Technical information for our customers

ESPEC

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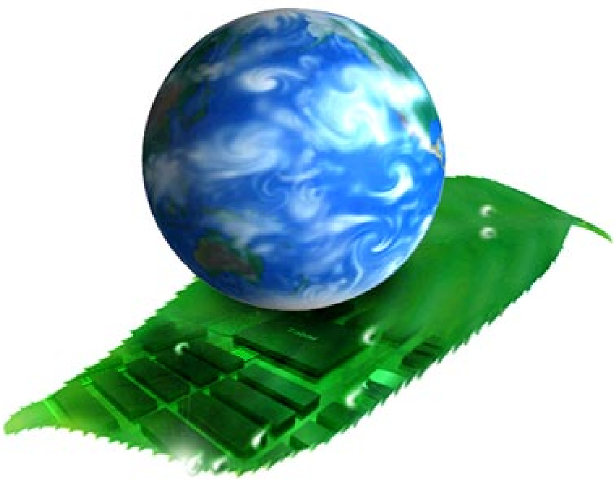
Special issue:
Evaluating Reliability



CONTENTS

TABAI ESPEC CORP.

Our Philosophy

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

ESPEC — our philosophy, our goal.

Corporate Data

TABAI ESPEC CORP.

Company Name:	TABAI ESPEC CORP.
Date founded:	July 25, 1947
Date incorporated:	January 13, 1954
Paid-up Capital:	6,778 million Yen (As of September, 1997)
Chairman:	Eiichi Koyama
President:	Kiyoshi Shimazaki
Senior Managing Director:	Yoshinobu Yamada
Managing Directors:	Susumu Nojii Toshikazu Adachi Nobuyoshi Shin
Directors:	Eishiro Hizukuri Yoshio Nakai Osamu Nakamatsu Hiromichi Fukumoto
Regular Auditor:	Katsuharu Nakano
Auditors:	Shoichiro Yoshioka Takuichi Omura Katsuyuki Kakihara
Employees:	577 (plus 57 temporary employees)

Product Guide

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

Evaluation Systems

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

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

Laboratory Chambers

Biomedical Chambers

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

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

Fundamental Concepts of Environmental Testing Techniques in Electricity and Electronics

Part 2: Fundamental concepts of the standard condition and movement of water or moisture for performing temperature and humidity tests

Toshio Yamamoto*

Part 2 in this issue discusses standard environmental values for environmental testing, and also analyzes the thermal stress and humidity stress related to humidity testing. Finally, the article explains the physical mechanism by which the moisture content in the test environment penetrates the specimen.

Contents

*Environmental Test Technology Center

1. *Introduction*

Aims and methods of environmental testing differ depending on the functions of products, their purposes, and the usage environments of the targeted markets. For example, when heaters are not properly maintained for the worst-case rainy season environment (e.g., removing accumulated dust from the internal equipment), the equipment will suffer from defective insulation and fail when the heater is brought out and turned on in the winter. Because of this, the home appliance manufacturer's group sets the worst-case conditions for absorbing moisture as the model test conditions for simulation. The communications equipment group as well, realizing the importance of the conditions and functions fulfilled by the communications equipment in the market, checks the failure mode from humidity absorption in the initial period. Therefore, these conditions use test methods presupposing acceleration.

As this illustrates, the differences in test purposes and test methods dictate completely different details in such areas as test sequence, test items, collecting and handling data, and evaluation methods and results.

Therefore, I would like to discuss a variety of topics such as on what sort of standards environmental conditions should be based when planning individual environmental tests, as well as what sort of effects temperature and humidity stress will have on products, and how to understand the mechanisms by which moisture penetrates the internal parts.

When performing environmental testing, the testers must first be aware of the standards for environmental conditions and base the tests on those conditions, and then they must determine the aims of tests and develop the proper test methods. Test planning, preparation and execution must be in accordance with those aims, and recovery procedures must be set in advance. The test must not be started before all these preparations have been completed, as this is a scientific test.

2. *Standard environmental values*

2-1 Standard environments determined by standards

In all standards, the standard conditions are established for the specific environments that serve as a common base in a particular series. Therefore, all individual standards are constructed on the premise that these standard values exist, but in most cases these are not individually noted. At this point, I would like to discuss these standard values based on the IEC standards.

(1) Standard reference atmosphere (standard conditions) ...(IEC 60068-1/JIS C0010)

—Temperature: 20°C

—Air pressure: 101.3 kPa (1013 mbr)

Note: The relative humidity is not prescribed, because in general calculated correction is not possible.

Parameters that should be measured are influenced by temperature and pressure, and when the correlation between them is known, they should be measured using conditions in part (3) below. If necessary, they should be compensated using the above “Standard reference atmosphere”.

(2) Standard atmosphere for referee measurements and tests (judgment conditions) ... (IEC 60068-1/JIS C0010)

Parameters that should be measured are influenced by temperature, pressure, and humidity, and when the correlation between them is not known, prescribed atmospheric conditions are chosen from the following table.

Table 2-1 Atmospheric conditions for judging

Temperature (°C)		Relative humidity (%)	
Nominal value	Close tolerance / Wide tolerance	Close range	Wide range
20	± 1 / ± 2	63 to 67	60 to 70
23	± 1 / ± 2	48 to 52	45 to 55
25	± 1 / ± 2	48 to 52	45 to 55
27	± 1 / ± 2	63 to 67	60 to 70

Note: Atmospheric pressure (kPa) is 86 to 106.

Notes:

1. The above values include values prescribed in ISO 554 (Standard atmospheres for conditioning and/or testing) and 3205 (Preferred test temperatures).
2. 25°C is required (hence used) for testing ICs and semiconductor devices. (Not included in ISO 554 and 3205.)
3. Close tolerances may be used for referee measurements, while wide tolerances may only be used when allowed by the referee specification.
4. Relative humidity may be ignored when it doesn’t affect test results.

(3) Standard atmosphere conditions for measurement and tests (standard conditions) ... (IEC 60068-1/JIS C0010)

This shows the standard reference ranges for atmospheric conditions for measuring and testing. (In other words, this points to all actions that affect the test, except test conditions inside the test equipment, and can be understood as referring to normal peripheral conditions and room temperature.)

Table 2-2 Atmospheric conditions other than test conditions

Temperature (°C)	Relative Humidity (%)	Atmospheric pressure (kPa)
15 to 35	25 to 75 (Absolute humidity ≦ 22 g/m^3)	86 to 106 (860 to 1,060 mbr)
10 to 40	For large specimens and specimens left inside the chamber the measurements and tests (However, judgment must be made according to the relevant specifications.)	

Notes:
1. Fluctuations in temperature and humidity should be kept to a minimum during serial measurements performed on specimens as one section of the test.
2. In sites where temperature cannot be kept within the limits on the upper level of the table when measuring large specimens or specimens left inside the chamber, it is possible to expand the temperature range to a low of 10°C to a high of 40°C as shown on the lower level of the table when allowed by the relevant specifications. (In JIS C0010, the upper limit for relative humidity is 85%, and is suited to Japanese domestic climate.)

Furthermore, military standards differ from standard reference values set by the IEC. For example, in the MIL-STD-810E (Environmental Test Methods and Engineering Guidelines, 1989) they are as follows.

(a) Standard ambient. Ambient measurements and checks (e.g.,pre-and post-test) are conducted at room ambient conditions as follows:

Temperature :	25°C ± 10°C
Relative humidity :	Uncontrolled room ambient
Atmospheric pressure :	Site pressure

(b) Controlled ambient. When the ambient conditions must be closely controlled, the following shall be maintained:

Temperature :	23°C ± 2°C
Relative humidity :	50 % ± 5%
Atmospheric pressure :	96.45 + 6.6 / –10.0 kPa

Note: Other allowable values for test conditions are prescribed, but are omitted here.

As you can see from this, it is necessary to be aware that standard reference condition values differ according to test standards.

2-2 Test chamber conditions

In IEC standards, there are currently no performance provisions that must be maintained by the test chamber performing the environmental test. There are also no prescribed methods of confirming that performance. Therefore, at present, standard test equipment is based on the manufacturer's experience and actual results, while test equipment for special purposes is based on discussions between the user and the manufacturer to work out the performance details. Often, this approach results in test equipment being designed specifically for individual products.

In Japan, the only test equipment manufacturer's group, the Testing Machinery Association of Japan, has created the following performance standards for environmental testing equipment.

JTM K01 Standards for performance of humidity chambers (1991)
JTM K03 Standards for performance of humidity rooms (1992)
JTM K05 Standards for performance of high temperature chambers (1991)

These standards were created by the manufacturers rather than the users, but they serve to organize the approach to testing equipment, as well serving as reference materials. At the very least, they effectively serve as standards clarifying rated performance for current standard testing equipment. However, in measuring humidity, differences from other public standards arise in some areas, and those areas are currently being revised, along with other areas.

For reference, the standard atmospheric conditions of these standards are as follows.

Temperature:	23 ±5°C
Humidity:	65 ±20%

2-3 Structure of environmental tests

According to IEC/JIS, environmental tests are structured according to the following work sequence to evaluate the influence of tests on specimens or serial tests.

a. Pre-conditioning
Specimens are treated to remove pre-test influences or to neutralize specific parts.

b. Initial examination and measurements
Necessary measurements are made prior to exposure to the test environment.

c. Conditioning
Specimens are placed in the prescribed test environment conditions to investigate the affects of the test conditions on the specimens.

d. Recovery
After exposure to environmental test conditions, specimens are stabilized before measuring characteristics.

e. Final examination and measurements
Necessary measurements are performed after exposure to the test environment.

Notes:
During the test conditions (during exposure) and during recovery, intermediate measurements may be requested, but in this case the IEC standards stipulate that the test environment not be disturbed once the test has begun. Therefore, specimens inside the chamber during the test cannot be removed from the test chamber for intermediate measurements.
Furthermore, in standard categories specimens are prescribed products to be tested according to standard sequences. (“Products” include systems and auxiliary parts that provide essential functions.)

3. Fundamentals of environmental testing

At this time, let's look at the fundamental relationship between the products and the environment, a relationship that forms the background to specific environmental tests. We shall look into how the environment affects the products as stress. For industrial products, at least for electrical and electronic products, fundamental environmental stress means temperature stress and humidity stress. In some cases we must also consider mechanical stress, electrical stress, or gas stress. In reality, the resulting stress is rarely from a single source, but instead is usually from a sequential combination of these stresses, or from a complex stress formed by a simultaneous combination of these stresses.

3-1 Heat stress

Heat stress is one of the most frequently discussed type of stress, the other being humidity stress, which we shall look at later. These types of stress are deeply implicated in a large number of actual failure phenomena. Heat stress is a physical phenomenon that can independently cause failure due to heat introduced from outside sources or due to heat generated by the part itself. In this case, when the product heats up, an internal structural part may be destroyed, or in the opposite instance, when heat is leaked externally, the product may experience a drop in temperature leading to weakened functionality or damage.

3-1-1 High temperature environments (temperature rise due to heat gain)

In general, the following results can be attributed to heat stress when the temperature rises:

1. Heating leads to a drop in viscosity of the substance, promotes softening of materials, generates mechanical and structural degradation such as weakened sealing functions, and also lowers electrical qualities.
2. Heating melts substances. In particular, when resins are heated above the glass transition temperature, resistance to distortion is reduced, and support cannot be maintained. When the temperature of a material nears its melting point, the original form cannot be held.
3. Because heating causes materials to expand, heating generates strain between materials restricted together when there is a difference in the thermal expansion coefficient of those materials, causing distortion.
4. Temperature rise due to heat gain promotes chemical reactions. In addition, heating results in the evaporation of decomposed substances in the materials as well as evaporating unreacted substances in resins through such means as sublimation and evaporation. These phenomena cause hardening and degradation of the product itself, as well as giving rise to corrosion of other materials.
5. Furthermore, repeated raising and lowering of the temperature leads to repeated expanding and contracting of materials, which can lead to stress on the attached parts and on the material itself, thus leading to destruction of the material (thermal fatigue).

By the way, in designing electrical and electronic parts, thermal design is extremely important in regard to the relationship between the part and the product in which it is to be used. The heat emitted by the operation of today's low-voltage-consumption home appliances remains an important topic.

A direct example of extreme environmental stress would be the equipment used aboard aircraft, especially supersonic aircraft and spacecraft such as the space shuttle. Besides being exposed to extremely harsh temperatures, this equipment also sustains an extremely severe temperature fluctuation gradient, obliging the parts to operate in a harsh, high-temperature environment. Aircraft operating environments have the following characteristics:

(1) Acceleration and increases in altitude (with sharp gradients for such increases and decreases),
(2) Electronic equipment concentrated in narrow equipment space,
(3) Increased functions and capacity of equipment, and an increase in the type of equipment,
(4) Miniaturization of equipment and concentration of heat-generating parts, and
(5) Power equipment unavoidably placed near other heat sources.

In such cases, the equipment's internal high-temperature environment softens materials with a low melting point, and in extreme cases causes the material to melt and run. For example, wax, grease, and compounds fall into this category. In aircraft in particular, any of these could cause an extremely dangerous situation. The temperature at which heat distortion begins in most materials known as heat-resistant plastics is not as high as you might think. The temperature at which insulation materials begin to degrade as a result of heat from the surrounding environment is also lower than might be expected. The previously mentioned differences in thermal expansion of different materials can cause installed parts to loosen, or cause overtightening. Heat can also cause problems due to breaking down such materials as seals. These types of aging processes normally occur at high temperatures, thus promoting the dissolving of organic materials as well as increasing the hardness of such materials as rubber and artificial materials, causing solidification.

Incidentally, equipment that normally emits a lot of heat has low electrical efficiency and emits most of its power consumption as heat. When this type of equipment is operated in an atmosphere with high ambient temperature or near other equipment emitting a lot of heat, there is a further influx of heat, causing problems. These phenomena, as has been noted, cause changes in the quality of the materials in the parts, and the molecules that make up the materials strongly affect the electrical characteristics. These types of changes are accelerated by temperature increases, producing early period failure both physically and chemically.

In general, the following can be done to avoid these problems:

(1) Improve the life and reliability of the components.
(2) Improve circuit stability in regard to heat resistance.
(3) Improve the heat resistance of the materials themselves.

These and other methods can be used, but since materials not activated by heat are currently rare, improving parts is easier said than done. In most cases, this will depend on developing newer, more stable materials.

