Technical information for our customers

ESPEC

TECHNOLOGY REPORT

1997

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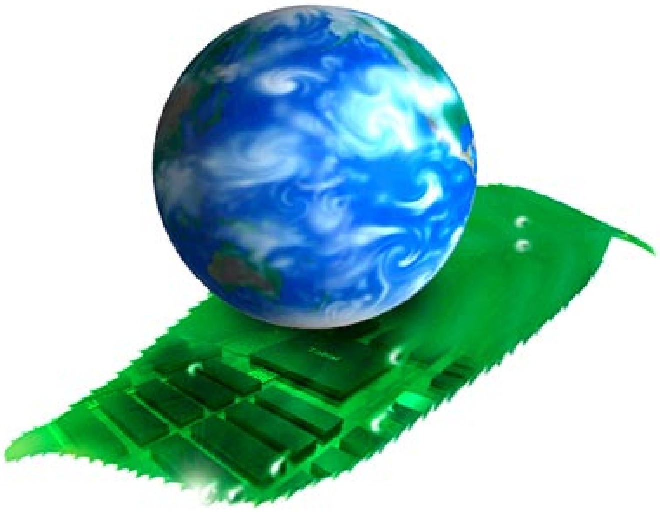
Special issue:
Evaluating Reliability



CONTENTS

TABAI ESPEC CORP.

50 years of progress at TABAI ESPEC

As an environmentally creative corporation, TABAI ESPEC has been developing pioneering products and revolutionary technology at all our locations. With our business theme of “environment”, we wish to continue building on our wide operational know-how and technological expertise and to continue making our corporate contribution to 21st century society.


The first Platinous A Series (1969)

1947
- The first president, Goro Tabai, founds the company for manufacturing scientific equipment.

1954
- Tabai Manufacturing Co.,Ltd. is established.

1960
- Starts development of environmental test chambers for the first time in Japan.

1962
- Production is begun for the temperature chamber (TABAI Perfect Oven).

1965
- Thermal shock chamber is developed.

1968
- Balanced Temperature and Humidity Control (BTHC) system is developed.

1969
- The Platinous Series (temperature and humidity chamber) is introduced.

1971
- Wet bulb wick method is developed.

1973
- Unified ultra low temperature system is developed (attains –136°C).

1974
- Fukuchiyama Plant is established.

1980
- Eiichi Koyama becomes President.

1981
- The Environmental Test Technology Center is established next to Fukuchiyama Plant.

1982
- Burn-in system is developed.

1983
- Corporate name is changed.
- Listed on the second section of the Osaka Stock Exchange.
- ESPEC CORP. (U.S.A.) is established.

1985
- Participates in TSUKUBA EXPO '85, Technocosmos.
- Listed on the second section of the Tokyo Stock Exchange.
- Joint-venture agreement with Shanghai Experimental Instrument Factory is signed.
- Snowfall and wind system is developed.


Large Scale Environmental Test Chamber (1980)

1986
- Listed on the first sections of the Tokyo and Osaka Stock Exchange.

1987
- The Environmental Test Technology Center is approved by IECQ as the first non-governmental test laboratory in Japan.
- Starts business for environmental testing (Commissioned Testing).

1988
- Temperature and humidity control system is developed using electronic linear control valve.

1990
- Supported the International Garden and Greenery Expo.
- Container type artificially lighted plant factory is developed.

1991
- Utsunomiya Techno Complex is established.

1992
- Eiichi Koyama becomes Chairman. Kiyoshi Shimazaki becomes President.
- The Environmental Test Technology Center (Fukuchiyama Test Center) is approved as an IECQ-Authorized Independent Test Laboratory Per ISO/IEC Guide 25.
- Technology is developed to meet freon standards by using combined refrigerants.

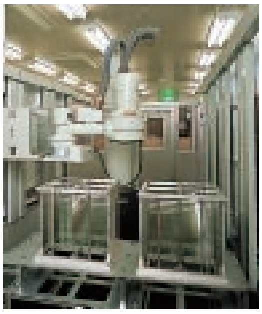
1993
- The Environmental Test Technology Center (Utsunomiya Test Center) is approved as an IECQ-Authorized Independent Test Laboratory Per ISO/IEC Guide 25.
- The quality management system is assessed and registered upon the ISO9001 (JIS Z 9901) by the Japanese Standards Association.

1995
- Guang-zhou Espec Environmental Equipment Corp. is established. (Joint-venture agreement with Environmental Simulation Engineering Corporation of CEPREI)

1996
- Kyoto Environmental Measurement Center is established. Environmental certification is begun.
- The “New energy generating field testing” cooperative research is begun in cooperation with the New Energy and Industrial Technology Development Organization (NEDO).
- Utsunomiya Future Laboratory Exhibit Hall is opened.
- The Fukuchiyama plant acquires certification for environmental management based on international standard ISO14001 (JIS Q 14001) from the Japan Audit and Certification Organization for the Environment (JACO).
- C&E Environmental Technology Co.Ltd. is established. (Joint-venture agreement with Environmental Simulation Engineering Corporation of CEPREI)

1997
- The Utsunomiya Techno Complex acquires certification for environmental management based on international standard ISO14001 (JIS Q 14001) from the Japan Audit and Certification Organization for the Environment (JACO).


The latest Platinous K Series (1997)


Automatic Clean-cure System (1990)

ESPEC

TECHNOLOGY REPORT

Greetings from the President

Our 50th anniversary

On July 25, 1997, we at TABAI ESPEC celebrated the 50th anniversary of our founding.

Our first president, Goro Tabai, founded the company in July 1947 to manufacture scientific equipment, and then established the Tabai Manufacturing Co., Ltd. in 1954. The name was subsequently changed to the TABAI ESPEC Corporation in 1983. In 1960, we pioneered the development of environmental testing equipment in Japan. Throughout the nearly four decades since, we have developed a wide variety of original products related to environmental testing, and we are grateful for the high evaluation those products have received.

Based on our business theme of “environment”, we at TABAI ESPEC offer environmental testing chambers and we also perform environmental testing for our customers. We have expanded our operations into a wide variety of related fields. We offer environmental testing facilities in large environmental testing chambers and in the field of electronic devices we offer production equipment related to semiconductors and liquid crystal. In the field of life environment, we offer agricultural equipment such as biomedical equipment and plant factories. In addition, we offer environmental measuring verification such as investigating and analyzing soil, atmosphere, and water quality. We have also entered the field of environmental business with our research into alternative energy sources using solar energy.

Looking ahead, we are striving to strengthen our technology development system, and we are developing unique new products in various fields such as environmental testing chambers, measuring systems, and electronic devices. In addition, in operations related to the environmental business, we are expanding our environmental measuring verification service, we are moving into environmental improvement, and we are laying the foundations for our ecosystem operations such as environmental consulting based on our wide know-how.

I would like to express my heartfelt gratitude to the many people both in Japan and in other countries who have supported our company, and I look forward to your continued kind support and valuable feedback.

Finally, we are also striving to make the “ESPEC Technology Report” into a technology report magazine that provides a worthwhile service to our valued friends, and we are making every effort to provide contents with real substance. I hope you will find it beneficial.

Kiyoshi Shimazaki
President

Fundamental Concepts of Environmental Testing Techniques in Electricity and Electronics

Part 1: Fundamental concepts of physics and chemistry regarding heat and humidity

Toshio Yamamoto*

This article is the first in a four-part series on basic issues concerning reliability and quality control in electricity and electronics. The issues to be covered deal mainly with "temperature and humidity testing", and are primarily directed toward beginning technicians who are participating in environmental testing.

The series is organized as follows.

Part 1: Fundamental concepts of physics and chemistry regarding heat and humidity
Part 2: Concepts concerning the behavior of standard environments and moisture required for designing temperature and humidity tests
Part 3: Concepts concerning the establishment of public test standards
Part 4: Concepts serving as reference for effectively applying environmental testing

The aim of this series is to present the fundamental concepts required for performing temperature and humidity testing, the most basic testing in the various kinds of test methods. In addition, we sincerely hope that these fundamental concepts will lay the foundation for understanding current environmental tests, designing the next generation of environmental tests, and developing new test methods.

Contents

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*Environmental Test Technology Center

1. Introduction

Fifteen years ago in Japan, the electrical and electronics industry used “environment” to refer to natural environments. Nowadays, though, the term is used to include other meanings.

The rapid development of industrial technology has widely popularized a great variety of industrial products which have provided enormous convenience in our lives. However, this situation is also leading to immense changes in the natural environment on a global scale. It is well-known that these changes are giving rise to a variety of current social problems.

Modern industrial products have increasingly numerous opportunities to be directly and strongly influenced by environmental changes, including naturally occurring periodic weather changes such as the changing seasons, and the environment of the geographical location, but even more by artificial environmental changes brought about by environmental changes in the rooms in which the products are placed, as well as by non-periodic operation of other products located close by. In other words, the influence of the artificial interior environment has become greater than the influence from the global natural environment. (Our own bodies are also receiving the effects of this same environmental influence on a daily basis.)

2. Physical properties of temperature and humidity

Temperature refers to thermal energy, and we can only grasp the level of thermal energy through some sort of matter. In other words, thermal energy is not matter. Because of this, we use appropriate instruments (thermometers and calorimeters) to index the order of coolness and heat and its increase and decrease-in other words the amount of thermal energy and the level of change in that energy.

On the other hand, humidity is a combination of water and dry air, and the water can easily change into a variety of forms within our life temperature zone. Occasional high and low temperatures cause the humidity values to fluctuate widely.

We know from experience that when a hot substance comes into direct contact with a cold substance, the hot one cools and the cold one warms. This change does not continue in perpetuity, but is rather one that reaches equilibrium after time, and the change stops. At this time the two substances involved are said to have reached thermal equilibrium. We should also note that as the temperature of a substance increases, molecular motion correspondingly increases in the molecules making up the substance. However, as the temperature drops, molecular motion also slows. It is well known that at extremely low temperatures, in the vicinity of –273°C, molecular motion in most molecules stops.

2-1 Molecular motion of gases

Fig. 1 illustrates the velocity of one oxygen molecule in a vacuum. As the temperature rises, the velocity increases. In other words, the higher the temperature of a gas, the greater the kinetic energy that it has (the thermal motion of the molecule increases).

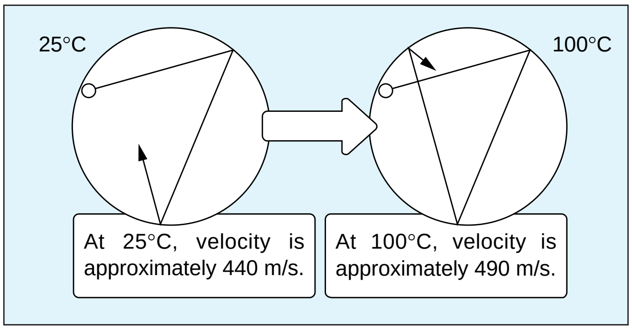


Fig. 1 Velocity of one molecule of oxygen

Next, let’s observe the molecular motion of groups of molecules.

2-1-1 With groups of identical molecules

Even when a number of identical molecules form a gas, the velocity of all the molecules making up the gas is not equal. Each of the molecules conforms to the uniform velocity distribution(1) determined by the temperature. As Fig. 2 clearly shows, the higher the temperature, the more the distribution is inclined toward an area of greater velocity. For example, the velocity distribution of N_2 molecules in nitrogen gas is as shown in Fig. 2. When most of the molecules are temporarily at the average velocity v for that temperature, the value of v for the N_2 molecules changes to 425 m/s at 0°C, 910 m/s at 1,000°C, and 1,220 m/s at 2,000°C.

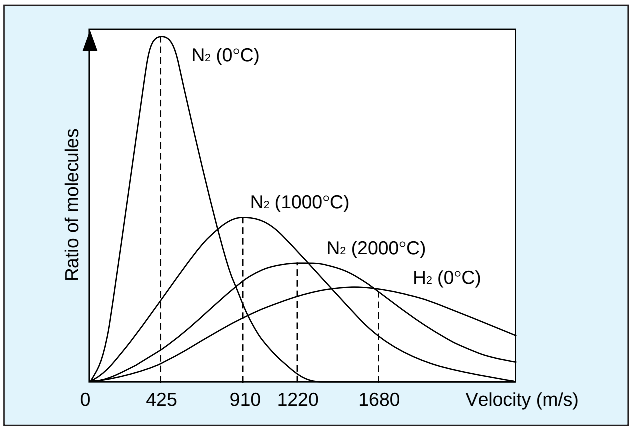


Fig. 2 Temperature and the distribution of molecular velocity

2-1-2 With groups of different types of molecules

Even at the same temperature, the velocity distribution of groups of molecules with lower molecular weight have a distribution more inclined toward an area of greater velocity than groups of molecules with greater molecular weight. For example, when comparing hydrogen molecules (molecular weight, 2) with nitrogen molecules (molecular weight, 28) as in Fig. 2, at the same temperature of 0°C, the velocity v of the H_2 molecules is 1,680 m/s, but the velocity v of the N_2 molecules is 425 m/s.

The higher the temperature, the greater the average molecular velocity v. This value of v is known to be in proportion to the square root of absolute temperature T. The average velocity can be found with the following formula, in which M is the molecular weight.

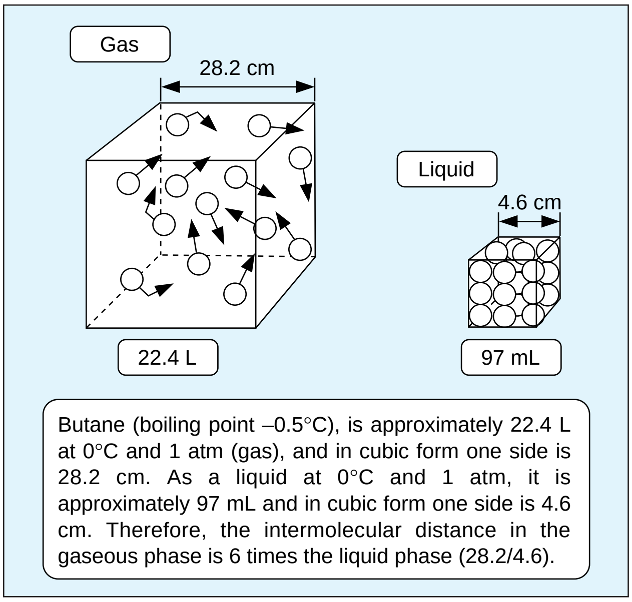
$$V = \sqrt{\frac{3RT}{M}} \qquad \text{(Where R is the gas constant.)}$$

This type of temperature change creates thermal stress by changing the velocity distribution of the molecules composing the substance that is in thermal equilibrium, i.e., stable. Therefore, changing the temperature of a substance causes repeated changes in velocity at the molecular level, so the substance is not static even though its macro stability can be observed. From the micro standpoint, a substance is normally in an unstable condition. The greater the change in temperature, the greater the loss of stability. To put it the other way around, the smaller the change in temperature, the greater the relative stability.

Next, let's consider humidity. When dealing with the subject of moisture content, the prerequisite for humidity, we must bear in mind the characteristics of water. Water is at its greatest density at 4°C (1 atm, 3.98°C), and undergoes phase changes according to the temperature. In other words, depending on the temperature, water will exist as water vapor (gaseous phase), water (liquid phase), or ice (solid phase). Within our life temperature zone we don't often see liquids freeze (with the exception perhaps of only glacial acetic acid(2) and benzol(3)).

By the way, when discussing phase change, we must not forget the existence of intermolecular force.

