What is Environmental Testing? Part 2

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One method of improving the quality of all industrial products is to confirm their quality through environmental testing. To achieve this confirmation, "test planning", "test execution", and "analyzing test results" must be carried out together as one unit.

We are presenting this explanatory series summarizing "environmental testing" for those people who may have heard of environmental testing but aren't aware of what it means.

In this article, the second in the series, we shall discuss "humidity testing".

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1. Introduction

Environmental testing reportedly got its start during World War II, when the United States military was experiencing an unusually high failure rate for some of its military equipment. The story goes that 60% of electronic equipment for aircraft use sent from the US to SE Asia was unusable on arrival. In addition, 50% of the spare electronic equipment stored in warehouses already failed when they were stored. Most of the failures could be considered caused directly by humidity or by humidity combined with some other factor.

Humidity is one of the main environmental factors that cause equipment to fail. At this point, we would like to discuss such issues as the effects of a high humidity environment on the widely used semiconductor devices and printed circuit boards, which it is no exaggeration to say are used in almost every type of equipment. We also intend to look at the testing methods for the influence of such a high humidity environment.

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2. Influence of High Humidity Environment

2-1 Examples of general failures caused by high humidity

Table 1 shows the principal failures caused by humidity.

Table 1 Principal failures caused by humidity

Failure				Environmental conditions used	Susceptible parts and materials
General classification		Intermediate classification or cause	Failure mode		
Humidity	Moisture absorption	Dispersion	Swelling Degradation of insulation Deliquescence	Humidity	Parts sealed, covered, or constructed using polar resins with low crystallization (e.g., polyamides and polyvinyl alcohol and phenolic resins), and parts generating low heat
Humidity	Moisture absorption	Hydrolysis	Chemical change	Temperature + humidity	Polycarbonate, polyester, polyoxymethylene, polybutadiene terephthalate
Humidity	Moisture absorption	Fine cracks (Hairline cracks, Breathing)	Moisture penetration Degradation of insulation Deliquescence	Humidity {heat shock, temperature cycle} + humidity Temperature/humidity cycle	Resin covered or sealed parts
Humidity	Corrosion	Battery corrosion	Color change Increased resistance Open circuit	Electrial potential from humidity + contact with foreign metal	Connector contacting electric potential of 0.2 V or more requires caution
Humidity	Corrosion	Electrolysis corrosion		Humidity + DC electric field	E.g., resistors, resin sealed ICs
Humidity	Corrosion	Crevice corrosion		Humidity	Cracks (e.g., terminals)
Humidity	Corrosion	Stress corrosion cracks	Damage	Ammonia (copper alloy) Chloride (stainless)	Alloys (e.g., brass, nickel silver, stainless)
Humidity	Corrosion	Hydrogen embrittlement		Plating acid bath	Steel
Humidity	Migration	Ion migration	Short circuit Insulation defect	Humidity + DC electric field	Bi, Cd, Cu, Pb, Sn, Zn, Ag
Humidity	Migration			Humidity + DC electric field + halogen ions	Metals that migrate when coexisting with halogen : Au, In, Pd, Pt
Humidity	Mildew		Insulation defect Quality variation Decomposition Corrosion	Temperature (25 - 35°C) + humidity (min. 90%)	Plastic materials (e.g., polyurethane, polyvinyl chloride, epoxy, acrylic, silicon, polyamide, phthalic acid resin)

Kiyoshige Echikawa: From the "Reliability Test of Electronic Components" (1985) Union of Japanese Scientists and Engineers

Failures due to humidity can be classified into a number of categories as in table 1, but here we would like to focus on corrosion and migration in a little more detail.

2-1-1 Failure due to corrosion of plastic packaged semiconductor devices

Integrated circuit chips form a large number of components on silicon substrate, and these components are connected by wiring to form circuits. Aluminum and aluminum alloys are often used in this wiring because they are economical and easy to process.

From the time plastic packaged integrated circuits first began to be produced, corrosion caused by moisture penetrating the package and causing open circuits the aluminum wiring had to be confronted as a major problem. Efforts were made to improve quality using resin materials, improving mold technology, and improving passivation film, but semiconductor devices have continued to be miniaturized, and so corrosion of packaged aluminum wiring is still a major problem today. The process of generating corrosion in aluminum wiring can be understood as follows.

Moisture penetration routes

- Moisture permeates through the package.
- Moisture penetrates through the resin and lead frame interface.

↓ Moisture reaches the chip surface.

Corrosion of Aluminum Wiring

- No bias voltage applied
  The bonding pad corrodes significantly. (The bonding pad has no water resistant film [= passivation film].)