To summarize, problems caused by stress due to rising temperatures are linked to (1) critical failure, (2) reduced operating life, (3) temporary physical changes, and (4) exposure to long-term severe high temperatures leading to permanent physical and chemical changes, and finally to permanent failure.

3-1-2 Low temperature environments (cooling due to heat loss)

Phenomena caused by cooling generally exhibit the opposite aspects as the phenomena caused by heat stress.

1. Cooling promotes solidification of structural materials, restricts the free movement of molecules, causes structural degradation, e.g., by crushing, and degrades electrical functions.
2. At low temperatures, the hardness of many resins drops markedly and the resins become brittle, becoming quite easily damaged by shock. This leads to cracking, compromises the effectiveness of seals, accelerates structural degradation, and lowers electrical quality.
3. Cooling increases the viscosity of materials, resulting in lowering the effectiveness of lubricants, and accelerating mechanical degradation from friction.

However, rather than receiving critical damage in a low temperature environment, products usually experience a loss of quality, such as functional degradation.

3-1-3 Low temperature and low pressure

When considering the earth’s environment from a global standpoint, the danger of low temperature environments exists not only in the polar regions, but at high altitudes as well. The relationship between altitude and temperature is shown as representative values in Fig. 3-1.

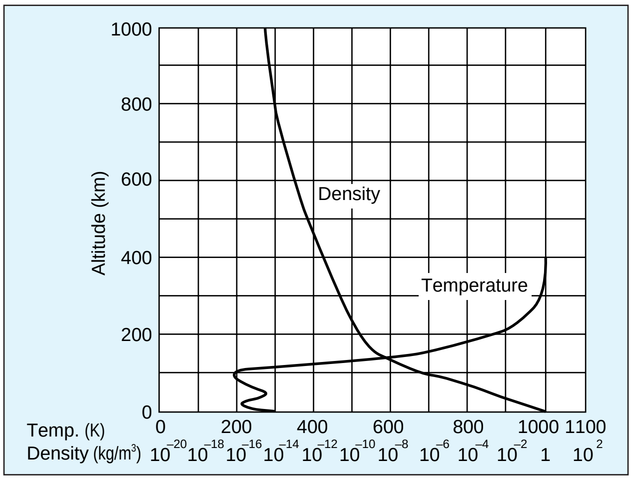


Fig. 3-1 Altitude distribution of atmospheric temperature and air density

At this point, for reference, I would like to briefly touch on the relationship between altitude and standard atmospheric temperature and pressure. Standard atmosphere is one atmospheric model, and in 1964 the “ICAO Standard Atmosphere” was supplied by the International Civil Aviation Organization (ICAO) as a representative international standard atmosphere. This is the same content as the lower strata of the “US Standard Atmosphere 1976” up to 32 km altitude.

This atmosphere is represented with temperature curves for three geopotential altitudes. Namely,

- Pressure/temperature on the earth's surface: 1013.25 hPa/15.0°C
- Temperature change ratio up to 11 gpkm altitude: –6.5°C
- Altitude, pressure, and temperature of boundary: 11 gpkm, 226.32 hPa, –56.5°C
- Temperature change ratio up to 20 gpkm altitude: 0.0°C/gpkm
- Temperature change ratio up to 32 gpkm altitude: +10°C/gpkm

Altitude is determined by the WMO (World Meteorological Organization, under the auspices of the United Nations) so that 1 gpm (geopotential altitude) is equal to 9.80665 m^2/s^2, and in areas of standard gravity (9.80665 m/s^2) 1 m altitude corresponds to 1 gpm. Even in other areas, the geopotential value represented by gpm is roughly equivalent to the altitude in meters. For details, please refer to the US Standard Atmosphere 1976.

3-1-4 Low temperature and electrical and electronic equipment

When temperature is at the level of –40°C, electrical and electronic equipment becomes difficult to operate on semiconductor devices, and human activity also slows. Because of this, most equipment is operated inside a heated building or similar arrangement. However, such equipment as cellular phones, or business communications equipment must be operated in all types of environments. Performance of electrical and electronic equipment operated in low temperature environments must have improved low-temperature characteristics for capacitors, inductors, resistors, and semiconductor parts such as CPUs, and components of parts and circuits are also affected. The simple solution would be to use a heater, but this is often not economically feasible. For example, equipment such as a tracking radar system that is mounted on an aircraft must be viable for operating in low-temperature environments without heating equipment.

Different contraction rates for different metal materials tends to induce mechanical failure at low temperatures as well. In addition, oil and grease harden at low temperatures, so special oil and grease must be used to lubricate moving parts, and daily maintenance is crucial.

Low temperature environments remove heat from products, and so they tend to cause phenomena that are opposite to those brought on by high temperature environments.

3-2 Humidity stress

When analyzing product failure, problems caused by humidity are found to be extremely common. Humidity testing results in characteristics that can be roughly summed up in the following three points.

(1) Extremely large fluctuations in the failure rate for parts and equipment
(2) Difficulty in specifying the causes of failure due to a tendency for variations in test results
(3) Great difficulty in correlating with nature, or with other types of tests or with others doing the same test.

Other characteristics include problems in measuring relative humidity over a long period and difficulties in maintaining measurement accuracy, and the great variety of treatment when testing is required.

Even when the level of humidity stress isn't high enough to cause a problem independently, these humidity characteristics create complex conditions when combined with other external disturbances such as contamination, and can be considered the cause of a very large number of failure modes occurring under complex conditions.

At this point, let's look at the physical characteristics of water, the basis of this type of stress.

3-2-1 Liquid phase

The electrical characteristics of water (liquid phase) includes three extremely interesting physical properties when handling humidity. They are density, viscosity, and surface tension. These properties change as temperature changes.

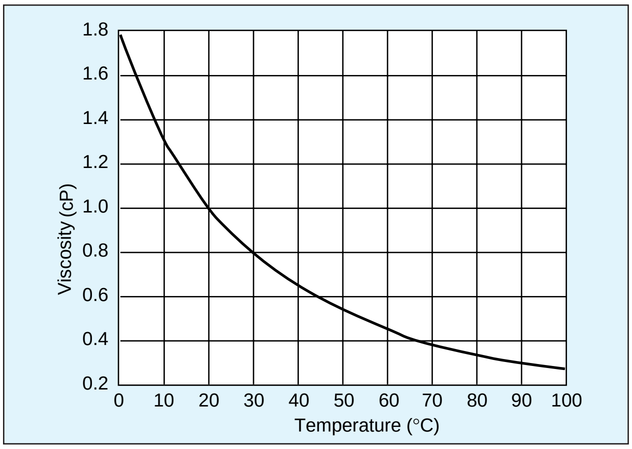


Fig. 3-2 Viscosity of liquid water vs. temperature

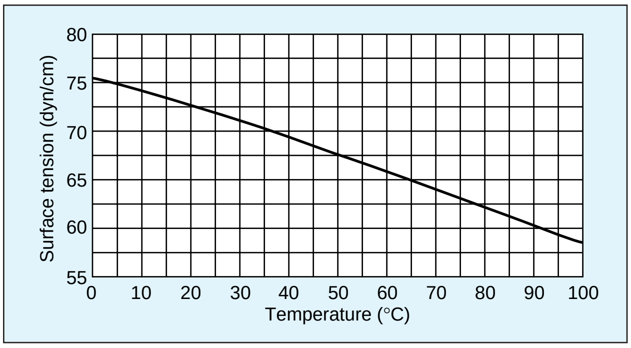


Fig. 3-3 Surface tension of water (against air) vs. temperature

Density changes from 0.998 g/cm^3 at 20°C to 0.958 g/cm^3 at 100°C. Fig. 3-2 shows changes in viscosity, and Fig. 3-3 shows changes in surface tension.

Furthermore, in electrical properties, the volume resistivity of pure water is approximately 20 M(Ω)/cm^3, but water is a solvent that becomes contaminated easily, and the electrical resistivity of the water film on the surface of a body of water shows a high tendency to change.

3-2-2 Gaseous phase

The representative physical constants of water in the gaseous phase are density, viscosity, pressure, and diffusion coefficient.

Viscosity is internal friction within a gas when being pulled by any layer. Fig. 3-4 shows changes in viscosity due to temperature. The diffusion coefficient is the quantity of water vapor that can pass through a layer of air, and at atmospheric pressure in c.g.s units is 1.6×10^{-10} (g/cm^2/sec).

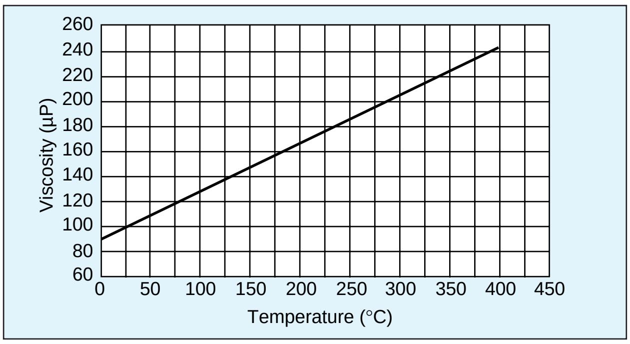


Fig. 3-4 Viscosity of water vapor vs. temperature

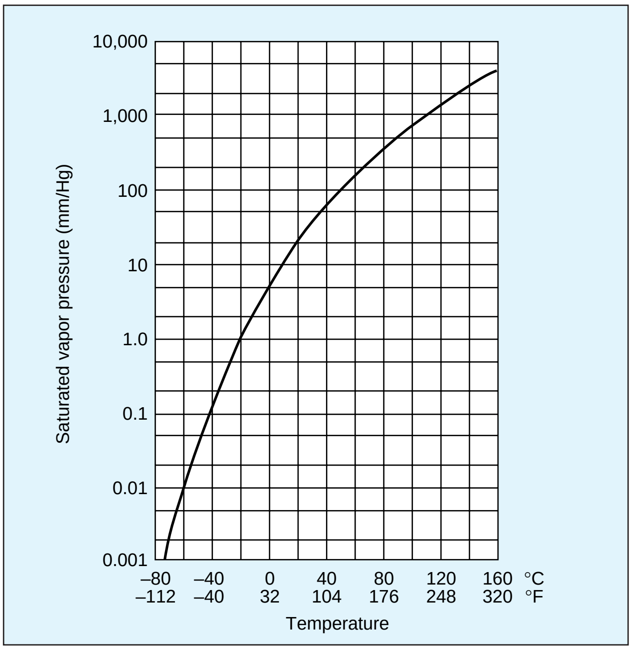


Fig. 3-5 Vapor pressure of saturated water vapor vs. temperature

In Fig. 3-5, the pressure changes of saturated air are shown as a function of temperature. A noteworthy characteristic is that between 40°C and 100°C the vapor pressure gradient increases roughly at a coefficient of 10.

Water vapor is a gas, and its temperature, pressure, and volume behave in accordance with the ideal gas law. Pressure from water vapor is partial pressure in the atmosphere, and in the natural atmosphere, is added to the partial pressure of other gases to form atmospheric pressure.

When the air is saturated with water vapor, the weight of the water present in the air varies according to the temperature, just as water vapor pressure does. Fig. 3-6 shows absolute humidity in the range from –60°C to +160°C in units of g/cm^3. In this type of saturated air, water vapor changes to the liquid phase when the temperature drops or when dirt and other condensation nuclei are present.

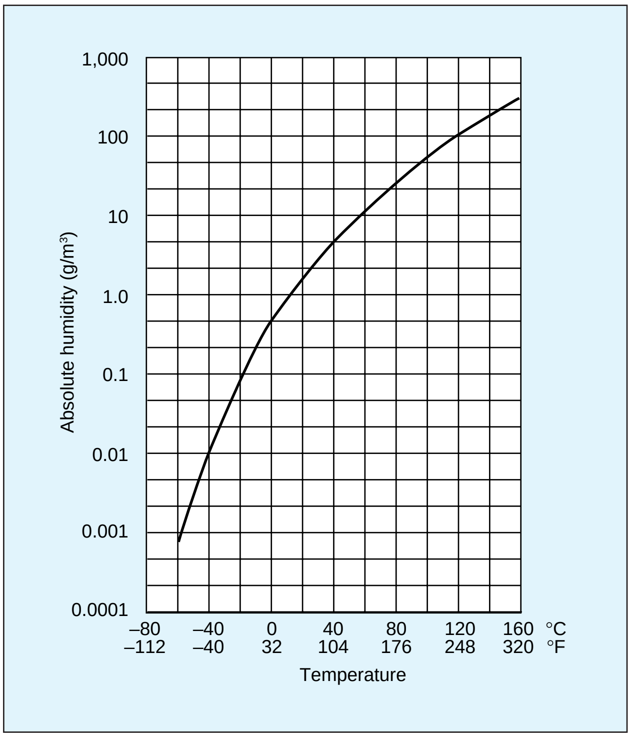


Fig. 3-6 Absolute humidity of saturated water vapor vs. temperature

Furthermore, water vapor has two interesting electrical characteristics. An increase in absolute humidity causes a drop in the Frashover voltage between the terminals of a product, and absorbs electromagnetic energy.

Fig. 3-7 shows the energy absorbed by water vapor from electromagnetic fields in a wide range of frequency bands.

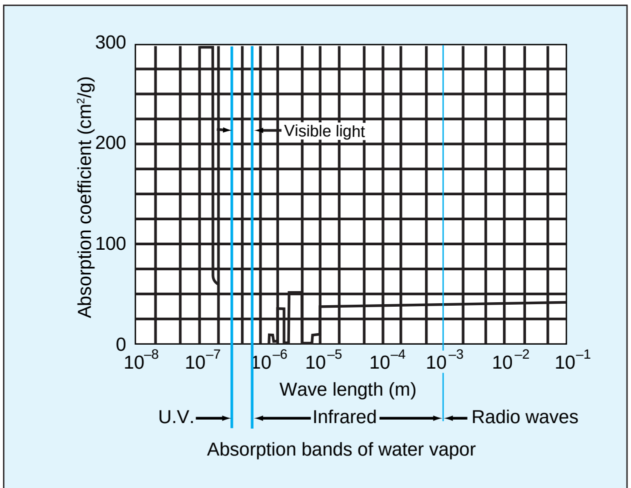


Fig. 3-7 Electromagnetic wave absorption bands of water vapor

3-2-3 Humidity environments in nature

Absolute humidity in nature is distributed throughout a wide range of geographical regions, but in general is higher in warm regions and lower in cold areas. In other words, this indicates that the capacity of air to maintain water vapor is higher in warm regions and lower in cold areas. The average value of absolute humidity in the atmosphere over land varies from 0.1 g/m^3 in the polar regions to approximately 27 g/cm^3 in the tropics. Occasionally in the tropics humidity as high as 32 g/cm^3 will be recorded.

