuration varies with temperature, set-up conditions, and the quantity of the Outgas. To insure product reliability, care must be taken with the type of packaging materials used, the packaging method, and the temperature during shipping.

1. Introduction

With the introduction of the Product Liability law, maintaining and supervising product reliability has become an urgent necessity. Modern products have attained very high levels of product reliability, but product failure may also result from packaging and shipping conditions[1]. Various reports have been published concerning the packaging problem, and awareness has been growing of the impact packaging materials have on the products they contain[2), 3)].

On the other hand, burgeoning concern for environmental problems has resulted in serious efforts to recycle paper and to simplify packaging. Efforts to replace styrofoam with corrugated cardboard as a cushioning material have been gaining ground due to the lack of satisfactory techniques for recycling styrofoam. These changes in packaging can be seen as factors having an impact on the products[4].

Accordingly, for this report we focused our attention on the corrugated cardboard used in packaging, shipping, and storing products, and we investigated the effects of temperature and various types of corrugated cardboard on products.

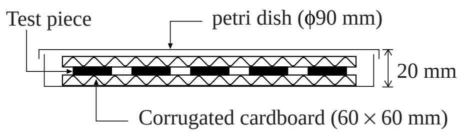
2. Test method considerations

Sulfuric acid is used in the refinement of pulp, which is the raw material for corrugated cardboard. Residual sulfuric acid ions in the corrugated cardboard produce H_2S gas, and this gas is widely known to cause discoloration and degradation[2]. We investigated methods of testing the affects on metal of gases emitted from various kinds of corrugated cardboard.

2-1 Preliminary Test 1: determining specimens

We performed preliminary testing to determine the types of corrugated cardboard and the test pieces to be used in the tests. Table 1 shows test conditions. The test method consisted of holding a test piece between two sheets of corrugated cardboard (60 × 60 mm) and exposing it to high temperature. We selected 80°C with 24-hour exposure for test conditions to reflect the transportation environment encountered by products shipped via sea freight[5]. Table 2 shows test results.

Table 1 Test conditions for Preliminary Test 1

Corrugated cardboard	11 types
Test pieces	Silver-plated, copper, aluminum, stainless steel
Test conditions	80ºC, 24 hours
Test conditions	

*Environmental Test Technology Center

Table 2 Test results for Preliminary Test 1

Corrugated cardboard				Results (discoloration)	
Application	Type	Packaged item	Producing country	Silver	Copper
Electrical equipment	A*	Transformer	Japan	×	△
	B	Power supply	Japan	×	△
	C*	Power supply	Philippines	×	△
	D	Power supply	Japan	×	△
	E	Instrument	Japan	×	△
Electronic parts	F*	IC	Thailand	△	○
	G	IC	Japan	○	◎
	H	IC	USA	△	○
Office equipment	I*	Printer	Japan	△	○
	J	Computer	Malaysia	△	○
	K	Computer	Singapore	○	○

Note 1: Asterisks (∗) indicate selected for main test
Note 2: Discoloration severity (as judged by visual inspection)
◎ No discoloration × Moderate discloration
○ Slight discoloration △ Severe discoloration

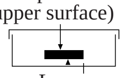
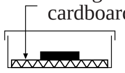
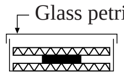
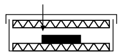
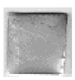
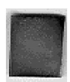
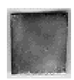
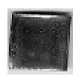
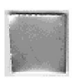
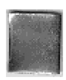
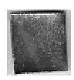
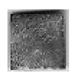
Silver-plated and copper pieces showed discoloration, while no discoloration was observed on aluminum or stainless steel pieces. Therefore, we selected silver-plated pieces for testing to facilitate comparing the different types of corrugated cardboard, as the silver-plated pieces sustained the most severe discoloration. Furthermore, electrical products were strongly affected by corrugated cardboard packaging, while electronic products and office equipment were relatively unaffected. Since there was a tendency for comparable levels of discoloration to occur within the same type of application, we ran this test by making random checks of one or two items in each application category of corrugated cardboard.

2-2 Preliminary Test 2: set-up condition considerations

We performed testing to determine the discoloration effects of set-up conditions on silver-plated test pieces. The test method consisted of exposing the test pieces to a temperature of 80°C for 40 hours, removing the silver-plated test pieces, and visually inspecting both the top and bottom surfaces. Table 3 shows the test methods and results.

A comparison of the surfaces of the silver-plated test pieces showed that surfaces not in contact with the corrugated cardboard were much more severely discolored than contact surfaces. Discoloration is presumed to have progressed due to the silver-plated test pieces being exposed to the convection currents of the gas generated. On the other hand, lack of discoloration on the surfaces in contact may be presumed to have resulted conversely from the lack of exposure to the convection currents. Therefore, the set-up was arranged to facilitate exposure to the convection currents of the gas, promoting ease of evaluation of the corrugated cardboard.

Table 3 Preliminary Test 2: A comparison of test results under differing conditions

			1. None	2. Inserted on one side	3. Inserted on both sides	4. With gap
Set-up 4 conditions						
Results	External	Upper		 Non-contact surface	 Contact surface	 Non-contact surface
		Lower		 Contact surface	 Contact surface	 Contact surface
	Charac-teristics		• No discoloration	• Slight discoloration in contact surface • Advanced discoloration in non-contact surface.	• Slight discoloration in contact surfaces	• Slight discoloration in contact surface • Very advanced discol-oration in non-contact surface

Note: "Contact" and "non-contact" indicate the condition of the silver-plated test piece in relation to the corrugated cardboard.

