Technical information for our customers

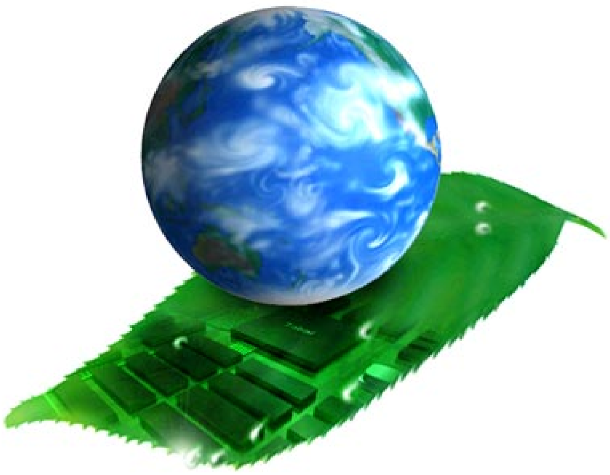
ESPEC

TECHNOLOGY REPORT

1996

No. 1

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: 6,778,900,000 Yen (As of March, 1996)

Chairman: Eiichi Koyama

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Managing Directors: Susumu Nojii, Toshikazu Adachi, Nobuyoshi Shin

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TABAI ESPEC SERVICE CORP. (JAPAN)

TABAI KANKYO SETSUBI CO., LTD. (JAPAN)

TABAI ESPEC KYOTO CORP. (JAPAN)

TABAI ESPEC HYOGO CORP. (JAPAN)

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

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.

ESPEC

TECHNOLOGY REPORT

Greetings from the President

On our first issue

To each one of our esteemed customers, I would like to express my heartfelt appreciation for your continued kind patronage of TABAI ESPEC and our products.

At TABAI ESPEC, where “Environment” is our business theme, we offer environmental testing equipment and perform “commissioned environmental testing” for the customer. We also perform “traceability” work to support obtaining ISO 9000 series certification. In addition, we are undertaking the development of a wide range of projects in our “Agribusiness”, such as the design and construction of our “Plant Factory”, which utilizes our environmental management technology in ecology.

In response to the globalization of our customers, we have established production laboratories in the US and China and have opened 15 agencies in 12 countries. We are building a worldwide system to be able to offer perfection in supplying products and services so that our customers around the world can enjoy peace of mind when choosing ESPEC products.

At TABAI ESPEC, starting last year we began collecting the know-how and information developed in this type of business activity for publication in a new technology report magazine introducing the latest trends and standards in technology related to environmental testing and reliability testing. The first issue of this magazine, “ESPEC Technology Report” was published in Japanese last year, and we are now very pleased to be able to present the first issue of our English version.

We shall be delighted if this publication provides any assistance to our valued friends and customers in their research and development activities in their leading edge fields.

Kiyoshi Shimazaki
President

What is Environmental Testing?

Yoshinori Kin*/Yasuko Sasaki*

To improve quality, the currently separate steps of "failure analysis", "environmental test planning", "environmental testing", and "test results analysis" should be unified into one common activity. However, at present due to such reasons as the large number of types of specimen and the complexity of evaluation technology, engineers engaged in individual research in each field carry out these steps separately. Because of this, the persons doing the testing rarely are aware of the purpose of the test or its effectiveness.

This series on environmental testing is for such persons as well as for those who have heard of "environmental testing" but aren't sure what it's all about.

Our greatest hope for this series is that each and every issue be enjoyed by such readers and that it lead to the ability to better carry out their duties. We are presenting "What is Environmental Testing?" and "Temperature Testing" as the first articles in the series, to be followed by "Humidity Testing" and "Temperature Cycle Testing". We hope you enjoy the articles.

Contents

For more detailed information related to this article, we have the following pamphlets available in English: "Method of Environmental Testing & Equipment", "Outline of Reliability Engineering", and "Standard for Performance of humidity chamber K01". In Chinese we have: "Environmental Testing Standards and Methods" and "Method of Environmental Testing & Equipment".

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.

*Overseas Business Department

1. Introduction

We are presenting this series to give an overview of "environmental testing". In this article we shall deal with "What is Environmental Testing?" and "Temperature Testing".

In the section on "What is Environmental Testing?", we would like to answer those who say, "I do environmental testing, but why are we doing it?" by giving a clear summary of the purposes, effectiveness, and standards of environmental testing.

In the section on "Temperature Testing", we would like to explain the effects and testing of temperature, which is known as the most important climatic-related environmental stress factor involved in the failure of parts and equipment.

2. An overview of environmental testing

2.1 The purpose of environmental testing

Evaluating the worth of manufactured goods is not limited to evaluating their function and performance.

- At what level can performance be maintained, and for how long? In other words, what is the product failure rate?
- How does performance change in response to the severity of the environment actually encountered?

That is to say, a crucial part of the worth of manufactured goods is in their quality.

However, when quality defects occur after products have been put on the market, the cost is not limited to the significant amount that can be lost in the damages. The greatest loss is in the loss of reputation.

To avoid such damages, quality must be confirmed before a product is put on the market. Environmental testing not only confirms quality through such tests as simulation testing and product life testing, it also can truly be called the indispensable prerequisite to quality assurance.

Environmental testing can be broadly categorized, as shown in Fig. 1, into "Climatic (natural) environmental testing" and "Mechanical (causal) environmental testing" as well as a combination of the two, "Combined environmental testing". Climatic-related environmental testing deals with environmental factors such as pressure, humidity, and temperature, while mechanical environmental testing treats such factors as shock and vibration.