While considering the surface conditions, a number of factors affect the absolute humidity in the various regions, and we cannot cover all the environments and classify them here. However, Fig. 3-8 shows the major types of regions in relation to absolute humidity and indicates the changes throughout the year. The types include polar, tropical, desert, and warm. Next, Fig. 3-9 shows the relationship between altitude and absolute humidity.

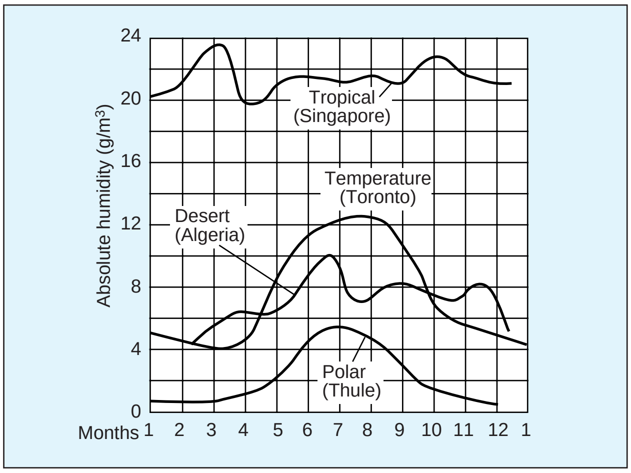


Fig. 3-8 Monthly changes in absolute humidity in each atmospheric region

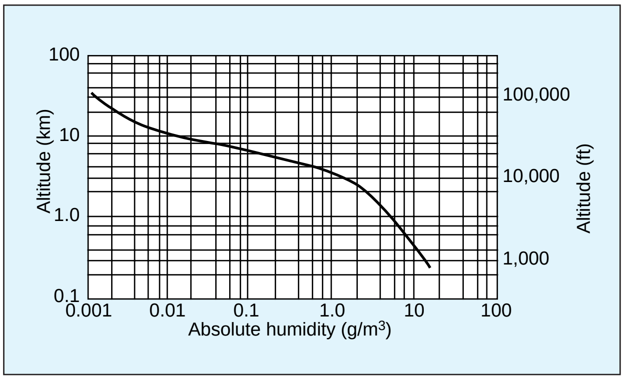


Fig. 3-9 The relationship between altitude and absolute humidity

Fig. 3-10 through 3-13 show daily fluctuations in temperature and water vapor. For further meteorological information, please refer to literature on geography.

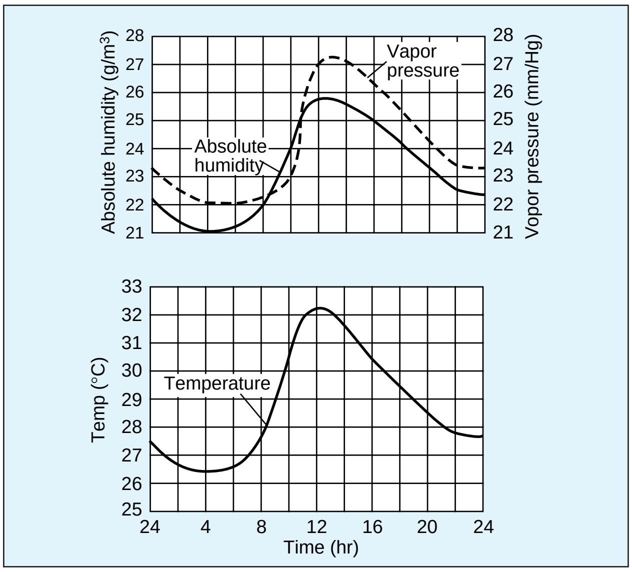


Fig. 3-10 Daily fluctuations (summer) in a tropical region (Singapore)

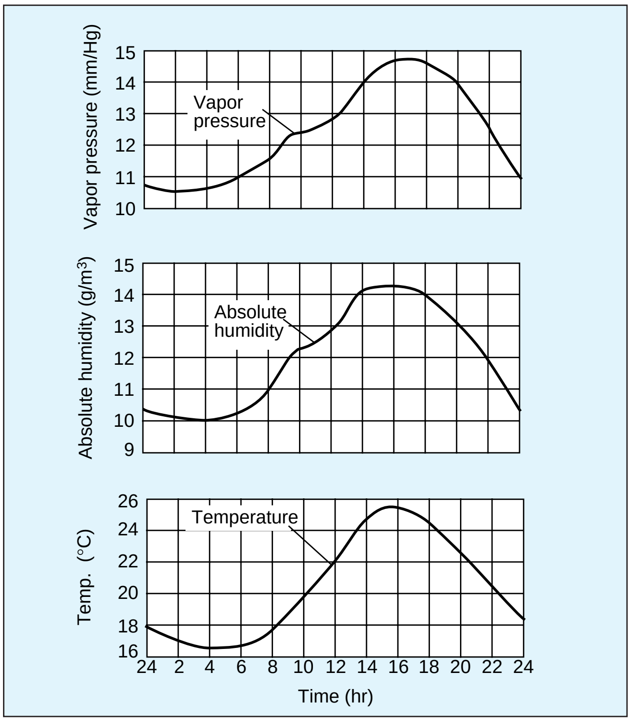


Fig. 3-11 Daily fluctuations (summer) in a warm region (Toronto)

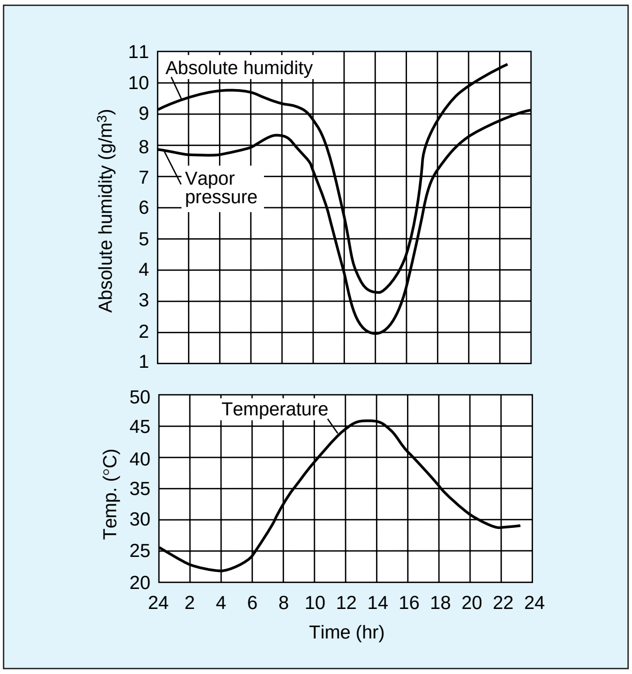


Fig. 3-12 Daily fluctuations (summer) in a desert region

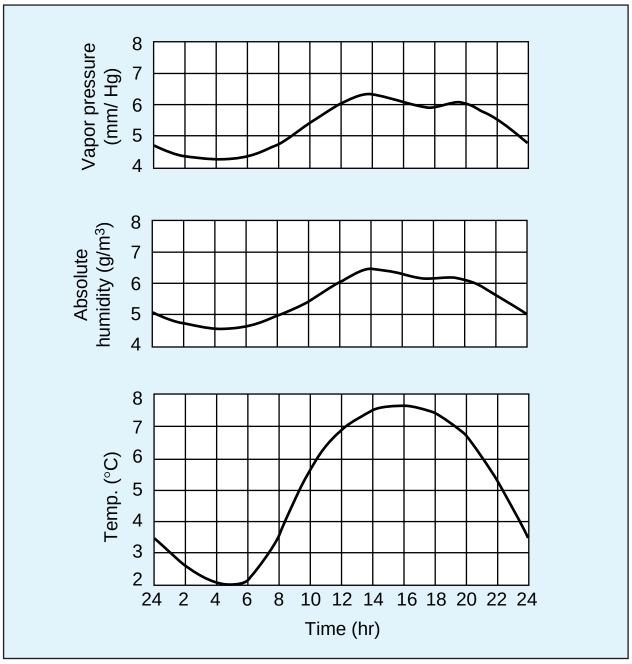


Fig. 3-13 Daily fluctuations (summer) in a polar region

3-2-4 Effects on electrical and electronic parts and materials

The failure rate due to natural temperature and humidity for equipment normally operated while set up on land is high compared to other normal environments. The problem is how water vapor is involved in the high failure rate sustained by these parts. If we assume that electrical and electronic parts are to be placed in a high-humidity environment, we can expect the following three phenomena to occur.

(1) If electromagnetic energy is present, it will be absorbed by the surrounding water vapor.
(2) An extremely thin film of water from condensation will form on the parts.
(3) Ensuing from a variety of weather changes, water vapor will penetrate the parts.

These phenomena produce the following changes in electrical characteristics.

1. The forming of a water film on parts and materials creates an electrostatic capacity effect due to electrical circuits forming and to a high dielectric factor. These effects change such values as Q, inductance, capacitance, loss factor, insulation resistance, and surface resistivity, and also serve to lower surface arc resistance.

2. When the materials are used for insulation, the internal loss of the volume resistivity is changed. When the materials are dielectrics, other complex changes are produced.
3. In particular, in dielectrics in a high-humidity atmosphere, the loss factor varies according to the frequency.
4. The dielectric factor of moist items increases with temperature.

Specific examples
1. In such phenomena as carbon film resistance, the limits of electrical resistance are exceeded if approximately 2 percent of that weight is moisture absorption
2. Most capacitors are unable to maintain necessary performance in regard to the dielectric constant if absorption exceeds 0.1 percent of that weight.
3. Quartz crystals are particularly sensitive to moisture, and failure may result from water vapor penetration totaling 0.004 percent of the volume of a sealed package.

4. Mechanisms of water penetration

I would like to organize the mechanisms of moisture penetration into an object.

Moisture penetration mechanisms can be broadly classified in the following two types:
(a) Diffusion through the materials (bulk) making up the parts or equipment, and
(b) Penetration through equipment seals.

Water vapor can only penetrate by diffusion through the materials when the molecular space of the component materials is greater than the diameter of the water molecule, which is 3.4×10^{-10} m (approximately 3.4 Å). The amount of diffusion of water vapor through the molecular space of the material is proportionate to the surface area of the aperture and the direction of flow of the pressure gradient of the water vapor.

Water vapor also has characteristic mechanisms for moving into the material, and a material penetration factor can be identified corresponding to the mechanism for the movement of vapor through the materials. For example, in a material with a diffusion factor of 10^{-7} g/cm^2/sec, moisture requires approximately 10 hours to permeate 1 mm and stabilize. Then, water vapor flows into the material until a steady state is created, and the quantity is determined by the penetration factor of the material existing along the route. In other words, even in substances in which sealing is mechanically complete, vapor will penetrate the material through further diffusion.

Even if we hypothesize a special condition of an environment of 100 percent water vapor, the water vapor penetration mechanism through leakage sites, we must not forget the existence of air together with the water vapor. In the market, there is an environment composed of air and water vapor as a composite gas, and in this situation penetration normally occurs through leakage sites. In general, the following two composite gas conditions can be found in the atmosphere.

(1) With low-pressure water vapor, the condition is mostly air.
(2) With high-pressure water vapor, the condition is mostly water.

Characteristic penetration mechanisms exist for a variety of situations found in these conditions.

Low pressure mechanisms are suited to conditions with less than 50 percent water vapor, and high-pressure mechanisms are suited to conditions from this point to conditions of 100 percent water vapor. In environments of saturation at 80°C or greater, the air:water ratio is 50:50. Thus, (1) the low-pressure water-vapor penetration process normally applies to saturation below 80°C, and (2) the high-pressure water-vapor penetration process applies to environments with saturation above 80°C. The penetration rates for each of those cases can be calculated as in Fig. 4-1.

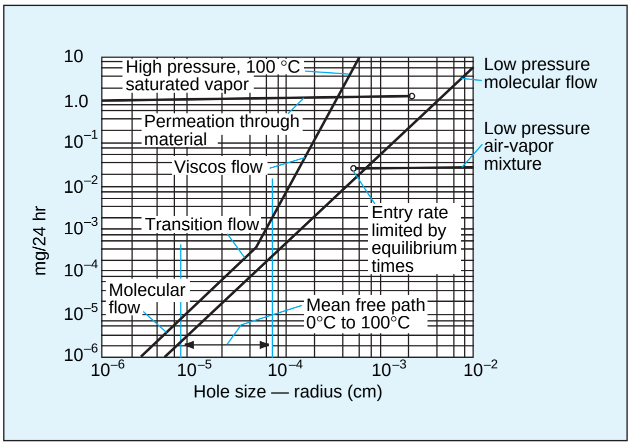


Fig. 4-1 Penetration characteristics of water vapor

4-1 Low pressure mechanisms (mostly air)

The mechanisms can be classified in two different types. Assuming that temperature, water-vapor pressure, and atmospheric pressure are constant:
(1) Water vapor penetrates and passes through by diffusing into air pockets along the route. In this case, the size of the air resistivity (penetration factor) along the route determines the amount of penetration. The penetration ratio varies according to the diameter of the holes.
(2) When a temperature cycle exists at this point, the pressure fluctuations extending along the route aid the passage of the air and water-vapor combination. The amount of water penetration is controlled by the partial pressure of the water vapor (i.e., the ratio of the air: water mixture) and the diameter and resistivity of the route.

The penetration mechanism varies according to the size and diameter of the holes. However, in penetration at low pressure, the variance is slight for small holes, but clearly appears in larger holes.

4-2 High pressure mechanisms (mostly water vapor)

When high temperature occurs simultaneously with high water-vapor pressure, three penetration mechanisms can be identified according to differences in the leakage sites or the diameters of the holes.