- Bias voltage applied

(Anode side reaction)

① Under normal environmental conditions, the surface of aluminum is passivated with an oxide film, and aluminum is stable.

② When bias is applied to aluminum wiring protected by passive state gibbsite [appearing as $Al_2O_3 \cdot 3H_2O$, or $Al(OH)_3$], the aluminum dissolves according to the following reactions, due to the anode surface absorbing moisture and Cl^- ions had been expanding inside the resin package.

③ First, surface hydroxides react to Cl^- ions, forming soluble salts.
$Al(OH)_3 + Cl^- \rightarrow Al(OH)_2Cl + OH^-$ ...... (1)

④ The substrate aluminum exposed because of this reaction then reacts with the Cl^- ions.
$Al + 4Cl^- \rightarrow Al\,Cl_4^- + 3e^-$ .... (2)

⑤ Once again, the absorbed moisture, caused by humidity penetrating inside the resin package, produces the following reaction.
$AlCl_4^- + 3H_2O \rightarrow Al(OH)_3 + 3H^+ + 4Cl$... (3)

⑥ Finally, this becomes $Al(OH)_3$. The $Al(OH)_3$ formed here, unlike the protective oxide film, does not form a seal. In addition, this product has a ratio of cubic expansion high enough to cause cracking in the protective oxide film, thus promoting corrosion.

⑦ The Cl^- ions formed in formula (3) are again consumed by reactions in formulas (1) and (2).
Through this chain reaction, a small quantity of Cl^- ions can produce a large amount of corrosion.

⑧ However, in a competing reaction, anodic oxidation occurs, and corrosion is suppressed as the oxidized layer thickens.

(Cathode side reaction)

① The concentration of hydrogen ions near the electrodes increases due to the absorption of moisture by the resin package, along with the reduction of oxygen caused by applying bias [formula (4)] as well as the generation of hydrogen [formula (5)].
$O_2 + 2H_2O + 4e^- \rightarrow 4(OH)^-$ .... (4)
$H_2O + e^- \rightarrow (OH)^- + (1/2)H_2$............. (5)

② In the presence of flaws such as pinholes, voids, and cracks in the oxide film protecting the aluminum, the OH^- ions formed here are diffused to the aluminum substrate, and the following reaction forms aluminum hydroxide just as at the anode.
$Al + 3(OH)^- \rightarrow Al(OH)_3 + 3e^-$........... (6)

③ The OH^- ions formed in the reaction in formula (5) are consumed in the reaction forming the aluminate ions, as follows:
$OH^- + Al + H_2O \rightarrow AlO_2^- + (3/2)H_2$ ..... (7)
At the cathode, reaction forming OH^- ions continues. This reaction is limited by current density.

④ The following reactions, utilizing cations such as Na^+ and K^+ inside the resin package, cause an increase in the concentration of OH^- ions,
$Na^+ + e^- \rightarrow Na$ .... (8)
$Na + H_2O \rightarrow Na^+ + OH^- + (1/2)H_2$ ...... (9)
promoting the reaction in formula (6), and so increasing corrosion.

⑤ Since aluminum is an amphoteric metal, acidic as well as alkaline electrolytic solutions form at the cathode, causing corrosion.
$2Al + 6H^+ \rightarrow 2Al^{3+} + 3H_2$ .... (10)
$2Al^{3+} + 6H_2O \rightarrow 2Al(OH)_3 + 6H^+$ ...... (11)
The hydrogen ions formed in the reaction in formula (9) are again consumed in the reaction in formula (8), promoting corrosion through a chain reaction.

From the "Semiconductor Device Reliability Handbook" (1988) of Matsushita Electronics Corporation

The corrosion reaction of Aluminum changes depending on whether bias voltage is applied. The following factors are thought to accelerate Aluminum corrosion.

① Poor adhesion between resin and lead frame interface (Due to the difference in each rate of expansion)
② Sealing materials are adulterated with impurities, or tainted by ions of impurities during assembly. (Due to the presence of impurities)
③ A high concentration of phosphorus used in the passivation film
④ Defects in the passivation film

2-1-2 Failures due to migration on printed circuit boards

Migration refers to the movement of matter.

Recently the problem of a high humidity environment causing ion migration (also called Electrochemical Migration) on printed circuit boards has become more serious due to the following reasons.

- The miniaturization of electric products concurrent with higher level functions has promoted finer wiring and increased layers of printed circuit boards.
- As electric products have become miniaturized, such products as computers and telephones have become mobile, bringing a corresponding increase in the severity of environmental stress.
- CFC (chlorofluorocarbon) regulations have changed the methods of cleaning such equipment as printed circuit boards, increasing the possibility of ion migration caused by flux that has been left due to poor treatment.
- There has been an increase in the number of printed circuit boards with current constantly applied, such as in the pre-heating function of televisions, causing ion migration to form more quickly.