First of all, when a gas is cooled or compressed, it becomes a liquid (in rare instances changing directly to a solid). For example, when air is compressed and cooled, it becomes liquid air, and when carbon dioxide is cooled, it becomes a snow-like solid (dry ice). These phenomena indicate that the molecules attract each other. This force is called intermolecular force, or Van der Waals force (Van der Waals, 1837 to 1923). This intermolecular force is created only when molecules are contiguous, and is rarely created when the intermolecular distance is great. Therefore, in solids and liquids, intermolecular force results in molecules being held almost immobile or merely able to flow. When the substance becomes a gas, the molecule can fly about almost freely (although within the range of mean free path(4)). For example, butane (C_4H_{10}) boils at 10°C, and at room temperature is a gas, but is a liquid in a gas lighter. This is because the butane is compressed and put into the lighter, forcibly reducing the intermolecular distance between the butane molecules. This compression creates intermolecular force, forming a liquid and making it possible to insert 200 times as much butane into the lighter.



Butane (boiling point –0.5°C), is approximately 22.4 L at 0°C and 1 atm (gas), and in cubic form one side is 28.2 cm. As a liquid at 0°C and 1 atm, it is approximately 97 mL and in cubic form one side is 4.6 cm. Therefore, the intermolecular distance in the gaseous phase is 6 times the liquid phase (28.2/4.6).

Fig. 3 1 mol of butane (liquid and gas)

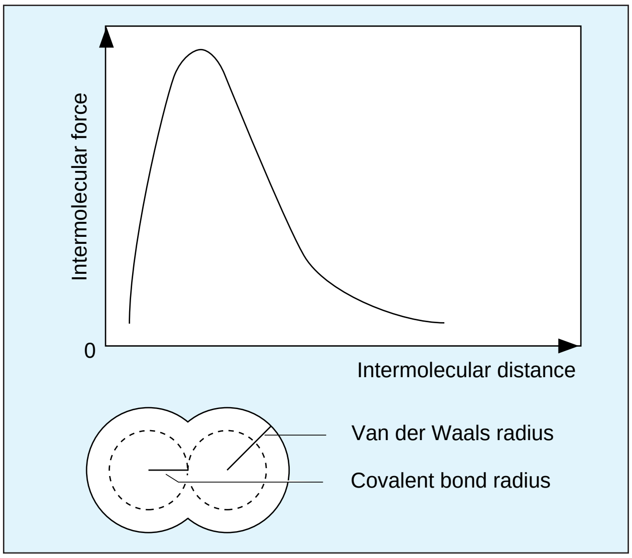


Fig. 4 Intermolecular distance

Intermolecular force is strongly affected by intermolecular distance, and is inversely proportional to the intermolecular distance raised to the power of 7. For example, if the intermolecular distance is doubled, the intermolecular force becomes $1/2^7$, i.e., 1/128. Intermolecular distance is a weaker force than chemical bonds (ionic bonds(5), covalent bonds(6), and metallic bonds(7)), but it is incomparably stronger than universal gravity. However, coming too close together creates repulsion force, so molecules can't approach closer than a certain uniform distance. The atomic radius determined from this distance is called the Van der Waals radius, which is considerably larger than the covalent bond radius.

We don't have room to go more into detail on this subject here, so if you would like to go into more detail on any of these items, please refer to other sources.

By the way, water undergoes a change in volume when changing from a liquid to a gaseous phase or to a solid phase, and because of that exerts an extremely strong mechanical force on its surroundings. Also, existing at the boundaries of the various changes are special characteristics such as the appropriate gain and loss of kinetic energy as latent heat(8) in cases in which there is no temperature change. Another current problem is that even when the amount of moisture is insufficient to cause problems as independent water, when combined with other major factors it can form a complex environment with properties that severely affect electrical and electronic products.

2-2 Vaporization and expansion

Heated water evaporates and becomes water vapor in a phenomenon known as evaporation, but this process change from the liquid phase to the gaseous phase is accompanied by expanding volume, a phenomenon known as evaporative expansion. According to the Ideal Gas Equation on the relationship between the temperature and pressure of a gas, when this expansion occurs in a closed system the internal pressure of the system increases in proportion to the temperature. For example, at 0°C and 1 atm, 1 cm^3 of water becomes 1.24 L when vaporized, in other words, it expands to 1,240 times its liquid volume. This phenomenon is shown in the following manner.

The Ideal Gas Equation

$PV = nRT$

We can substitute the following values:

$P = 1$ atm

$R = 0.082$ atm/°C · mol

$T = 273$°C, and

$n = 1/18$ mol/gm

in the following formula:

$V = nRT/P$

to confirm that the result is 1.24 L.

For example, when water (liquid) 18 cm^3 evaporates, it becomes:

$$\text{Water (liquid) } 18\text{ cm}^3\text{ (gm)} \xrightarrow[\text{1,240 times}]{\text{vaporizes}} \text{water vapor (gas) } 22.4\text{ L}$$

2-3 Freezing and expansion

Volume expansion due to freezing occurs on a very small scale compared to vaporization expansion, and it also relies much less on temperature. When 1 cm^3 of water freezes at 0°C and 1 atm, the volume becomes 1.09 cm^3, a 1.09 times increase. This value can be found in the following manner. The density of water at 0°C and 1 atm is 1 gm/cm^3, so the volume of 1 cm^3 of water has a weight W_L of 1 gm. When this freezes, at 0°C and 1 atm, the density d_s of ice = 0.917 gm/cm^3, so the volume can be found as follows.

$$Vs = \frac{W_L}{ds} = 1.09\text{cm}^3$$

In other words, when 1 cm^3 of water (liquid) freezes:

$$\text{Water (liquid) } 1\text{ cm}^3 \xrightarrow[\text{1.09 times}]{\text{freezing}} \text{ice (solid) } 1.09\text{ cm}^3$$

The reason for this freezing expansion is as follows.

Within liquid water are groups of water molecules that are linked together by hydrogen bonds (bonds formed when the positively charged H atoms in the molecules form mutual electrostatic attractions with negatively charged atoms in other molecules, in this case oxygen atoms). When the temperature drops, the thermal motion of water decreases and the groups become larger, and at around 0°C most of the water molecules are linked by hydrogen bonds. Then, as the temperature drops below 0°C, the water molecules lose the ability to move freely, becoming crystallized. Therefore, the water molecules in ice form an orderly crystal lattice. This crystalline structure contains a large number of gaps, and so the volume occupied is greater than water. Most substances become denser as the temperature drops and less dense as the temperature rises. (Temperature is inversely proportional to density, forming the basis for the use of substances such as alcohol or mercury in thermometers.) This property of water differs from other substances, and is an exception to the general rule that the solid phase is less dense. When ice melts and water molecules become able to move, molecules are able to enter the gaps causing water to become more dense, and so ice is able to float. (Example, icebergs)

Expressing the existence of water as humidity refers to the amount of water vapor in the air. The unit of humidity generally used as an environmental factor in environmental testing is called relative humidity, which is based on the capacity standard. Relative humidity is defined by the following formula.

$$RH = \left(\frac{e}{E}\right) \times 100 \ \ (\%)$$

Where,

RH = relative humidity,

e = the moisture content actually present of the air's uniform capacity at the uniform temperature, and

E = the maximum moisture content possible at the temperature condition in e, at the saturation moisture content in the air.

This moisture content is also shown in proportion to a certain water vapor pressure.

3. Chemical properties of temperature and moisture

Thermal energy, the index of temperature, is not matter so it is not directly involved in chemical reactions. Thermal energy can penetrate or leave matter. It can come into being and be extinguished inside matter, and can intensify or calm the motion of molecules forming matter. It can effectively speed or slow chemical reactions. At the same time, chemical reactions occurring inside matter can create new thermal energy or exhaust thermal energy as a product of the reaction. However, when the reacting substances of a chemical reaction are consumed, the reaction will stop regardless of temperature.

Thermal energy plays a supporting role in relation to moisture, but the main role in this domain is the moisture itself, and its absolute mass. Most chemical reactions occur in solvents, so we can assume that water molecules play some sort of role.

3-1 The structure of the water molecule

The water molecule has an extremely wide variety of functions. We have already noted that the state of water changes according to the temperature. The water molecule is composed of one oxygen atom and two hydrogen atoms. The structure forms a tetrahedron with the oxygen atom at the center, and the hydrogen atoms receiving the two electrons from the oxygen atom are at the two peaks, i.e., the location of the protons. The distance between the center of the hydrogen atoms and the center of the oxygen atom is approximately 10^{-10} m (1.0Å), and the two hydrogen atoms enclose the oxygen atom at an angle of approximately 105°.

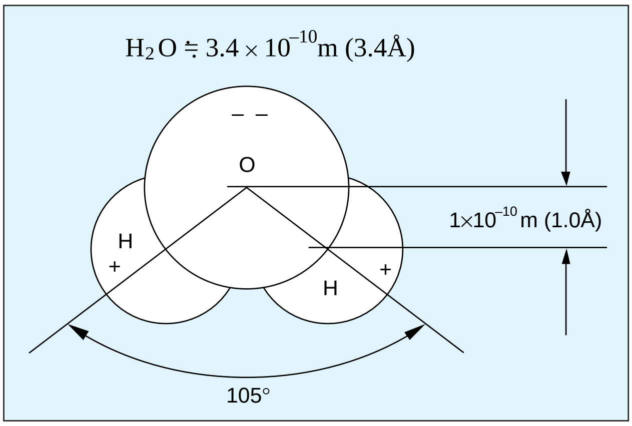


Fig. 5 The structure of water

3-2 Properties of water

The more pure the water, the lower its ability to conduct electricity, but regardless of how much it is purified, water will always have some level of conductivity. This is because an extremely small amount of H_2O ionizes into H^+ and OH^- and maintains an ionization equilibrium as shown in the following formula.

$$H_2O = H^+ + OH^-$$

This ionization equilibrium is not only true for pure water, but also holds true for water in aqueous solutions of acids, bases, salts, and so on. This relationship can be shown using the equilibrium constant. In pure water and weak aqueous solutions the relationship can definitely be seen as constant, and can be described with the following formula.

$$[H^+]\,[OH^-] = K\,[H_2O] = K_w$$

This K_w is called the ionic product of water, and is a constant that changes according to the temperature. This constant value is always maintained in any sort of aqueous solution, whether pure water, acid, base, salt or other.

In pure water it is $[H^+] = [OH^-]$. By measuring the electrical conductivity of pure water, this value can be established as 1.0×10^{-7} mol/L at 25°C. Putting this value in the above formula gives us

$$K_w = [H^+]\,[OH^-] = (1.0 \times 10^{-7}\ \text{mol/L})^2$$
$$= 1.0 \times 10^{-14}\ \text{mol}^2/\text{L}^2$$

However, as we have already noted, the ionic product changes according to temperature, and the higher the temperature the greater the value of the ionic product.

Furthermore, as a property of water, one molecule has the same characteristics as one drop or one cup of water (a giant molecule). Also, ions such as the hydrogen ion H^+ and the hydroxide ion OH^- have an extremely high mobility ratio. In other words, H^+ and $[H_3O]^+$ (oxonium) ions move toward the cathode, and the OH^- ions move toward the anode.

Water is generally very good at dissolving ionic compounds, but at room temperature reacts with metals such as sodium, potassium, and calcium. Water vapor reacts with iron to create hydrogen and form oxides and hydroxides, and hydrolyzes with substances such as nonmetallic halides and esters. (Hydrolysis is dissolution inside the molecules that compose the substance, i.e., changing the bonds inside the molecules.) A comparatively large number of substances react in this way.

4. Activation state and activation energy

When dealing with the problems of failure analysis and life of electrical and electronic parts, attention repeatedly focuses on activation energy. This is because the degradation of part functions is deeply related to the manner in which the chemical reaction proceeds.

4-1 What is activation state?

We stated in section 2-1 that the distribution of kinetic velocity (kinetic energy) of gas molecules inside a container is uniform in response to that temperature. We further noted that if the temperature of the gas inside the container is raised, the kinetic energy of the molecules tends to be greater. These phenomena are intimately related to the chemical reaction of matter. For example, even if iodine(9) is put into the container and left at room temperature, a decomposition reaction does not occur, but with a temperature of 400°C a decomposition reaction occurs as shown by the following formula.

$$2HI \rightarrow H_2 + I_2$$

In general, when the temperature of a gas is raised:

a) Molecular motion becomes more energetic, and the collision frequency of the molecules inside the container increases.

b) As the kinetic energy of the molecules increases, when they collide there is an increased probability of rearranging the connections between the atoms. (This is chemical reaction.)

The molecules that have collided don't all react. Within the particles of the reactants (such as ions and molecules) only the particles above the uniform energy react. To make all the remaining particles react, more energy would have to be applied. (Refer to Fig. 6)

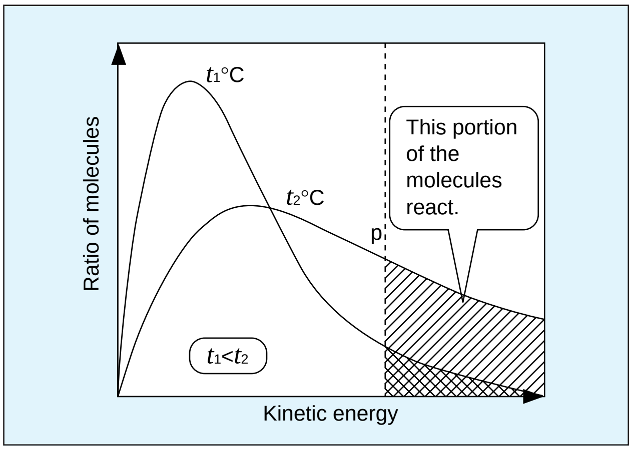


Fig. 6 Energy of particles able to react

For a reverse reaction, let's look at the process that produces hydrogen iodide (HI). When high energy molecules collide in the direction shown in Fig. 7, a reaction is started. In this case, the H_2 molecules and I_2 molecules don't react directly. They first pass through an intermediate state in bonding as 2 molecules of HI.

$$I_2 + H_2 \rightarrow \text{[intermediate state]} \rightarrow 2HI$$

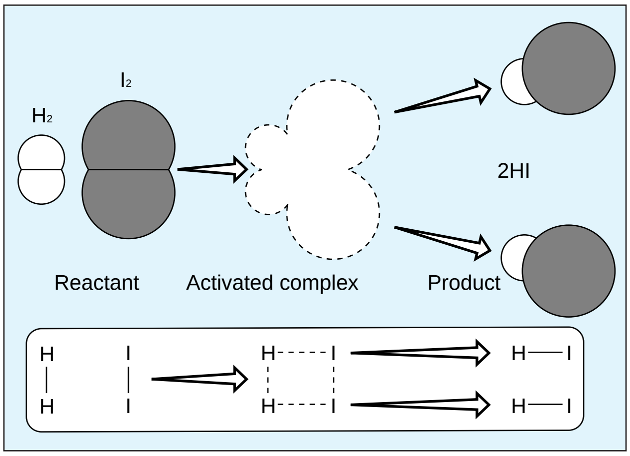
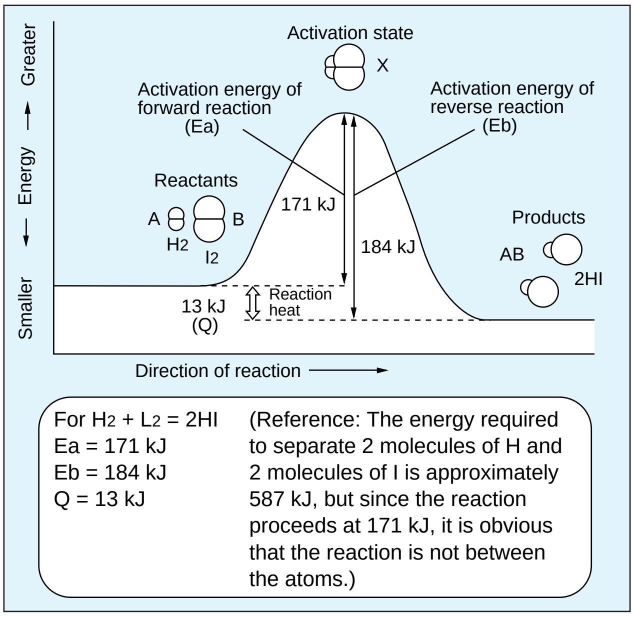


Fig. 7 Model of the activated state

This intermediate state has more energy than the average energy of the original reactants (the H_2 and I_2 molecules). Once this state has been reached, energy is immediately released and the molecules become stable product molecules (HI). This intermediate state is called the activating state. The dissolution of 2HI that we discussed earlier must also pass through this activated state. In chemistry, this type of intermediate body is called an activated complex.