(1) When the hole diameter is smaller than the mean free path (7×10^{-5} cm), the amount of influx varies according to the resistance of the route and water-vapor pressure. When flow resistivity is compelled to change directions, the rate will be determined by the diameter and length of the route, and by the penetration factor in the air along the route. (Molecular flow)

(2) When the hole diameter is larger than the mean free path, the amount of influx is proportionate to the square of the pressure and resistance of the route. In this case, resistance is determined by the fourth power of the diameter, the length of the route, and the viscosity of the water vapor. (Viscous flow)
The amount of penetration is proportionately larger with large leakage rather than with small.

(3) When the hole is about the same size as the mean free path at the transition point between the above two types of flow, the amount of penetration is proportionate to somewhere between the first to second power of the water-vapor pressure, creating a mixture of both currents. Leakage in a closed box with remaining air affects the amount of influx when there is a temperature cycle, but that case is rare. (Transition flow)

4-3 Liquid phase penetration

In a water vapor test, just as in a penetration test in liquid, influx is possible in the liquid phase as shown in Fig. 4-2. When the diameter of the hole is at least 2×10^{-3} cm, liquefaction (capillary condensation) depends on the pressure and the resistance of the route, and the influx then occurs in the liquid phase. Resistance is determined by the fourth power of the diameter, the viscosity and density of the water, and the length of the route. In that case, the penetration pressure can be seen as simple water pressure or a pressure differential due to the difference in temperature.

When the diameter of the hole is smaller than 2×10^{-3} cm, surface tension obstructs the flow of water within a temperature range considered likely. The route of leakage is probably filled, but water vapor occurs from the leading edge of water facing this route. Vapor penetration depends on thermal conditions, route diameter, and the penetration factor of the air along the route. When the route becomes smaller, the vapor that evaporates from the leading edge surface diffuses through the route. The water-vapor pressure in this case causes saturated water vapor at the temperature that corresponds to the water temperature.

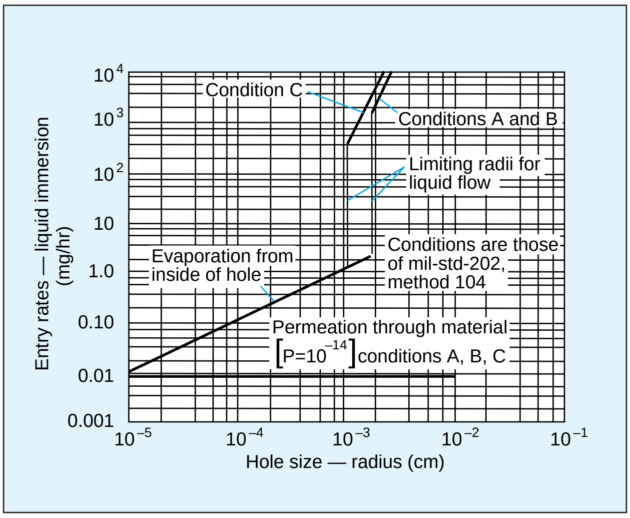


Fig. 4-2 Characteristics of water penetration

5. Summary

In this article, we have looked at the conditions of standard environments that form the basis for all environmental testing. In all public test standards and private standards as well, these conditions always form the basis for individual tests. Although special exceptions exist, efforts are being made unify standard values in the near future for each standard that now has differences due to use in different fields, and all standards are to be based on the IEC/ISO standards.

We have shown that physical concepts aid in understanding the phenomena caused by thermal stress and its relationship to products, which forms the basis for environmental testing. Physical concepts are also crucial to understanding humidity stress and the moisture penetration mechanisms. As a result, I believe you have seen that detailed, wide-ranging physical analysis to understand the minute phenomena. In general, chemical concepts are required subsequent to this. For example, chemical concepts are required to from the time during moisture penetration that contamination occurs, and from the point that moisture reaches the electrical circuits in the parts and units. Mastering these fundamentals at the outset provides the understanding that principles are fundamental and general, and that the failure phenomena of actual products are not unique and special occurrences. Based on acquiring these fundamentals together with lots of experience, one can look at and handle actual test specimens and without hesitation plan what should be done, and perhaps even predict the results before testing.

*Fig. 3-2 to 3-9 and Fig. 4-1 to 4-2 are reproduced from the following document.
International Series of Monographson Electronics and Instrumentation Volume 5
Environmental Testing Techniques and Material 1962
Pergamon Press

[Bibliography]

1) International Series of Monographson Electronics and Instrumentation Volume 5 Environmental Testing Techniques and Material 1962 Pergamon Press
2) MIL-STD-810E Environmental Test Methods and Engineering Guidelines
3) IEC 60068-1 Environmental testing Part 1: General and guidance (1989)
Amendment 1 (1992-05)

Report 1

Humidity Measurement and Control in the HAST

Toshio Yamamoto*

HAST stands for Highly Accelerated Temperature and Humidity Stress Test, a test with environmental parameters of temperature and humidity. HAST is also called the Pressure Cooker Test (PCT) or the Unsaturated Pressure Cooker Test (USPCT). The major differences in testing methods from general evaluation tests for resistance to humidity are first that the temperature and humidity environment are set above 100℃, and second that the test is performed in an atmosphere with a high density of water vapor.

The purpose of HAST is to accelerate moisture penetration into the internal parts of the specimen by raising the water vapor pressure inside the test chamber to a level that is drastically higher than the water vapor pressure inside the specimen, and then to evaluate the specimen's resistance to humidity.

In this article, we shall look at environmental factors such as temperature and humidity that are related to testing in this type of special environment. I shall also discuss the current state of actual testing equipment and test standards, as well as the methods of measuring and controlling humidity at temperatures exceeding 100℃.

1. Environment During Testing

1-1 Relative Humidity in HAST

The relative humidity dealt with in HAST differs from the concept of relative humidity as defined under atmospheric pressure. Relative humidity under atmospheric pressure is defined as "the amount of water vapor actually contained in a constant volume of air, compared to the maximum (saturation) amount of water vapor possible to be contained in that air at that temperature", based on the assumed relationship that from the standpoint of pressure that the dry air pressure + the water vapor pressure = the total pressure. This total pressure value is normally in the vicinity of the atmospheric pressure, and the water vapor pressure is controlled by the atmospheric pressure, since the vapor pressure cannot rise above the atmospheric pressure. However, here we shall consider the atmospheric pressure in HAST as isolated within a completely sealed container in an atmosphere made completely of water vapor without air.

First, let's hypothesize the existence of dry air and water vapor under atmospheric pressure in the enclosed space of volume V at temperature T as in Fig.1.

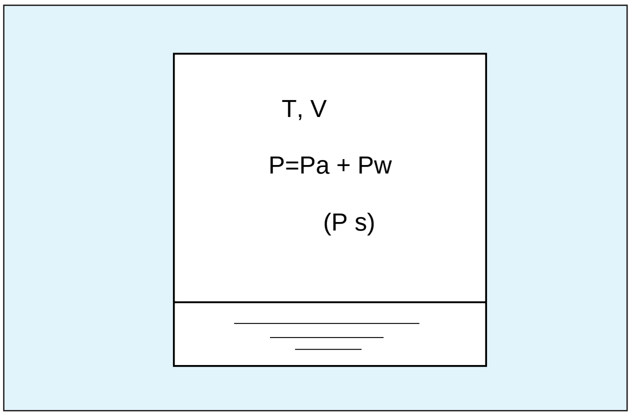


Fig. 1 Enclosed space under atmospheric pressure

The relative humidity ψ is defined by the following formula, given that the various partial pressures occurring at temperature T are Pa, the dry air pressure, Pw, the water vapor pressure, and Ps, and the saturation pressure of water vapor.

$$\psi = \frac{Pw}{Ps} \times 100 \ (\%RH)$$

At this time, we need to carefully note that ψ is calculated as unrelated to total pressure P and the dry air partial pressure Pa.

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Next, if we hermetically seal this space and somehow expel the dry air Pa, the space will be filled only by the water vapor, so the relationship becomes

$P = Pw = Ps.$

Therefore, within this space the water vapor can be treated as an independent ideal gas, and by setting either the temperature or the pressure automatically determines the other. In other words, PV = nKT (K = the Boltzman constant) or PV = RT. However, in reality this type of linear form doesn't hold true. Instead:

$PV = RT + Pf(P.T)$

P: pressure
V: volume
R: gas constant
T: temperature
f (P.T): correction term for pressure and temperature

This type of correction term becomes part of the equation. Including the compensation of this correction term, HAST uses the water vapor table (compiled by the Japan Society of Mechanical Engineers) based on the K function showing the relationship between temperature and saturation water vapor. (This is the case within Japan.)

Within a hermetically sealed space as in Fig. 2, if we posit a saturated water vapor environment in the temperature occurring at that time, and we heat up a partial area (the area enclosed by the dotted line) within that space, then if we say that T' > T, we can regard that space as a region of unsaturated water vapor. Then, if we set Ps' as the saturated water vapor pressure corresponding to temperature T' in this partial area, and we have Ps' as the saturated water vapor pressure for the peripheral space, we can define this as

$$\psi' = \frac{\text{Peripheral space saturated water vapor pressure (Ps)}}{\text{Saturated water vapor pressure at the temperature in the partial area (Ps')}} \times 100 \text{ (\%RH)}$$

this is called the relative humidity occurring in HAST.

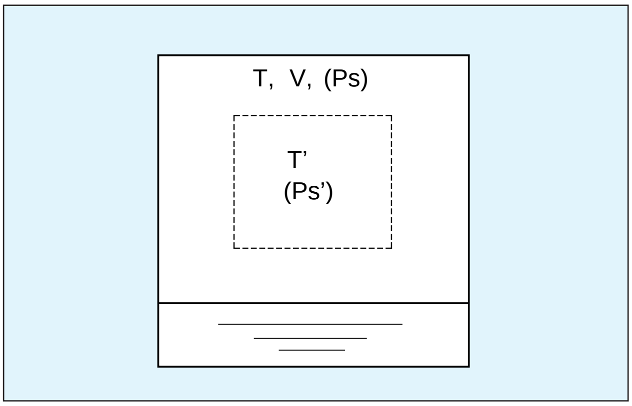


Fig. 2 Hermetically sealed space

How to read the steam table (next page)

The steam table can be used as follows.
For example, when the temperature within the sealed space is 130°C, and the RH is at 90%, the pressure becomes 0.2431 MPa abs., and the saturation temperature becomes 126.5°C.

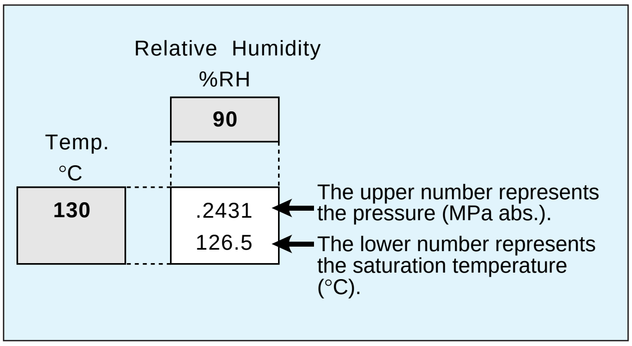


Fig. 3 How to read the steam table

*** K function (equivalent saturation pressure)**

The constant shows the saturation line, and this curved line is also the boundary of the partial region. The formula showing the equivalent saturation pressure β_k as the function of the equivalent temperature θ is as follows:

$$\beta_k(\theta) = \exp\left[\frac{1}{\theta} \cdot \frac{\sum_{\nu=1}^{5} k_\nu(1-\theta)^\nu}{1+k_6(1-\theta)+k_7(1-\theta)^2} - \frac{1-\theta}{k_8(1-\theta)^2+k_9}\right]$$

For the value of the constant included in the K function

$k_6 = 4.167\,117\,320 \times 10^0$
$k_7 = 2.097\,560\,760 \times 10^1$
$k_8 = 10^9$
$k_9 = 6$

The source: 1968 JSME STEAM TABLES

The steam table created from the above formula is shown in Table 1 (next page).

Table 1 Steam Table (Dry-bulb temperature 100 to 141 °C)

Pressure . MPa abs . / Saturation Temperature (°C)												
Temp. °C	**Relative Humidity %RH**											**Temp. °C**
	100	**95**	**90**	**85**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	
100	.1013 100.0	.0963 98.6	.0912 97.1	.0861 95.5	.0811 93.9	.0760 92.1	.0709 90.3	.0659 88.4	.0608 86.3	.0557 84.1	.0507 81.7	**100**
101	.1050 101.0	.0997 99.6	.0945 98.1	.0892 96.5	.0840 94.8	.0787 93.1	.0735 91.2	.0682 89.3	.0630 87.2	.0577 85.0	.0525 82.6	**101**
102	.1088 102.0	.1033 100.6	.0979 99.0	.0925 97.5	.0870 95.8	.0816 94.0	.0761 92.2	.0707 90.2	.0653 88.1	.0598 85.9	.0544 83.5	**102**
109	.1385 109.0	.1316 107.5	.1247 105.9	.1177 104.3	.1108 102.5	.1039 100.7	.0970 98.8	.0900 96.7	.0831 94.5	.0762 92.2	.0693 89.7	**109**
110	.1433 110.0	.1361 108.5	.1289 106.9	.1218 105.2	.1146 103.5	.1074 101.7	.1003 99.7	.0931 97.7	.0860 95.5	.0788 93.1	.0716 90.6	**110**
111	.1481 111.0	.1407 109.5	.1333 107.9	.1259 106.2	.1185 104.5	.1111 102.6	.1037 100.7	.0963 98.6	.0889 96.4	.0815 94.0	.0741 91.5	**111**
119	.1923 119.0	.1827 117.4	.1731 115.7	.1635 114.0	.1539 112.1	.1442 110.2	.1346 108.2	.1250 106.0	.1154 103.7	.1058 101.2	.0962 98.5	**119**
120	.1985 120.0	.1886 118.4	.1787 116.7	.1688 114.9	.1588 113.1	.1489 111.2	.1390 109.1	.1291 106.9	.1191 104.6	.1092 102.1	.0993 99.4	**120**
121	.2049 121.0	.1947 119.4	.1844 117.7	.1742 115.9	.1639 114.1	.1537 112.1	.1434 110.0	.1332 107.8	.1229 105.5	.1127 103.0	.1025 100.3	**121**
129	.2621 129.0	.2490 127.3	.2359 125.5	.2228 123.7	.2097 121.7	.1966 119.7	.1835 117.5	.1704 115.2	.1573 112.8	.1442 110.2	.1311 107.4	**129**
130	.2701 130.0	.2566 128.3	.2431 126.5	.2296 124.7	.2161 122.7	.2026 120.6	.1891 118.5	.1756 116.2	.1621 113.7	.1486 111.1	.1351 108.3	**130**
131	.2783 131.0	.2644 129.3	.2505 127.5	.2366 125.6	.2227 123.7	.2087 121.6	.1948 119.4	.1809 117.1	.1670 114.6	.1531 112.0	.1392 109.1	**131**
139	.3513 139.0	.3337 137.2	.3161 135.3	.2986 133.4	.2810 131.3	.2635 129.2	.2459 126.9	.2283 124.5	.2108 121.9	.1932 119.1	.1756 116.2	**139**
140	.3614 140.0	.3433 138.2	.3252 136.3	.3072 134.3	.2891 132.3	.2710 130.1	.2530 127.8	.2349 125.4	.2168 122.8	.1988 120.0	.1807 117.1	**140**
141	.3717 141.0	.3531 139.2	.3346 137.3	.3160 135.3	.2974 133.2	.2788 131.1	.2602 128.8	.2416 126.3	.2230 123.7	.2044 120.9	.1859 117.9	**141**
	100	**95**	**90**	**85**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	

1-2 Humidity Measurement and Control

As temperature and humidity control is naturally based on the presumed ability to measure these factors, in this section we will treat measurement and control as identical.