3. Test methods

We then tested the four types of corrugated cardboard (A, C, F, & I in Table 2) that had been selected with the preliminary tests. Table 4 shows test conditions, and Fig.1 shows test methods. A weight of 30 g was deemed suitable for determining the level of corrosion caused by corrugated cardboard. Each type of corrugated cardboard was put into 900 mL glass bottles, and then a silver-plated test piece was dangled from the lid, which was sealed. These specimens were then exposed to 40°C or 80°C heat for 100, 200, or 300 hours. The silver-plated test pieces were hung so that they would dangle at a distance of 2 to 3 mm above the corrugated cardboard. Each type of corrugated cardboard was evaluated by observing the appearance of the silver-plated test piece, by EPMA analysis*1, by contact resistance measurement, and by solderability testing by the wetting balance method.*2

Table 4 Test conditions

Test conditions	40°C, 80°C
Test time	100, 200, 300h
Corrugated cardboard	4 types (A, C, F, & I in Table 2) Weight: 30 g
Test pieces	Material: Silver-plated test pieces Dimensions: 50 × 20 × 0.2 mm Plating thickness: 3µm

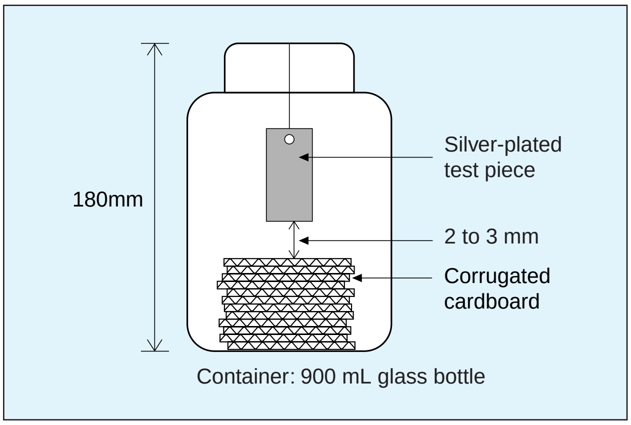


Fig. 1 Test method

4. Results and observations

4-1 Appearance

The silver-plated test pieces were scanned, and the scanned images were examined. Fig. 2 shows test results.

Discoloration was much more pronounced at 80°C than at 40°C, and the test confirmed that the higher the temperature, the greater the discoloration of the test pieces. This correlation stems from the temperature's effect of increasing the sulfuration reaction speed, but we hypothesize that the temperature may also increase the quantity of gas produced. One characteristic of the discoloration was that it progressed from the four corners of the silver-plated test pieces. In comparing the effects of the different types of corrugated cardboard, type C (for electrical equipment and power supply) was found to cause the greatest discoloration.

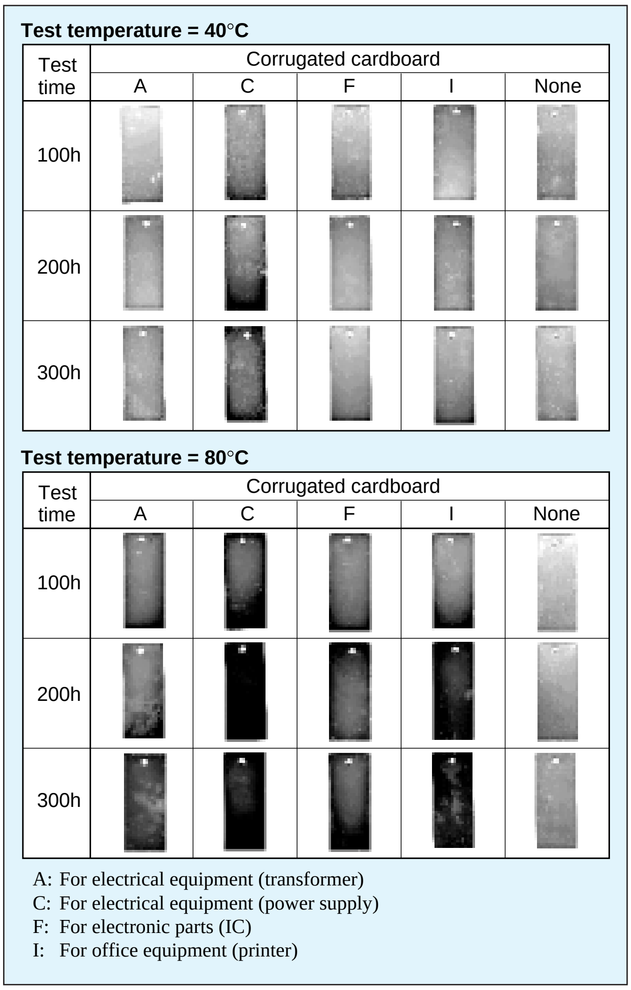


Fig. 2 Appearance results

4-2 Surface analysis

We performed EPMA analyses on the surfaces of the silver-plated test pieces. The analytical method consisted of measuring the degree of discoloration at the four corners (where it was more severe) of each silver-plated test piece. We then found the average value for the level of sulfuration (by weight percent). Fig. 3 shows the measurement results for the level of sulfuration by EPMA analysis.