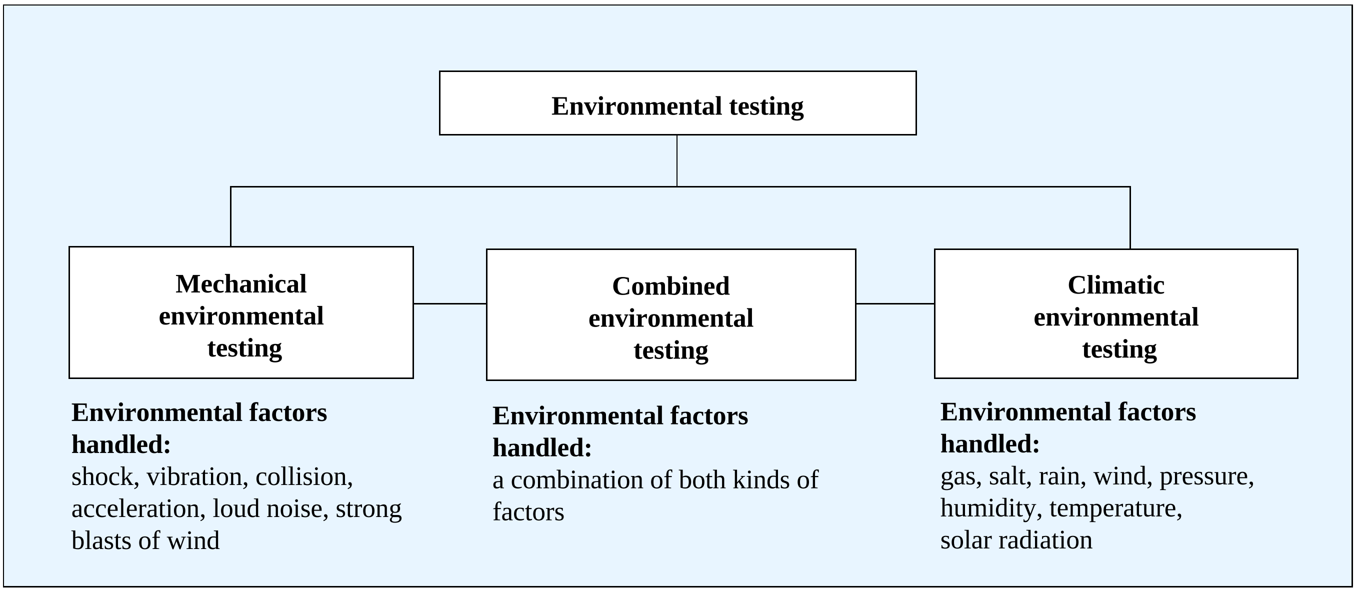


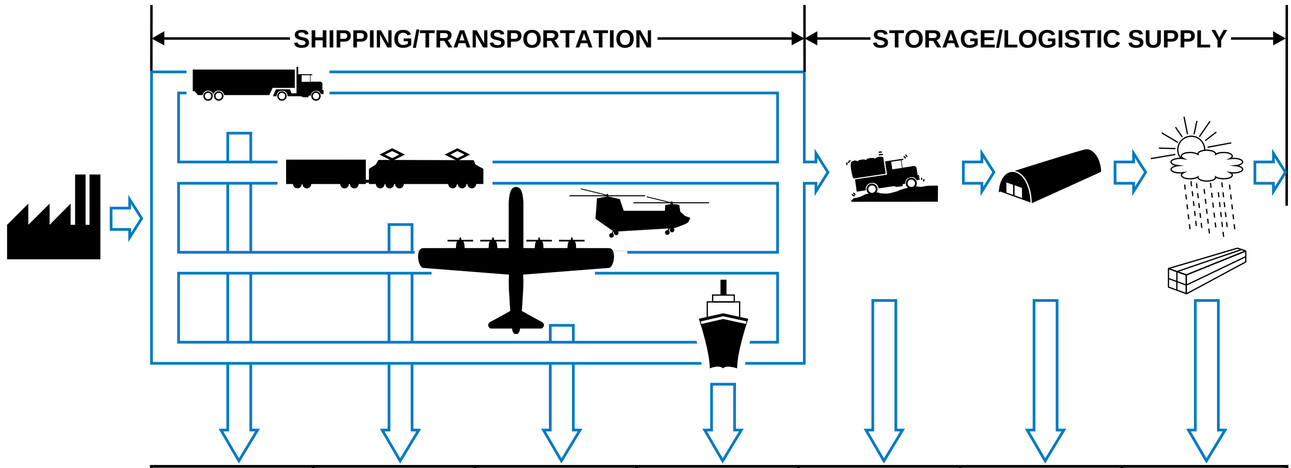
Fig 1 Types of environmental testing

Table 1 Environmental factors of climatic environmental testing and their major effects

Environment	Effects
Wind: Gusting and turbulence	Causes structural degradation and destruction, obstructs aircraft control functions, cools parts and surfaces at low wind speed, generates heat from friction at high wind speed, and causes functional failure due to invasion and adhesion of foreign matter.
Precipitation: Dew, frost, hail, rain, sleet, snow	Causes structural degradation and destruction, leaches heat from parts and structures, promotes corrosion, causes electrical failure, and damages protective film.
Sand and dust	Causes marring and abrasion of finished surfaces, increases surface friction, contaminates lubricants, clogs pipes, and promotes fatigue, cracking, and chipping of materials.
Atmospheric salt and brine spray	Conductivity of salt solution degrades insulation resistivity and promotes electrolytic etching and chemical corrosion of metals.
Humidity	Moisture invades porous substances, causes oxidation from conductance and corrosion between conductive materials, causes materials such as gaskets to swell, and extremely low humidity causes brittleness and granulation.
Solar radiation	Generates ozone, causes colors to fade, rubber to lose elasticity, and heat to rise inside containers, and results in heat-related aging.
High temperature	Causes changes in factors such as resistance, inductance, capacitance, power factors, and dielectric constants, destroys moving parts through softening and swelling of thermal insulation, causes finished surfaces to swell, causes parts to age through heat aging, promotes oxidation and chemical reactions, changes viscosity of and evaporates lubricants, and causes structural overloading due to physical expansion.
Low temperature	Embrittles and lowers flexibility of resin and rubber, changes electrical constants, causes moisture to freeze, increases viscosity of lubricants and causes gelling, increases heat loss, causes finished surfaces to crack, and causes structural overloading due to physical expansion.
Thermal shock	Causes permanent change in electrical performance, and sudden overloading of materials causes cracking and mechanical failure.
High or low pressure	Causes effects such as rupturing, exploding, and destruction of structures such as buildings, containers, and storage tanks, causes leakage of air-tight seals, causes damage due to internal bubbles forming, distorts flight characteristics of aircraft, missiles, and artillery shells, causes display errors in instruments such as altimeters, and changes electrical characteristics.
Gas	Promotes metal corrosion, degrades dielectric strength, creates explosive atmosphere, changes thermoelectric transfer characteristics, and promotes oxidation.

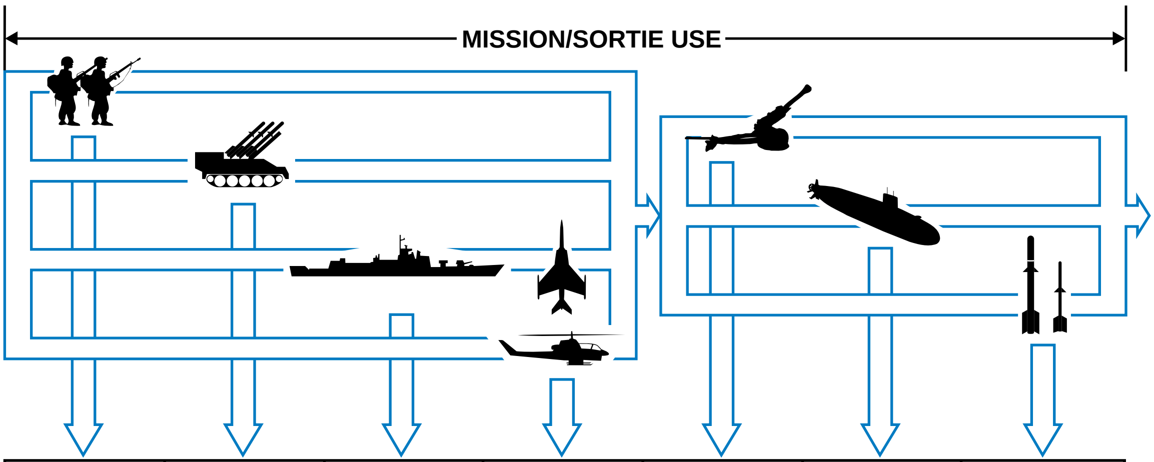
2.2 The environment that products encounter

At this point we will quote MIL-STD-810E, which introduces actual examples of environmental conditions encountered by products manufactured at the factory.



	Handling & Road Transportation	Handling & Rail Transportation	Handling & Air Transport	Handling & Ship Transport	Handling & Logistics Transport (Worst Route)	Storage, Sheltered (Tent, Shed, Igloo)	Storage, Open
Environmental Stress Generation Mechanisms (Induced)	Road Shock (Large Bumps/ Potholes) Road Vibragion (Random) Handling Shock (Dropping/ Overturning)	Rail Shock (Humping) Rail Vibration Handling Shock (Dropping/ Overturning)	In-Flight Vibration (Engine/Turbine Induced) Landing Shock Handling Shock (Dropping/ Overturning)	Wave-Induced Vibration (Sinusoidal) Wave Sine Shock Mine/Blast Shock Handling Shock (Dropping/ Overturning)	Road Shock (Large Bumps/ Holes) Road Vibration (Random) Handling Shock (Dropping/ Overturning) Thermal Shock (Air Drop)	None	None
Environmental Stress Generation Mechanisms (Natural)	High Temperature (Dry/Humid) Low Temperature Rain/Hail Sand/Dust	High Temperature (Dry/Humid) Low Temperature Rain/Hail Sand/Dust	Reduced Pressure Termal Shock (Air Drop Only)	High Temperature (Dry/Humid) Low Temperature Rain Temporary Immersion Salt Fog	High Temperature (Dry/Humid) Low Temperature Rain/Hail Sand/Dust Salt Fog Solar Radiation Reduced Pressure	High Temperature (Dry/Humid) Low Temperature/ Freezing Salt Fog Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/ Freezing Rain/Hail Sand/Dust Salt Fog Solar Radiation Fungus Growth Chemical Attack

Fig. 2 The environment that products encounter (continued)



	Deployment & Use by Foot Soldiers/Ground Personel	Deployment & Use on Land Vehicles (Wheeled/ Tracked)	Deployment & Use Aboard Ships	Deployment & Use on Aircraft Including Captive Stores (Fixed/ Rotary Wing)	Delivery to Target Projectile	Delivery to Target Torpedo/ Underwater Launched Missile	Delivery to Target Missile/ Rocket
Environmental Stress Generation Mechanisms (Induced)	Handling Shock (Dropping/ Slamming/ Overturning) Firing/Blast Shock Acoustic Noise Explosive Atmosphere Electromagnetic Interference	Road/Off-Road Vibration (Surface Irregularities/Tread Laying) Engine-Induced Vibration Acoustic Noise Handling Shock (Including Bench) Road/Off-Road Shock (Large Bumps/Holes) Land Mine/Blast Shock Weapon Firing Shock/Vibration Explosive Atmosphere Electromagnetic Interference	Wave Induced Vibration (Sinusoidal) Engine-Induced Vibration Acoustic Noise Wave-Siam Shock Mine/Blast Shock Weapon Firing Shock Explosive Atmosphere Electromagnetic Interference Increased Pressure (Submarine)	Runway-Induced Vibration Aerodynamic Turbulence (Random Vibration) Maneuver Buffet Vibration Gumfire Vibration Engine-Induced Vibration Acoustic Noise Take-Off/Landing/ Maneuver Acceleration Air Blast Shock Catapult Launch/ Arrested Landing Shock Handling Shock (Including Bench) Aerodynamic Heating Explosive Atmosphere Electromagnetic Interference	Firing Shock Firing Acceleration Handling/Loading Shock Acoustic Noise Aerodynamic Heating Explosive Atmosphere Electromagnetic Interference	Launch Acceleration Handling/Launch Shock Engine-Induced Vibration Acoustic Noise Pyrotechnic Shock (Booster Separation) Explosive Atmosphere Electromagnetic Interference	Launch/Maneuver Acceleration Handling/Launch Shock Engine-Induced Vibration Aerodynamic Turbulence (Random Vibration) Acoustic Noise Aerodynamic Heating Explosive Atomosphere Electromagnetic Interference
Environmental Stress Generation Mechanisms (Natural)	High Temperature (Dry/Humid) Low Temperature/ Freezing Thermal Shock (Storage to use) Rain/Hail Sand/Dust/Mud Salt Fog Solar Radiation Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/ Freezing Thermal Shock (Storage to use) Rain/Hail Sand/Dust/Mud Salt Fog Solar Radiation Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/ Freezing Thermal Shock (Storage to use) Rain Salt Fog Solar Radiation Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/ Freezing Thermal Shock (Storage to use) Rain Salt Fog Solar Radiation Rain Impingement Sand/Dust Impingement Fungus Growth Chemical Attack	Thermal shock (Storage to use) Rain Impingement Sand/Dust Impingement	Immersion Thermal Shock	Rain Impingement Sand/Dust Impingement