In the field of electronic devices, migration is generally classified into the three major categories of ion migration, electromigration, and stress migration. In this article we shall discuss the serious problem of ion migration as it relates to humidity.

Mechanism generating ion migration

When printed circuit boards absorb moisture in the area between the metal of the wiring, and then bias voltage is applied, metal from the anode is ionized and moves toward the cathode. The reduced metal from the cathode then extends toward the anode as dendrites.

If the reduced metal reaches the anode, short circuits and insulation defects occur between the wires.

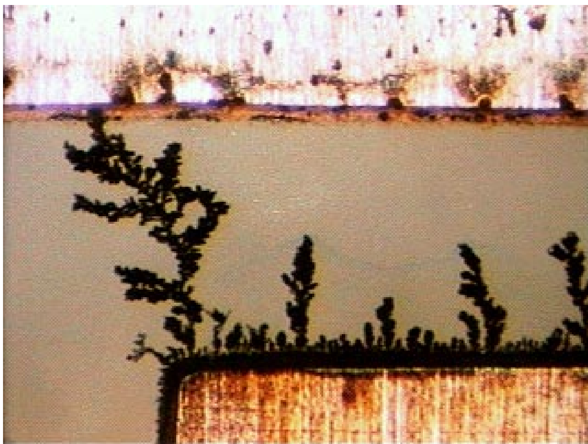


Photo. 1 Example of ion migration

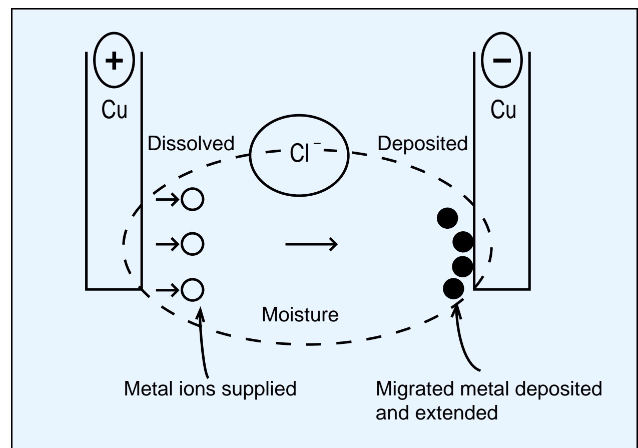


Fig.1 The mechanism generating ion migration

The acceleration factors for generating this type of ion migration can be understood as follows.

① Moisture absorption or dew condensation on the printed circuit board material in the space between the metal patterns
② Temperature change of the printed circuit board
③ Strong and weak bias voltage applied
④ Distance between the metal patterns
⑤ Ionized foreign matter such as halogen and alkali adhering to the surface of the printed circuit board

3. High Humidity Testing Methods

Now, to give one example of high humidity testing methods, we shall discuss testing methods for semiconductor devices.

3-1 High Humidity Testing Methods for Semiconductor Devices

A large number of high humidity tests have been performed to evaluate aluminum corrosion in the early stages.

Those testing methods are shown in Table 2.

These testing methods can be broadly classified into two types: methods that leave the semiconductor devices in a high humidity environment, and methods that apply bias voltage to the semiconductor devices while they are in high humidity.

We must be very careful to clearly understand one point, that the failure mode differs for each testing method.

3-1-1 Temperature-Humidity Bias Test (THB)

As one method of high humidity testing, this test has changed from 40°C at 90%RH → 60°C at 90%RH → 85°C at 85%RH, improving reliability as test conditions have become more severe.

This 85°C 85%RH test is the most common test today, and is standardized in such standards as IEC 749, Semiconductor Device Mechanical and Climatic Test Methods, and JIS C 7021, Type Designation System for Discrete Semiconductor Devices.

3-1-2 Pressure Cooker Test (PCT) and Unsaturated Pressure Cooker Test (USPCT)

Progress is again being made in improving reliability of semiconductor devices, and many semiconductor devices now endure the long period THB test without failure, so test time for determining acceptable quality for products has also increased. Because of this, a number of tests are now being performed to reduce test time. These mainly fall into the broad classifications of PCT and USPCT, and now the pressure cooker test is widely recognized as an accelerated test for humidity resistance and has been standardized by the IEC (International Electrotechnical Commission). (Summarized in “Report 2” in this issue.)

Next, we shall discuss the difference between PCT and USPCT.