Using EPMA analysis, we checked the sulfuration of the silver caused by each type of corrugated cardboard. The greatest level of sulfuration was found in test pieces with the greatest discoloration, i.e., pieces exposed to corrugated cardboard type C (for electrical equipment and power supply). This finding clearly demonstrated the relationship between sulfuration and discoloration. Furthermore, the level of sulfuration was greater at 80°C than at 40°C, indicating that higher temperature accelerates the sulfuration.

4-3 Measuring contact resistance

We measured the contact resistance of the surfaces of the silver-plated test pieces. The test method consisted of applying contact pressure of approximately 0.098N (10gf) at constant load with an Au probe with curvature radius R = 0.8 mm and measuring with a milli-ohmmeter. Contact points were located at the four corners of the specimens, the same places at which EPMA analyses were done, and we calculated the average measured values. Fig. 4 shows the test results.

The characteristics of the changes in contact resistance due to the different types of corrugated cardboard showed roughly the same tendencies as the degree of discoloration and the level of sulfuration, leading to the conclusion that the results were due to sulfuration. Items with extremely high resistance values attained close to 10 ohms. This level of resistance can easily cause failure due to defective contact and defective soldering.

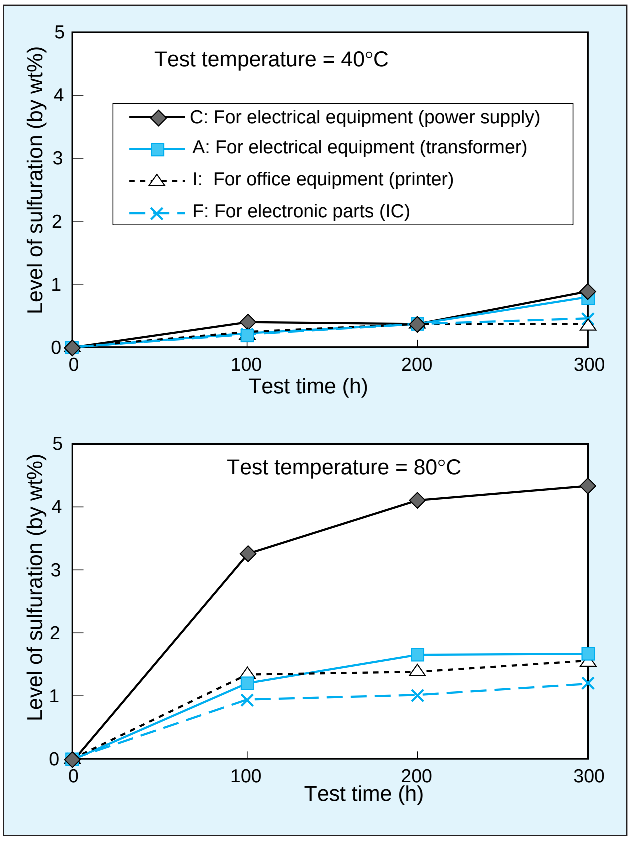


Fig. 3 Level of sulfuration

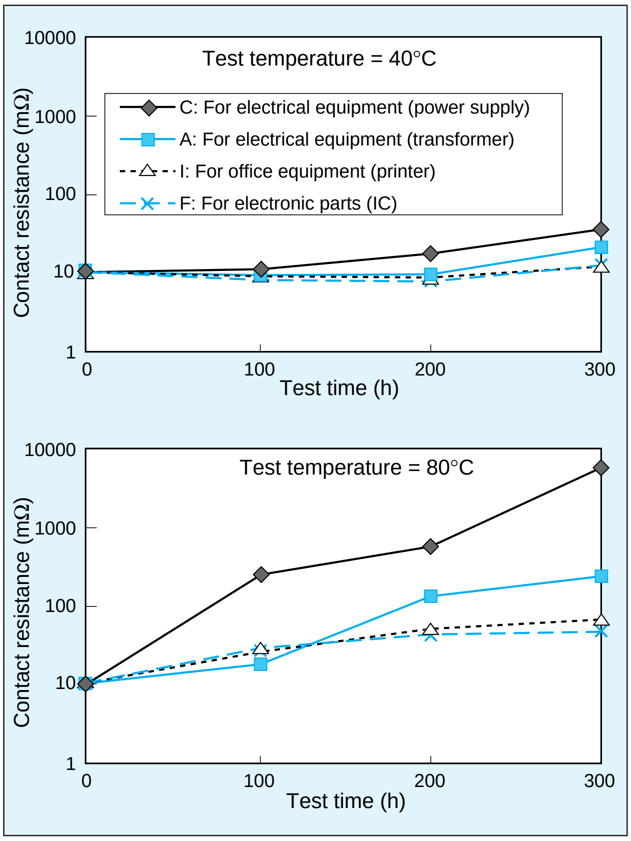


Fig. 4 Contact resistance measurement results

4-4 Solderability testing

To investigate the effect of sulfuration on the condition of the soldered connections, we used solderability testing (wetting balance method) and evaluated zero cross time. Zero cross time indicates the time elapsing from the point at which the test piece is immersed in the solder bath until the force (F) received from the solder bath reaches zero. Fig. 5 shows the principle involved in solderability testing (wetting balance method) and the type chart obtained from the test. Table 5 shows the test conditions.