As previously noted, when relative humidity is mentioned in the context of HAST, we make conversions using the saturation vapor pressure occurring at various temperatures. However, an actual problem in the test space is that since we cannot directly obtain partial area pressure Ps', we measure the temperature and convert it to the pressure. In addition, we are able to directly measure the peripheral space pressure (Ps) using a precise pressure gauge, but it is difficult to obtain a gauge with long-term stability, and so in this case as well it is in actual practice simpler to make a pressure conversion from the temperature.

Fig. 4 shows the principle of the actual test equipment. Furthermore, a chamber with a sealed space uses a pressure vessel since the internal pressure is greater than the atmospheric pressure.

For the working space, a heater for humidifying water is installed at the bottom of the pressure vessel, humidifying water is stored there, and a heater for moisture is installed inside the working space. Temperature sensors are placed at various suitable sites, and the temperature is monitored. A suitable method is used to expel the air from within the pressure vessel, creating a completely water vapor atmosphere.

The required water vapor within the pressure vessel is supplied by heating the humidifying water with the heater for humidifying water. Subsequently, water vapor that enters the working space is reheated with the heater for moisture, becoming hotter than the water vapor in the peripheral space. We can assume that at this time the water vapor atmosphere inside the working space is unsaturated. If we do not reheat, the test space will become the saturated atmosphere at the peripheral space temperature.

Water vapor that has left the working space radiates heat onto the walls of the pressure vessel and cools, finally condensing and returning to humidifying water. This type of moisture circulation creates and sustains the testing environment.

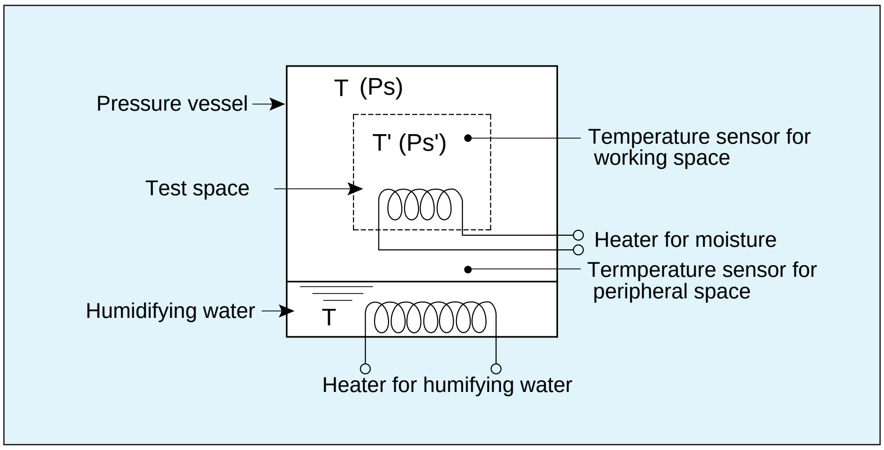


Fig. 4 Principle of the test equipment

2. Actual test equipment

The HAST equipment currently being used can be classified as follows.

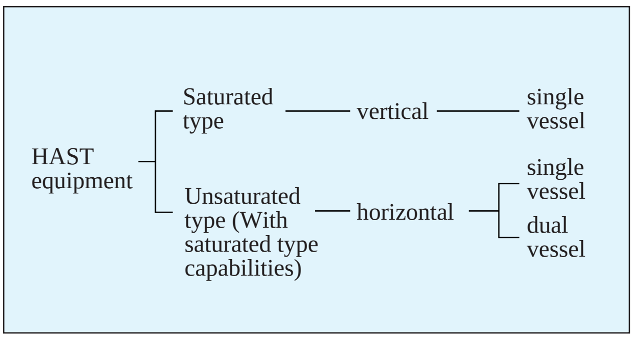


Fig. 5 Classification of HAST equipment

By function, the equipment can be classified as either the saturated type that can’t create an unsaturated environment, or as the unsaturated type able to create both the saturated atmosphere as well as the unsaturated environment. The unsaturated type is constructed as either a single vessel type set horizontally with a single pressure vessel, or as a dual vessel type with the humidifying water inside a separate vessel from the test vessel. Theoretically, it is possible to build a single vessel, vertical unsaturated type, but in reality the vertical type has a variety of drawbacks making it difficult to use, and almost all vertical equipment is of the saturated type.

Originally, HAST equipment was built based on remodeling medical autoclaves, and was mostly of the vertical type. The principle of that structure is shown in Fig. 4. This system is easy to understand, but in actual practice there is a tendency for condensation to form on the ceiling of the pressure vessel and to drip on the specimens during testing, making it difficult to maintain test reproducibility. In such an environment, it isn't possible to include electrical tests such as bias impression, so this arrangement has gradually been falling out of favor. However, this type is still used at times when importance is attached to connection with past tests.

Meanwhile, the manufacturers developed a horizontal model of the unsaturated type in an attempt to make improvements. The horizontal model retained the functions of the vertical model, but got rid of its drawbacks. In addition, a number of new functions were added, stimulating a rush of new applications. In particular, this model is becoming established as equipment for official reliability evaluation. In fact, IEC Pub. 60068-2-66 takes up test standards for HAST.

At this point, I would like to give a simple introduction of the structure and system of the mainstream horizontal equipment.

The horizontal model can be either single vessel or dual vessel, but both types employ essentially the same system. While there are no major differences, some differences appear due to the developmental approaches taken by individual manufacturers, for example whether there is a vapor circulation fan system, as well as differences in methods of measuring temperature and humidity.

The single vessel type horizontal equipment shown in Fig. 6 has the pressure vessel divided into the working space and the peripheral space.

The key feature of this type is the use of a circulation fan. The water vapor current circulated by the fan inside the working space corresponds to the flow of natural currents, so it averages about 0.3 m/s. The water vapor is generated from the humidifying water at the bottom of the working space, then is reheated by the heater for moisture just before being sucked into this fan, and so becomes hotter than the water vapor in the peripheral space as it is circulated into the working space. After the water vapor has gone through the working space, it reverses course in the area of the front door area, then is cooled as it returns through the space between the working space partition and the pressure vessel inside wall, and some of the vapor condenses and returns to the humidifying water. The shortage is resupplied from the humidifying water and takes the circulation loop. In this way, the specimen can be continuously supplied with a new and uniform environment.

The actual test equipment includes several types of auxiliary equipment for testing and safety.

Also, voltage impression terminals are provided in the unsaturated atmosphere for electrical testing such as bias impression testing done in the unsaturated atmosphere.

Furthermore, there is one temperature sensor inside the working space and one more in the humidifying water, but the newest equipment uses a system with a wet and dry bulb method installed, and is able to provide graded control for raising and lowering temperature and humidity.

The humidifying water can also be considered as one part of the equipment, and either distilled water or high quality deionized water is used. This is to avoid adversely affecting the specimens even in the HAST region with highly activated moisture. In particular, water with a high chlorine content such as tap water should never be used, nor should well water. Furthermore, most of the equipment parts, including the pressure vessel and most of the structural parts, are made of stainless steel to resist corrosion and degradation.

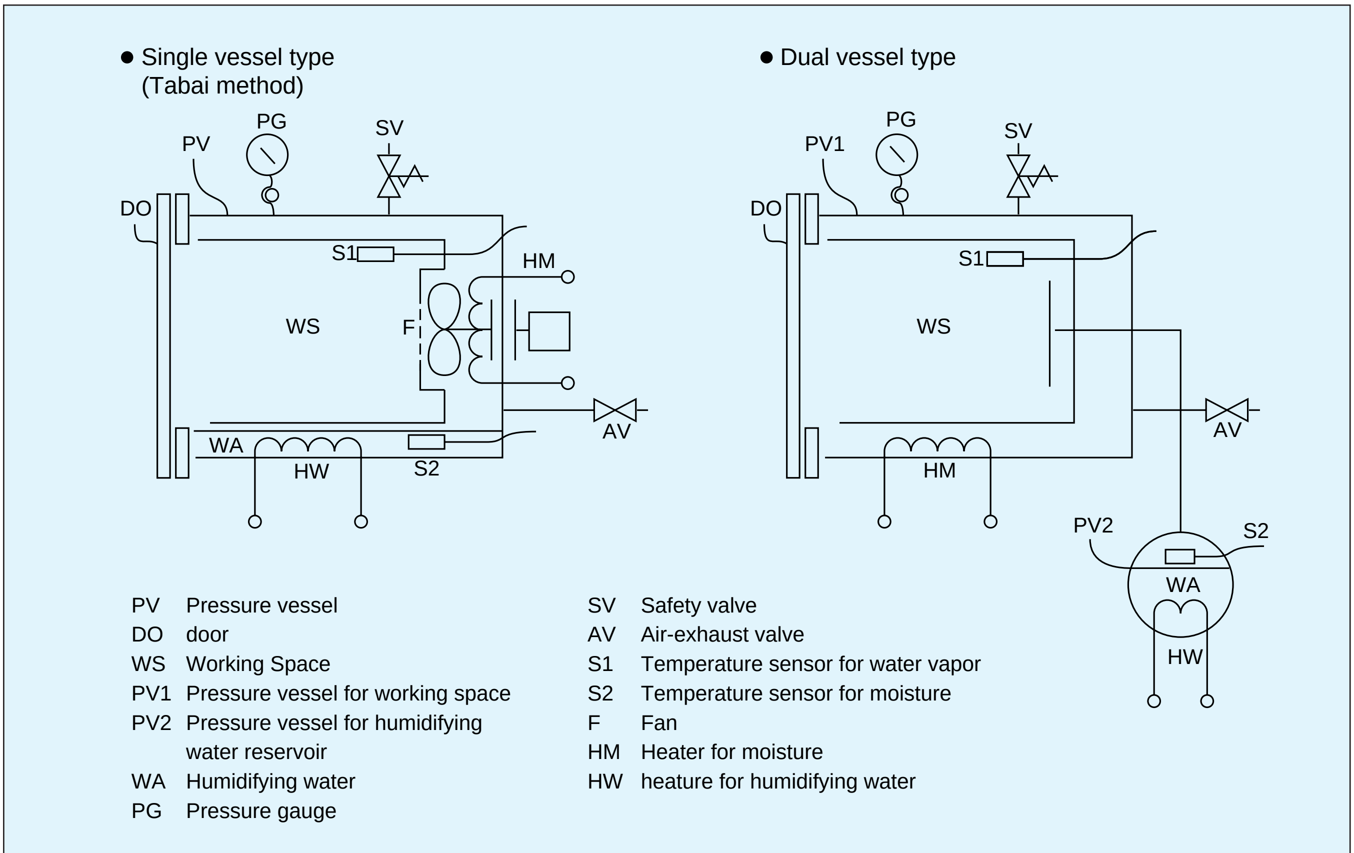


Fig. 6 Actual structure of test equipment

Photo 1 TABAI HAST CHAMBER
Model: EHS-411MD (Dual vessel)

3. Test Standards

The following are official test standards that apply to HAST.

International standards

(1) IEC Pub.60068-2-66 (1994-6) Environmental testing. Part 2: Test Methods-Test Cx; Damp heat, Steady state (unsaturated pressurized vapor)

(2) IEC Pub.60749 AMMENDMENT 1 (1991-11)
Semiconductor devices
Mechanical and climatic test methods
5C Damp heat, steady-state-highly accelerated

National standards

(3) JEDEC (Joint Electron Device Engineering Council) STANDARD (1988-6) No.22-110 (U.S.A.)
Test Method A110
Highly-Accelerated Temperature and Humidity Stress Test (HAST)

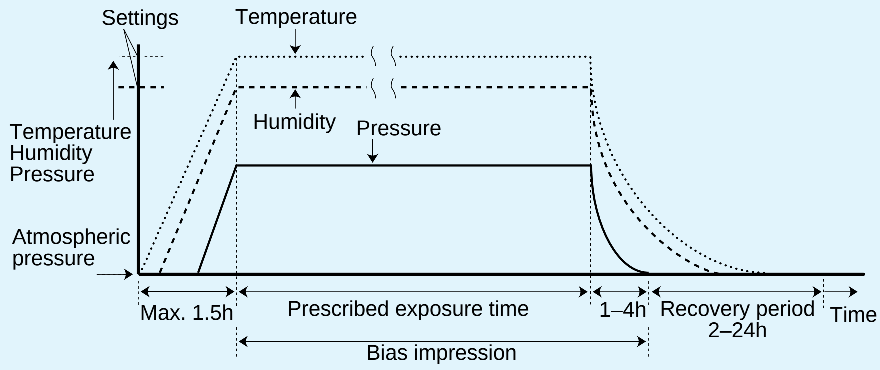
(4) EIAJ (Electronic Industries Association of Japan) ED-4701 (1992-2) (Japan)
Environment and Duration test methods for Semiconductor Devices
Method B-123 Unsaturated vapor pressure test

The most recent among these is IEC Pub. 60068-2-66 dealing with special standards for HAST serial test methods. This publication is found in Part 2 dealing with test methods. The annex, in particular, is quite substantial, and contains a detailed explanation of HAST. The annex presents a summary of such areas as the physical meaning of HAST, explains how humidity is measured and how the equipment is maintained, and offers a representative test equipment system. In addition, the steam table in the annex is positioned as a section of the main document, and the annex gives binding force to the regulations on temperature and humidity presented in the main document.