Note: USPCT is now called HAST (Highly Accelerated Stress Test). However, to maintain the PCT and USPCT distinction we shall continue to use USPCT in this article.

Table 2 Typical semiconductor device accelerated humidity resistance test

No.	Test item	Details	Typical temperature and humidity condition
1	Temperature-humidity storage test	Exposing devices to an atmosphere of fixed temperature and relative humidity (less than 100%RH)	60°C 90%RH 85°C 85%RH
2	Temperature-humidity bias test (THB)	Same as above + bias applied	Same as above
3	Boiling test	Dipping devices in boiling water	In 100°C deionized water
4	Pressure cooker test	Exposing to saturated water vapor above 1 atmospheric pressure	121°C 100%RH
5	Unsaturated pressure cooker test	Exposing to unsaturated water vapor above 1 atmospheric pressure	121°C 85%RH
6	Unsaturated pressure cooker bias test	Same as above + bias applied	Same as above
7	Pressure cooker test + Temperature-humidity bias test	Making pressure cooker test as pre-treatment for temperature-humidity bias test	121°C 100 %RH 8H + 85°C 85%RH
8	Temperature cycle test + Pressure cooker test	Making temperature cycle test as pre-treatment for pressure cooker test	125°C to –55°C 5 times + 121°C 100%RH
9	Series test	Series test or compound test consisting of each type of the above humidity resistance test combined with mechanical test or heat resistance test	—

From the “Semiconductor Device Reliability Handbook” (1988) of Matsushita Electronics Corporation

(1) Pressure Cooker Test (PCT)

Test chamber consists of a pressure vessel containing a water heater to create a 100%RH (saturated) atmosphere. Because the atmosphere is at 100%RH, dew condensation readily forms on the surface of the test specimens and on the inside walls of the test chamber. Also, in the chamber there is a risk of dew condensation (water droplets, min. 100C°!) dripping from the ceiling onto the specimens. Because of that, preventive measures are usually taken such as erecting drip protection hoods, but it is difficult to assure complete protection.

Likewise, during the normal ramp-up of temperature and humidity, the temperature of the specimens rises more slowly than the temperature of the surrounding steam, so dew condensation on the surface of the specimens can't be avoided. In any case, failures that differ from failures occurring in the field can be caused by the penetration of a large quantity of dew condensation.

(2) Unsaturated Pressure Cooker Test (USPCT)

The Unsaturated Pressure Cooker was created to compensate for the shortcomings of the Pressure Cooker. The air temperature (dry bulb temperature) and water temperature are individually controlled inside the test chamber. By making it possible to control humidity at less than 100%RH, both dew condensation on the surface of the specimens as well as dripping onto the specimens are prevented.

Recently, humidity is also controlled after the test to prevent specimens from drying out, and the most suitable test chamber is a chamber that avoids sudden changes in the test environment.