Table 5 Test conditions for solderability testing

Solder temperature	235°C
Immersion speed	15 mm/sec.
Immersion depth	5 mm
Immersion time	10 sec.
Solder type	H63A (JIS Z 3282)
Flux	Rosin (30% by wt.)

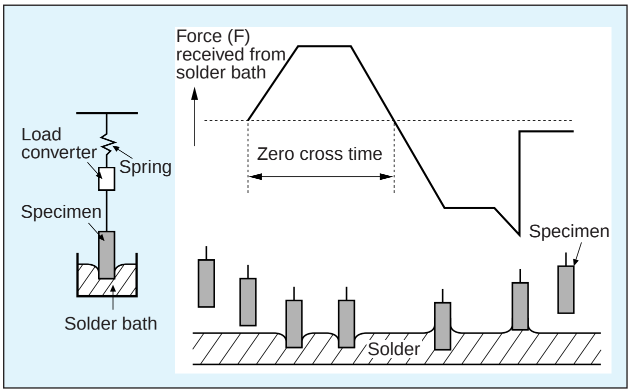


Fig. 5 Principle involved in solderability testing (wetting balance method) and type chart obtained [7]

Fig. 6 shows the results. Smooth wetting was obtained with the test pieces set up without corrugated cardboard, while zero cross time was not even obtained within the 10-second limit for corrugated cardboard types I (for office equipment and printers) and C (for electrical equipment and power supply). Defective appearance was also confirmed for corrugated cardboard types I and C.

These results confirm a deterioration in solder wetting, and indicate that sulfuration has a major impact on the condition of the soldered connections.

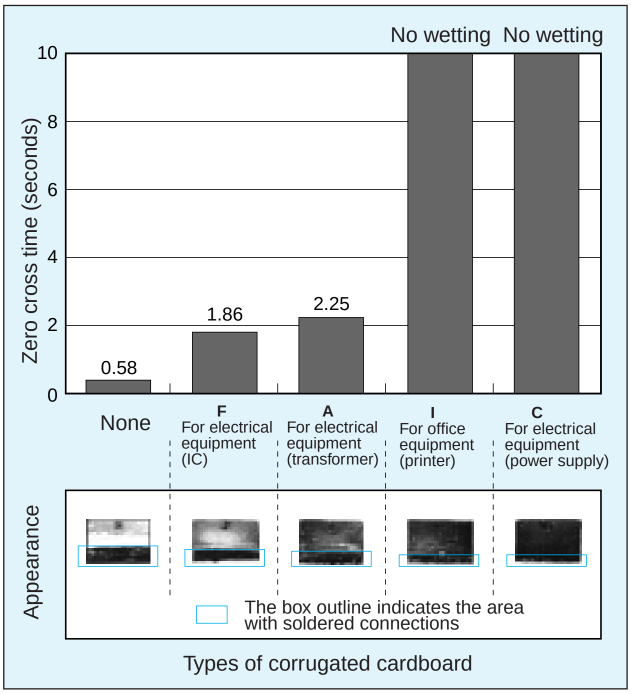


Fig. 6 Test results of solderability testing

5. *Conclusion*

The primary factor in the discoloration and degradation of electrical characteristics in the silver-plated test pieces is the sulfuration resulting from gas emitted from the corrugated cardboard. Sulfuration is controlled by the amount of gas emitted, the temperature conditions, and the set-up conditions. The amount of gas emitted varies with the type of corrugated cardboard, and this variation is determined by the level of residual sulfuric acid ions left by the pulp refinement process. We can also assume that differences in temperature conditions result in changes in the speed of the sulfuration reaction as well as changes in the amount of gas emitted. In addition, differences in set-up conditions produce differences in the amount of exposure to the gas emitted, affecting sulfuration.

Corrugated cardboard is a factor influencing product reliability, and care must be taken in such matters as the type of raw materials used, the temperature during shipping, and the packaging methods used. High humidity is also reported to increase the sulfuration reaction speed, and so the level of ambient humidity during packaging must also be considered[6].

In the future, there should be an increase in demand for corrugated cardboard because of changes in packaging conditions. Because of this, matters such as the relationship with recycled paper, the effect of humidity conditions, the correlation with the actual environment, and the effects on the actual product must be investigated more thoroughly.

6. Acknowledgements

We would like to take this opportunity to express our gratitude to everyone at the fifth sectional meeting of the Union of Japanese Scientists and Engineers reliability development technical research society for their advice on summarizing this report. We would also like to thank Technology Headquarters Department Chief of DDK, Ltd. for providing the specimens as well as advice on test methods.

Definition of terms

*1 EPMA analysis

In this method, an electron beam is aimed at the surface of the specimen, and the characteristic X-rays that are emitted from that place are measured, and the chemical elements of an infinitesimal section of the solid surface are analyzed. The types of chemical elements are determined by the wavelengths, while the concentrations of the chemical elements are determined according to the strength. The EPMA (electron probe micro-analyzer) scans the surface of the specimen, and is able to observe the two-dimensional distribution of the chemical elements.

A non-destructive analysis of infinitesimal areas can be done for all chemical elements above Be, and so this method has a wide range of applications, such as analyzing impurities and minerals in metals, and in the fields of science and biology.