4-2 Activation energy

In the reaction A + B = AB + QkJ in Fig. 8, the energy (Ea) required to activate all reactants (A + B) to condition X is called the activation energy. In other words, the difference between the energy of the reactants and the energy of the activated state is the activation energy. This X immediately releases energy (Eb) and becomes a product (AB). In other words, it is also the activation energy of the reaction AB → A + B. In this case, Q corresponds to added heat from outside that can raise the constant energy of the particles not yet having reached a reactive level to such a level at which they can react. This indicates that reactants in chemical changes must generally cross the peak of activation energy before they can become products.



For $H_2 + L_2 = 2HI$
Ea = 171 kJ
Eb = 184 kJ
Q = 13 kJ

(Reference: The energy required to separate 2 molecules of H and 2 molecules of I is approximately 587 kJ, but since the reaction proceeds at 171 kJ, it is obvious that the reaction is not between the atoms.)

Fig. 8 Activation energy

4-3 The role of temperature in reaction rate

When an aqueous solution of sodium hydroxide (caustic soda) is added to hydrochloric acid, a neutralization reaction occurs, but this reaction is so extremely fast that it ends the instant that it is mixed. On the other hand, reactions involving the rusting of iron spikes and copper plates proceed slowly over a long time. However, the speed at which chemical reactions proceed depends on the type of reaction. Even with the same type of reaction, the reaction rate will vary depending on the reacting substances and the reactant states.

The reaction rate can be shown either in units of time of the rate at which the reactants are used up, or the rate at which the products increase. Either way, the relationship is as follows.

$$[\text{Reaction rate}] = [\text{proportional constant}] \times [\text{density of reactant or product}]$$

The proportional constant is determined by the temperature, and the formula that shows this relationship between the reaction rate and density is called the rate equation. In general, the higher the temperature the faster the reaction rate. For example, if the temperature rises 10°C the rate constant becomes 2 or 3 times greater, so such expressions as the 10°C rule are used.

In 1889, the Swedish physicist Arrhenius discovered the linear relationship between the logarithm of the rate constant K (log K) and the inverse number (1/T) of the absolute temperature T (= 273+t°C) as shown in Fig. 9. This relationship is quite often used in failure analysis when analyzing chemical reactions between substances and when calculating the rate constant.

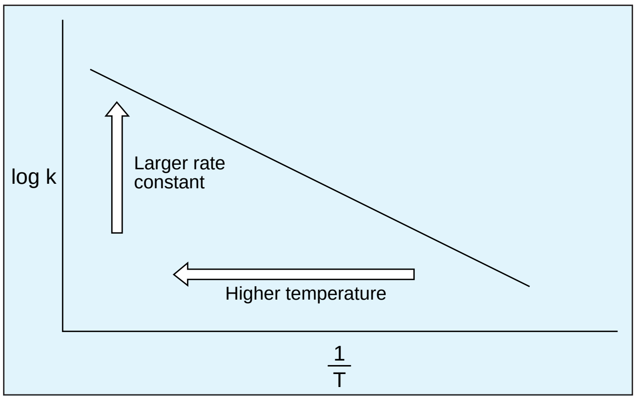


Fig. 9 The relationship between the rate constant and temperature

The explanation given above forms the basis for the thermal stress and humidity stress tests that we perform, and is intimately related to the failure of many products. In the actual market environment, many electrical and electronic products fail due to physical distortion caused by differences in the amount of thermal expansion between materials used to construct the product. As a result, gaps are left at the interface of materials with different coefficients of thermal expansion, and in extreme cases cracks are introduced into sealing material made of the same material. Moisture can penetrate through these cracks or through the surface of the material through long contact. As the moisture contacts the passageway it dissolves a variety of contaminants from the material interface, and as the water gets mixed in, it reaches the inner electrical circuits. At this point it reacts chemically with the materials forming the circuits. Furthermore, electrical current and electrical and magnetic fields strongly recreate these reactions. The reactions are also strongly affected by temperature. In this way we can see that failure results from purely physical phenomena and chemical reactions occurring repeatedly at the same time and creating complex stress. When physical causes and chemical causes occur in succession or together, the related phenomena speed degradation of the product. If the durability of the product is exceeded, this can lead to cessation of functions and product failure.

5. Accelerated testing of temperature and humidity

In the initial stages of its development, environmental testing was used to perform simulation testing of the earth’s natural environment. However, current environmental testing has come a long way from the original simulation testing, and that change is due to artificially accelerated testing. According to IEC 50 (191), an accelerated test is explained as “A test in which the applied stress level is chosen to exceed that stated in the reference conditions in order to shorten the time duration required to observe the stress response of the item, or to magnify the response in a given time duration.”

However, it would be rash to decide that trustworthy reliability for the market environment has been established merely on the basis of products having endured a test that is more severe than the standard conditions. In fact, products that have passed extremely rigorous test conditions have occasionally been found to fail in quite mild environments. For example, when only temperature stress is applied to ester resins such as polyester and carbonate they show a life of tens of thousands of hours even at 150°C. When the coefficient of water absorption is also in the range of 0.1 percent, moisture absorption causes almost no changes in the substance. However, when temperature and humidity are applied at the same time, for example, an item that has a 27-year life at conditions of 20°C and 100% RH has a life of just three days at 35°C and 100% RH. In addition, if metallic ions and alkali ions are present during hydrolysis, or if copper transition elements and pigment are present during polypropylene oxidation decomposition, these kinds of substances indicate the action of an acceleration catalyst, and decomposition occurs rapidly in this situation.

When planning a test, one must grasp the appropriate details of stress, and fully comprehend the results of such matters as the types and individual combinations of stress. One should be well aware that merely increasing the severity of test conditions does not produce accelerated testing.

6. Summary

First of all, from the qualitative standpoint, product failure begins with the causes that degrade the characteristics of materials used in a product, combined with external physical and chemical causes. Next, we consider influences from the product itself and from a variety of environments in its surroundings that speed degradation and cause substances that react to be consumed, causing early degradation or cessation of product functions. A number of factors can cause product failure, but among them the most fundamental region of study concerning reliability of electrical and electronic products concerns phenomena originating in temperature and humidity (moisture content).

The matter of actually handling environmental testing as a job entails confirming product endurance under test conditions, exposing product weaknesses as early as possible, and correcting those weaknesses. Naturally, after the product has been improved, confirmation testing must be carried out. For these reasons, this discussion in Part 1, as well as in the follow-up articles, focuses thoroughly on acquiring the basic knowledge of physics and chemistry as well as knowledge about test standards. This basic knowledge and experience is essential for providing a basis for further learning. Also, in the area of test design, ability to fully predict the details of failure and the mechanisms leading to failure before testing makes it possible to create a more effective test.

Our theme in the next issue will be "Fundamental concepts of the standard condition and movement of water or moisture for performing temperature and humidity tests", and we will be discussing standard environments, thermal stress, humidity stress and their relationship to electrical and electronic product failure.

[Glossaries]

(1) **Velocity distribution**:

It used to be thought that when the temperature of a group of the same type of molecules was equal, their velocity would also be equal, but this can only be said of the average velocity of the individual molecules. A distribution curve of the velocity for a given instant is shown in Fig. 2. (The work of Maxwell, England, 1860, and Boltzmann, Austria, 1868 led to this conclusion.) This distribution is caused by changes in velocity when the molecules frequently and incessantly collide with each other.

(Reference: The higher the temperature, the lower the velocity distribution peak shown in Fig.2. This can be seen as indicating that when balls at various speeds collide with stationary balls, the stationary ball will be set in motion and the moving ball will stop. In this way, the gas molecules repeatedly and incessantly collide. By the way, regardless of how high the average velocity is increased by raising the temperature, there will always be at least some molecules that are going slower. At higher temperatures, naturally, the molecular velocity increases. The surface area of the graph peak represents the total number of molecules, which remains constant. Given that the surface area is constant, when the ends of the peak spread out, the top of the peak must become lower.)

(2) **Glacial acetic acid**:

CH_3COOH, boiling point 118°C, used as a solvent for oil and resins.

(3) **Benzol**:

C_6H_6, boiling point 85°C, used to manufacture styrene and fenol.

(4) **Mean free path**:

For gas molecules as well as electrons within crystals, this is the average distance traveled from one collision to the next collision.

(5) **Ionic bonds**:

Bonds in which positive ions and negative ions attract each other with electrostatic force. (Example, NaCl)

(6) **Covalent bonds**:

Bonds formed when the valence electron is shared between two separate atoms. (Example, C_n)

(7) **Metallic bonds**:

Bonds in which the electrons are evenly distributed between neighboring atoms, and the metal ions form mutual attractions. This is similar to one form of ionic bond. (Example, $(Na)_n$)

(8) **Latent heat**:

The amount of heat gained or lost through phase transition.

Water ↔ water vapor 2267 kJ/kg (539.8 kcal/kg = 41 kJ/mol at 100°C)

Water ↔ ice 334 kJ/Kg (79.7 cal/kg)

(Reference: Why is a greater amount of heat needed to make steam than to melt ice? The reason is that the heat to melt ice is the amount of thermal energy needed to loosen the attraction between molecules caused by the intermolecular force within each molecule. The heat to vaporize water is the amount of thermal energy needed to completely separate the molecules. Because of this, greater energy is required to vaporize water.)

(9) **Hydrogen iodide (HI)**:

Water soluble, colorless, used as an organic synthesis reagent.

Report 1

Evaluation Method for Ion Migration Using Dew Cycle Test (Part 3)

Hirokazu Tanaka*/Yuuichi Aoki*/Shigeharu Yamamoto*

The growth of Dendrites due to Ion Migration is intimately related to water present, and thus obtaining reproducible test results requires a uniform supply of moisture. In a previous issue of this magazine (April '96), we looked at dew condensation conditions as a method of supplying that moisture. We also reported on Dew Cycle Test Chambers that use both a uniform quantity of dew condensation and uniform dew condensing time in a cycle repeatedly alternated with drying. For our report this time, we have designed prototype experimenting equipment enabling us to directly observe dew condensation conditions, thus allowing us to investigate the causes of Dendrites growing in the Dew Condensation Cycle Test. We have performed experiments to confirm changes in dew condensation conditions and also to confirm the relationship between dew condensation and the growth of Dendrites. At this time, we would like to report on the results of repeated test cycles confirming that water from dew condensation covering the gap between electrodes causes the substrate surface to become subject to wetting and causes Dendrites to grow.

The authors announced the research details that form the basis of this report in [The third International Conference on Reliability Maintainability and Safety in China] presented at Guangzhou, China from November 12 to 15, 1996.

1. Introduction

The degradation and failure of printed circuit board (hereafter, PCB) insulation due to the effects of dew condensation and moisture absorption has become a well-known problem. Changes in lifestyle have promoted the miniaturization of electronic equipment and also have contributed to the diversification of environments in which such equipment is used. The miniaturization of electronic equipment has increased the mounting density of PCBs and made the distances between electrodes minute. On the other hand, the changes in usage environments has placed a great variety of environmental stress on the PCBs. The occurrence of dew condensation at the minute distances between electrodes causes the degradation and failure of insulation due to such phenomena as Ion Migration. At Tabai Espec, to evaluate tolerance of dew condensation, we have developed Dew Cycle Test Chambers that simulate actual environmental conditions. (Photo 1)

Using this test equipment we are able to evaluate Dendrite growth due to Ion Migration, and do so with reproducible test results. In parts 1 and 2 of this report we examined the development of the test equipment and the methods of testing, but until now we had not yet elucidated the mechanism of Ion Migration caused by dew condensation.

Photo 1 Dew Cycle Test Chamber (Model DCTH-70, produced by TABAI ESPEC)

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*Environmental Test Technology Center

In this report we shall discuss the causes of Dendrite growth on the surface of PCBs in tests using Dew Cycle Test Chambers and we shall analyze the results. First of all, we used a TV camera to observe the dew condensation conditions (time, size and quantity of dew condensing) during tests using Dew Cycle Test Chambers. Next, we performed experiments on the relationship between water from dew condensation and the growth of Dendrites. Finally, the results of analyzing the surface of the tested specimens confirmed the process leading to degradation and failure of insulation. Water from dew condensation caused changes in the surface of the PCBs: the surface became subject to wetting and Dendrites grew due to water from dew condensation covering the gap between electrodes.

2. Test Conditions and Test Results

The samples used were tandem compound electrode pattern, corresponding to JIS type 2 as specified in Japan Industrial Standard (JIS)-Z-3197. Materials used were glass cloth epoxy (JIS: GE4) for the substrate boards, and copper was used as the electrode metal. Table 1 shows test conditions and Fig. 1 shows specimens. The test equipment used was the Tabai Espec Dew Cycle Test Chamber shown in Photo 1. Failure was determined by removing specimens after every tenth cycle and observing under an optical microscope. Specimens with Dendrites that grew between the electrodes and resulted in breakdowns were judged as failures. Fig. 2 gives a Weibull probability plot of test results, and Photo 2 shows Dendrites grew during testing. The shape parameter from the results yields a wear-out failure of m = 2.7.