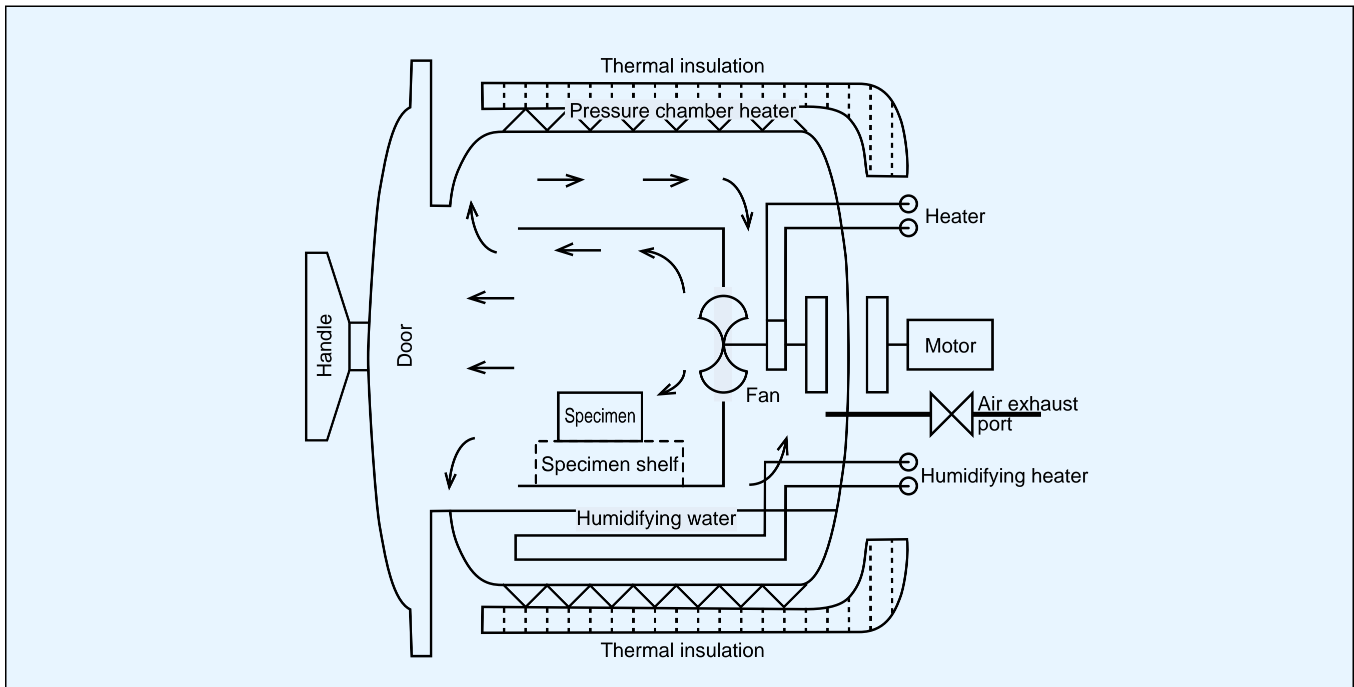


Fig.2 TABAI ESPEC's Unsaturated Pressure Cooker

Table 3 A comparion of the Pressure Cooker and the Unsaturated Pressure Cooker

Pressure Cooker	Unsaturated Pressure Cooker
• Test chamber simple and economical	• Test chamber complicated and expensive
• Strong effects of dew condensation	
• Poor correlation to failure modes in the field	• Good correlation to failure modes in the field
• Poor test reproducibility	• Good test reproducibility
• Difficult to apply bias	• Easy to apply bias

Kiyoshi Takahisa/Shigeharu Yamamoto/Yoshihumi Shibata/Terunori Saeki/Hideo Iwama:
From the "Reliability Test of Device and Components" (1992) Union of Japanese Scientists and Engineers

3-1-3 Acceleration in tests for humidity resistance of semiconductor devices

A number of actual semiconductor device acceleration models have been announced based on results of various types of humidity resistance tests. However, at present no common acceleration model exists for all types of semiconductor devices.

Fig.3 introduces an example of publicly announced data.

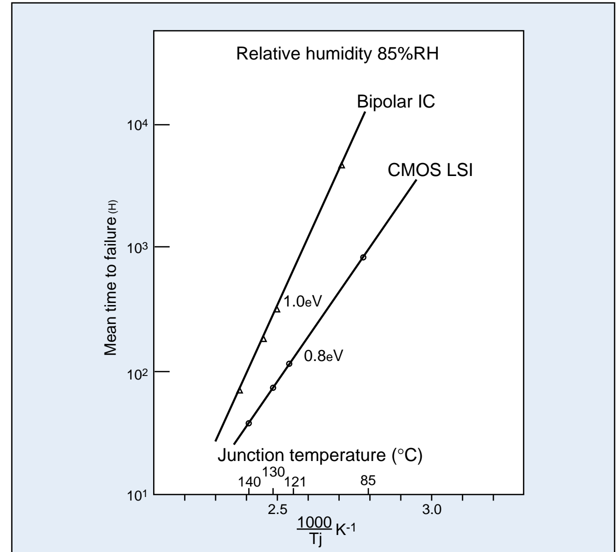


Fig.3 Dependence of MTTF on temperature (Bipolar IC, MOS LSI)

From the "Semiconductor Device Reliability Handbook" (1988) of Matsushita Electronics Corporation

3-1-4 A comparison of the merits and demerits of high humidity tests

The following points are vital not only for humidity testing, but also when performing all kinds of environmental testing.

- "Correlation" (Whether the failure, failure mode, and failure mechanism are the same as those actually occurring in the field)
- "Accelerability" (How many times greater is the test result failure rate than the field failure rate)
- "Reproducibility" (Whether anyone at any time can obtain the same results)

A comparison of the merits and demerits of each high humidity test according to the above points is shown below.

Table 4 Comparison of humidity resistance testing methods

Test name	(Correlation) Failure mode	Accelerability	Reproducibility
1. Temperature-humidity storage test	△	×	○
2. Boiling test	×	△	△
3. Pressure cooker test (PCT)	×	○	△
4. Temperature-humidity bias test	○	○	○
5. Unsaturated pressure cooker bias test	○	◎	○

Note: ◎ very good ○ good △ a little insufficient × inferior

From the "Semiconductor Device Reliability Handbook" (1988) of Matsushita Electronics Corporation

3-2 Ion Migration Test Method for Printed Circuit Boards

As high humidity test methods for printed circuit boards, tests are performed at 40°C, 90%RH + bias and at 85°C, 85%RH + bias.