To unify IEC standards on test severity (test conditions), this publication conforms to Pub. 60749. The essentials of this standard constitute the first time that a comprehensive proposal created in Japan has been adopted internationally for official standards.

At this point I would like to describe the test procedure (the temperature and humidity sequence) in these regulations. (This explanation corresponds to Fig. 7.)

*This figure is not presented in the standards sheet.



Conditions in the ramp-up period

- Up to 3 hours ramp-up time is allowed when exposure time exceeds 48 hours.
- Relative humidity is not to exceed 85%
- Air remaining during this time shall be expelled from the chamber using water vapor.

Conditions in the ramp-down period

- Relative humidity is not exceed 85%
- Fundamentally, ramp-down shall be achieved by natural cooling.
- When ramping down pressure using pressure-releasing equipment, pressure must not be released rapidly.
- Pressure must never go below atmospheric pressure.

Fig. 7 Outline diagram of test procedure

(1) Initial measurements

A pre-test inspection is to be performed to confirm that each specimen conforms to the relevant specification, and shall include such areas as dimensions, functions, and a visual check.

(2) Testing

Specimens at room temperature shall be placed into the test equipment (hereafter, test chamber) at the same room temperature, and then necessary activities such as hooking up electrical wiring shall be done.

Test chambers that supply humidifying water shall then have the door closed and be heated to the temperature and humidity settings. After heating to around 100°C, the air-exhaust valve (AV in Fig.6) shall be opened and the air remaining in the chamber shall be expelled along with part of the vapor. When the atmosphere inside the chamber becomes completely water vapor at around 100°C, the valve shall be closed and heating shall continue to the target values for temperature and humidity. From this point the pressure (vapor pressure) inside the chamber shall be gradually ramped up until reaching the setting conditions. The test time count shall begin at the point at which the setting conditions have stabilized, and the specimens shall be left in this environment for the prescribed time. When required, electrical tests such as bias impression shall be performed simultaneously.

(3) Intermediate measurement

Requested measurements of the specimens (mainly electrical measurements) shall be allowed, but the test environment must not be disturbed. Therefore, the provisions stipulate that the operation of the chamber may not be stopped at an intermediate point, and specimens may not be removed.

(4) Recovery

After the prescribed test time is up, the test chamber shall cool down naturally or shall be gradually cooled down under control that approximates natural cooling, the pressure shall be ramped down, and the chamber shall return to its original condition.

After the pressure has been ramped down to the vicinity of atmospheric pressure, specimens shall be removed from the chamber and final measurements shall be made within 24 hours.

The procedure detailed above gives a rough outline of the test sequence including the control pattern for the test equipment. Fig.7 describes this process with extremely ideal straight lines, but in reality the temperature levels do not move so evenly during ramp-up and ramp-down of the temperature and humidity. However, large fluctuations in test conditions are not recognized. This unevenness occurs because the pressure vessel has an extremely large heat capacity. This uneven temperature occurs for a very short period compared to the length of the test and occurs at comparatively low temperature and humidity (below 100°C), so in actual practice we can ignore the effect on the specimens.

4. Problems in measurement and control

Humidity in HAST is handled in a simple environment composed of a nearly ideal water-vapor atmosphere after the air has been expelled. Therefore, in principle we can look at this theoretically as an ideal gas.

When problems occur in measurement and control, they result inevitably from the fact that each part in the equipment, including the temperature sensor, must be made using state of the art technology.

Since HAST is basically a highly accelerated test that works by strengthen environmental stress to extreme levels, there is a possibility of degradation of the precision of the measuring equipment due to the equipment's ability to withstand the environment or deterioration or problems with cleanliness. I believe we must consider these points when attempting to maintain precision.

The following points in particular are important for measurement control.

(1) Degradation from the protective cover in storage of the measurement element due to material quality and processing method
(2) Smudging or corrosion of the measurement probe due to substances emitted from the specimens
(3) Smudging or endurance of the gauze for the humidity bulb when using the dry bulb method

These items also hold true when performing humidity testing under normal atmospheric pressure.

However, these phenomena occur very quickly in the HAST environment, i. e., a high pressure vapor atmosphere above 100°C. Therefore, the primary factor is the dulling of the sensitivity of the temperature sensor, resulting in control errors and instability.

These problems are difficult to resolve, and the most effective means of handling them is to clean and maintain the parts inside the test chamber every day.

In addition to such problems originating from the hardware, we must also recognize non-hardware problems. For example, current equipment is not constructed to directly expel the remaining air just before starting the test, and each equipment manufacturer sets the timing for closing the air-exhaust valve from the actual test values. Because of this, a very slight difference occurs in the amount of air that is expelled in a cold start (a start with the test chamber cold) and a hot start (a start with the test chamber warmed up). Another problem comes from the gas emitted from the specimens and the air dissolved in the humidifying water that are gradually released into the test chamber during the test, making it difficult to strictly say that the environment is completely a water vapor atmosphere. If this amount is large enough, it is likely to bring on the problems already discussed early on, and the presence of oxygen will cause the new problem of oxidation of the equipment inside the chamber as well as the specimens themselves. In such a case, the natural result is that the temperature and humidity values based on the steam table will not be correct.

To resolve this problem, some might believe that a vacuum pump should be used before starting the test, and gas should be released by baking the specimens and the humidifying inside the test chamber to forcibly extract the dissolved oxygen. However, if this is done after the specimens are placed in the chamber, it would—if even temporarily—expose the specimens to an unnecessary environment, ruining the basis for evaluation.

From a practical standpoint in testing, these problems are not currently seen as being especially important.

However, to maintain high precision and reproducibility in testing, it is vital for the user to always perform the test under identical conditions.

5. Summary

The HAST test method is “the measurement and control of humidity above 100°C”. Moreover, the environment is essentially obtained by creating a saturated water-vapor atmosphere. This is based on not having any gas present other than the water vapor.

In this sense, I must reemphasize that the definition of relative humidity is fundamentally different than relative humidity under atmospheric pressure. In other words, it is based on the definition explained in item 1, “Environment During Testing”, and the RH is found by making conversions according to the steam table using the K function. Several equipment systems are in use, but all are designed and produced in accordance with this definition (in Japan). As I stated before, the test standards have already been put in order and put into practical service, being actually applied in a multitude of ways. However, even in this type of situation we cannot say that no problems stem from the severity of the environment. To avoid even a few of these problems, we are currently supervising the equipment daily, in particular in regards to the all-important cleanliness. It is difficult to claim that the equipment has been perfected, as a number of problems (areas for improvement) still remain.

From a practical point of view, these equipment problems are not really very important when compared to the amount of stress in the test. However, we believe it is vital that we as the manufacturer renew our efforts to resolve these problems.

Report 2

Reliability of wood materials in environmental testing

Yuuichi Aoki*/Hirokazu Tanaka*/Shigeharu Yamamoto*

The January 1995 Hanshin earthquake in Japan destroyed many homes made of wood.

Although that temblor showed the power of an earthquake to demolish buildings, reports also indicate that part of the problem was the decay caused by moisture absorption in the wood used in the foundations of the homes. Moisture absorption by wood influences such factors as strength and dimensions, and can be considered a major cause of degradation. Conventional environmental testing to evaluate wood materials has emphasized early period characteristics, and has been unable to evaluate changes over time. However, we noticed changes in the characteristics of wood materials due to changes in the surrounding environment, and we tested this phenomenon. The results leave room for further study, but we propose that the results can serve as useful test data using environmental testing equipment.

1. Evaluating wood materials through environmental testing

Wood loses strength through decay caused by absorbing moisture, but another problem is that moisture changes such characteristics of wood as strength, dimensions, and elasticity. In general, wood materials are dried before use, but wood used in construction is susceptible to high humidity near areas using water or in places with poor ventilation, such as under the floors, or in sites with large temperature differentials, which tend to cause dew condensation to form and promote decay from insect damage. In an outdoor environment, day/night changes and seasonal changes in temperature and humidity cause repeated moisture absorption and drying, affecting the characteristics of wood. Such influences cause degradation in wood construction materials.

Table 1 shows the names of the items set by JIS (Japanese Industrial Standard) standards as methods of evaluating wood construction materials (in JIS Z2101, Methods of testing for wood).

Among these items, test methods concerning the environment apply to evaluating water and moisture absorption characteristics, but such testing cannot be considered sufficient to evaluate degradation over time. We also noticed changes in the shape of wood caused by the wood absorbing and releasing moisture due to fluctuations in the surrounding environment, and we tested this phenomenon.

*Environmental Test Technology Center

Table 1 Test items in JIS Z 2101

NO.	Items
1	Method of measuring average width of annual rings, moisture content and specific gravity of wood
2	Method of testing for shrinkage in volume of wood
3	Method of testing for water absorption of wood
4	Method of testing for moisture absortion of wood
5	Method of compression test for wood
6	Method of tension test for wood
7	Method of bending test for wood
8	Method of shear test for wood
9	Method of cleavage test for wood
10	Method of impact bending test for wood
11	Method of testing for hardness of wood
12	Method of creep test for wood
13	Testing methods for nail withdrawal for wood
14	Method of abrasion test for wood
15	Method of testing for decay of wood
16	Method of inflammability test for wood

When considering the parameters of the life of wood, one characteristic that must be considered is creep*1. Fluctuation in the surrounding temperature greatly affects creep in wood. In this article, we shall report on our environmental testing studies of the deformation of wood known as the "drying set"*2 phenomenon, caused by creep due to changes in the moisture content of wood.

Changes in the ratio and velocity of creep are brought on by the surrounding humidity and the moisture content of wood. One example of this is contained in a report on accelerated testing of the drying cycle using pressure reducing equipment. According to this report, when 25 percent of the fracture load by bending is applied in the initial period, beam deflection increases to approximately 10 times the amount of deflection of the initial period. (Refer to Fig.1.)

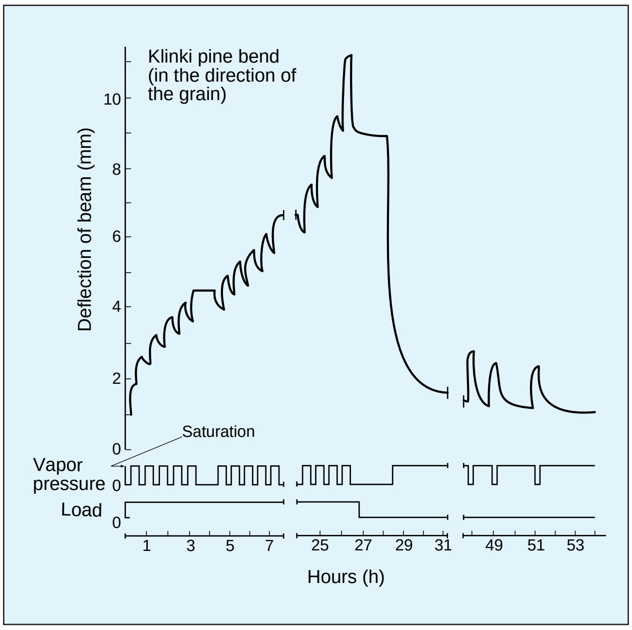


Fig. 1 Moisture absorption/drying cycles and creep deformation [1)]

2. Moisture absorption by wood

2-1 The relationship between wood and water

The moisture content of wood can be classified under the two major headings of bound water and free water. Bound water is absorbed into the cellular walls of the wood due to hydrogen being bound, and is deeply involved in such changes as bending and dimensional changes. Therefore, bound water can be considered to be one part of the wood. Free water, though, remains between the cells, and only affects such properties as weight, thermal conduction, and electrical conduction.

The amount of water within wood is shown as the moisture content and is calculated with the following formula.

$$\text{Moisture content (\%)} = \frac{\text{weight of bound water + free water}}{\text{weight of cellular walls}} \times 100$$

Besides measuring the weight, specific methods for measuring the moisture content include such methods as measuring electrical resistance or measuring the dielectric constant.

Fig. 2 shows one example of changes in electrical resistance with the moisture content of wood.

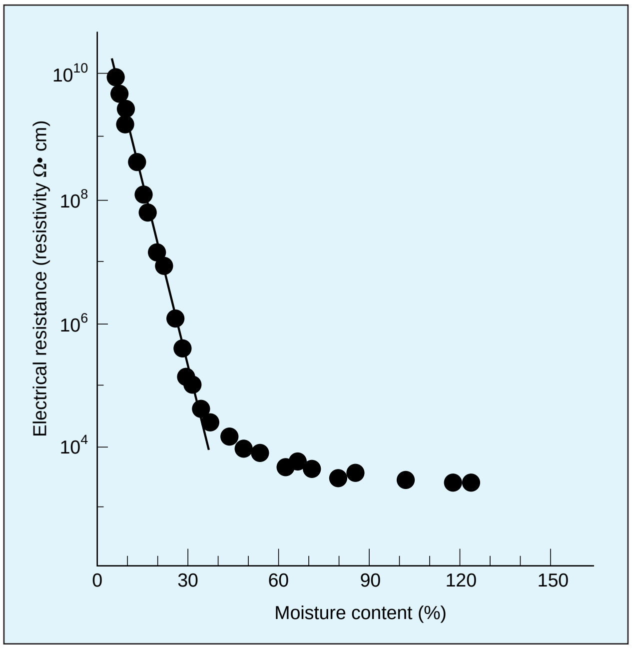


Fig. 2 The moisture content of wood and electrical resistance [2)]

*1 When constant pressure stress is continuously applied to wood, the resulting progressive distortion over time is called "creep". Moisture fluctuations as well as the moisture content of the test materials greatly affect the ratio and velocity of creep.

*2 Changes in the moisture content while wood is under pressure stress causes plastic distortion such as bending and twisting. Deformation permanently set into the wood by creep during the drying process is referred to as "drying set".

When the cellular walls become saturated with bound water and there is no free water in the lumens (cellular cavities) of the cells, the condition is known as the fiber saturation point.

This value does not depend on the type of wood, and represents approximately a 30 percent moisture content. Fig. 3 shows drawings of the relationship patterns.