Fig. 2 The environment that products encounter (suite)

2.3 Relationship between environmental factors and failure

Products fail due to environmental conditions. Few reports have been made on the relationship between failure and these environmental factors, but Hughes Aircraft Co. (USA) has done so, and we would like to introduce their report in Fig. 3.

This report attributes about 60 percent of all environmentally-induced failure to incidental temperature and humidity.

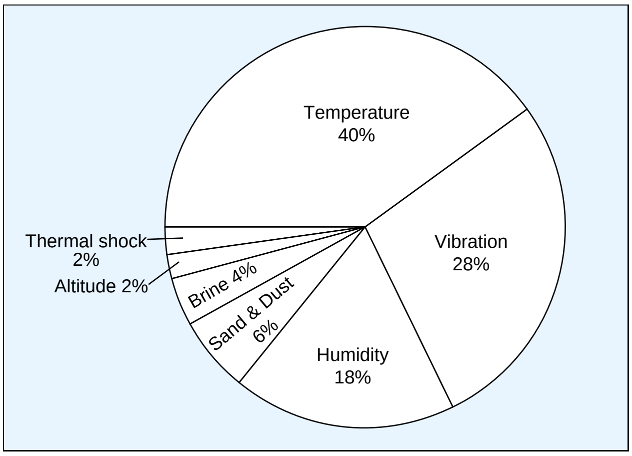


Fig. 3 Relationship between environmental factors and failure at Hughes Aircraft (USA)

2.4 Relationship between environmental testing and life cycles/processes of products

Environmental testing is performed to predict environmental conditions in which products will actually be used and to maintain quality in the predicted environment. Environmental testing is generally carried out from development and production stages in the following manner.

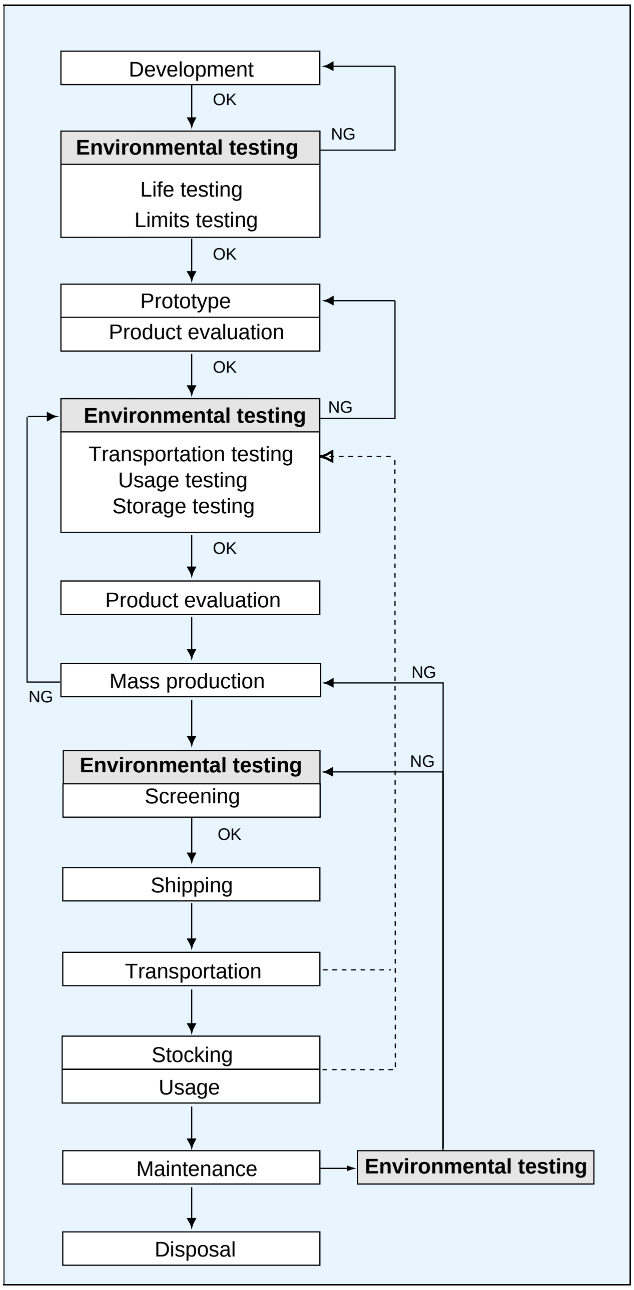


Fig. 4 Relationship between environmental testing and life cycles and processes of products

2.5 Standards for environmental testing

The IEC standards and MIL standards have been established as representative standards for environmental testing.

The International Electrotechnical Commission established the IEC standards for international standardization of the electrical and electronic fields. Publication 68 of the IEC standards consolidates "Basic environmental testing procedures". European countries form the core of the member nations of IEC, while the MIL (military) standards were originally established to standardize procurement of US military weapons and equipment.

MIL-STD-202 establishes testing standards for "electronic and electrical component parts". MIL-STD-750 sets testing standards for "semiconductor devices". MIL-STD-810 presents testing standards for "environmental test methods and engineering guidelines" ("procedure"), and MIL-STD-883 gives testing standards for "microelectronics". Today these standards do not merely apply to procurement of military equipment, but are widely used both in the US and throughout the world as basic standards for dealing with equipment. At this point, we would like to present the organization of the IEC and MIL testing standards that are so widely employed throughout the world.

Table 2 IEC Pub. 68 items on climatic environmental testing

Standard number	Test number and item
68-1 (1988)	Part 1: General and guidance Enumerates a series of environmental tests and appropriate severities, and prescribes various atmospheric conditions for measurements for the ability of specimens to perform under normal conditions of transportation, storage and operational use. Amendment No.1 (1992)
68-2-1 (1990)	Part 2: Tests — Tests A: Cold Concerns cold tests on both non-heat-dissipating and heat-dissipating specimens.
68-2-2 (1974)	Tests B: Dry heat Contains Test Ba: Dry heat for non-heat-dissipating specimen with sudden change of temperature; Test Bb: Dry heat for non-heat dissipating specimen with gradual change of temperature; Test Bc: Dry heat for heat-dissipating specimen with sudden change of temperature; Test Bd: Dry heat for heat-dissipating specimen with gradual change of temperature.
68-2-3 (1969)	Test Ca: Damp heat, steady state Describes a continuous test at a steady temperature of 40°C and a relative humidity of 90-95%.
68-2-5 (1975)	Test Sa: Simulated solar radiation at ground level
68-2-9 (1975)	Guidance for solar radiation testing
68-2-10 (1988)	Part 2: Test — Test J and guidance: Mould growth
68-2-11 (1981)	Test Ka: Salt mist
	Test L: Sand and dust
68-2-13 (1983)	Test M: Low air pressure
68-2-14 (1984)	Test N: Change of temperature
68-2-28 (1990)	Part 2: Tests — Guidance for damp heat tests
68-2-30 (1980)	Test Db and guidance: damp heat, cyclic (12+12-hour cycle) Determines the suitability of components, equipment and other articles for use and/or storage under conditions of high humidity when combined with cyclic temperature changes.
68-2-33 (1971)	Guidance on change of temperature tests
68-2-38 (1974)	Test Z/AD: Composite temperature/humidity cyclic test
68-2-39 (1976)	Test Z/AMD: Combined sequential cold, low air pressure, and damp heat test
68-2-40 (1976)	Test Z/AM: Combined cold/low air pressure tests
68-2-41 (1976)	Test Z/BM: Combined dry heat/low air pressure tests
68-2-42 (1982)	Test Kc: Sulphur dioxide test for contacts and connections
68-2-43 (1976)	Test Kd: Hydrogen sulphide test for contacts and connections
68-3-1 (1974)	Part3: Background information Section One — Cold and dry heat tests
68-3-1A (1978)	First supplement
68-3-2 (1976)	Section Two — Combined temperature/low air pressure tests