Table 1 Test conditions

Temperature and humidity conditions	5°C 60% RH ↔ 25°C 90% RH at 20 minute intervals
Number of cycles	200 cycles
Voltage applied	5V DC
Specimen quantity	30 specimens
Prior processing	Ultrasonic cleaning in alcohol (IPA), then heat treatment at +100°C for 30 minutes

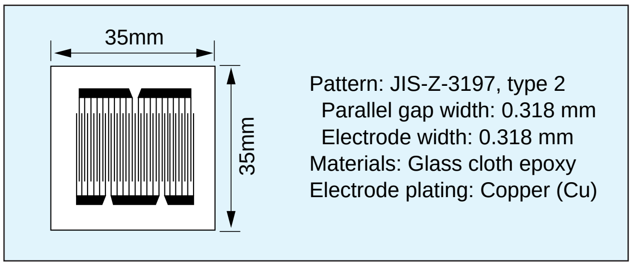


Fig. 1 Specimens

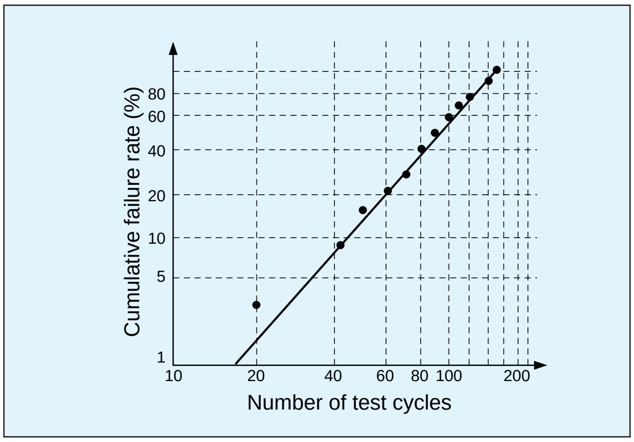


Fig. 2 Weibull probability plot of test results

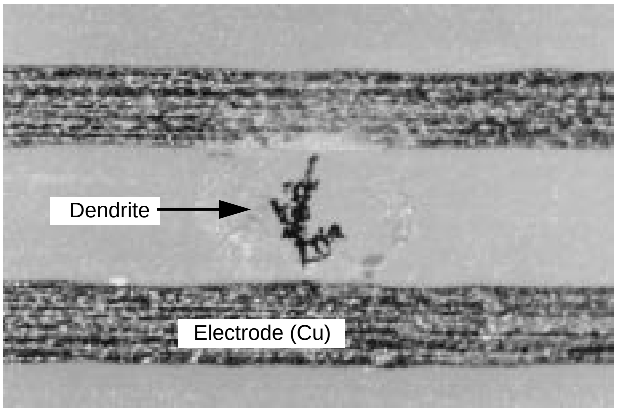


Photo 2 Failure condition

3. Observing dew condensation conditions during the dew cycle test

3-1 Cnfirming the quantity of dew condensing

We measured the amount of water (quantity of dew condensing) adhering to the surface of the PCB during the Dew Cycle Test, and we measured the dew condensing time. We found the quantity of dew condensing by measuring changes in weight, and we found the dew condensing time by measuring the current leakage between electrodes. Fig. 3 shows the results. Dew condensation approaches its peak about 1 or 2 minutes after changes are made in the temperature and humidity, after that drying gradually begins, and after about 10 minutes drying is complete. There was no change in quantity of dew condensing in different cycles, and we repeated cycles with reproducible results of dew condensation and drying.

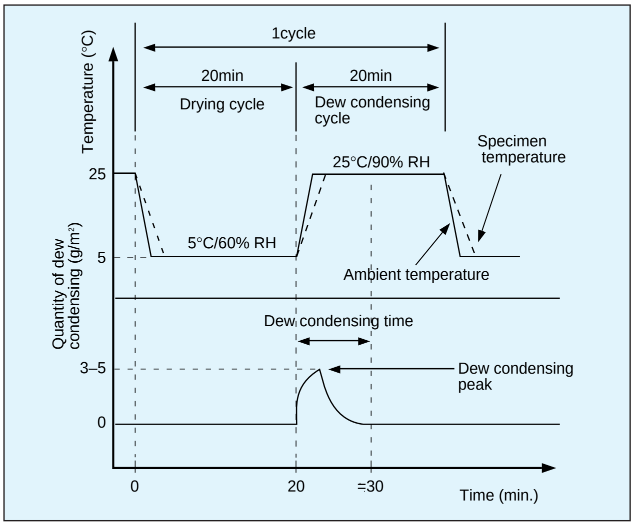


Fig. 3 Quantity of dew condensing and dew condensing time during test cycles

3-2 Changes in dew condensation conditions during the test

We set up a TV camera inside the test chamber and continuously photographed the dew condensation conditions during the Dew Cycle Test. Photo 3 shows the condition of water adhering due to dew condensation during the test. In the initial condition, the size of dew condensing is about 5 to 10 µm, easily small enough compared to the gaps between electrodes. As test time passed (repeated cycles) the water lost the shape of round droplets. After that, water formed a continuous film spreading out from both electrodes, and in some areas covered the entire gap.

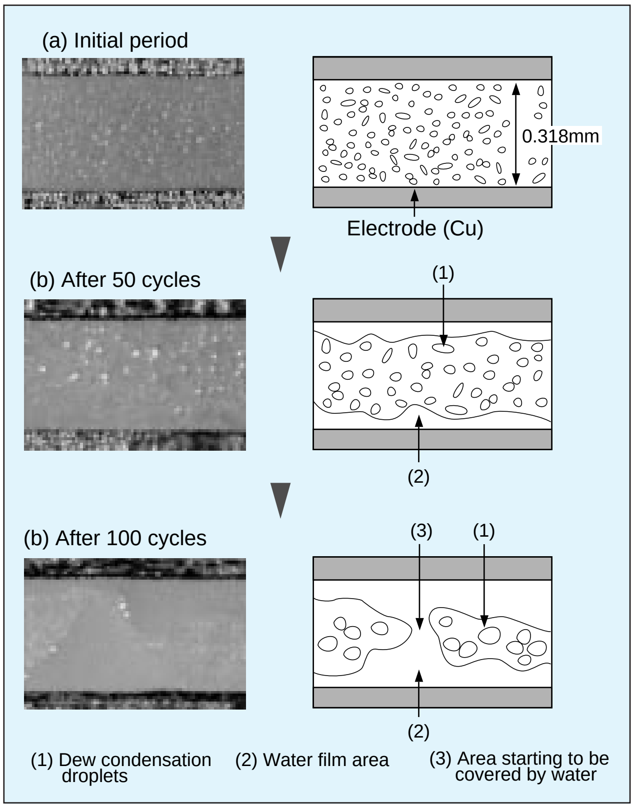


Photo 3 Changes in dew condensing conditions during testing

4. The relationship between dew condensation and failure

To clarify the relationship between dew condensation and failure, we devised prototype experimenting equipment to do nothing but cause dew condensation. This experimenting equipment accurately controls the quantity of dew condensing, and at the same time allows the process of the phenomenon to be observed. Fig. 4 shows the configuration and Fig. 5 shows the capacity of the equipment. Using this experimenting equipment, we tested the relationship between failure and the size and quantity of dew condensing, as well as at what dew condensation cycle the failure occurred. Specimens and test cycle conditions used in the experiment were the same as those given for the previously mentioned test (Item 2).

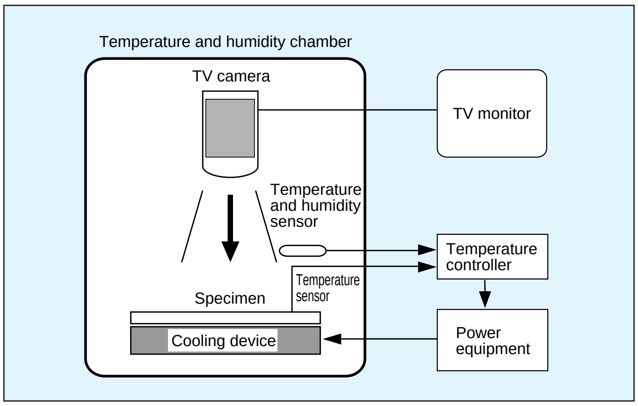


Fig. 4 Configuration of dew condensation experimenting equipment

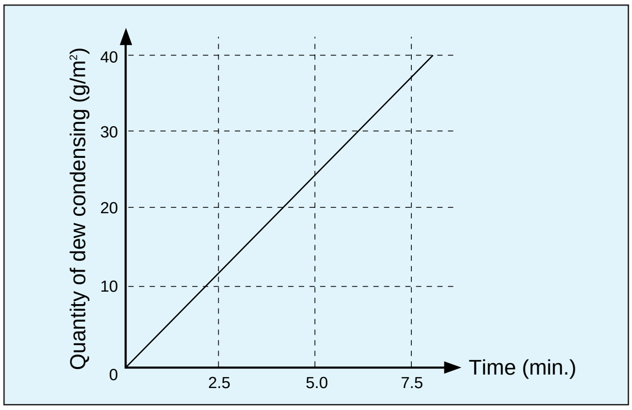
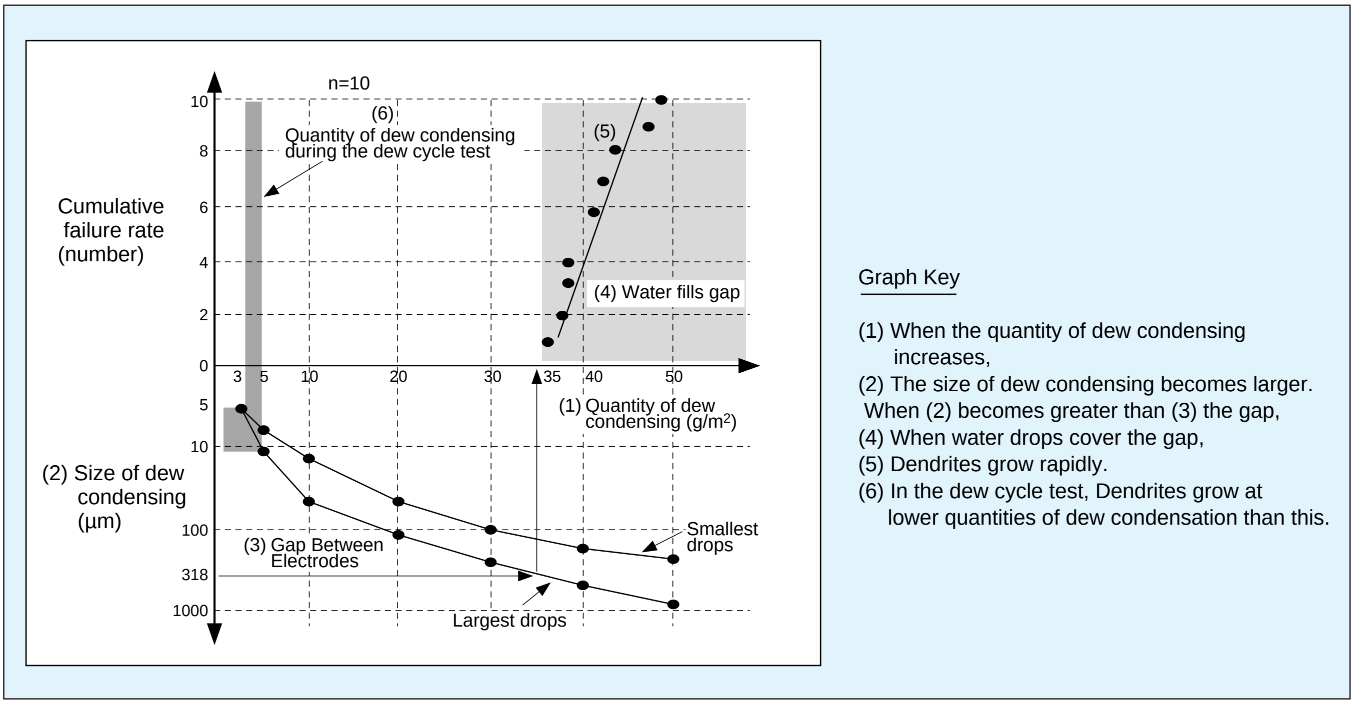


Fig. 5 Capacity of dew condensation experiment equipment

4-1 The relationship between failure and the size and quantity of dew condensation (Experiment 1)

One report states that Dendrites grow in a short amount of time when the gap between electrodes is covered with water.(3) This result is obtained using the experimenting method called the water drop method.(4) We obtained the same results using our prototype equipment. Fig.6 shows the results. When the quantity of dew condensing exceeds 35 g/m^2, the size of dew condensing becomes larger than 0.3 mm and the water begins to cover entire areas between the electrodes. From that time, Dendrites grow rapidly. Specimens have been cleaned and heat-treated, and measurements of the size of the dew condensing is the value measured from the camera images.



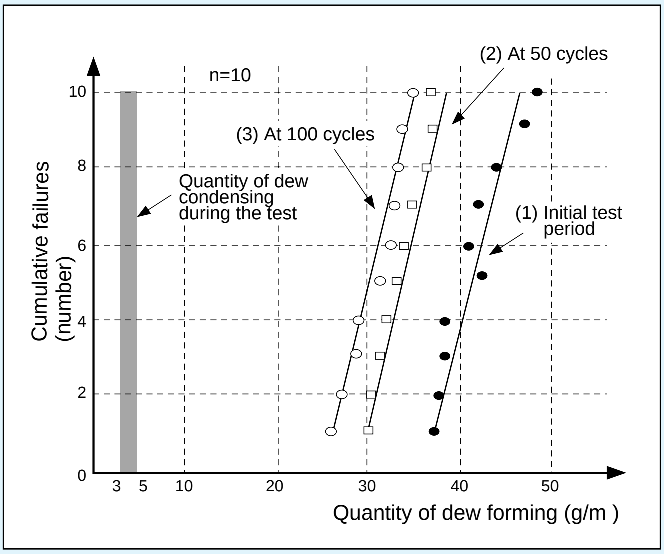
Graph Key

(1) When the quantity of dew condensing increases,
(2) The size of dew condensing becomes larger.
When (2) becomes greater than (3) the gap,
(4) When water drops cover the gap,
(5) Dendrites grow rapidly.
(6) In the dew cycle test, Dendrites grow at lower quantities of dew condensation than this.

Fig. 6 Relationship between failure and the size and quantity of dew condensation

4-2 Confirming the relationship between failure and the quantity of dew forming due to the test cycles (Experiment 2)

Using our prototype experimenting equipment, we gradually increased the quantity of dew condensing on the specimens used in the Dew Cycle Test. Fig. 7 shows the results of our investigation into the relationship between the quantity of dew condensing and the growth of Dendrites. Water spreads more easily as the number of cycles increases, and Dendrites covering the gap between the electrodes grow with less quantity of dew condensing. The quantity of dew condensing in the Dew Cycle Test is from 3 to 5 g/m^2, but failure occurred in this experiment at a lower quantity of dew condensing. Specimens used in this experiment were first put through a uniform cycle in the Dew Cycle Test then removed from the test equipment and let stand at room temperature. However, specimens in the Dew Cycle Test are not removed but are continuously tested, so we hypothesize that the moisture from repeated forming and dissipating of dew condensation was absorbed into the PCB, and the influence of that moisture caused the failure at lower quantities of dew condensing in the experimenting equipment.



Graph Key

(1) Tandem compound substrate boards not completing the dew cycle test
(2) Tandem compound substrate boards after 50 test cycles
(3) Tandem compound substrate boards after 100 test cycles

This graph shows the relationship between failure and the quantity of dew condensing when the amount of adhering dew condensation is increased in the various specimens. These results show that the greater the number of dew test cycles, the less dew condensation required for Dendrites to grow.

Fig. 7 The relationship between failure and the quantity of dew forming at different test cycles

5. Surface analysis

We can hypothesize that substances responsible for changing the wetting characteristics of the PCB surface are hydroxides from the electrode metal, impurities from the air, and (mainly) organic substances that have been eluted from the PCB materials (Fig. 8). We used an SEM (scanning electron microscope) to observe the surface of the PCBs. (Photo 4)

We were able to confirm substances adhering around the minute holes in the surface of the PCBs used in the Dew Cycle Test. An elemental analysis of these adhering substances detected copper. We can assume that this matter is copper that was little by little ionized and eluted from the repeated dew condensation and drying in the Dew Cycle Test. Also, in the area around where the Dendrites grew, the analysis detected bluish white copper hydroxide ($Cu(OH)_2$). The minute holes in that area were completely covered by copper hydroxide. We can presume that the cause of the water from dew condensation making the surface of the PCB conducive to wetting is mainly due to the effect of the ionization of the metals from the electrode, but we can also presume that a complex relationship exists with other substances.