However,

- Short circuit failures between the metal patterns lasting for a long period are rare, but failures involving unstable flow of leak current are common.
- When current flows along the metal extended as dendrites, sometimes during the test the metal separates like a fuse and recovery occurs from insulation defects.

Because of that, it is desirable to continuously measure leak current during the test to observe the growth of ion migration.

Recently, to increase test acceleration beyond the formula of high temperature + high humidity + bias, the spotlight is being focused on dew cycle testing, such as 5°C, 60%RH ↔ 25°C 90%RH. Companies, especially automobile manufacturers, are setting company standards for this type of test.

(For information on dew cycle testing, refer to Report 1 and Report 2 in Technology Report No.1.)

For your reference, we are providing below a list of measure to prevent ion migration in table 5, and a list of metals causing ion migration in table 6.

Table 5 Ion migration prevention measures

Ion Migration Prevention Measures

1. Control the quantity of water vapor.
2. Prevent dew condensation.
3. Avoid environments with sudden changes in temperature.
4. Examine materials for protective films.
5. Prevent contamination by foreign matter.
6. Wash products properly.
7. Study the moisture absorption characteristics of flux before using.
8. Have no electrostatic focusing at the anode.
9. Increase the distance between the terminals.
10. Use lower voltage and lower energy consumption.
11. Increase the density of printed circuit board material.
12. Eliminate areas of exposed metal.
13. Improve bonding between different materials on the printed circuit board.
14. Air condition installation sites. (Lower humidity.)
15. Improve resin materials.

Table 6 Metals causing ion migration

Metals causing by distilled water + electric field*1	Metals causing by distilled water + electric field*1 +halogen*2	Metals only causing with other conditions
Bismuth Cadmium Copper Lead Silver Tin Zinc	Gold Indium Paladium Platinum	Aluminum Antimony Chrome Iron Nickel Rhodium Tantalum Titanium Vanadium

Note: *1 At distance of 1 mm, bias has been changed from 1 to 45 V DC.
*2 A 0.001 to 0.1 mole solution of NaCl or KCl.

A.Der Marderosian: From the “International Microelectronics Symposium”, pp. 134 - 141, 1978

Coffee Break

Since ancient times people have devised a variety of methods for measuring humidity.

Leonardo da Vinci, who was active in the 15th and 16th centuries, utilized the phenomenon that objects become heavier when they absorb moisture to devise the balance hygrometer in Figure. The plate on one side holds an object that readily absorbs and gives off moisture, while the other side holds an object that doesn't absorb moisture. When humidity rises, the object that absorbs moisture becomes heavier, and the balance tilts. The degree of tilt measures the amount of humidity. Considered from the precision of the balances of that day, it would seem impossible to measure humidity with a high degree of accuracy, but it was able to show large changes and was used to confirm the seasons and forecast weather.

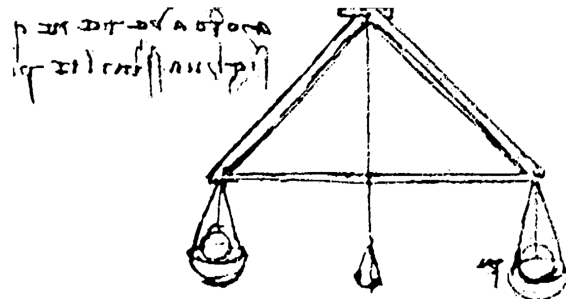


Fig. The balance hygrometer devised by Leonardo da Vinci

3-3 Humidity Testing Precautions

Table 7 lists precautions required when performing humidity testing.

Table 7 Humidity testing precautions

(1) Considerations for measuring equipment and test chamber

① A dirty wet bulb wick (e.g., gauze) can cause humidity measurements to be off by 5 to 10 %, so it is vital to inspect for wick smudging and degradation.

② Water with a high amount of impurities, such as tap water, must never be used for humidifying water.

(2) Precautions concerning the composition of specimens

① When performing THB testing, the surface temperature rises for specimens that generate a lot of heat, and relative humidity decreases in the immediate vicinity, making corrosion less likely to occur. For such cases, test conditions must be arranged in the following manner.

- Voltage consumption max. 100 mW .... continuous electrical current
- Voltage consumption min. 100 mW .... one hour ON, 3 hours OFF

② Humidity conditions inside the test chamber must be confirmed with specimens inside.