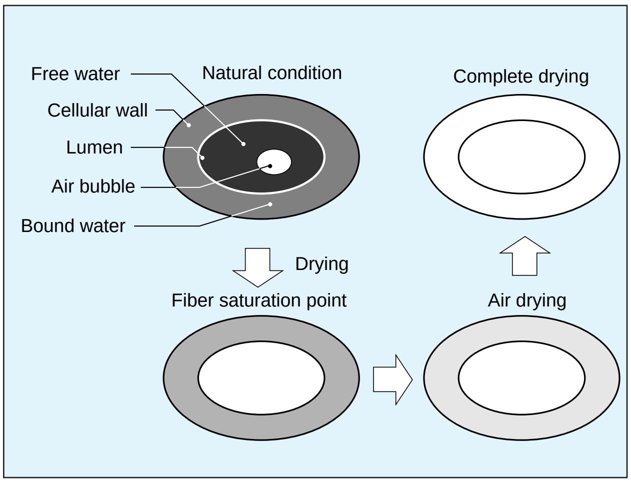


Fig. 3 Wood moisture patterns

The moisture content of wood is roughly determined by the surrounding temperature and humidity, and changes in these conditions cause repeated absorption and release of moisture. Under stable conditions of surrounding temperature and humidity, the moisture content of wood remains constant. This is called the Equilibrium Moisture Content (EMC). Fig. 4 shows a graph of the EMC of wood.

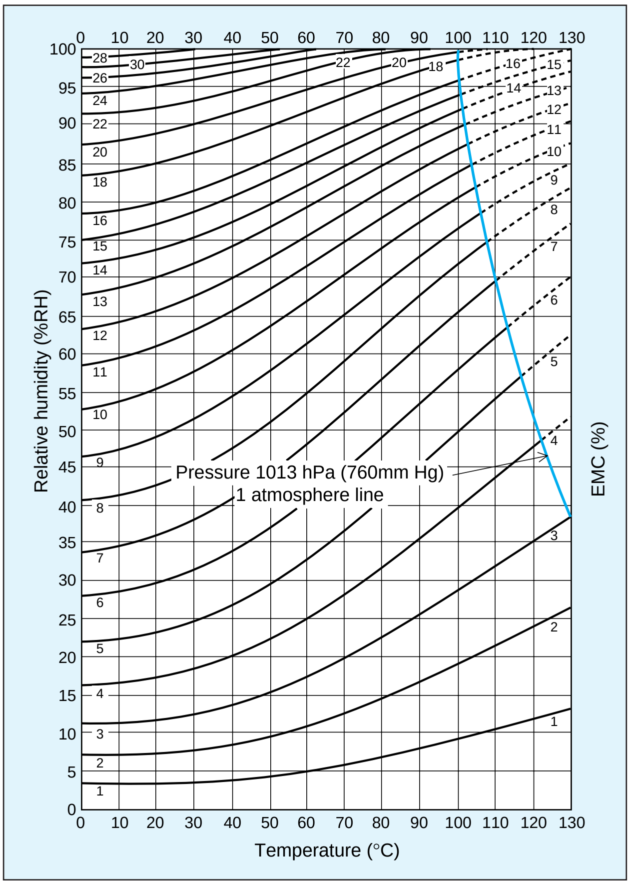


Fig. 4 Equilibrium Moisture Content of wood [2)]

The EMC does not vary by type of wood, but is determined by the diverse types of habitat.

The moisture absorption and moisture release characteristics of wood stem from these properties, which cause wood to regulate the moisture of the surrounding environment. One advantage of using wood materials in home construction is this humidity regulation effect. Wood characteristics also differ according to the direction of the grain, and the moisture content affects the degree of contraction and expansion.

2-2 Dew condensation of wood

When a temperature differential occurs between wood and the surrounding environment, dew condensation occurs below the dew point temperature. In homes, a lot of dew condensation is caused by the surrounding concrete walls or metal items, but condensation also stems from the wood itself, and the wood gradually absorbs the water condensation. Over a long time, this process causes severe problems due to damage from decay-producing bacteria and mold. Furthermore, the tendency of dew condensation to form inside the walls of homes and the tendency of the condensation not to dry leads to long-term effects.

2-3 Moisture absorption characteristics in the presence of dew condensation

We investigated the moisture absorption time of wood in dew condensation environments and high humidity environments. Table 2 and Fig. 5 show the test method and the specimens. The results indicate that moisture absorption velocity is not increased in a dew condensation environment. Fig. 6 shows that the fiber saturation point is achieved at roughly the same time.

Table 2 Moisture absorption ratio measurement conditions

Specimens	Wood type: cedar Quantity: 20 pieces Dimensions: 30 × 30 × 5 mm (JIS Z 2101) [Refer to Fig. 5]
Test conditions	(1) High temperature, high humidity: 40ºC, 90% RH (2) Dew condensation cycle: (30 min. each) 10ºC, 60% RH ↔ 40ºC, 90% RH
Measurement method	Moisture content measured by weight

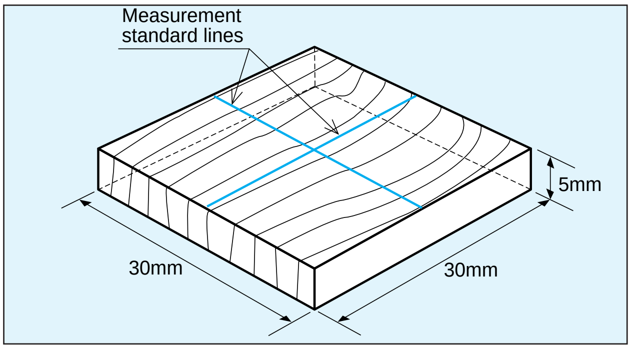


Fig. 5 Moisture absorption characteristics prescribed by JIS

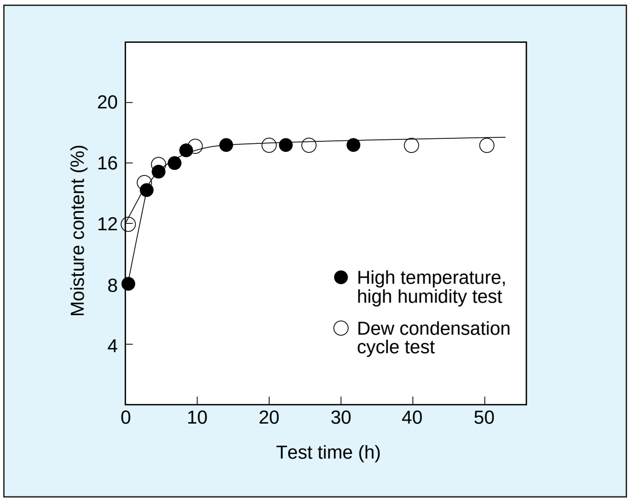


Fig. 6 Moisture absorption time

3. Evaluating wood characteristics through environmental testing

To perform a reproducible environmental test of creep deformation caused by drying set, we can consider the temperature and humidity cycle test using the temperature and humidity chamber or the dew condensation cycle test using the dew condensation cycle tester. These tests can apply repeated changes in temperature and humidity, and so should be effective.

3-1 Test methods

To see how creep deformation changes with drying time, we strictly controlled the actual environmental changes and performed temperature and humidity cycle tests and dew condensation cycle tests repeatedly alternating drying and moisture absorption. For comparison, we also performed high-temperature, high-humidity tests and standard condition tests (at normal temperature and humidity). (The “high temperature” in these tests refers to temperature that would be felt as high by humans in normal life.) The wood specimens were tested under a continuous load applied at the center of the specimen. The test methods are shown in Table 3 and Fig.7 and 8.

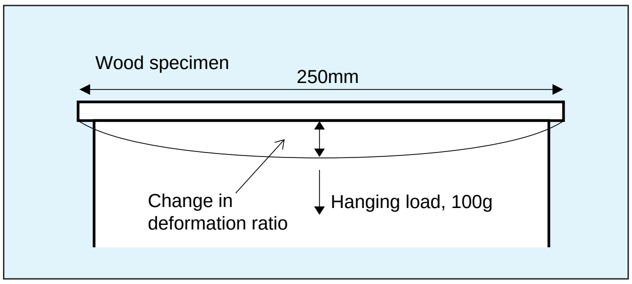


Fig. 7 Load method

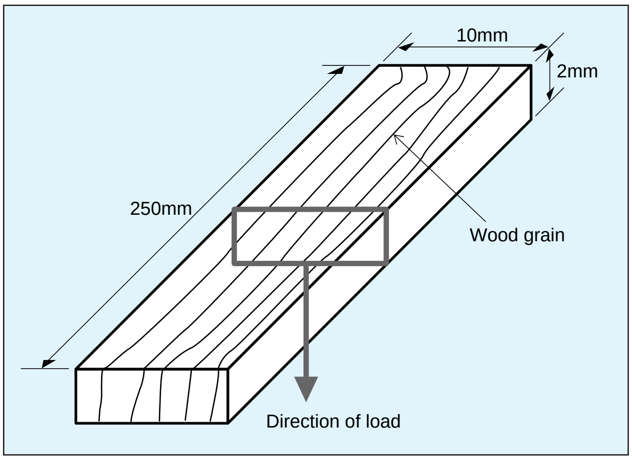


Fig. 8 Relationship between the wood grain and the direction of the load

Table 3 Measurement conditions for changes in creep characteristics due to the environment

Specimen	Wood type: white cedar (fixed grain direction and initial strength) Dimensions: 250 × 10 × 2 mm Quantity: 20 pieces
Test conditions	Pre-treatment: 24 hours at 20°C and 65% RH (1) Humidity cycle: 40°C, 30% RH ↔ 40°C, 90% RH (30 min. each) (2) Dew condensation cycle: 10°C, 60% RH ↔ 40°C, 90% RH (30 min. each) (3) High temperature, high humidity: 40°C, 90% RH (4) Standard conditions: 20°C, 65% RH
Load method	100 g load hung from center of specimen. Refer to Fig.7
Measurement method	Deformation ratio measured at each cycle.

3-2 Test results

Fig. 9 shows the test results. Under condition (1), the humidity cycle test, the creep ratio showed large changes, and as the test progressed the changes were much greater than those under other conditions. Under condition (4), the standard conditions, increase in the creep ratio was minimal, while there wasn't much difference in the results shown by condition (2), the dew conensation cycle test, and condition (3), the high-temperature, high-humidity test.

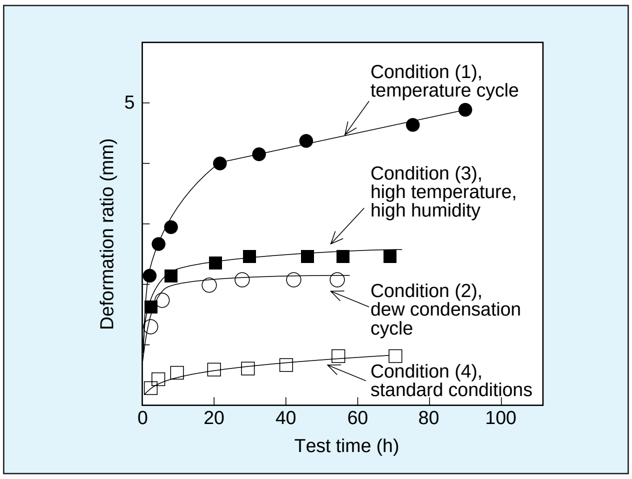


Fig. 9 Creep deformation in environmental tests

3-3 Considerations

We were able to reconfirm that the greater the change in moisture content, the greater the creep deformation. Furthermore, at normal temperature and humidity, the increase in the creep ratio was minimal. These results can be attributed to the temperature and moisture effects on the strength and elasticity modulus of wood.

In the dew condensation cycle test, we thought that moisture absorption would be affected by dew condensation, but the results showed almost no difference under high temperature and high humidity. We believe this can be attributed to insufficient drying in the dew condensation cycle test compared to the high-temperature, high-humidity test. Therefore, differences in the drying conditions greatly affected the creep deformation in these tests, and the test that most strongly promoted creep was the humidity cycle test. We postulate that increasing the drying capacity of the dew cycle test would accelerate the creep deformation. However, the conditions used in each test chamber had variances in such factors as wind speed and start-up temperature and humidity, so there remains plenty of room for research in these results.

4. Conclusion

Creep deformation due to continuous load on wood can be considerable due to repeated moisture and drying even when the load is small. This fact can be confirmed with the humidity cycle test.

Our homes constructed with wood materials are subjected to repeated changes in environmental stress due to temperature and humidity, leading to undeniable degradation of the wood materials. In areas where dampness tends to accumulate, such as under the floor, measures are already taken to keep humidity uniform by using wood materials that effectively regulate the humidity.

The naturally-occurring cycle of absorbing and releasing moisture leads to mechanical changes caused by expansion and contraction, so it is possible that absorbing distortion and increasing strength may be effective in improving drying set characteristics in complex structures in which intersecting grains from different pieces of wood enclose a layer of glue.

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Topics

Introducing measurement evaluation systems

Yoshinori Kin*

1. *Introduction*

Technology for miniaturizing electronic equipment and yet producing higher performance has been making enormous strides. At the same time, companies are competing to take the lead in developing new products, while demands for safety and reliability have become increasingly severe. Environmental testing requirements additionally stress the importance of “more accurate” and “more effective” testing.

In this report, I would like to discuss the validity of serial measurements of electrical characteristics of specimens and introduce evaluation systems for that purpose.

1-1 To evaluate more accurately

The increasing demand for higher product performance has led to many cases in which slight changes in the environment can produce changes in characteristics leading to failure. These changes would not previously have caused problems.

This situation has placed enormous demands on environmental testing to raise the accuracy of evaluation.

— Accurately capturing changes in characteristics

Some types of failure, such as insulation degradation due to ion migration, or increased resistance due to cracking, are difficult to detect without reproducing the specific environments in which they occur. Therefore, to accurately capture the cause of failure, it is essential to measure the specimen characteristics during a series of environmental changes.

— Expanding the quantity of the data needed for analysis

The ability both to clarify the causes of failure as well as to predict life expectancy more accurately is based on the ability to analyze data in which both failure and time of occurrence can be accurately detected and can be compared with environmental conditions. One must secure enough data to make a statistically valid judgment, considering dispersion.