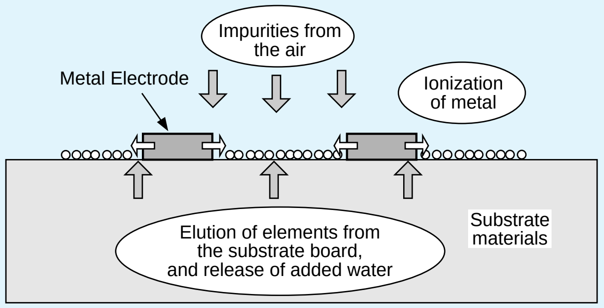
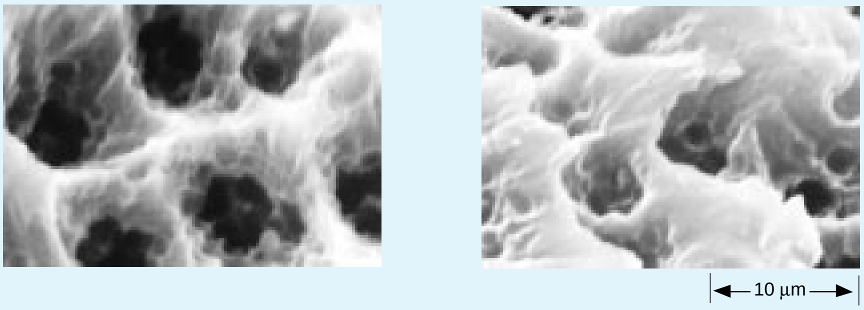


Fig. 8 Cause of changes in wetting characteristics



(a) Initial period

(b) After 100 cycles

Photo 4 Observation with SEM (2000×)

6. Conclusion

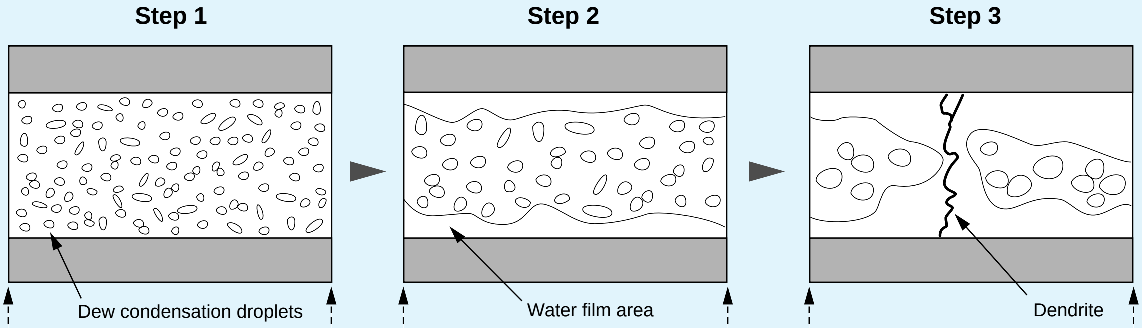
Analysis through observation of dew condensing conditions and using dew condensing experimenting equipment has confirmed the following about results of the Dew Cycle Test.

(1) The size and quantity of dew condensing during the test is well within the size allowable compared to the gaps between electrodes.
(2) The greater the number of test cycles, the more conducive to wetting the surface of the substrate board becomes.
(3) When the gap between the electrodes is covered with water, Dendrites grow rapidly.
(4) The greater the number of test cycles, the more conducive to wetting and the lower the quantity of dew condensing that is required for Dendrites to grow.

From the above, we can assume the following about Dendrites growing in the Dew Cycle Test. Repeated dew condensing and drying result in elution and adhering of electrode metals and other substances, and the surface of the substrate board becomes conducive to wetting. This condition results in water covering the gap between electrodes. When this has occurred, failure occurs fairly shortly afterwards. We can hypothesize the process up to degradation of insulation in the Dew Cycle Test as follows. (Fig.9)

Step 1: Small droplets of dew condensation water adhere, but no degradation of insulation occurs.
Step 2: Areas of wetting on the surface of the substrate boards gradually increase, but no degradation of insulation occurs.
Step 3: Areas between electrodes covered by water rapidly cause degradation of insulation.

Changes in the wetting characteristics in steps 1 and 2 can be presumed to be major causes affecting the life cycle in the Dew Cycle Test.



	Step 1	Step 2	Step 3
Condition of dew condensation	Size of dew condensing is small	Substrate board surface becomes conducive to wetting, and size of dew condensing becomes larger	Water covers the area between electrodes
Dendrites	Do not grow	Do not grow	Grow rapidly
Insulation degradation	No defects	No defects	Defects occur

Fig. 9 Process of insulation degradation in the dew cycle test

7. A final word

Ion Migration is intimately related to the water present, and obtaining reproducible test results requires uniform amounts of water. In the tests performed for this report, the size of dew condensing was easily small enough compared to the gaps between electrodes. When the quantity of dew condensing caused the size of dew condensing to become wider than the gap between electrodes, water covered the gap between electrodes and Dendrites grew rapidly. Because of these results, this test did not serve as a test of life expectancy. Care must be taken with this point when conducting a reproducible evaluation of life expectancy with the Dew Cycle Test.

The purpose of environmental testing is to cause the same characteristic changes that occur to a product during usage and to be able to evaluate the product quickly. The Dew Cycle Test method conforms to this purpose not only for Ion Migration, but can also be considered suitable for evaluating insulation degradation.

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Report 2

Great Expectations for the Combined Environmental Reliability Test (CERT)

For high assembly level or finished products

Hiromichi Fukumoto*

A large number of failures in the field are caused by conditions resulting from how the surrounding environment interacts with the internal characteristics of a product, creating the immense challenge of discovering this interaction as quickly and cheaply as possible. One means of doing so is the Combined Environmental Reliability Test (hereafter, CERT), based on combining accelerated factors. When using this test, both the environmental conditions for product use and product characteristics are considered in advance, and used to hypothesize the types of failure likely to occur. After first contemplating conditions unlikely to produce failure, a CERT profile is drawn up according to a reproducible mechanism for the test failure modes. In this report, I would like to present a brief explanation and introduction that can also serve as a guideline for inaugurating CERT. We shall take a close look at the correlation between failure modes and environmental stress factors and I shall discuss accelerated results, including new failure modes occurring under conditions of both combined and independent stress failure modes being used. We shall also consider application of stress failure modes to reliability testing under combined conditions that are as close as possible to the actual environment.

1. *Introduction*

Recent years have brought clear indications of changes in the demands by society as well as changes in the needs of corporate management for safety and reliability, i.e., quality, of not only electronic devices, but equipment in other fields as well. When looking at the forces behind these changes, one can see that the strongest influence comes from the mandates for safety and environmental measures. In other words, these are compulsory needs linked to the product liability law, ISO 14,000 and CE marking, as well as changes in materials and products resulting from those needs and producing increasing revision in all areas, including policies for development, design, and quality. Secondly, calls are also being made for reducing product development time as well as evaluation time for the wear-out failure phase occurring in the field. These goals cannot be attained without revising the time-consuming system for confirming reliability. Thirdly, the expanding use and scope of systems and networks has brought a corresponding risk of affecting the entire system through failures in terminals or attached equipment, and resulting in a trivial defect causing an unthinkable loss. And finally, the new age emphasis on human experience has led to the pursuit of “quality perceived by the five senses”.

These developments have generated fresh desire for progress in safety and reliability testing, and as one measure for making headway in that direction, we have great expectations for results of CERT profiles in combined stress, and so we are devoting new studies to this area.

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*Strategic Planning Department

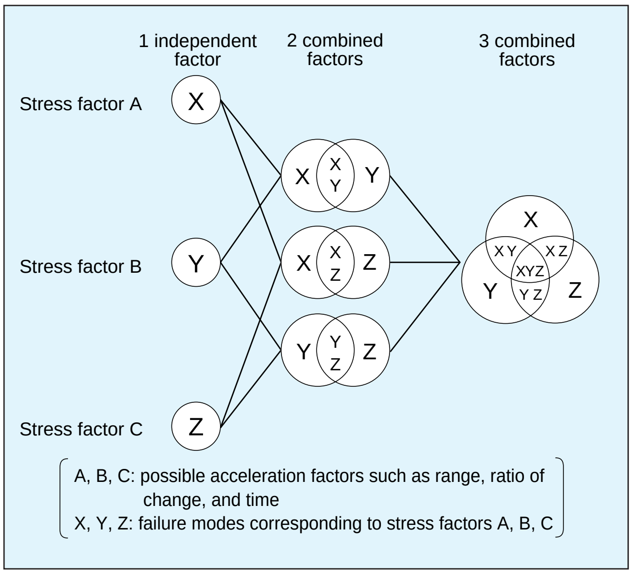
2. Great expectations for CERT along with some basic items

2-1 CERT effectiveness

The intensity of Environmental Stress Testing (hereafter, EST) and Environmental Stress Screening (hereafter, ESS) depends on such factors as the range of stress, the ratio of change, and the number of factors and cycles. Even in independent stress testing, increasing the complexity can accelerate the test 3 to 5 times. In CERT testing, 2 or more environmental factors are combined with the aim of accelerating each factor 3 to 5 times, producing an overall acceleration of tens or hundreds of times. Combining stress factors not only accelerates the failure mode for each stress factor, it also raises the possibility of introducing completely new failure modes.

Fig.1 shows the types of failure modes introduced by combining stress factors. In actual testing the results are not as simple as they are represented in the drawing, but you can see that X, Y, and Z are the failure modes corresponding to independent stress factors A, B, and C when applied independently. Combining two stress factors creates the new failure modes XY, XZ, and YZ, and combining all three factors results in the additional XYZ mode, while at the same time accelerating each failure mode (X, Y, and Z). The combined ABC environment more nearly recreates the environment encountered in the field than do the independent environments.

Because of this, we have great expectations that CERT will be able to achieve important results by predicting failure modes and testing according to failure mechanisms.



A, B, C: possible acceleration factors such as range, ratio of change, and time
X, Y, Z: failure modes corresponding to stress factors A, B, C

Fig. 1 Types of combined stress results

2-2 Failure and test conditions

Even in the same product one can find wide variances in safety and reliability depending on field environment conditions, manufacturing conditions, and characteristics of the product composition. Therefore, we must clearly acknowledge that failure does not occur or accelerate merely under test conditions. In other words, failure is caused by factors such as heat, current, stress, and strength of electric field characteristics concentrated at specific areas of the product, or by changes in or interruptions to those concentrations, as well as by characteristics (materials, composing parts, processing methods, and device structure) built in during the process of designing and manufacturing the product. This complex process leading to failure means that we must study test conditions from the standpoint of product characteristics and draw up a CERT profile. The test profile of any individual product is specific to that product, so if the test profile isn't reconsidered when the product changes, a mistake caused by the misapplication of MIL-STD-810C (Environmental Test Methods) produces the risk of the mistaken standards becoming incorporated into the design conditions and resulting in completely unexpected failures in the field. In other words, despite the fact that the usage environment no longer matches the characteristics of the product, the standards become part of the design conditions, so there is a danger of unexpected failures occurring in the field.

2-3 CERT as security against unexpected failure

Failure often occurs unexpectedly when we may be paying attention, but not quite closely enough. Quite frequently when considering an unexpected failure after the fact, one realizes that the failure was entirely predictable and thus usually avoidable.

Classifying failure according to physical and chemical causes produces 30 general classifications and 70 subclassifications. In spite of these groupings already being known and researched by specialists, many product designers are still unaware of them and produce designs that are tripped up by these failures. Also, extreme values can be produced by using optimum acceleration conditions rather than maximum acceleration conditions, resulting in intended improvements actually diminishing performance. As time passes, failure can also occur due to unexpected environments or conditions such as a combination of materials whose characteristics aren't suited to the environment or aren't suited to each other.

We can consider these problems using the CERT effects in item 2-1, develop an actual environment CERT profile, and use it to guard against failure in the field. This approach is based on the fact that when analyzing actual failures in the field quite a few serious problems are caused by conditions with a combination of stress factors.

3. Examples with hints for drawing up a CERT profile

Table 1 (page 19) gives examples of independent stress used in CERT for high assembly level or finished products. This table can be used to study the use of CERT by focusing on actual examples which can give us some hints.

The wide variety of causes for failure, such as seen in Table 1, includes such factors as rubbing, expansion, contraction, contamination, dehumidifying, evaporation, condensing, dew condensation, moisture absorption, chemical and physical reactions to light, changes in mechanical stress, changes in the friction coefficient, or changes in the heat transmission rate. I would like to discuss the effects of actual CERT examples according to test purposes and the failure modes (mechanisms) caused by the above-mentioned factors. Please note that numbers (1) through (15) as used here will correspond to the types of independent stress shown in Table 1.

3-1 CERT using temperature, humidity, and vibration

The three factors of temperature, humidity, and vibration are basic environmental factors that are ubiquitous throughout the earth, and as such compose the core of CERT factors. Research can confirm that 80 percent of all failures in the field can be correlated to these three factors (temperature 40%, humidity 20%, and vibration 20%). In a breakdown of the products in the environmental test equipment field shipped by our company, fully 85 percent of these products currently include the ability to test these three factors independently or combined. All other environmental stress factors such as gas, sand, dust, snow, saltwater, atmospheric pressure, and exposure to sunlight are based on combinations with temperature and humidity (or vibration) and so these three environmental factors always form the basis when designing CERT.

3-1-1 Combined failure modes caused by a drop in the friction coefficient

When applying heat stress with a temperature cycle, we can confirm failure modes such as failure caused by materials from differences in material quality (thermal expansion coefficient) and mass (heat capacity) as well as other modes such as mechanical failure or failure due to changes in electrical characteristics. On the other hand, when performing CERT with temperature, humidity, and vibration combined and applying independent stress failure mode acceleration, we can confirm the occurrence of new failure modes caused by the combined stress multiplication effect.

(1) Failure mechanisms

When a product with different thermal expansion coefficients is moving (expanding and contracting) in temperature cycle (1), "peeling" and "loosening" occur. If humidity (3) is applied at that point, moisture penetrates into the cracks, and the coulomb friction coefficient drops in the joints and contact areas. Applying vibration (8) at this point will increase the overall response at a specific frequency. For example, when changing from a dry to a wet condition, the response of the joint surfaces doubles due to the drop in the friction coefficient. In this way, by repeatedly applying factors such as movement, absorption, freezing, and resonance, we are able to evaluate new failure modes produced by significantly accelerating the independent factor failure mode as well as utilizing the three-factor combined multiplication effect. Also, if we make a combination by replacing vibration (8) with vibration (10), continuing the resonance in the specific frequency leads to rupture even at the low acceleration of 0.1G.