Table 3 Representative methods of MIL-STD environmental testing

MIL-STD-202F	
Method No.	**Title**
	Environmental tests (100 class)
101D	Salt spray (corrosion)
102A	Temperature cycling ...Cancel effective 31 Dec. 1973
103B	Humidity (steady state)
104A	Immersion
105C	Barometric pressure (reduced)
106F	Moisture resistance
107G	Thermal shock
108A	Life (at elevated ambient temperature)
109B	Explosion
110A	Sand and dust
111A	Flammability (external flame)
112E	Seal

(Physical characteristics testing omitted)

MIL-STD-883D	
Method No.	**Title**
1001	Barometric pressure, reduced (altitude operation)
1002	Immersion
1003	Insulation resistance
1004.7	Moisture resistance
1005.8	Steady state life
1006	Intermittent life
1007	Agree life
1008.2	Stabilization bake
1009.8	Salt atmosphere (corrosion)
1010.7	Temperature cycling
1011.9	Thermal shock
1012.1	Thermal characteristics
1013	Dew point
1014.10	Seal
1015.9	Burn-in test
1016	Life/reliability characterization tests
1017.2	Neutron irradiation
1018.2	Internal water-vapor content
1019.4	Ionizing radiation (total dose) test procedure
1020.1	Dose rate induced latchup test procedure
1021.2	Dose rate upset testing of digital microcircuits
1022	Mosfet threshold voltage
1023.2	Dose rate response of linear microcircuits
1030.1	Preseal burn-in
1031	Thin film corrosion test
1032.1	Package induced soft error test procedure (due to alpha particles)
1033	Endurance life test
1034	Dye penetrant test

(Mechanical testing omitted)

MIL-STD-810E	
Method No.	**Title**
500.3	Low pressure (altitude)
501.3	High temperature
502.3	Low temperature
503.3	Temperature shock
505.3	Solar radiation (sunshine)
506.3	Rain
507.3	Humidity
508.4	Fungus
509.3	Salt fog
510.3	Sand and dust
511.3	Explosive atmosphere
512.3	Leakage (immersion)
513.4	Acceleration
514.4	Vibration
515.4	Acoustic noise
516.4	Shock
519.4	Gunfire
520.1	Temperature, humidity, vibration, altitude
521.1	Icing/freezing rain
523.1	Vibro-acoustic, temperature

MIL-STD-750C	
Method No.	**Title**
1001.1	Barometric pressure (reduced)
1021.1	Moisture resistance
1026.3	Steady-state operation life
1027.3	Steady-state operation life (LTPD)
1031.5	High-temperature life (non operating)
1032.2	High-temperature (non operating) life (LTPD)
1035.3	Intermittent operation life
1037.2	Intermittent operation life (LTPD)
1038.2	Burn-in (for diodes and rectifiers)
1039.4	Burn-in (for transistors)
1040	Burn-in [for thyristors (controlled rectifiers)]
1041.3	Salt atmosphere (corrosion)
1046.2	Salt spray (corrosion)
1051.5	Thermal shock (temperature cycling)
1056.7	Thermal shock (glass strain)
1061.1	Temperature measurement, case and stud
1066.1	Dew point
1071.5	Hermetic seal

(Mechanical testing omitted)

3. *Temperature testing*

3.1 Effects of temperature

As can be seen in the report from Hughes Aircraft Co. (USA), a strong relationship exists between temperature and failure.

The main types of temperature-induced failure are given in the following table.

Table 4 Main types of temperature-induced failure

Failure				Environmental conditions involved	Susceptible parts and materials
General type		Classification (cause)	Failure mode		
Temperature	High temperature degradation	Degradation	Strength degradation, Insulation degradation	Temperature + time	Plastic materials, resins
		Chemical change	Heat disintegration	Temperature	Plastic materials, resins
		Softening, Melting, Evaporating, Sublimation	Distortion	Temperature	Metals, plastic materials, thermal fuse
		High temperature oxidation	Formation of oxide film	Temperature + time	Contact point materials
		Thermal diffusion (formation of metal compounds)	Broken wire	Temperature + time	Metal plating involving different metals, and contact areas
	Secondary destruction	Semiconductor	Hot spot	Temperature, voltage, electric power	Non-uniformity, fin installation
	Heat accumulation combustion	(Remaining heat combustion)	Combustion	Heating + Drying + Time	Plastics (such as wood chips with vinylon or polyurethane paint)
	Whiskers	Intrinsic	Short circuit, insulation defect	High temperature (200 - 400°C)	Ag, Au, Cu, Fe, Mg, Ni, Pb, Pd, Pt, Ta, Ti, W, Al
		Non-intrinsic	Short circuit, insulation defect	High temperature (400 - 1000°C)	Halogen compounds of Cu, Ag, Fe, Ni, Co, Mn, Au, Pt, Pd
	Migration	Electromigration	Disconnection, broken wire	Temperature (0.5Tm) + Current (density $10^6 A/cm^2$)	E.g., W, Cu, Al (especially A1 wiring on IC)
	Creep	Metals	Fatigue, damage	Temperature + Stress + Time	Springs, structural parts
		Plastics	Fatigue, damage	Temperature + Stress + Time	Springs, structural parts
	Low temperature brittleness	Metals	Damage	Low temperature	Body-centered cubic crystalline (e.g., Cu, Mo, W) and close-packed cubic crystalline (e.g., Zn, Ti, Mg) and their alloys
		Plastics	Damage	Low temperature + Low humidity	Crystalline with high vitrification temperature Tg (e.g., cellulose, vinyl chloride), also non-crystalline with low elasticity (e.g., styrene, methyl methacrylate, ureaformaldehyde resin)
	Flux loose	Flux steam adheres to cold metal surface	Noise, imperfect contact	Low temperature	Especially parts attached to printed boards (e.g., switches, connectors)

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

3.2 Temperature-related accelerated testing

When discussing the life of manufactured goods generally, the expression "θ°C rule" can be used. This expression can be used as in the "10°C rule" to mean that a 10°C rise in the ambient temperature cuts life in half, a 20°C rise in ambient temperature cuts life in one quarter, etc. This rule indicates how strongly temperature influences life (failure).

To put it another way, it is possible to cause failure that cuts life in half by raising the ambient temperature. This is known as accelerated life testing.

The Arrhenius model is widely used for acceleration of temperature-related stress. In the Arrhenius model, life and the inverse number of absolute temperature are always shown as straight lines on the semilog graph.

For acceleration factor K,

$$K = \frac{L_1}{L_2} = \frac{\exp\left(\frac{Ea}{RTo}\right)}{\exp\left(\frac{Ea}{RTa}\right)} = \exp\left\{\frac{Ea}{R}\left(\frac{1}{To} - \frac{1}{Ta}\right)\right\}$$

A: Constant
Ea: Activation energy (eV)
R: Boltzmann's constant 8.6159×10^{-5} (eV/°K)
T: Absolute temperature (°K)
= 273.15 + Celsius temperature t°C
t: Celsius temperature (°C)
To: Criteria temperature (°K)
Ta: Test temperature (°K)
L1: Life (h) at test temperature *Ta* (°K)
L2: Life (h) at criteria temperature *To* (°K)
Given that *Ta* > *To*.

Ea is termed "activation energy" and varies according to the specimen provided. *Ea* also varies according to the failure mode even for the same specimen. The relationships between activation energy *Ea*, life *L*, and acceleration factor *K* are shown in Fig. 5 and 6.

The greater the activation energy, the greater the acceleration in temperature testing.