(Source: “Iwanami Physicochemical Dictionary, Fourth Edition”, Iwanami Shoten. 1987)

*2 Wetting balance method

This method is used to investigate changes in the wetting time of specimens. The method detects the vertical surface tensile force for the receptivity of the specimen to solder by immersing the specimen into a bath of molten solder and recording the relationship between receptivity and time. The method is designated in JIS C 0053.

(Source: Tokuzo Kanbe, “Evaluating Plating”, Maki Shoten. 1998)

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Topics 1

Applications of the Thermorecorder Series

Hiroyuki Enoki*

1. Introduction

Temperature and humidity control are employed in various fields, and one of those fields is that of quality control. In general, even quality that is ensured at the design stage becomes increasingly difficult to oversee at each successive stage, from the production stage through the distribution and consumption stages.

Both the time and distances involved from the production stage to the consumption stage can be cited as major factors for this difficult in controlling quality. A look at the actual situation shows that once a product has becomes unsafe due to lax control at even one site in any of these stages, it becomes difficult or impossible to return the product to its original condition of safety.

In this report, we shall present an actual application in which the Tabai Espec Thermorecorder Series is used chiefly for temperature and humidity control at the difficult-to-oversee stage of distribution.

2. Temperature and humidity control at the distribution stage

When a product is shipped, appropriate temperature and humidity must be maintained for each product. For example, frozen foods must be kept at a certain temperature (for example, –18°C) or less from the time they are shipped from the plant until they reach the consumer. Other products such as pharmaceuticals also require strict temperature control.

When we examine the details, we can cite the following topics at the distribution stage.

(1) Storage stage
- Temperature irregularity due to storage sites and product stacking methods during storage in the warehouse
- A difference between the product temperature and the specified temperature setting
- Temperature and humidity fluctuations from day to night and from season to season due to storage in warehouses with no temperature and humidity adjustment functions

(2) Shipping stage
- In cooler trucks, rising temperature over time inside the storage area
- In freezer trucks, temperature maintenance in the center where air does not circulate
- Rising temperature due to opening and closing the truck doors (especially in summer)
- Coolant and cooler box effectiveness
- With new shipping routes, can the targeted temperature and humidity conditions be maintained with the existing equipment?

(3) Temperature control at the sales stage
- Rising temperature while temporarily placed in the backyard of the store
- Temperature and humidity control when stored or displayed at the retail outlet

The following problems occur in the course of making actual confirmations, and even when the importance of control is recognized, in many cases it is impossible to maintain.
- Power supply maintenance and wiring are faulty and impractical.
- The size of the equipment presents obstacles to shipping.
- Implementation is inordinately expensive.
- The equipment is too difficult to operate and so the task cannot be delegated.
- The succeeding data control is too difficult because it is recorded on paper.

3. An overview of the thermorecorder series

Using the Tabai Espec temperature and humidity data logger “Thermorecorder Series” that has resolved these problems, you can easily grasp the history of temperature and humidity changes with this single unit even throughout every stage of the entire distribution process.

Basic functions: Measures temperature and humidity and stores in main unit memory. Can convert data in memory to graphs and tables on the computer, and confirm.

*R&D Center

Special features

- Because the measurement values are displayed on the liquid crystal section of the main unit, can be used as a portable unit.
- Dry-battery operation eliminates the trouble of maintaining and wiring a power supply, and the battery can be replaced by the customer (battery life, 2 years maximum, varies with model type).
- Compact, pocket-sized unit eliminates the worry of maintaining footprint space.
- Can reduce management costs.
- Measurement values are stored in memory on the main unit, so the unit need not be connected to a computer during measurement and memory storage.
- The data in memory can be displayed on the computer in graphs and tables using special software (standard accessory).

Storing the data as a text file makes the data available for detailed analysis with spreadsheet software.

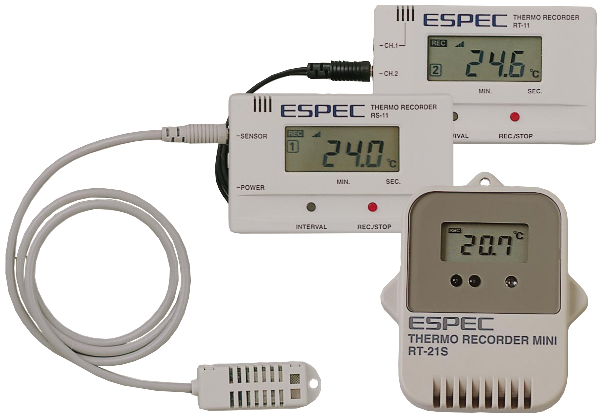

Photo 1 The Thermorecorder

Table 1 Thermorecorder product listing

The following products are offered in our current lineup in the Thermorecorder Series

	Thermorecorder	
Model	**RT-11**	**RS-11**
Basic functions and special features	• Two-site temperature measurement with storage in memory • Basic Thermorecorder equipment • Standard attachments: special software and communications cables	• One-site temperature measurement with storage in memory and one-site humidity measurement with storage in memory. This unit is the only one in the series that measures humidity. • Standard attachments: special software and communications cable
Measurement range	External sensor: –40 to +110°C Internal sensor: –10 to +60°C External wide-range temperature sensor (optional): –60 to +155°C	External temperature and humidity sensor Temperature: 0 to 50°C Humidity: 10 to 95%RH
Resolution	0.1°C	0.1°C, 1%RH
Battery life	Approximately 1 year	Approximately 1 year
Data memory	8000 units of data × 2 channels	8000 units of data × 2 channels
Dimensions	W88 × H55 × D24 mm	W88 × H55 × D24 mm