(2) CERT program example

- (1) × (3), (1) × (8) — 10 cycle
- (1) × (3) × (8) — (8) Random (Refer to Fig. 2)
  - — (8) Sine (at 5 to 200 Hz, 0.5G, 5 min. sweep)
- (1) × (3) × (10), (1) × (10) — Fixed at product resonance frequency, 1.0G
- (7) × (1) — At constant 95^{+5}_{-0} % RH, temperature cycle 30C°↔60°C
- (7) × (8), (9), (10) — According to purpose of the test

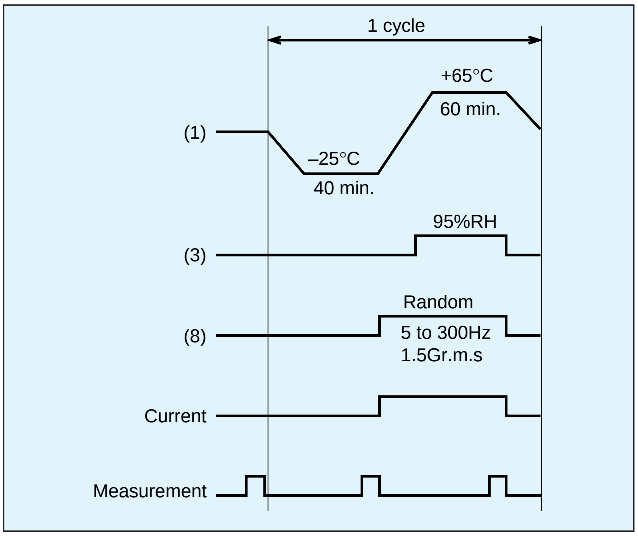
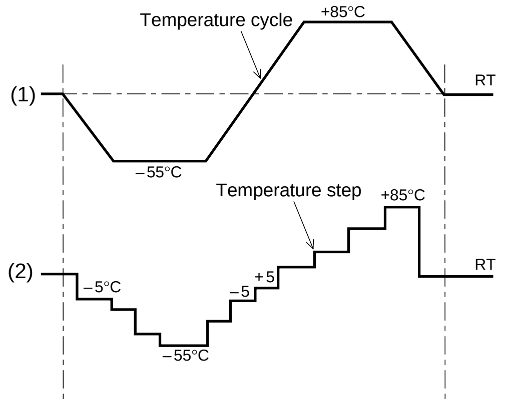
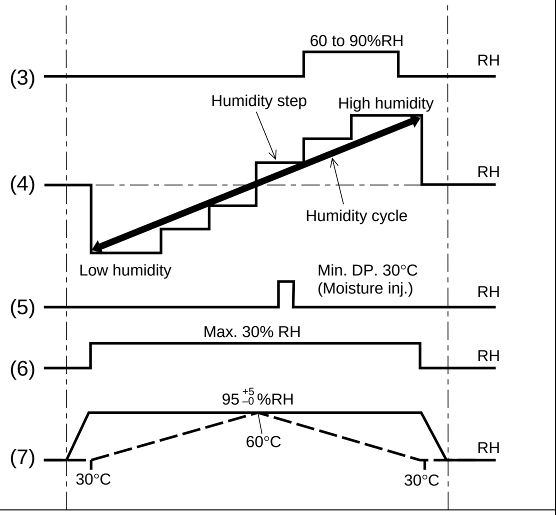
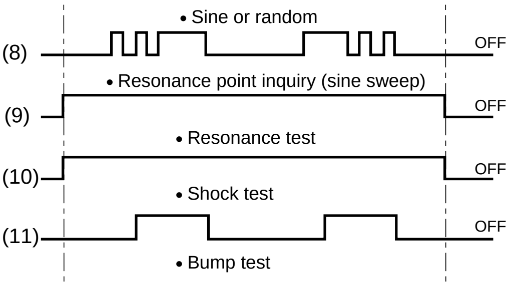
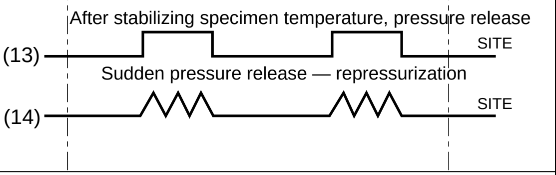
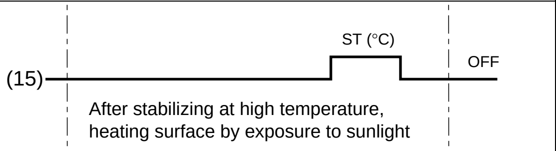
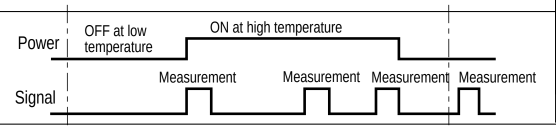
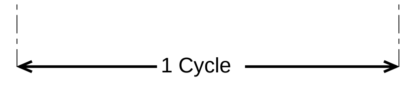


Fig. 2 Temperature-humidity-vibration CERT

Table 1 Examples of independent stress, failure (mode), and test equipment (for high assembly level and finished products)

	Representative types of independent stress	Stress levels	Failure (modes)	Test equipment
[A] Temperature		Rate of temperature change in (1) Low | 0.5 to 2.5°C/min. Mid | 5 to 15°C/min. High | 30 to 90°C/min. Test temperatures in (1) and (2) (°C) Low temp. | High temp. +5 | (+125) −5 | (+105) −10 | (+100) −25 | (+95) −35 | +85 −40 | +70 −55 | +55 (−65) | +40	∗**Caused by heat stress (expansion, contraction)** Failure of material surface, mechanical failure, cracking ∗**Caused by extreme temperature Changes in electrical characteristics, failure of sensitive parts** • Increased wear on moving parts due to expansion and contraction, or due to degradation of lubrication • Surface degradation and distortion • Increase or decrease in viscosity or flexibility • Promoting heat aging, or oxidation or chemical reaction due to heat aging • Changes in electrical characteristics E.g., resistance, inductance, capacitance, power factor, dielectric constant • Sealing defect in seal or gasket	• High temperature test • Low temperature test • Temperature cycle test • Thermal shock test
[B] Humidity		∗**As a rule, test conditions follow standards, actual examples, and actual environments** ∗**One example of humidity conditions** %RH | 0°C 95^{+5}_{-0} | 30↔60 95 | 20 to 85 90 | 50 to 70 85 | 85 (45–) 20 to 95 | 85 60 | 20 to 65 50 | 25 to 60 30 to 90 | 5 to 15 20 | 71, 85 5 to 20 | 10 to 35 2-5 max | –35 to +55 45 to 98 | –35 to +70 30 | 40 to 60	∗**Changes in humidity and temperature cause condensing and moisture absorption in parts and devices, and lead to corrosion, insulation degradation, and other problems.** ∗**Caused by extreme humidity** Degradation of mechanical strength, distortion, and embrittlement • Absorption of moisture content, adsorption (high humidity), increase in conductivity, corrosion, and expansion in electrolytic materials • Evaporation of moisture content, drying (low humidity), contraction, static electricity, increased wear of moving parts • Loss of plasticity • Short circuit caused by dew condensation • Sticking due to corrosion and contamination of lubrication	• Temperature and humidity test • Try test • Temperature and humidity cycle test • Moisture resistance test • Dew condensation test 5°C 60%RH ↔ 25°C 90%RH –30°C Free ↔ 25°C 90%RH • Humidity absorption test
[C] Vibration		∗**Transfer test** 5 to 200 Hz, 1 to 5G, sine, random, shock ∗**Resonance point inquiry** 10 to 2000 Hz, 0.4G max., sine sweep ∗**Resonance test** From fixed to ±3 Hz sine sweep, 5G max. ∗**Screening** 10 to 2000 Hz, 1 to 5G, sine, random	∗**Caused by mechanical stress** Mechanical failure due to resonance, fatigue, loading stress, and other ∗**Caused by looseness and wear** Increase in wear of moving parts • Wires rubbing together • Loose clamps, fasteners, and other • Broken insulation at contact point, short circuiting, and • Defective contact • Cracking and breaking • Electrical noise, optical misconfiguration	• Vibration test Sine random shock • Combined multi-axial test Multiaxial, multi-dimensional vibration test that is near actual environment and that can be done in two or three directions at the same time
[D] Altitude		∗**Examples of altitude conditions** kPa | mmHg | kPa | mmHg 84.2 | 633 | 11.6 | 87 59.9 | 450 | 4.4 | 33 29.9 | 225 | 0.13 | 1	∗**Reduced thermal transfer coefficient of the air, reduced electrical strength, boiling at low temperature, and other** • Sparks, corona, ozone, air bubbles • Reduction of crystal oscillator load • Breakage of sealed parts and structure	• Altitude test
[E] Exposure to sunlight		Atomosphere (°C) | ST (°C) 45 to 85 | 80 to 125 25 to 35 | 60 to 80	∗**Extreme thermal stress distribution** • Surface degradation, distortion, embrittlement weakening, color fading • Reduced elasticity, heat aging, heat warping • Internal heat rise, physical and chemical changes	• Exposure to sunlight (surface heating) test • Sunlight equivalence test
[F] Power, signal		∗**One example of source voltage** Rated +5 to +10% Rated –2 to –10%		
[G] Time		(1) Number of cycles: 5 to 200 (to 1000, to 2000) cycles (2) Test time: 12 to 500 (to 1000) hours (3) Soak time: 10 to 60 minutes (until specimens stabilize)		

(3) Combined failure mode and acceleration

(a) Independent failure mode acceleration series (failure mode with independent temperature, humidity, and vibration)

- Defective contact, open, short, defective insulation, battery corrosion
- Defects in fixed tools and fixed methods, part mounting defects, neighboring parts rubbing
- Gear engagement, chemical contamination, seal defects
- Materials and methods of attaching and joining, surface roughness of materials

(b) Combined failure mode series (failure mode with combined temperature, humidity, and vibration)

- Solder defect, broken lead, relay contamination, defective part determination
- Hardware looseness, peeling of coating from metal-resin group
- Characteristic defect of parts with no acceptance inspection, or inspection difficult to perform
- Continuous cracks in conductor pattern, through holes, or interior of multilayer substrate board
- Defects caused by cracks in parts due to soldering of Surface Mount Device (SMD) and cracks in solder
- Open or short circuits, at connectors or contact parts
- Defects caused by peeling or cracking of adhesion, filling, or coating
- Combined acceleration of independent failure mode in (a)

3-1-2 Cracking, corrosion, and fatigue related to the combined failure mode

(1) Fatigue and stress corrosion

It is well known that fatigue and stress corrosion are accelerated in the combined environment of temperature, humidity, and vibration, and that these two failure modes can appear independently or simultaneously. Failure such as embrittlement destruction of metals and stress corrosion cracking are accelerated by stress stemming from temperature change (1), and vibration (8) in a corrosive atmosphere (e.g., gas) and humidity conditions (3) and (7). In general, vibration causes fatigue through mechanical stress, but temperature and humidity also influence this process. Therefore, as the temperature rises there is a tendency toward shorter fatigue life.

(a) CERT program example

- (1) × (3) × (8)
- (7) × (8)

Refer to Fig. 3 (fatigue, corrosion, and stress corrosion)

- (2) high temperature × (10), (2) × (8) × (15), (2) × (4) × gas (corrosive gas)

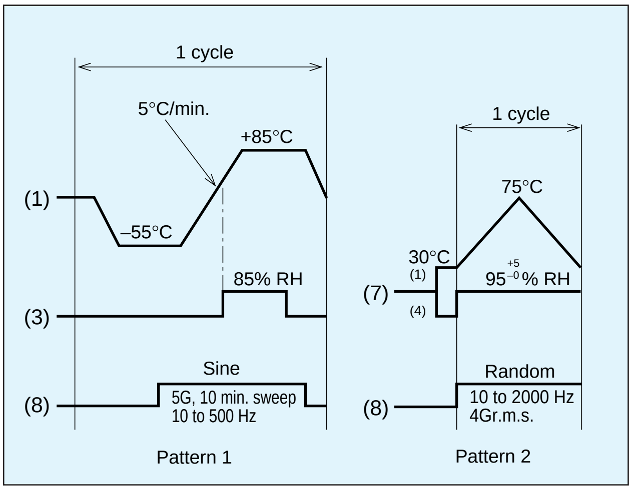


Fig. 3 CERT temperature, humidity, and vibration

(b) Combined failure mode and acceleration

- Extreme acceleration of corrosion and stress corrosion cracking
- Changes in strength and elasticity, and determination of structure, materials, and parts composing product
- Degradation of solder and adhesive

(2) Surface coating destruction and corrosion

Humidity causes surface corrosion, but does not strongly stimulate the interior of the substance. Therefore, in normal humidity tests (3) and (4), it is difficult to evaluate such areas as surface coating, sealing method (gasket, sealant), undercoating, and adhesion and joining methods.

Repeated expansion and contraction using temperature cycle (1) produces cracking in the surface coating and sealed sections. Applying humidity (3) and (4) at this point causes the moisture content to penetrate the interior. As the moisture diffuses through the interior it causes chemical reactions (oxidation, reduction, and neutralization) that take ionic substances from the periphery and from other components, and induce hydrolysis and electron movement.

Next, as a new interface is created, it produces precipitation of new substances, it causes corrosion, and accelerates under combined conditions. If vibration (8) is also applied at that point, the stress system response increases within the mechanism and accelerates corrosion and breakage of the corroded section. Results can include such problems as changes occurring in electrical resistance and PCB capacity, which can cause functional loss.

(3) Electrolytic corrosion

We know that when humidity is present in a direct current electrical field, electrolytic corrosion occurs in the presence of Cl (chlorine) and F (fluorine) ions. In particular, Al (aluminum) produces hydrochloric acid in the presence of chlorine ions, causing it to corrode. In condition (2) of this failure mode also, we can greatly accelerate the time leading to failure.

3-2 CERT using temperature, humidity, vibration, altitude (changes or drops in air pressure), and exposure to sunlight

Along with the demands for reducing product development time and evaluation time of the wear-out failure phase occurring in the field, I have presented a summary of the fact that when we analyze failure occurring in the field we often find that failure based on conditions combining various stress factors constitutes a major problem. As one approach to solve this problem, we find that in reproducing, independently and/or simultaneously, such conditions as temperature (A), humidity (B), vibration (C), altitude (D), and exposure to sunlight (E), chiefly in developing steps, performing EST and ESS, there is a CERT for confirming safety and reliability for all phases of the Bathtub curve (endurance life: initial failure, random failure, and wear-out failure), as well as for evaluating influences occurring under field conditions.

Below are presented some aims for CERT and their anticipated results.

- Establish external stress that reproduces as closely as possible the environmental conditions that the product encounters from the time of shipping from the factory until it is discarded, and aim for measures and/or development to obtain reliability under conditions of those kinds of stress.
- Aim for measures and/or development to find a truer correlation between the reliability values in testing and the reliability values in the field.
- In spite of the problems in failure analysis and measurement evaluation technology, aim to develop measures that can perform accelerated testing under more severe stress for the various factors than found in the field environment, and at the same time to reduce test time by combining factors.
- Think of roughly the same conditions as the product is exposed to in actual use, and be able to evaluate the influence occurring in the actual environment. Also, be able to promote the combined failure mode occurring from a combination of stress factors, and be able to take corrective measures in advance.

Current CERT testing is extremely close to these aims as it can independently and/or simultaneously test stress factors A, B, C, D, and E in these ways and is now able to reproduce a combined environment almost identical to that actually occurring.

Looking at shipping trends at TABAI ESPEC, there is almost no actual equipment that can simultaneously combine the five factors ABCDE, with most equipment able to handle ABCD and ABCE (i.e., using ABC as a base, add D (altitude) and E (exposure to sunlight) but not simultaneously). The major trends in testing are ABCDE for space equipment, ABCD for aircraft and space equipment, and ABCE for automobiles, cellular, and portable equipment.

Fig. 4 gives the TABAI ESPEC "Combined Environment Reliability Test Equipment: CERT Series" as a reference example of equipment.

Specifications

- Temperature: Air temperature, –70 to +150°C, 5°C/min.
  Wall surface temperature, –60 to +180°C (radiant heating and cooling walls)
- Humidity: 20% RH to 98% RH
- Altitude: Atmospheric pressure to 0.14kPa (1 mm Hg)
- Vibration: 5 Hz to 2000 Hz, random or sine
- Options: Dry air, moisture inj., ECA (External Cooling Air)
- Test area inside dimensions/capacity:
  CERT-22 W1500 × H1000 × D1500 mm/2.25 m^3
  CERT-33 W1500 × H1500 × D1500 mm/3.375 m^3

Fig. 4 TABAI ESPEC's Combined Environment Reliability Test Equipment: CERT Series

3-2-1 CERT using temperature, humidity, vibration, and altitude

(1) Trends in equipment and testing

To control the temperature of the chamber and the temperature of the specimens in this type of CERT equipment, the chamber has not only general ventilation, but also radiant heating and cooling inner walls as standard equipment to cover atmospheric pressure regions where there is less or no heat transmission from convection currents. (Refer to Fig. 4.) In addition, we can provide systems tailored to special needs, such as the dry air system to control low air pressure, low humidity (max. 10% RH) and no dew condensation, or the moisture injection system to cause dew condensation when atmospheric pressure and temperature rise, or the ECA (External Cooled Air supply) system programmed to heat and cool specific areas of the specimen.