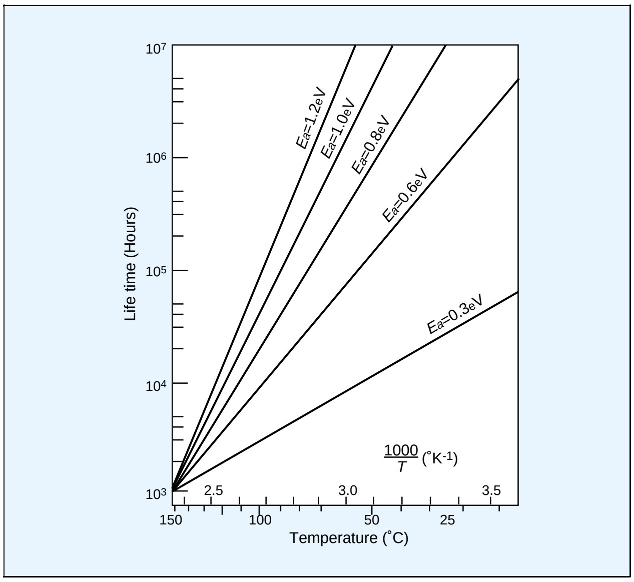


Fig. 5 Relationship between temperature and life
From the "Semiconductor Device Reliability Handbook" (1988) of Matsushita Electronics Corporation

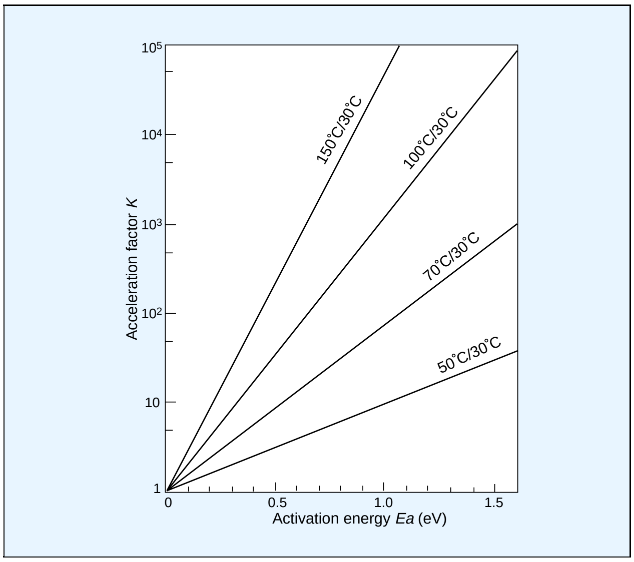


Fig. 6 Relationship between activation energy and acceleration factor
From the "Semiconductor Device Reliability Handbook" (1988) of Matsushita Electronics Corporation

Table 5 Semiconductor device failure mechanism and activation energy

Device name	Failure type	Failure mechanism	Activation energy (eV)
IC	Disconnection	Compound forms between the metals Au-Al	1.0
IC	Disconnection	Electromigration of Al	0.6
IC (plastic)	Disconnection	Al corrosion	0.56
MOS IC (memory)	Short circuit	Destruction of oxide film	0.3 - 0.35
Diode	Short circuit	Destruction of PN junction (solid phase reaction of Au-Si)	1.5
Transistor	Short circuit	Electromigration of Au	0.6
MOS device	Variation in threshold voltage	Polarization of phosphorescent glass	1.0
MOS device	Variation in threshold voltage	Na ion drift in Si oxide film	1.2 - 1.4
MOS device	Variation in threshold voltage	Slow trapping of Si-Si oxide film surface	1.0

From the "Mitsubishi Semiconductor Reliability Handbook" (1985) of Mitsubishi Electric Corporation

3.3 What is Screening?

In general, when the failure rate for parts and equipment is graphed, it describes a “bathtub curve” like the one seen in Fig. 7. The failure rate varies according to operating time.

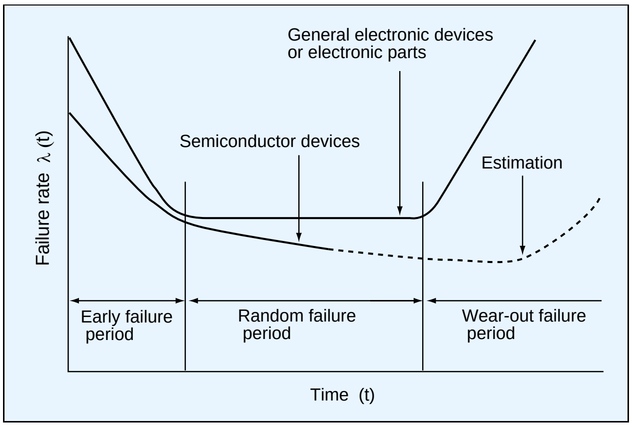


Fig. 7 Failure rate curves lines for typical electronic devices or parts and for semiconductor devices

The cause of failure for these items differs according to the period in which the failure occurs and can be roughly divided in the following way.

Table 6 Cause of failure by failure period

Failure period	Early failure period	Random failure period	Wear-out failure period
Most common causes of failure	• Defective design • Defective manufacturing • Defective material • Unsuitable for environment	• Defective pressure resistance • Extraneous surge • Misuse • Fluctuation in environmental conditions	• Corrosion • Oxidation • Fatigue • Performance degradation

A process called screening is performed to eliminate early period failures and to reduce the number of defects in marketed products. Screening is often used and involves testing under high temperature conditions and testing in heat cycles.

To determine the ideal method of screening, we must first analyze early period failures and establish what types of stress are most likely to induce such failure. Fig. 8 shows an example of the screening procedure.

Screening includes such processes as debugging and burn-in. These terms are defined in the following manner.

Screening

Non-destructive stress in principle is administered to probe basically all products and eliminate existing weakness.

Debugging

Part or equipment operation is carried out in the initial period either before starting to use the product or after starting to use the product. Debugging is a process of searching for weakness and correcting them.

Burn-in

To stabilize performance, equipment is operated for a period of time before use.

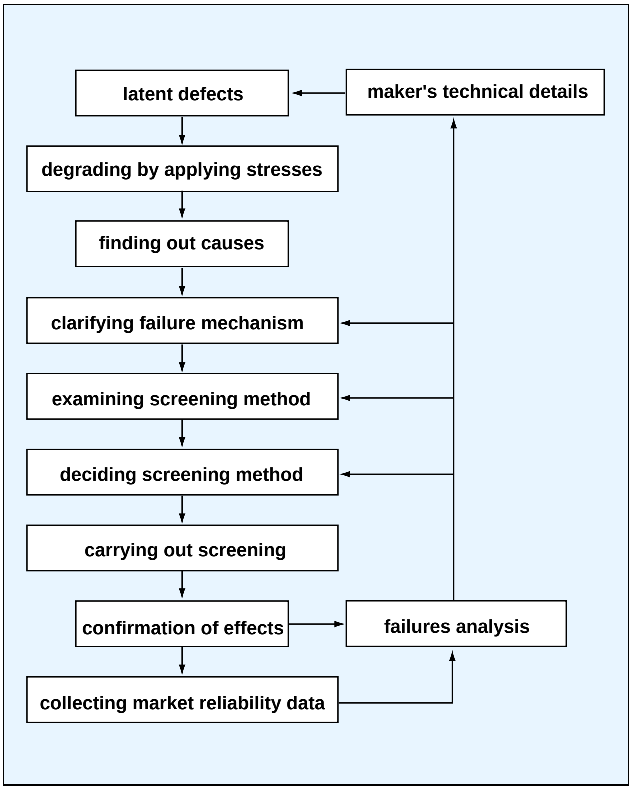


Fig. 8 Example of screening procedure

3.4 Precautions to be taken when performing temperature testing

When actually performing testing, consideration is required for some points. At this time we would like to define points on which precautions must be taken when performing temperature testing.

Table 7 Temperature testing precautions

(1) Precautions with measuring equipment

① Select test equipment, repair tools, and test chambers that can tolerate extended use with the least likelihood of failure. Ease of maintenance is another important consideration.

② Check for volatile materials such as oil and gas inside the chamber. Check for smells. The effect of such materials must be verified in advance.

③ For large specimen there may be a temperature and humidity difference between the upstream and downstream sides, so position specimen carefully.

(2) Precautions with specimen configuration

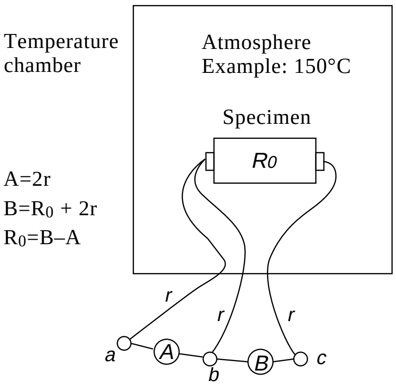
① Place specimen so that electrical inductance doesn’t occur between specimen and so that specimen don’t affect the heat of other specimen. Also, insure that specimen can easily be removed and replaced for measurement during testing.

② Prevent specimen heating or cooling caused by heat radiation or heat conductance from the temperature chamber.

③ Check temperature conditions inside the chamber with specimen present.

(3) Precautions when configuring test system

① Use a measuring system that is not affected by drift, by temperature characteristics of each part, or by resistance or temperature characteristics of the lead wire used for measuring.



Example of compensation for lead wire resistance

Note:

When measuring between b and c, lead wire value 2r is included in the measurement. Installing a dummy lead wire between the specimen and point b makes it possible to measure the resistance between a and b and subtract that from the amount measured between b and c, obtaining an accurate measurement.