	Thermorecorder Mini		**Mini Base**
Model	**RT-21S**	**RT-30S**	**RT-21B**
Basic functions and special features	• One-site temperature measurement with storage in memory • Using an internal temperature sensor, this unit has the best moisture resistance in the series.	• The same as the RT-21S except with an external sensor • Using an external sensor, improves the thermal time constant	• Provides as a set the software and the main unit for uploading the data from the RT-21S and the 30S memory to a computer. • One unit can handle multiple Thermorecorder Mini units.
Measurement range	Internal temperature sensor: –40 to +80°C	External temperature sensor: –60 to +155°C	
Resolution	0.1°C	0.1°C	***
Battery life	2 years minimum	2 years maximum	***
Data memory	16000 units of data	16000 units of data	***
Moisture resistance	Waterproof model (equivalent to JIS C 0920 class 7)	Waterproof model (equivalent to JIS C 0920 class 4)	***
Dimensions	W47 × H62 × D19 mm		W66 × H29 × D92 mm

Special software		
Basic functions and special features	Data from the Thermorecorder Series main unit is displayed on a computer in graphs and tables and can be printed out.	
	Can take data from other equipment types in the Thermorecorder Series and display the data in graphs.	
	Simultaneously displays 8 channels of data (graphs and tables).	
	Can output data to text files.	
	Can control the Thermorecorder Series main unit (useful for such activities as programming the memory starting time).	
Operating environment	OS:	Japanese or English Windows 3.1, 95, 98, or NT (3.51 or 4.0)
	Computer:	For CPU of Intel i486 or better

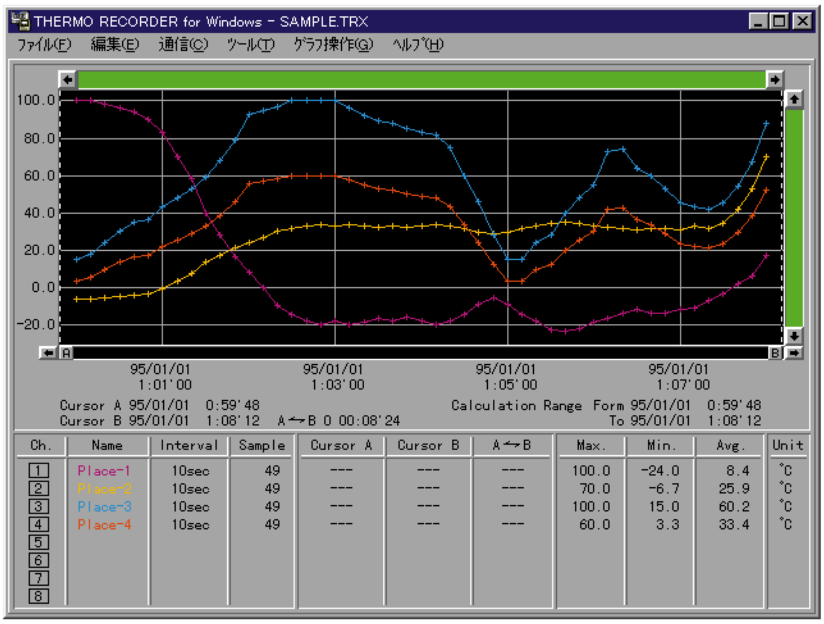

Photo 2 Display example

4. Examples of application at the distribution stage

The Thermorecorder Series has reduced the previously troublesome task of controlling temperature and humidity at the distribution stage to a familiar routine, and this equipment is now being used in the following actual applications.

- The temperature history during shipping is shown to the user. Customers are using this feature to obtain reliability as well as to show differences between companies.
- Used to measure temperature distribution within the warehouse, and check against in-house standards.
- Used to investigate the relationship between temperature and quality for vegetables in the distribution stage.
- Used to check the effectiveness of package insulation during shipping.
- Used to monitor temperature when procuring raw materials from abroad, or when exporting.

A variety of such applications are in use at the distribution stage mainly for foods and pharmaceuticals.

Application examples

- A certain product is transported to the airport by truck, and after being restacked, the temperature is monitored during shipping by airplane from Osaka to Hokkaido. (From Osaka to Sapporo, Hokkaido, takes about 2 hours, covering 667 miles [1200 kilometers].)
- The graph shows when the temperature rose during shipping by truck, when restacking, and during warehouse storage prior to sales.
- For example, if we find a problem due to temperature rise during shipping by truck, we can take countermeasures such as reducing the time the doors are open or installing a curtain.