Tests that have used this equipment have mainly been applications for one section of equipment mounted on aircraft or equipment mounted on automobiles (e.g., engine and ECU systems, sealed equipment systems), to identify failure that can occur under combined conditions resembling the actual environment, and to evaluate device characteristics occurring in storage and during transportation. However, in the present day and age, we have seen the miniaturization and increasingly mobile use of communications equipment, instrumentation equipment, AV equipment, computers and other equipment, along with their use in an ever-expanding range of environments, which has brought increasing opportunities for such stress as altitude and exposure to sunlight. Accordingly, the range of CERT use has expanded in step with these, to identify failure occurring in use at high altitudes and during air shipping and to take corrective measures in advance.

(2) Example of altitude CERT program

- (2) × (4) × (8) × (13) —— Refer to Fig. 5.
- (2) × (13) —— Abnormal heating
- (2) × (6) × (10) × (13) —— Wear
- (2) × (13) —— Limited region overheating
- (2) × (3) × (8) × (14) —— Coating breaking
- (1) × (4) × (10) × (14) —— Defective seal
- (2) × (6) × (8) × (13) —— Corona, electrical
- (2) × (13) —— discharge

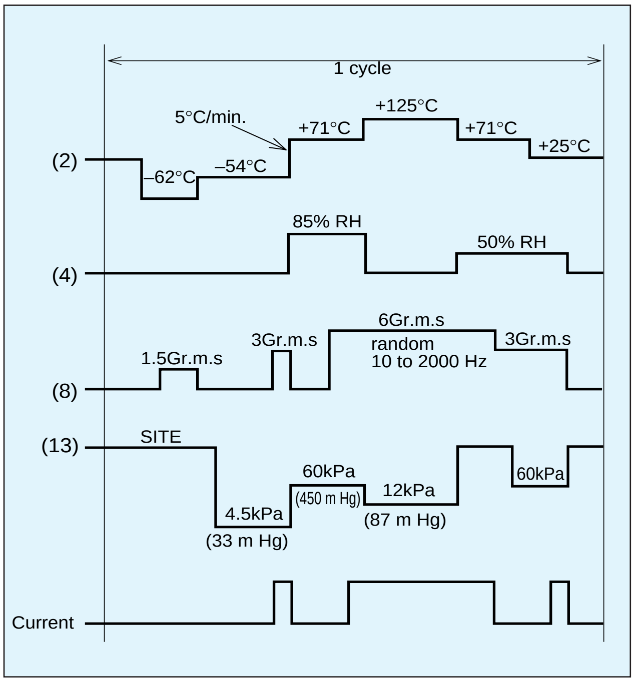


Fig. 5 Example of CERT with temperature, humidity, vibration, and altitude

(3) Test items for acceleration and combined failure modes

(a) Acceleration array of independent failure (modes occurring with independent atmospheric pressure testing)

- Use changes in atmospheric pressure to accelerate such items as action and leakage of respiration and promote failure modes such as an insulation drop, electrical breakdown, leakage from sealed containers, breakage and explosion of containers, and defective seals.
- Failures occur such as unstable operation of device due to corona and electrical discharge, drop in the life of electrical contact points, reduced load of liquid crystal oscillator.
- Temperature of device rises due to reduced thermal transfer coefficient with localized overheating of parts generating heat and emitting light.
- Degradation of functions due to physical and chemical deterioration of low density materials, degradation of elasticity, or penetration of low temperature section, contact section, or rotating section by generated gas.
- Low temperature boiling, evaporation of lubrication, or overloading, overheating, or wear of the rotating section.

(b) Array of combined failure mode (modes occurring with combined temperature, humidity, vibration, and altitude testing)

- (a) In addition, in a temperature, humidity, and vibration CERT failure mode, combined acceleration is possible in a mode with significant environmental effects from atmospheric pressure.
- Instability in engine start-up and combustion.
- Moving parts and system lock or looseness, structural parts coming loose or coming off.
- Electrical machinery systems failure due to frosting, dew condensation, or freezing
- Failure based on respiration, evaporation, or expanding and contracting of sections joining different types of materials. (Adhesion, molding, coating)
- Distortion and breakage of structural parts
- Breakage or failure of glass or optical system equipment
- Cracking of solid fuel
- A CERT profile can be drawn up with exposure under actual usage conditions, so it is possible to evaluate environmental effects using the actual environment.

3-2-2 CERT using temperature, humidity, vibration, and exposure to sunlight

(1) Trends in equipment and testing

In addition to the CERT systems with chambers that control temperature, humidity, and vibration, we also provide systems with lamps and irradiation intensity control for exposure to sunlight testing. The type of lamp differs according to the purpose of the test.

For example, when conditions of sunlight equivalency are required, xenon and halogen lamps are used either independently or in combination using wavelengths closely resembling sunlight to control “total amount of sunlight” in test conditions. On the other hand, when specimen surface temperature alone is important, inexpensive infrared lamps can be used to heat the surface, using “temperature” control in this case.

I shall deal with sunlight exposure testing with the infrared method in this item, but it is roughly the same as the testing trends and information in part (1) of item 3-2-1.

Temperature, humidity, vibration, and exposure to sunlight: CERT profile and environmental effects (exposure to sunlight test)

Evaluating the characteristics and endurance of equipment suffering surface heating under exposure to sunlight in addition to temperature, humidity, and vibration

<Accelerated evaluation of development> ◁ **Environmental effects of exposure to sunlight** ▷ **<Accelerated evaluation of quality>**

Effects of extreme heat stress on part surface

Strength is evaluated in regard to distortion and breaking due to heat stress from surface exposure to sunlight.

(1) Distortion, breaking, softening, and degradation of elasticity in such items as glass, resin, adhesives, case housings, and surface-mounted parts

(2) Sticking, looseness, or overheating of rotating or sliding parts

Effects of radiant heating on interior and periphery

Evaluating changes in the characteristics due to radiant heating from surfaces exposed to sunlight

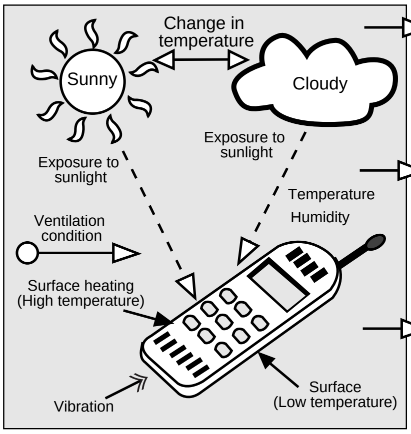
(1) Electrical characteristics, malfunctioning, softening, and degradation of elasticity of sealants, adhesives, substrate board, peripheral parts, and anti-moisture coating

(2) Overheating and changes in characteristics of parts generating heat and emitting light

Accelerated failure modes caused by temperature, humidity, and vibration

Example of exposure to sunlight and example of equipment subject to testing

<Example of conditions on cellular phones>

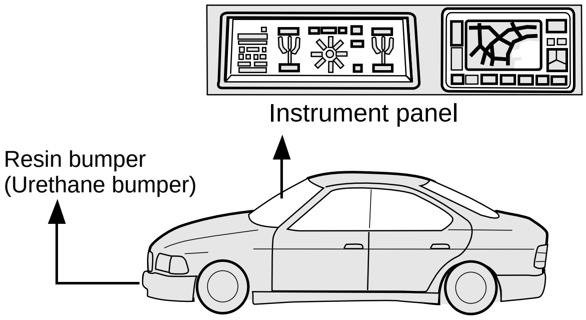


▷ Left outdoors (sea, mountains, four seasons), or inside a sunroom or automobile

▷ Conditions causing other stress (gas, dust, salt, dew condensation)

▷ Sunlight energy (Max. 1000 W/m^2)

<Example of automobile conditions>



<Compact mobile equipment that can be used outdoors>

- Communications equipment
- AV equipment
- Instrumentation equipment
- Medical equipment
- Military mobile equipment
- Cameras, personal computers, and others

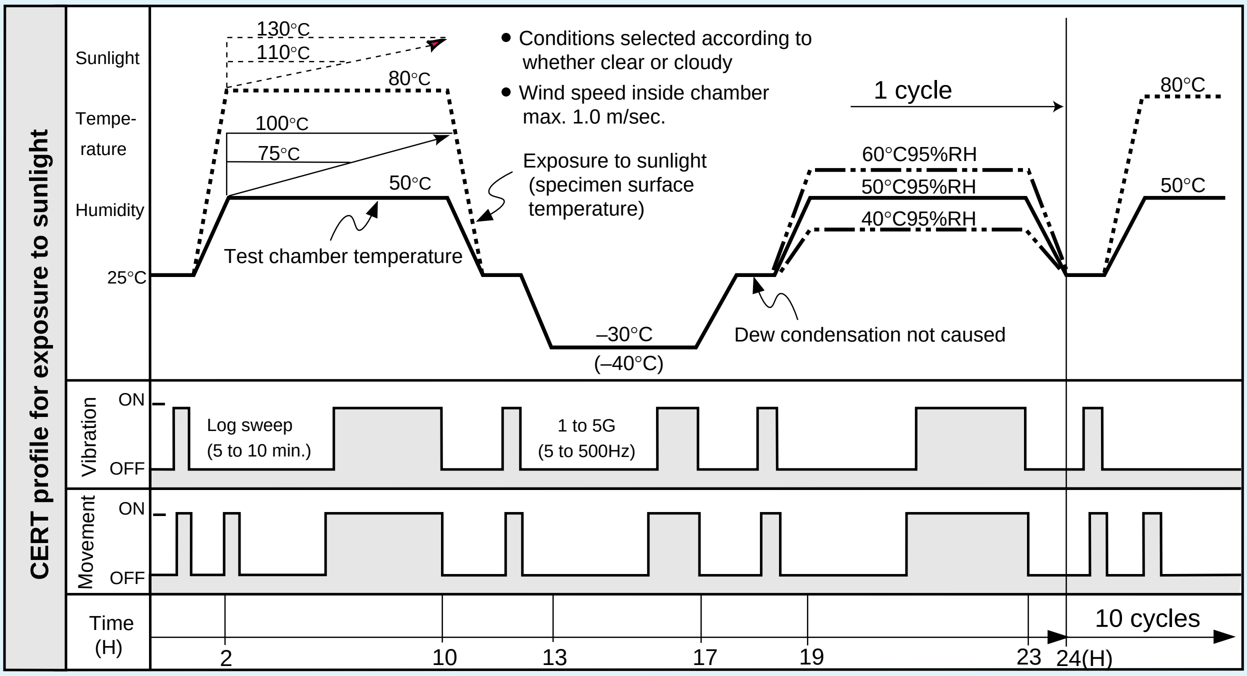


Fig. 6 Example of test conditions and effects (concrete examples of temperature, humidity, vibration, and exposure to sunlight)

(2) An example of a CERT exposure to sunlight program

- (2) × (4) × (8) × (15) —— Refer to Fig. 7
  Distortion and breaking
- (1) × (8) × (15) ——— Surface coating

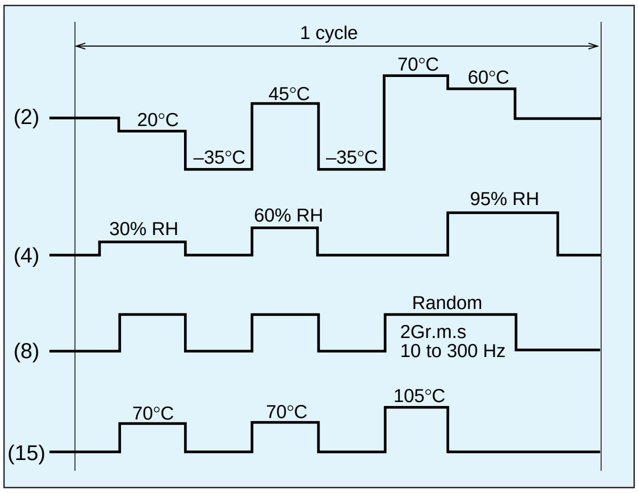


Fig. 7 A CERT example with temperature, humidity, vibration, and exposure to sunlight

(3) Test subjects for effects of acceleration effectiveness and environmental stress

Characteristics and endurance of a device are evaluated when the surface is heated in a sunlight exposure environment.

- Strength is evaluated for such conditions as warping and breaking under heat stress caused when a single side or a single surface is exposed to surface heating.
- Case housings, parts installed on the surface
- Glass, resin, coating
- Internally installed parts and machinery are evaluated for effects of surface heating.
- Softening and loss of elasticity of adhesive and sealant
- Sticking or looseness of rotating or sliding parts
- Malfunctioning or defective contact at electrical contact points
- Overheating of structure and parts generating heat and emitting light
- Acceleration of failure mode produced by temperature, humidity, and vibration

3-3 Key points in performing CERT

(1) In the resonance test (10), the test method must be selected according to the resonance mode shown in Fig. 8. In particular, when the resonance characteristics are sharp, normally a ±3 Hz sine sweep is desired to cause exposure at the peak.

(2) The effects of the vibration test generally depend on the axis of applied vibration (XYZ directions), so a test with triaxial capacity is planned.
In addition, one axis may have a stronger effect. (This tendency is strong in random vibration.)

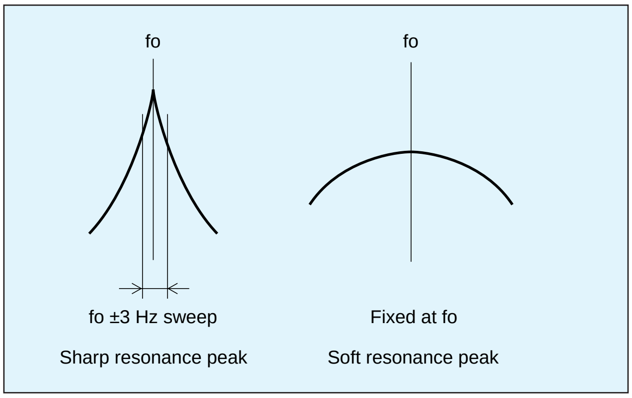


Fig. 8 Selecting test method according to resonance mode

(3) Due to miniaturization, surface-mounted substrate boards usually have few parts connected by soldered leads, and independent vibration stress produces almost no effect. CERT is also effective in this type of case.

(4) The test effectiveness is higher when the temperature range of temperature cycle (1) is at least Δ = 80°C.

(5) As a rule, the specimen power supply is OFF from the beginning of the temperature drop to the end of the low temperature period. The purpose is to achieve the target temperature quickly.

(6) When there is a change in the rate of temperature change, the soak time must be reconfirmed. Particular care is needed when the rate of change has increased, as the intended strengthening of stress becomes the opposite, a weakening.

(7) It depends as well on the atmospheric pressure of the test day, but as a rule it is better to avoid a 100°C (boiling) test and a 0°C (freezing) test. This is because erratic heat conditions may result when the specimen contains moisture in the test chamber with its precision settings and precision adjustments. However, it may sometimes be a bold idea to perform tests under these conditions.

(8) Humidity absorption (humidity resistance) tests and dew condensation tests have different objectives, so conditions are not set to produce dew condensation during a moisture absorption/ moisture resistance test.