② Measurement terminal contact resistance causes major data errors especially when measured resistance is low. In such cases, replace two-terminal (network) with four-terminal (network) for measuring.

(4) Precautions during and after testing

① Install automatic counters and automatic shutdown equipment for cycle testing to prevent forgetting.

② Maintain uniform temperature inside the temperature chamber, with minimal influence from room temperature and electrical fluctuation. Ensure that neither heat radiation nor heat absorption by the specimen changes the temperature inside the chamber.

③ Confirm that the temperature is uniform in every area inside the temperature chamber. Also, minimize positioning differences inside the chamber.

④ Removing specimens immediately after testing inside the temperature chamber (environmental testing chamber) is completed causes stress to the specimen and can provoke unexpected results, so remove specimen only after specimen have cooled to ambient temperatures.

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

3.5 Temperature testing equipment

Photo 1 Temperature chamber

TABAI ESPEC's Temperature Chambers (Industrial Ovens) has found applications in a variety of industries all over the world. They are used for high-temperature testing as well as heat treatment and drying during manufacturing. Now a new range of TABAI ESPEC chambers incorporating newly developed instrumentation is making its debut in the temperature chamber series.

Specifications for representative products

Model	Temperature range	Inside dimensions W × H × D mm (in)
PH-201	+20°C (+36°F) above room temp. to +200°C (+392°F)	600 × 600 × 600 (23.6 × 23.6 × 23.6)

Photo 2 Ultra low temperature chamber

Despite its compact size, however, this Compact Ultra Low Temperature Chamber is equipped with superlative functions. There are T-instrumentation for fixed value operation, and P-instrumentation for programmed operation covering 10 patterns, 99 steps per pattern. Our innovative refrigeration system is automatically activated and deactivated according to the set temperature. In addition, a digital temperature indicator-controller is employed, and the PID control system ensures accurate temperature control. Also, the chamber corresponds to the environmental test chamber network, E-BUS.

The chambers come in for types, depending on the desired instrumentation and temperature range. You can choose the most suitable models from the lineup according to your applications and test purposes.

Specifications for representative products

Model	Temperature range	Inside dimensions W × H × D mm (in)
MC-710	−75 to +100°C (−103 to +212°F)	400 × 400 × 400 (15.7 × 15.7 × 15.7)
MC-810	−85 to +180°C (−121 to +356°F)	

Coffee Break

Q. The terms "temperature fluctuation" and "temperature variation" are used to describe performance in environmental testing equipment. What do these terms mean?

A. Internationally standardized standards don't exist, and the terms themselves may differ for each standard. Also, currently, different measurement methods are employed, but here we shall cite the BS standards (British Standard) for definition of terms, and the ASTM standard (American Society for Testing and Materials) for summary of measurement method.

■ **Temperature fluctuation**
(called "temperature constancy" at Tabai Espec)

The difference between the maximum and minimum temperatures at any one point in the working space during a specified time interval. (From BS 4864)

■ **Temperature variation**
(called "temperature differential" in ASTM D 2436, and "temperature uniformity" at Tabai Espec)

The difference at any moment between the temperature at the centre of the working space and at any other point in the working space. (From BS 4864)

*ASTM (American Society for Testing and Materials) D 2436 (Forced-Convection Laboratory Ovens for Electrical Insulation)

■ **Measurement method**

① Data collection
Install temperature sensors for measurement at nine points inside the oven: 50 mm (2 in) from each of the 8 corners of the oven and in the geometric center of the oven.
Record totally 45 measurements for data: five measurements for each temperature sensor at five minute intervals.

② Method of deriving "Temperature fluctuation"
Record the difference between the maximum and minimum temperatures of the five successive readings for each of the nine thermocouples. From these nine differences, select the two greatest and average these. Record this average as the temperature fluctuation.

③ Method of deriving "Temperature differential"
Select the highest of the 45 readings, and from each of these subtract the average of the 45. Select also the two lowest and subtract each from the average. Then select the two largest differences and average them. Record this average as the temperature differential.

*In Japan, published by the Testing Machinery Association of Japan:
JTM K 01 "Standard for performance of humidity chambers",
JTM K 03 "Standard for performance of environmental temperature and humidity room", and
JTM K 05 "Standard for performance of high temperature chamber".

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"Method of Environmental Testing & Equipment" (1984)

6) MIL-STD-810E (1989)

7) BS 4864 (1973)

8) ASTM D 2436 (1985)

Report 1

Evaluation Method for Ion Migration Using Dew Cycle Test (Part 1)

Yuuichi Aoki[*1]/Hirokazu Tanaka[*1]/Shigeharu Yamamoto[*1]/Osamu Obata[*2]

Ion migration has customarily been evaluated through high-temperature, high-humidity testing. However, due to ever-widening application of electronic equipment resulting in use under a variety of conditions, the need for evaluation based on dew condensation has greatly increased.

In view of this, we have developed a dew cycle test chamber. This equipment can reproduce a uniform level of dew condensation, making it possible to quickly evaluate ion migration caused by dew condensation, a feat that has until now not been possible. In this paper, we shall present a technical examination of the dew cycle test chamber and actual examples of the evaluation process. We shall also report our findings on the effectiveness of the test chamber.

The material in this paper was presented at the 24th Symposium on Reliability and Maintainability sponsored by the Union of Japanese Scientists and Engineers, and was awarded the R&MS Award for Recommended Best Paper. This report contains some revisions to that paper.

1. Introduction

In recent years, miniaturization of electronic equipment and high density mounting of parts has resulted in minute spacing between semiconductors. At the same time, freon regulations have resulted in parts not being rinsed with freon, causing flux residue to remain. These factors are behind the scourge of ion migration (hereafter called migration) causing shorts between conductors and resulting in equipment failure.

In particular, changes in operating environment for portable equipment and mobile on-board machinery often cause dew condensation, resulting in migration. Test methods and test equipment to evaluate migration caused by dew condensation have been under study, but as yet have left a lot to be desired. In an attempt to fill this breach, we have developed a prototype dew cycle test chamber for evaluating migration caused by dew condensation. We shall report on our evaluation of the technology and the testing methods.

2. Migration

Migration occurs when moisture adheres between electrodes made of materials such as copper, solder, or silver. As voltage is applied, the electrons carrying the Coulomb charge created by the ionization of the positive electrode flow toward the negative electrode. The charged electrons is reduced at the negative electrode and extends back toward the positive electrode. Photo 1 shows migration of copper and of solder.

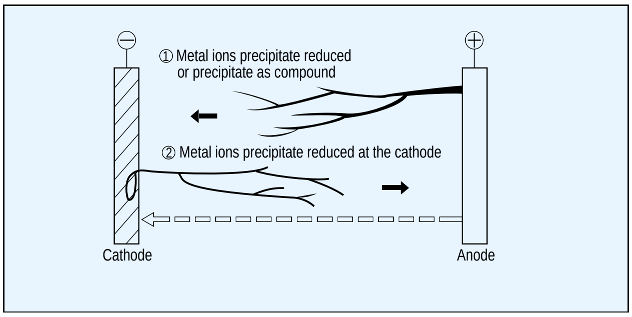
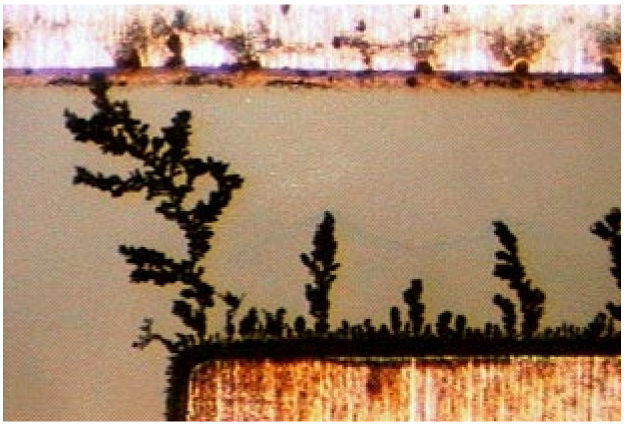


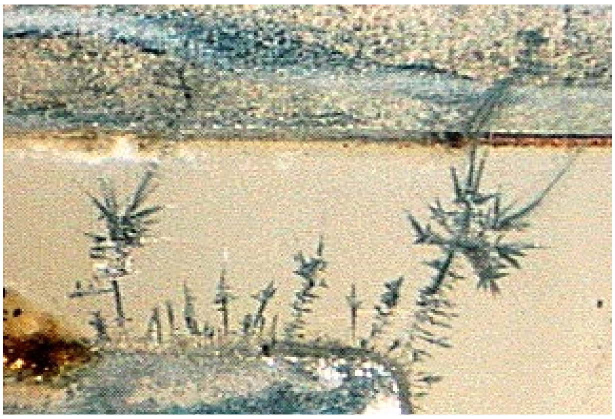
Fig. 1 Pattern of ion migration

From the "Insulation Reliability of Printed Circuit Boards: the Insulation Reliability Research Group Technology Report" (1994) Japan Institute for Interconnecting and Packaging Electronic Circuits

*1 Environmental Test Technology Center
*2 Product Design Department



a. Copper migration



b. Solder migration

Photo 1 Examples of migration

3. Conditions Required for Dew Cycle Test

Little progress been made in quantitatively determining the condition of dew condensation, and the mechanism producing it. Because of this, it is vital that the conditions for dew condensing test be both reproducible and in uniform quantities.