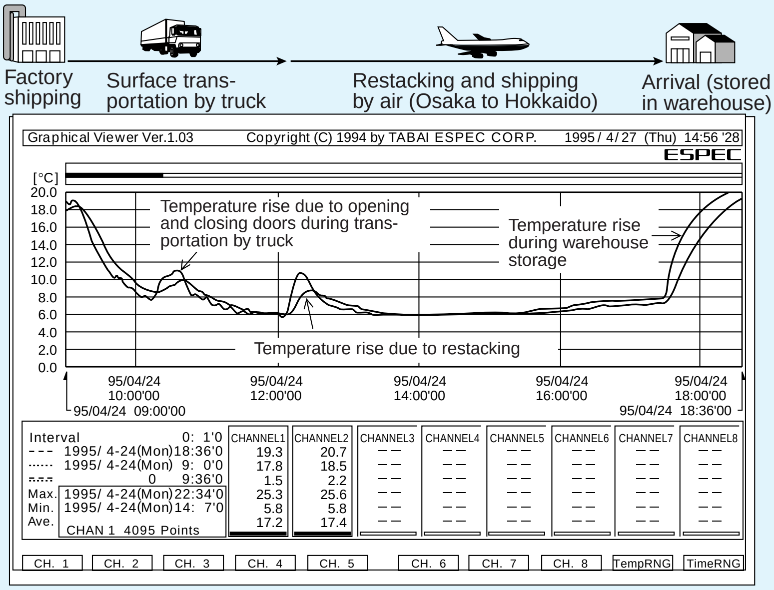

Fig. 1 An example of using the Thermorecorder

5. *Examples from other fields*

In the previous items, we presented examples of applications at the distribution stage, but temperature control is being used in a variety of other fields as well.

The Thermorecorder Series can be operated with ease without special training, and accepting the point that temperature and humidity can be controlled cost-effectively, this solves the previous customer worry about not being able to easily monitor temperature (humdity). This equipment will doubtless be used for temperature and humidity control in a variety of fields.

Example 1: Agricultural experiment station, university department of agriculture

- Used in evaluating local climate the size of a Japanese rice paddy.
  * Drawing attention for its effective local application in rural development, the temperature and humidity environment is an important factor in such matters as crop selection and agricultural climatic disasters, and requires evaluation of local climate.
  * Often used in mountainous regions, which have complex topography.

- Used to measure climate and soil temperature to be used as test data for all types of cultivation.

- Used to control nutrient solution temperature in hydroponic cultivation.

Example 2: Agricultural Improvement and Extention Centers and individual farmers

- Collecting temperature data to predict the time of the peach blossoms. The peach blossom season is predicted to facilitate work planning and secure workers.
  * Because the data from the meteorological agency can differ somewhat from the temperature in one's own field.

- Checks nighttime and daytime temperature and humidity data in the greenhouse, and engages the air conditioning settings on days when necessary. (Countermeasures for problems with dryness or high and low temperatures)

- Checks the difference between air conditioning settings and the temperature and humidity in the area of the plants, and performs appropriate temperature and humidity control (appropriate to good plant cultivation).

- Controlling water temperature in wet fields

Example 3: Construction and building materials

- Used for checking the effectiveness of insulation by measuring temperatures inside the living space before and after remodeling of residential buildings.
  * Used to append comparative data on the effectiveness of insulation as sales promotion materials.
  * Used to check product development and to gather field data.

- Used to measure temperature and humidity in such places as halls and inside closets where mildew is likely to occur, and to investigate ventilation and the quality of materials.

- Used to collect quantitative temperature and humidity data for subjective details in research on the comfort impact of construction materials on ordinary homes, such as “the humidity is uncomfortable”, or “it is somewhat chilly”.

Example 5: Equipment manufacturers

- Freezing damage complaints have multiplied for equipment installed outdoors. Although quality evaluation testing was not possible up till now, outdoor temperature and humidity conditions are now collected in the environment of actual use for all products, and feedback is given for quality evaluation testing conditions.

- In construction work such as installing elevators, during construction the equipment is temporarily placed outdoors in an environment that differs for the actual installation environment. At such times, the actual environment is measured and quality evaluation feedback is given.

Example 6: Others

- Used as an educational tool for academic subjects.

- Used to control temperature in the installation area of precision instruments inside equipment such as computers and in unmanned telephone exchange equipment.
  * Used to confirm that the temperature environment is maintained for normal equipment operation.
  * Used to confirm the relationship between the room air conditioning temperature and the actual temperature and the equipment.
  * Used to pre-check the temperature and humidity of the installation area.

We presented one example, but as you can see, this equipment is used in a variety of applications controlling temperature and humidity.

6. Conclusion

The first unit of the Thermorecorder Series that we have presented went on sale in 1994 as the RT-10 model. Since then, the series has undergone series and model changes, and we are pleased to note that the equipment has been very well received.

We plan to continue to respond to customer needs for temperature and humidity control with further improvements to present ever higher quality for our valued customers.

Topics 2

Tabai Espec product preparedness for the year-2000 problem

Masashi Kinugawa*

1. What is the year-2000 problem?

Earlier this century, computer programmers used to input a two-digit number for the year instead of a four-digit number (e.g., 1999 would become 99). This approach was adopted to deal with the severe limitations of computer memory and disk space that programmers faced at the time, as well as to eliminate wasted time and effort in inputting data. As a result, the year 2000 becomes "00" in these programs, meaning that they cannot distinguish between the year 1900 and the year 2000. If these programs incorrectly assume the year 1900 when processing this "00" data, the calculations could produce an error that will cause the program to crash. This two-digit "00" confusion is the core of the year-2000 problem.