1-2 To evaluate more effectively

Effective evaluation is impossible without compressing the time period to obtain the results in a timely manner. To do so, the time required for testing must be compressed.

— Compressing test time

Labor-saving efforts must be sought in all testing work, from specimen preparation to data collection, test equipment management, and data analysis. Temperature characteristics testing, for example, requires an enormous amount of time when relying on workers to operate the environmental testing equipment to obtain characteristics data at each temperature and to record the data at each temperature.

1-3 The need for measurement evaluation systems

As noted above, real time serial measurements of the electrical characteristics of the specimen are crucial to accurately capturing failure generation. Furthermore, simultaneously recording data of environmental changes and characteristics changes is also important to evaluating accurately.

At Tabai Espec, we are developing measurement evaluation systems to fulfill these requirements.

Tabai Espec has developed the following evaluation systems.

- Ion Migration Evaluation System
- Printed Wiring Board Conductor Resistance Evaluation System
- Electromigration Evaluation System
- Semiconductor Parameter Automatic Evaluation System

Of the above four systems, I would like to present the Ion Migration Evaluation System and the Printed Wiring Board Conductor Resistance Evaluation System in this article.

*Overseas Business Department

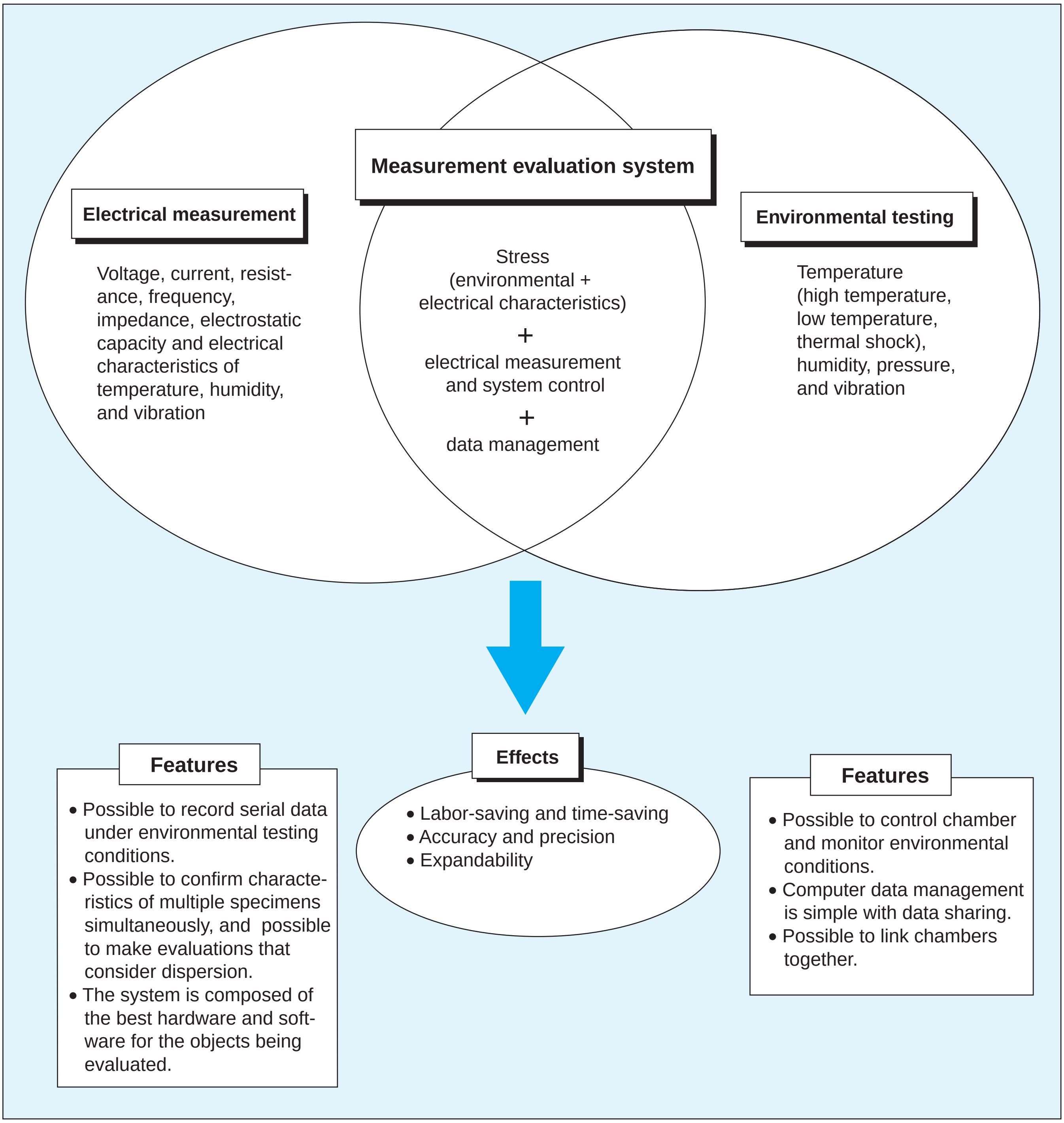

Fig. 1 Tabai Espec's measurement evaluation system concept

2-1 Outline of ion migration evaluation

Ion migration is the ionization of precipitated metals from one electrode being transferred to the other electrode, occurring in such places as the insulation spaces between electrodes in printed wiring boards. This phenomenon occurs in the presence of an electrical field and in the presence of moisture in the insulation spaces between the electrodes.

Photo 1 Copper ion migration

Main conditions for ion migration occurrence

- Potential difference exists between the conductors (metals) isolated by insulation.
- Humidity or moisture absorption is present in the insulation.

Metal is ionized and moves on the insulation (anode → cathode)

↓

and is reduced on the other electrode. The metal precipitates,

↓

and the precipitated metal grows (cathode → anode).

- The presence of impurities facilitates ionization, accelerating the process.

Usage conditions and environments of printed wiring boards

- Not washed, due to CFC regulations

Moisture absorption due to remaining flux, accelerating ionization

Flux composition
- Resin; hygroscopic properties
- Activator; metal dissolving, ionization
- Solvent; transfer promotion

- Problem with hygroscopic properties of resin seals with installation of CSP and flip chips
- Use of various types of adhesives. (conductive adhesives, TAB circuits composed)
- Constant electrical flow from battery in memory backup circuits
- As electronic equipment is made more handy, higher frequency of moisture contact and absorption

↓

Ion migration conditions are prepared

Hardware composition

- High consistency due to increased functionality in lighter and more compact equipment

Finer pitch patterns

Substrate boards with built-up construction

FPC

↓

Strong electrical field

Short insulation distance

Increased probability of ion migration

Failure occurs in a short time

↓

Great necessity for evaluation

Fig. 2 Necessity for an ion migration evaluation system

2-2 Example of current ion migration evaluation, and Tabai Espec's ion migration evaluation system features [Model: AMI-025-P]

Example of current ion migration evaluation

D.C. voltage is applied in a high-temperature & high-humidity environment (e.g., 85% RH at 85°C, or 90% RH at 121°C), and at each of a series of pre-set times (e.g., 48 hr, 96 hr, 240 hr, 480 hr) the specimens are removed from the temperature and humidity chamber and the insulation resistance is measured. The results of the measurements are recorded in a graph.

Problems with the current ion migration evaluation system

(1) Measurements made after removing the specimens cannot accurately capture the time that failure occurred because of this rapid ion migration growth in an environment conducive to occurrence.

(2) At the time of measurement the specimen may have returned to a high insulation condition (normal insulation condition). Because ion migration is extremely fragile, at the instant the growth reaches the opposite electrode overcurrent causes the ion migration to fuse.

(3) Further time is required for processing the data. A lot of time is taken up with operation and checking before measuring the insulation resistance, because measurement voltage must be applied.

↓

The Tabai Espec Ion Migration Evaluation System features [Model: AMI-025-P]

(1) While stress voltage is being applied within the temperature and humidity chamber, insulation resistance is being continuously measured, accurately capturing the time of failure.

(2) The system has a leakage detection function. After leakage has been detected, stress voltage application is stopped, preserving the ion migration condition at the time leakage occurs.

(3) This constitutes a linked system with the temperature and humidity chamber, which is capable of recording temperature and humidity data while measuring insulation resistance, resulting in considerable savings in labor for processing data.

Photo 2 Ion Migration Evaluation System

2-3 Main specifications of the Tabai Espec Ion Migration Evaluation System [Model: AMI-025-P]

Table 1 Main Specifications

Model	AMI-025-P
Insulation resistance measurement range (D.C. measurement range)	$1 \times 10^6\ \Omega$ to $3 \times 10^{13}\Omega$ (when 100 V applied). Min. measurement value $1 \times 10^6\ \Omega$ (3pA to 100 μA)
Leak touch detection range	1 to 100 μA
Measurement voltage	3 to 100 V DC (in 0.1 V steps)
Applied stress voltage	3 to 100 V DC (0.1 V step possible, and setting independent of measurement voltage also possible)
Test time	Maximum 9,999 hours
Resistance measurement intervals	Min. 0.1 hours (in 0.1 hour steps)
Resistance measurement time	Time required for one measurement: Approx. 60 sec. standard 25 channel + charge time (user set)
Leak touch detection intervals	Continually (except insulation resistance measurement time) Detection speed: Max. 100 μsec. (regardless of number of channels)
Number of measurement channels	25 channels standard (max., 300 channels)
Measurement cables (triaxial cables)	1.5m attachment from relay unit Heat resistant to +260°C, 2 layer shielded construction

3-1 Outline of conductor resistance measurement

When heat stress is repeatedly inflicted on PWB, cracking occurs in the through hole sections and the solder junctions due to difference in the thermal expansion coefficient.

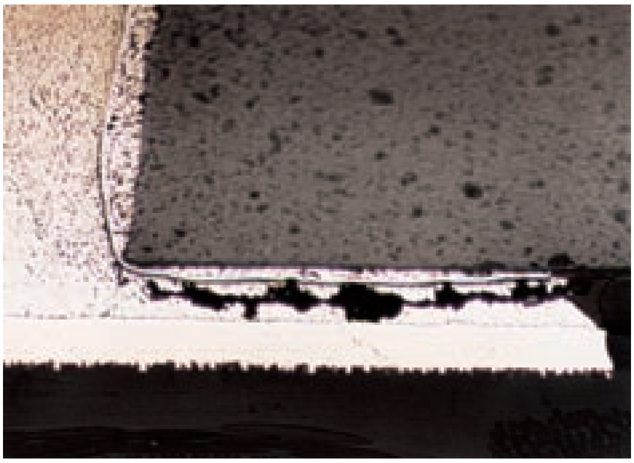

Photo 3 Cracking in soldered joints

Conditions for microcracking

- Repeated stress is inflicted due to the difference in thermal expansion coefficients of the conductive sections (solder, and through holes) and board materials (such as resin).
- Heat stress is inflicted on the solder joints, and distortions occur in the constitution. Heat stress and mechanical stress are repeatedly inflicted on solder that has lost intensity.

↓

Cracking occurs.
Failure mode; open, defective contact

Parts subject to conductor resistance evaluation

- Solder joints
- Joints of different kinds of metals
- Through holes on PWB

Environments surrounding PWB and solder joints

- Miniature electronic equipment with high density mounting is susceptible to heat stress as well as repeated heat stress brought on by turning the equipment on and off.
- Small parts have low heat capacity, making them sensitive to changes in the ambient air. (Temperature changes abruptly.)

Hardware composition

- Higher density of equipment is attended by finer pitch in the print pattern and a much greater amount of multiple layering.
- The use of high-density mounting such as BGAs (ball grid arrays) for the IC package is accompanied by an increased number of parts with metal joints. These joints are difficult to check visually.

↓

- Large heat stress
- High frequency of cracking caused by stress concentration due to differences in thermal expansion coefficients
- Strength degradation due to more minute patterns and solder junctions

↓

Increased necessity for evaluation

Fig. 3 Necessity of conductor resistance measurement

3-2 Example of current junction evaluation and main features of the Tabai Espec Printed Wiring Board Conductor Resistance Evaluation System [Model: AMR-040-P]

Example of current conductor resistance measurement

Specimens are exposed to temperature cycle conditions (e.g., 125°C ↔ –65°C), and at each preset number of cycles (e.g., 25, 50, 100, 500 cycles) the specimens are removed from the thermal shock chamber and the conductor resistance is measured. The results of the measurements are recorded in a graph.

Problems with current junction evaluation

(1) Even if cracks appear due to differences in the thermal expansion coefficients, some of the cracks make contact again under normal conditions, with no degrading of resistance values. In such cases, defects are often overlooked.
(2) Because specimens are removed for measuring at preset cycles, it is impossible to accurately capture the cycle number at which cracking occurred.
(3) Too much time is required for processing data.

↓

Main features of the Tabai Espec Printed Wiring Board Conductor Resistance Evaluation System [Model: AMR-040-P]

(1) Because conductor resistance is continuously measured under low and high temperature environments, cracks are not overlooked.
(2) Using 4 terminal measurement method, minute resistance can be measured with high accuracy in the range of 10^{-3} to 10^4 Ω.
(3) This constitutes a linked system with the environmental testing equipment. The system is capable of recording temperature data while measuring resistance, resulting in a considerable savings in labor for data management.

Photo 4 Printed Wiring Board Conductor Resistance Evaluation System

3-3 Main specifications of the Tabai Espec Printed Wiring Board Conductor Resistance Evaluation System [Model: AMR-040-P]

Table 2 Main Specifications

Range of resistance measurement	1×10^{-3} to 1×10^{4} Ω (guaranteed value at measurement cable terminal)
Measurement intervals	Min. 6 sec. (10 channels), possible in 6 sec. steps
Measurement range	10mΩ, 100mΩ, 1Ω, 10Ω, 100Ω, 1kΩ, 10kΩ and AUTO range (measurement at optimum range in each channel)
Measurement current	AC 1µA, 10µA, 100µA, 1mA, 10mA (rms)
Measurement frequency	1kHz
Maximum applied voltage during measurement	Max. 20 mV
Measurement method	4 terminal measurement method (measurement cable terminal)
Number of measurement channels	40 channels standard; Max., 280 channels
Measurement cables	4 heat-resistant flat cables 1.5m attachment from relay connector, heat resistant to +260°C

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JIS Z 9901-1994
Registration Number
JSAQ 004

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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