- The major conditions for dew condensing test are: reproducibility and quantitative uniformity.

1) Reproducibility: Must be able to constantly reproduce the same conditions inside the test chamber.
2) Quantitative uniformity: Must be able to quantitatively determine conditions of dew condensation (moisture quantity and duration).

Functions required by the dew cycle test chamber are noted in Table 1.

Table 1 Functions required by the dew cycle test chamber

1	**Temperature, humidity**	Allows accurate control (stability, uniformity, and control accuracy)
2	**Dew condensation**	Able to form and dry uniform dew condensing quantity on specimen surface for uniform duration
3	**Wind speed**	Allows suitable control of wind speed that can be considered to exert an influence on condensation adhering to the specimen
4	**Instrumentation**	Able to measure temperature of dew condensation on specimen and to connect a cable to apply voltage to specimen, and measure electrical characteristics
5	**External influence**	Avoids excess stress to specimen from shock or vibration causing dripping or disturbance to dew condensation

4. Dew Condensation Process

Migration in the dew cycle test can be assumed to be related to the quantity and duration of dew condensation. Fig. 2 shows the relationship of quantity and duration of dew condensation to specimen temperature when ambient temperature and humidity are abruptly raised.

4-1 The Process of Dew Condensing and Evaporating

a. Dew Condensing

When the temperature of the specimen is lower than ambient temperature, the surface of the specimen cools moisture from the air, forming dew condensation.

b. Dew Evaporating

After the temperature of the specimen has reached equilibrium with the ambient temperature, dew condensation will begin to evaporate unless the ambient temperature is at 100%RH.

c. Heating

After the dew condensation has evaporated, the temperature of the specimen reaches equilibrium with ambient temperature.

4-2 Evaluating the Dew Condensation Process

a. Changes in Specimen Temperature

Theoretically, the temperature of the specimen rises in steps in the above process, but in reality the change is more gradual as represented by the dotted line in the middle graph in Fig. 2. This gradual change is due to such factors as the conductivity and heat capacity of the specimen as well as response to heat transfer with the atmosphere.

b. Effect of Wind Speed

A high ambient wind speed during the process of dew condensation causes greater heat transfer between vapor and the specimen, so one might suspect that dew condensation would form more rapidly. However, such a sweeping statement is not possible, due to influences such as heat transfer, thermal capacity of the specimen, and heat transfer due to sensible heat and hydrophilic property. In addition, in the process of evaporating, a large amount of heat is transferred between atmosphere and dew condensation, speeding up evaporation time and shortening the duration time of dew condensation. Since other factors exert influence on conditions for forming dew condensation (such as layer condensation and drip condensation), great care must be taken regarding test chamber wind speed.

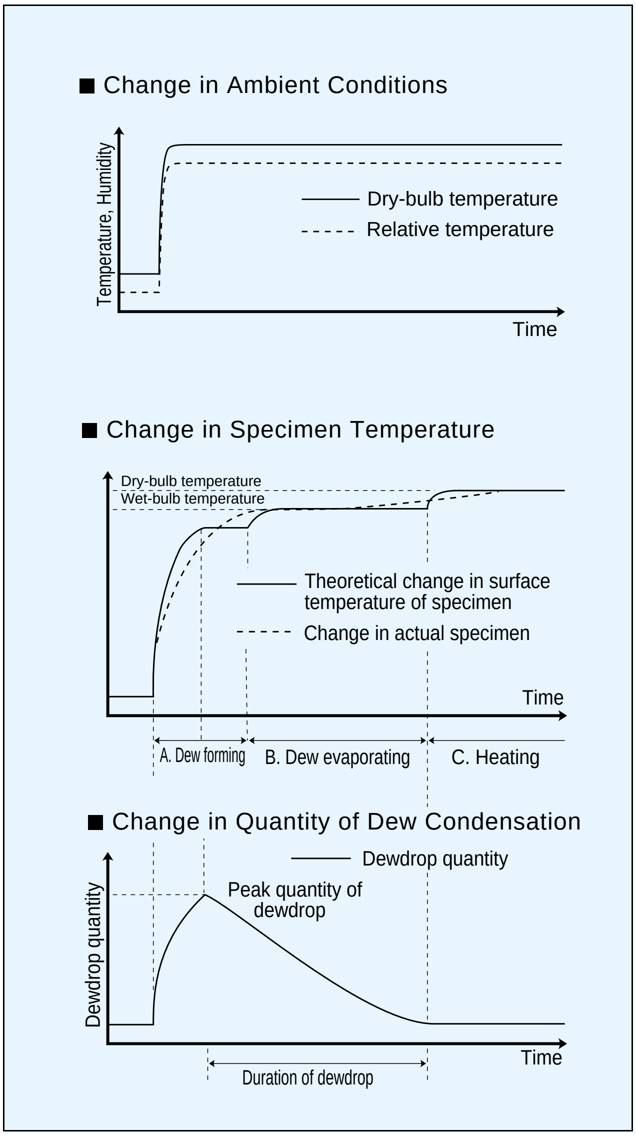
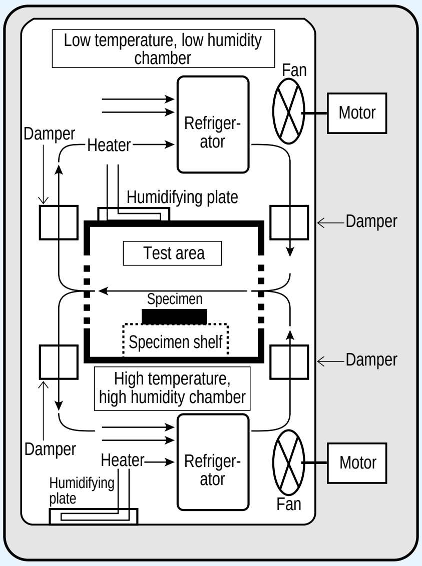


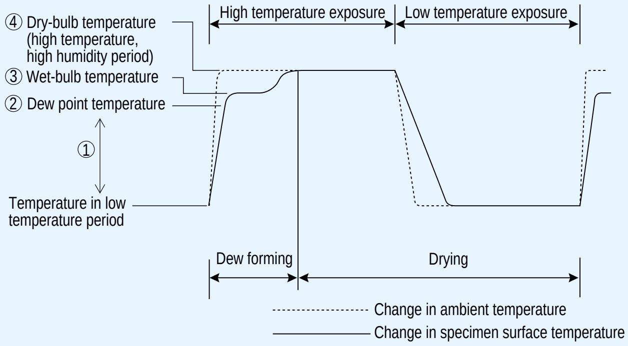
Fig. 2 Relationship between quantity and duration of dew condensation

5. Dew Cycle Test Chamber

Various means can be devised to reproduce dew condensation in the dew cycle test chamber. The method we have used in this design shown in Fig. 3 utilizes a damper changeover to switch the air in the test area between the low- temperature,low-humidity chamber and the high-temperature, high-humidity chamber.



■ "Dew Condensing" and "Drying" Processes



① When temperature and humidity are abruptly raised inside the test chamber, the thermal capacity of the specimen is greater than air so the temperature of the specimen rises more slowly than ambient temperature. The difference in temperature during this time lag causes dew condensation to form.

② Dew drop begins to evaporate when temperature reaches dew point.

③ Equilibrium is reached at wet-bulb temperature.

④ When dry-bulb temperature is reached (the high-temperature, high-humidity temperature), all dew condensation evaporates from the surface of the specimen, which dries completely. Repeatedly alternating between the low temperature conditions and the high-temperature, high-humidity conditions reproduces the conditions causing dew condensing and drying.

Fig. 3 Design of the dew cycle test chamber

Photo 2 Dew cycle test chamber produced at Tabai Espac

6. *Examples of Testing*

These dew cycle tests were made to determine the number of cycles required before migration occurred under the following conditions. In our opinion, the settings of dew cycle test chamber reflect actual environmental conditions and are more suitable than hasher condition such as 85°C at 85%RH.

Because of this, we selected test conditions from within the range of temperature and humidity in which general electrical and electronic appliances (excluding special production equipment) are operated. Preliminary testing indicated that 5 minutes was sufficient to allow dew condensation to form on and evaporate from the substrate board. We have added 10 additional minutes for a total of 15 minutes. On the specimen, we used a tandem compound electrode pattern corresponding to JIS type 2, as seen in Fig. 4.