In addition, the year 2000 is a leap year, and the programs may not be able to process that date correctly, either. When the number of the year can be divided by four with no remainder, the year is a leap year, with the exception that end-of-the-century years ending in double-zero are not leap years unless also divisible by 400 with no remainder. The year 1900 was not a leap year. Therefore, if the "00" is interpreted as 1900, the computer will assume that the year is not a leap year.

These problems and their resulting implications are generally referred to as "the year-2000 (or "y2k") problem. More recently, the y2k term has also been used to refer to problems not directly related to the "year 2000" date itself, but are problematic because of processing other dates. (E.g., September 9, 1999, known as 9/9/99, could generate errors in some computer programs.)

2. Tabai Espec product readiness

At Tabai Espec, we have confirmed that our main product line, the Platinous Series, and most of our other products are unaffected by the year 2000 problem.

To verify our product readiness, we have used tests based on Sematech 2000 to test all our products that contain built-in calendar functions. ("Sematech" stands for "Semiconductor Manufacturing Technology", a US semiconductor industry group with members from the US government, academia, and private industry. This group established the "Sematech 2000" test for testing for year-2000 problems.) We are also investigating the hardware aspect of equipment that has no calendar functions, and we are verifying that this equipment is also unaffected by the year-2000 problem.

However, we do have a few products that either are or might be affected by the problem. Those products were produced according to specially ordered or supplementary specifications, and have complex, diverse systems. These items must be tested individually to determine their readiness for the year 2000.

Below is a list of products requiring testing.

Product name
Application Wise Central Control System [This includes the entire system and all connected equipment.]
Elastic Modulus Measuring Evaluation System
Burn-in Chamber
Automated Production Equipment
Combine Environmental Reliability Test Chamber
Large Scale Stratosheric Environmental Test Chamber
Low Pressure & Low Temperature Environmental Simulator
Hyperbolic Oxygen Therapy Chamber
Vibration Test Chamber (Combined specification)

*Quality Assurance Department

3. How Tabai Espec is meeting the challenge

At Tabai Espec, we are presenting information to our valued customers concerning how the year-2000 problem affects the equipment you have ordered from us. We are also providing support in every way possible to help our customers.

We would like to present the following method for dealing with the year-2000 problem.

(1) Upon customer request, we at Tabai Espec will consult with the customer about investigating and taking corrective measures for equipment ordered from us.

(2) We would like to request that the customer handle matters for equipment that can be dealt with by simply correcting the leap year date or by inputting the proper date on January 1, 2000.

(3) Products that are connected to computers through ports such as the GP-IB or RS-232C can have problems caused because the computer or its operating system are not year-2000 compliant. Please contact the manufacturer or the retail outlet about the year-2000 readiness of these products.

4. Summary

As noted above, we at Tabai Espec have already verified that the majority of our products are not affected by the year-2000 problem. For information on the status of each individual product, please refer to the product details offered on the Tabai Espec homepage. (http://www.espec.co.jp/us/products/2000/2000.htm)

I would like to reaffirm our commitment at Tabai Espec to providing support in every way possible to our valued customers by providing information and helping with corrective measures. If you have any questions, please contact us.

Please direct your inquiries to: E-mail: PM-KAIGAI@espec.co.jp

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JIS Z 9901-1994 Registration Number JSAQ 004

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ISO 9001/JIS Z 9901

Quality Management System Assessed and Registered

The Quality Management System of TABAI ESPEC CORP. has been assessed and registered based upon the International Standard ISO9001-1994 and JIS Z 9901-1994, by the Japanese Standards Association (JSA).

Products or Services: Development, Design, Production, Installation and Servicing of Environmental Test Chambers, Environmental Test Equipments, Environmental Equipments for Production and Semiconductor Test Equipments.

The associated company within the scope of registration:
- ■ TABAI ESPEC SERVICE CORP.
  23-12, Taimahigashimachi, Neyagawa-shi, Osaka 572-0072, JAPAN
  Servicing and Installation of Environmental Test Equipment
- ■ TABAI KANKYO SETSUBI CO., LTD.
  5-45, Shindenkitamachi, Daito-shi, Osaka 574-0052, JAPAN
  Designing, Production and Installation of Environmental Test Equipment

ISO 14001-1996

ISO 14001 (JIS Q14001)

Environmental Management System Assessed and Registered

The Environmental Management System at TABAI ESPEC CORP. Fukuchiyama Plant, Utsunomiya Techno Complex and TABAI ESPEC SERVICE CORP. Head Office have been assessed and registered based upon the International Standard ISO 14001: 1996 and JIS Q14001: 1996, by Japan Audit and Certification Organization for Environment (JACO).

Name of organization	Approval Certificate No.	Subject to certification
Tabai Espec Corp., Fukuchiyama Plant	EC96J1046	The design and manufacture of Environmental test equipments and Semiconductor test equipments
TABAI ESPEC CORP. Utsunomiya Technocomplex	EC96J1081	The development, design and manufacture of Burn-in test systems and Evaluation systems
Tabai Espec Service Corporation Head Office	EC97J1050	The installation, inspection and maintenance for Environmental Test Equipments and Semiconductor Test Equipments
TABAI KANKYO SETSUBI CO., LTD. DAITO SITE	EC98J1033	The manufacture and installation of Environmental Test Equipments

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