(3) Precautions during and after testing

① Temperature and humidity distribution inside the test chamber must be uniform throughout. In other words, differences due to position must be minimal.
For example, in a humidity test at min. 90%RH with temperature below normal, if the temperature drops 1°C, humidity becomes 100%RH and forms dew condensation. Because of this, even when the distribution dispersion inside the chamber is a maximum of 1°C, this can have a major impact on test results.

② A means must be devised to prevent droplets of moisture forming on the ceiling of the test chamber from dripping onto the specimens. Removing the specimens abruptly after the test is finished creates stress on the specimens, causing unexpected results, so the specimens are removed after they have returned to normal temperature. The pressure cooker test (PCT) in particular has the following types of dangers.

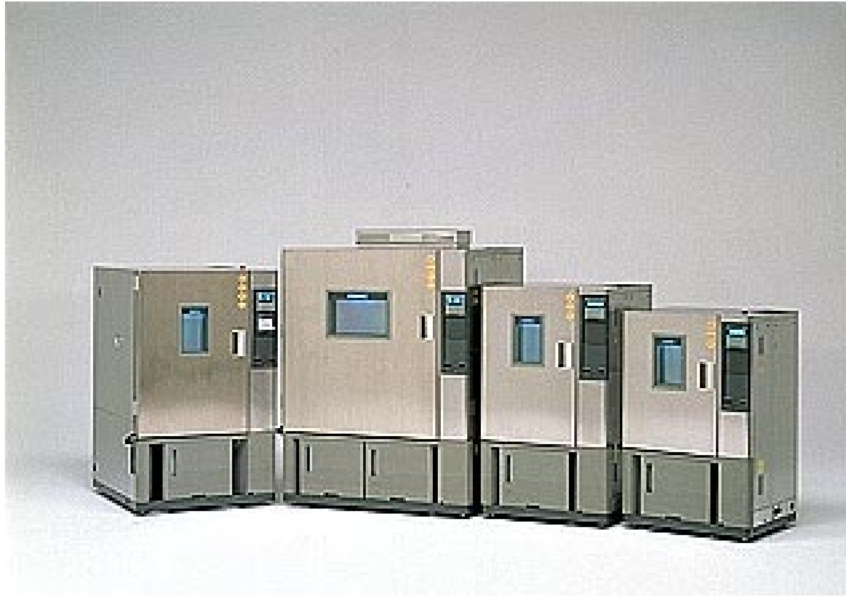
Types of stress possible on specimens after the pressure cooker test (PCT)

Pressure shock	If the air is ventilated immediately after the heater is turned off, the shock from the pressure abruptly dropping to atmospheric pressure may causes cracks in the specimens.
Temperature shock	The moisture content in the specimens boils due to the pressure drop, and the force of the expansion could cause the specimen material to break.

Kiyoshi Takahisa/Shigeharu Yamamoto/Yoshihumi Shibata/Terunori Saeki/Hideo Iwama:
From the "Reliability Test of Device and Components" (1992) Union of Japanese Scientists and Engineers

4. Test Equipment for Humidity Testing

- ***Platinous S Series***



- A wide range of temperature and humidity control.
- Overheat-free refrigeration capability.
- An electronic auto-expansion valve providing energy-saving refrigeration system.
- Space-saving vertical heat exhausting system which enables a chamber to be set flush with the wall.
- Easy water supply through cartridge tank (15 ℓ /10.5 ft^3) even under operation.
- P-instrumentation, a programmed operation mode, for 16 patterns, 512 steps in total; T-instrumentation, a fixed value operation mode, for direct setting of relative humidity in %RH.
- Corresponding to environmental test chamber network system, E-BUS.

Specifications for representative products

Model	Power supply	Temperature & humidity range	Inside dimensions W × H × D mm (in)
PL-1S	200V AC ± 10% 3ø 3W 50/60Hz 220V AC ± 10% 3ø 3W 60Hz 380V AC ± 10% 3ø 4W 50Hz	–40 to +100°C (–40 to +212°F) 20 to 98%RH	500 × 600 × 400 (19.7 × 23.6 × 15.7)
PL-2S			500 × 750 × 600 (19.7 × 29.5 × 23.6)
PL-3S			600 × 850 × 800 (23.6 × 33.5 × 31.5)
PL-4S			1000 × 1000 × 800 (39.4 × 39.4 × 31.5)
PSL-2S		–70 to +100°C (–94 to +212°F) 20 to 98%RH	600 × 850 × 600 (23.6 × 33.5 × 23.6)
PSL-4S			1000 × 1000 × 800 (39.4 × 39.4 × 31.5)
PDL-3S		–40 to +100°C (–40 to +212°F) 5 to 98%RH	600 × 850 × 800 (23.6 × 33.5 × 31.5)
PDL-4S			1000 × 1000 × 800 (39.4 × 39.4 × 31.5)