(9) When including altitude stress in a combined test, the temperature of the specimen must always be monitored because the air density drops and the thermal transfer coefficient worsens. This makes it difficult for the specimen to reach the temperature target. In this type of situation, radiant heat and cooling equipment can be used together in the equipment provided in the test chamber. By the way, heat exchange using general ventilation equipment reaches its limits at 11.6kPa (87 mm Hg) and completely ceases to function below 4.4kPa (33 mm Hg), so radiant heating and cooling equipment are essential.

(10) I mentioned in item 2-2 that failure occurs based on the combination of conditions of the test and the product characteristics (materials, composing parts, processing methods, and device structure), but in the complex environment profile of CERT, if a hypothesis of the failure mechanism based on the internal characteristics of the product is not reflected in the test profile, it becomes difficult to specify the cause when failure occurs, and when drawing up a revised failure mechanism profile it becomes necessary to retest.

(11) In vibration testing, the multiaxial, multidimensional test equipment can be used to avoid the complex set-up and changeover work in reproducing the vibration environment close to the actual environment, and in the XYZ triaxial test.

3-4 The acceleration test and the acceleration factor

To understand the basic philosophy, refer to “Guidance for acceleration testing and reliability” in issue No.4 of the Japanese edition of Technology Report. The section on environmental test standards and environmental test methods is almost completely devoted to accelerated testing. Here, we shall consider the common problem of the acceleration factor, for which a solution has not been forthcoming. Research is being carried out on devices and special failure modes reporting many examples, but when a high assembly level beyond the PCB is reached, the situation becomes too complex to serve as the subject of debate and research. Rather, when the temperature is raised by 30°C in a test of completed products, just how much acceleration is achieved depends on the individual product and its characteristics, and the subject becomes even more difficult. At present we can only compare results with past test data and experience, and the problem presents no quick solutions.

Further, concerning item (4), let me note that the values specified are the greatest common denominator from a variety of irregular data.

(1) How to determine acceleration

Because this is a relative problem, we must base it on something such as past data.

1) With the same specimen, set two or more different stress levels, and using the same failure mode as the judgment standard, perform a “life test”. In this case, we must carry out prior screening and remove initial failure.

2) When data from actual test results has been plotted onto a graph of “test time — cumulative failure rate”, if the curve of stress parameters has the same distribution, this can be determined as related to acceleration.

(2) How to consider acceleration tests

These tests are carried out in accordance with failure mechanisms, but at present this process cannot easily be accelerated uniformly.

Therefore, acceleration test planning must be done to reduce the reaction process that requires so much time. Because of that, the deciding factor is knowing how the product breaks down, and knowing the mechanism leading to failure.

(3) IC acceleration factor

This example was reported more than 10 years ago, but it is included here for reference.

Table 2 Acceleration factors for moisture absorption time in every type of environment (for ICs)

No.	Moisture absorption conditions	Acceleration factor	
1	Interior storage	1	• Measuring changes in weight after storing for 1 year yields an acceleration factor of 1 for interior storage. • The acceleration factor of the pressure cooker test is ten times the factor for the humidity absorption test.
2	Soaking in distilled water	11	
3	High temperature, high humidity (65°C, 95% RH)	125	
4	High temperature, high humidity (85°C, 85% RH)	310	
5	Boiling	1240	
6	Pressure cooker (134°C, 100% RH, 3 atm)	3100	

Table 3 Acceleration factors from actual testing of cumulative failure rate from test time (for dual high-powered ICs)

No.	Test conditions	50% life	Acceleration factor	
1	30°C, 81% RH	(2,780,000Hr)	(1.8×10^{-3})	• The values for condition No.1 are hypothetical • There is temperature dependency in the acceleration factor.
2	85°C, 81% RH	3,300Hr	1	
3	115°C, 81% RH	446Hr	7.4	
4	130°C, 81% RH	85Hr	38.8	
5	150°C, 81% RH	10.4Hr	266	

(J.E.Gunn model)

(4) Acceleration trends with high assembly level specimens

Table 4 When changing temperature Ta in the constant temperature storage test

No.	Constant temperature storage temperature Ta	Effects and acceleration factor
1	Ta < 50°C	Up to 50°C, no major differences in effects are anticipated from changing Ta.
2	60°C < Ta < 120°C	Increases 80 to 100% for every 10°C rise (with 60°C as 1).
3	Ta > 120°C	Increases 40 to 60% for every 10°C rise (with 60°C as 1). However, damage to the specimen is highly probable.

Table 5 When changing temperature change rate Tr in the temperature cycle test

No.	Temperature change rate Tr	Effects and acceleration factor
1	Air: Tr < 2°C/min.	Up to 2°C/min. no major differences in effects are anticipated from changing Tr.
2	Air: 5°C/min. <Tr < 10°C/min.	Factor increases 10 to 20% for every 1°C/min. increase (with 5°C/min. as 1)
3	Air: 10°C/min. < Tr < 30°C/min.	Factor increases 15 to 30% for every 1°C/min. increase (with 5°C/min. as 1)
4	Liquid: Tr > 40°C/min.	Increases 4 to 6 times with an inactive liquid (with air as 1)

Table 6 When changing temperature range ΔT of the temperature cycle test (When Tr = 5 to 15°C/min.)

No.	Temperature range Δ	Effects and acceleration factor
1	ΔT < 80°C	Up to a temperature range width of 80°C, no major differences are anticipated from changing the ΔT.
2	ΔT > 80°C	Increases 10 to 20% for every 10°C increase in width of ΔT.

Table 7 When changing the degree of acceleration of sine wave vibration (20°C<Ta<100°C)

Vibration is not essentially an accelerated test. It is meant to be done at actual environment frequencies and G characteristics and does not fundamentally belong in this item.

No.	Degree of acceleration St	Effects and acceleration factor
1	St < 1G	Even low-level vibration can produce dramatic results depending on the purpose.
2	2G < St < 10G	Factor increases 40 to 60% for every 1G increase (with 2G as 1)
3	St > 8G	Fatigue occurs readily, making it difficult to confirm failure.
• The higher the exposure temperature, the greater the effects, and at 100°C the effect increases 2 to 3 times over the effect at 20°C.		

4. In conclusion

I have discussed expectations for CERT, aims and hints for introducing this type of testing, key points for performing the tests, and guidelines for acceleration factors, but there are difficulties associated with adjusting failure modes and accelerated effects in a combined stress environment for high assembly level specimens. However, accelerated effects of failure modes occurring in a combined environment or failure modes in independent environments and actual failures occurring in the field are actually produced by a combination of stress factors in a combined environment. I believe there are great expectations for CERT concerning how to confirm such matters as the fact that safety and reliability differ even in the same product depending on the production conditions and the life cycle environment conditions, and whether such problems can be corrected in advance. Also, since the enactment of the product liability law, the manufacturer bears responsibility for safe use even for products that have reached the wear-out stage, and so CERT can be used to ensure safe use in the field throughout the life of the product. In addition, we have great expectations for CERT as a means of reviewing system safety and reliability evaluations to counterbalance the “production while developing and improvement while producing” stance to shorten the time it takes to get products to market.

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Topics

Two main TABAI ESPEC plants acquire ISO 14001 certification

Yoshinori Kin*

1. Introduction

With the 21st century just around the corner, problems in the global environment such as global warming, acid rain, destruction of the ozone layer, desertification, destruction of the forests, and pollution of the oceans are becoming ever more grave. International solidarity has spurred efforts to preserve the global environment to begin in earnest. In this atmosphere of international cooperation, the International Organization for Standards (ISO) enacted the Environmental management systems (ISO 14001 and 14004) on September 1, 1996 and the Guidelines for environmental auditing (ISO 14010, 14011, and 14012) on October 1, 1996.

TABAI ESPEC acquired ISO 9001 certification in December 1993 and has immediately undertaken the challenge of the ISO 14000 series as well. The Fukuchiyama plant acquired the ISO 14001 certification from the Japan Audit and Certification Organization for the Environment (JACO) in December 1996, followed closely by the Utsunomiya Techno Complex in March 1997.

Below is a summary.

Facilities

Site area:	54,822 m^2
Green belt area:	3,827 m^2
Operation:	August 1974
Number of employees:	220
Production:	18.1 billion yen (1996)

Production scale (1996):

Temperature and humidity chambers and low temperature chambers	—	1,700
Ovens	—	2,900
Other		

Audit: Japan Audit and Certification Organization for Environment

Approval standards: ISO14001:1996

Approval Certificate No.: EC96J1046

Subject to certification:

The design and manufacture of Environmental test equipments and Semiconductor test equipments

Fig. 1 The Fukuchiyama Plant

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*Overseas Business Department

Our company has accepted a trust from the New Energy and Industrial Technology Development Organization (NEDO), a special status corporation under the jurisdiction of the Ministry of International Trade and Industry (MITI), to work as a co-developer in their “solar energy field test” project. We have been spending a considerable period of time gathering 15 items of data concerning solar energy, reporting back to NEDO, and installing that generating equipment in the Utsunomiya Techno Complex. In addition, we have erected an exposition hall (the Future Lab) to help spread the word about environment-friendly solar energy.

Facilities

Site area:	30,320 m^2
Floor space:	4,792 m^2
Operation:	November, 1991
Number of employees:	54
Production:	1.6 billion yen (1996)
Production items:	Burn-in Test Systems, Measurement Systems

Audit:	Japan Audit and Certification Organization for Environment
Approval standards:	ISO14001:1996
Approval Certification No.:	EC96J1081

Subject to certification:
The development, design and manufacture of Burn-in test systems and Evaluation systems

Fig. 2 The Utsunomiya Techno Complex

2. Enacting basic company-wide environmental management policies

ISO 14001 is a management system to reduce the stress to the environment caused by corporate activities and targets both economic development and environmental conservation. This means that the corporation must strive to consider the global environment in every area of activity and to reduce stress caused to the environment through its activities. The corporation must also independently construct an environmental management system and have that system clearly disclosed to a third party. In April 1996, TABAI ESPEC enacted its “Basic company-wide environmental management policies” and at the same time established and activated the “Company-wide environmental management committee”.

3. Enactment of environmental policies at each site

We have enacted the basic philosophy, basic policies, and environmental management objectives at each site based on the “Basic company-wide environmental management policies”. In addition, we have established active working groups subordinate to each environmental management committee.

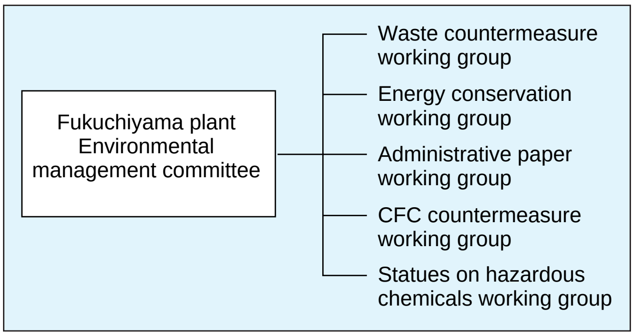

Fig. 3 Examples of working groups at the Fukuchiyama plant

Basic company-wide environmental management policies

Basic philosophy

The TABAI ESPEC group regards conserving the environment as one of the greatest problems facing the world today and recognizes this problem as fundamental to corporate management. Therefore, in all corporate activities we shall consider “the environment” and then act or make revisions to our activities, while striving to continually improve environmental management.

Basic policies

1. In every area of operation we shall work to promote energy conservation, reduce the amount of material disposed of, effectively utilize resources, and protect the environment.
2. We shall develop technology to conserve energy and resources and to promote recycling and ease of dismantling so that we can present products with minimal stress to the environment.
3. To the utmost possible, we shall substitute other materials for materials that destroy the ozone layer, such as freon, materials causing global warming, and other hazardous materials, and cut back on the amount that we discharge such materials.
4. In addition to observing laws and regulations concerning the environment, we shall establish independent standards and make even greater efforts for improvement.
5. We shall provide full environmental management organization and operating systems, and strive to clarify the locus of responsibility, while at the same time improving management and striving to provide full company internal regulations for activities to conserve the environment.
6. To improve environmental awareness of employees, we shall engage in education and publicity for the employees.
7. We shall make internal and external reports as necessary concerning the state of environmental management.
8. We shall perform environmental audits and strive to improve maintenance of independent management.
9. While striving to enhance technology to improve the environment, we shall research alternative energy and make every effort to contribute to society as a whole.

Fig. 4 “Basic company-wide environmental management policies”

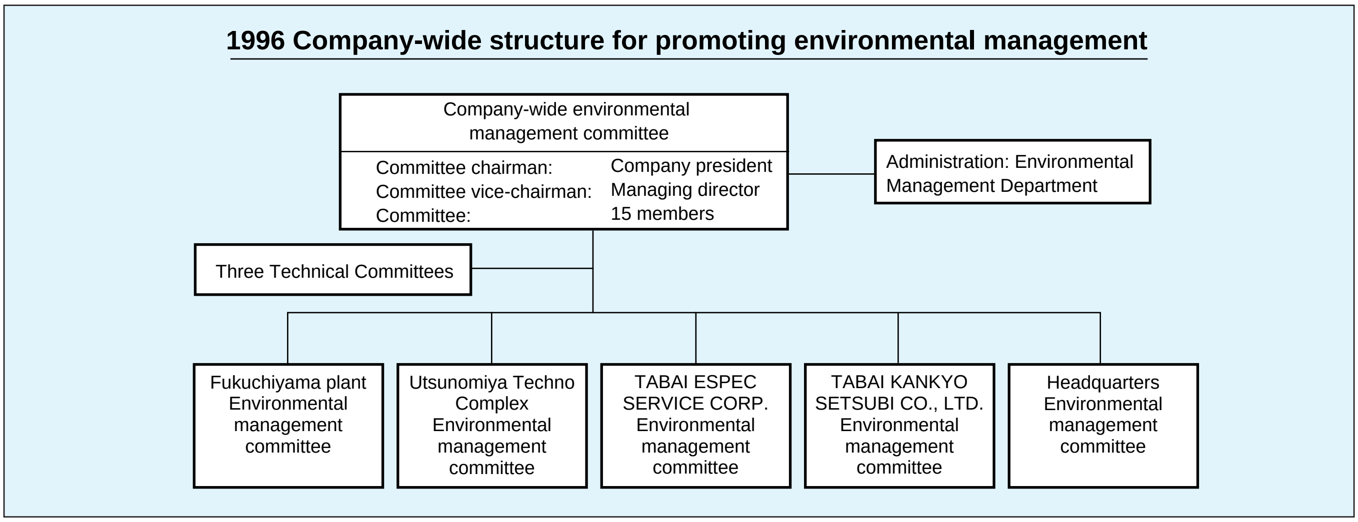

Fig. 5 Company-wide environmental management committee

4. Internal environmental auditing

We have established an “internal environment audit team” at each site, and the teams are periodically performing internal audits. After selecting personnel from within the company and giving them training from external sources, we have registered them as auditors.

5. Future challenges

Acquiring the ISO 9001 certification and the new ISO 14001 certification was not our most important objective, our most important objective is to maintain and incorporate them after acquiring certification. Since maintaining the environment is a problem in which there can be no going back, we can truly say that maintaining and incorporating these measure is the more important task. Since TABAI ESPEC was founded, we have contributed to the development of technology with an environmental theme. To avoid embarrassing that corporate theme, we wish to accept the challenge now of protecting the global environment.

ESPEC

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Registration Number
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JAB Certificate Number
R001

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.

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 Techno complex	EC96J1081	The development, design and manufacture of Burn-in test systems and Evaluation systems
TABAI ESPEC SERVICE CORP. Head Office	EC97J1050	The installation, inspection and maintenance for Environmental test equipments and Semiconductor test equipments

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