• *Unsaturated Pressure Cooker (HAST SYSTEM)*

The models come in two types.The Standard type permits programmed operation for both unsaturated control and saturated control. The Multi-type is equipped with our innovative wet and dry bulb temperature control system. This model directly controls temperature and humidity by using the chamber data obtained through a wet and dry bulb thermometer. In this way, the temperature and humidity can be precisely controlled throughout the entire test period. This means that even in the periods before and after the test, the environment can be precisely controlled. A high-precision control of temperature and humidity is attained, and the repeatability of the test is greatly enhanced.

Specifications for representative products

Model	Power supply	Temperature, humidity & pressure range	Inside dimensions ø × L mm (in)
TPC-212(M)	200V AC 1ø 50/60Hz 220V AC 1ø 50/60Hz	+105.0 to +142.9°C (+221.0 to +289.2°F) 75 to 100%RH 0.2 to 2.0kg/cm^{2}G (2.8 to 28.4 psi)	295 × 330 (11.6 × 13.0)
TPC-222(M)			395 × 450 (15.6 × 17.7)
TPC-412(M)		+105.0 to +162.2°C (+221.0 to +324°F) 75 to 100%RH 0.2 to 4.0kg/cm^{2}G (2.8 to 56.8 psi)	295 × 300 (11.6 × 11.8)
TPC-422(M)			395 × 450 (15.6 × 17.7)

For more detailed information related to this article, we have the following pamphlets available in English:

- "PROBLEMS IN PRESSURE COOKER TEST"
- "PROBLEMS IN PRESSURE COOKER TEST (II)"
- "HAST PRESSURE COOKER TESTING OF ICs"
- "UNSATURATED TYPE PCT EQUIPMENT & TESTING ENVIRONMENT"
- "ADVANCED HAST APPARATUS"
- "HAST UNDER AIR AND STEAM"

In addition to the above, we have many pamphlets which are available in Japanese. If you are interested in any of those, please contact us.

[Reference Bibliography]

1) Kiyoshige Echikawa:
"Reliability Test of Electronic Components" Union of Japanese Scientists and Engineers (1985)

2) Matsushita Electronics Corporation:
"Semiconductor Device Reliability Handbook" (1988)

3) Kiyoshi Takahisa/Shigeharu Yamamoto/Yoshihumi Shibata/Terunori Saeki/Hideo Iwama:
"Reliability Test of Device Components" Union of Japanese Scientists and Engineers (1992)

4) A.Der Marderosian:
"International Microelectronics Symposium", pp.134-141 (1978)

Corrections to issue No.1 and apology

In "What is environmental testing?", an article of understanding the technology, the following two points were mistaken on page 11.

(1) $K = A \cdot \exp\left(\frac{-Ea}{RT}\right) = \frac{L_1}{L_2} \quad \rightarrow \quad K = \frac{L_1}{L_2}$

(2) Fig.5
On the vertical "Life time" scale, the number 10^3 was inadvertently left out.

In addition to correcting this oversight, we would like to apologize for the inconvenience.

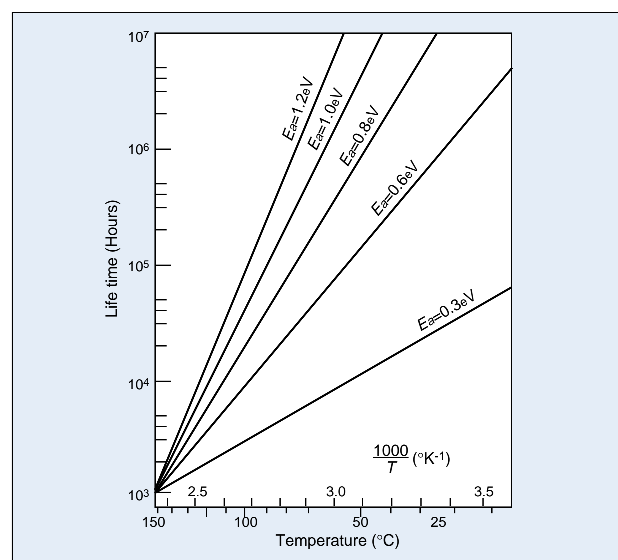


Fig.5 Relationship between temperature and life

From the "Semiconductor Device Reliability Handbook" (1988) of Matsushita Electronics Corporation