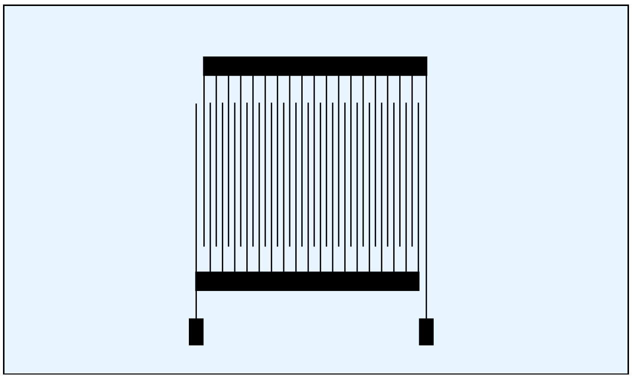


Fig. 4 Tandem compound electrode pattern corresponding to JIS type 2

6-1 Test Conditions

Table 2 presents test conditions.

Table 2 Test Conditions

Temperature, Humidity	5±2°C 60±5%RH (25 minutes) ←→25±2°C 90±5%RH (15 minutes)	
Specimen	Material	Glass epoxy substrate board
	Pattern	Tandem compound electrode pattern corresponding to JIS type 2
	Sample number	n=9
	Substrate board dimensions	50 mm x 120 mm
	Voltage applied	DC 5V

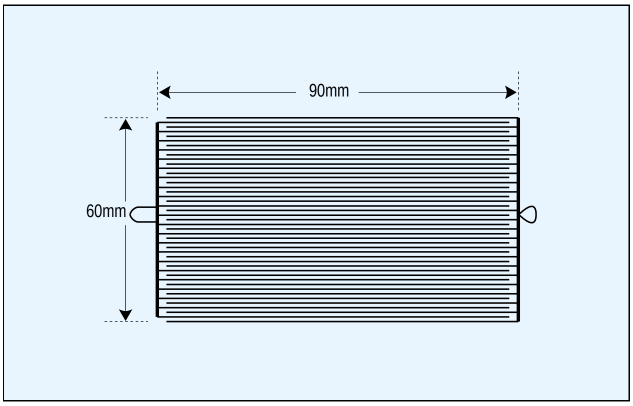


Fig. 5 Gold-plated tandem compound substrate board

6-2 Confirming Dew Condensation

We set electrical current leakage measured between electrodes on the tandem compound substrate board as an indicator of dew condensation levels. As shown in Fig. 5, we used a gold-plated tandem compound substrate board (developed by this company) to measure the electrical current leakage.

6-3 Measuring Migration

To measure migration, we moved the specimen during the test and checked for migration using a stereoscopic microscope.

6-4 Test Results

Fig. 6 gives a Weibull probability plot showing the observation cycle and the rate of migration occurrence. Photo 3 (on next page) shows migration.

A Weibull analysis of the results yielded a form modulus of m = approximately 1.8, and an average wear-out failure life of 15 cycles (L50). No dispersion occurred in separate areas of the pattern.

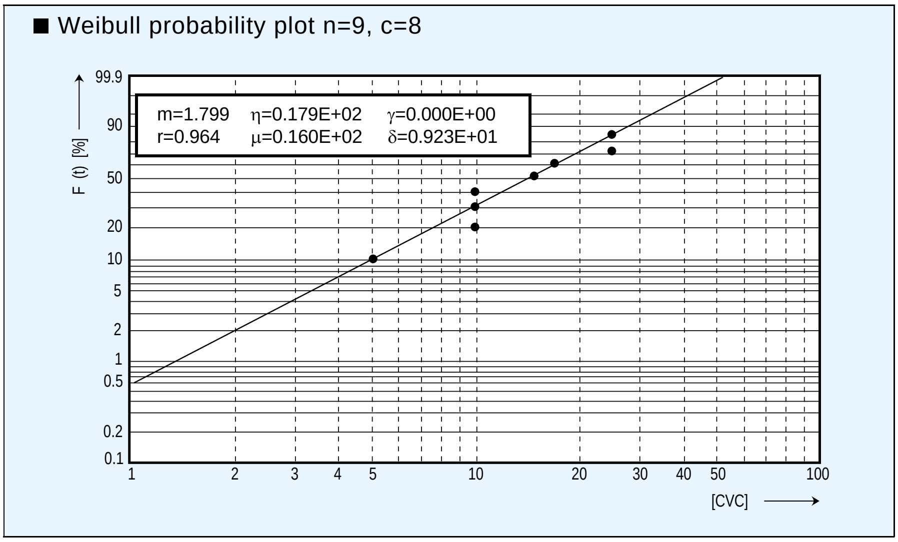


Fig. 6 Weibull probability plot data on migration in the dew cycle test

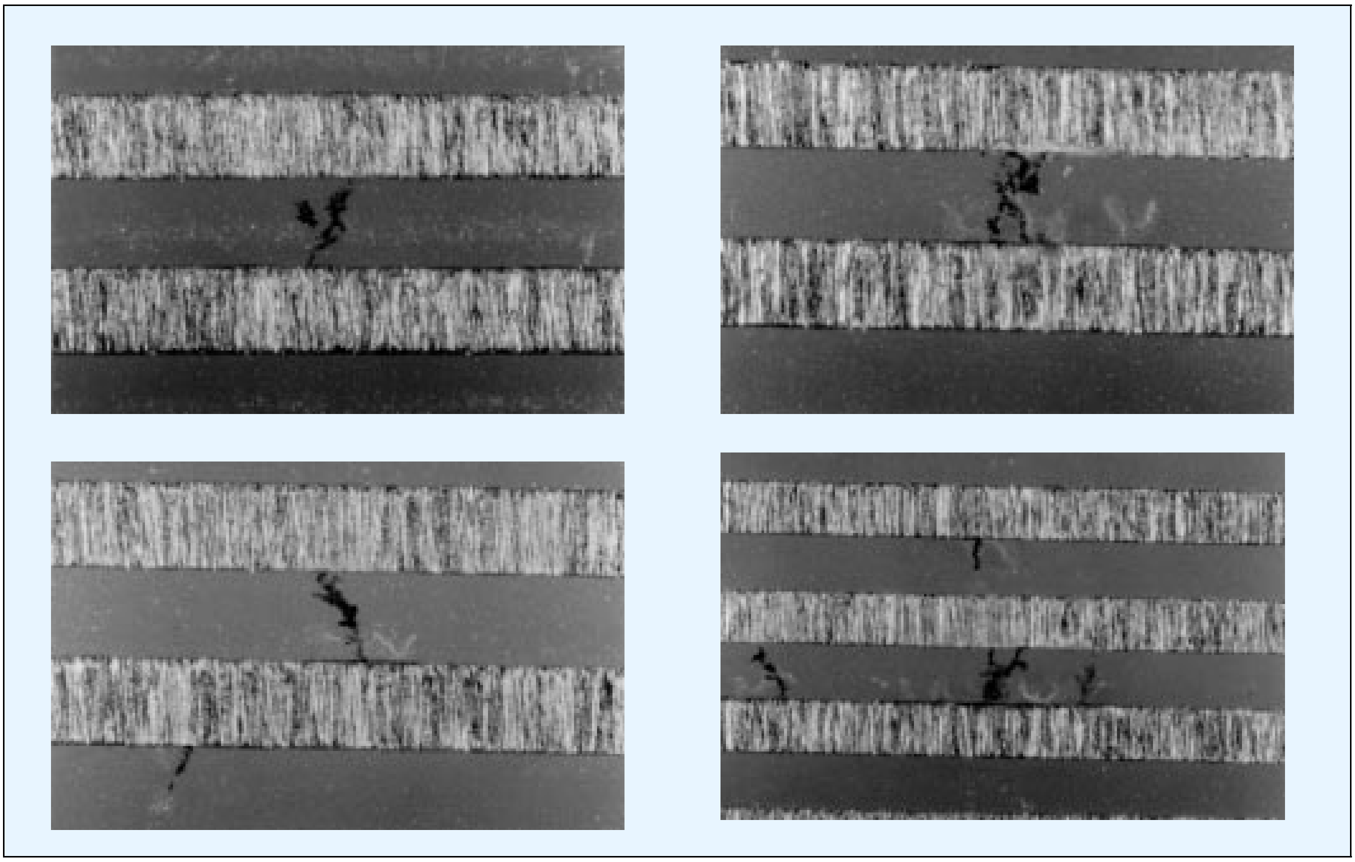


Photo 3 Migration occurrences in the dew cycle test

7. A Critique of the Dew Cycle Test

7-1 Quantity and Duration of Dew Condensation

The following tendencies were seen in quantity and duration of dew condensation in test results measuring electrical current leakage from the electrodes for measuring dew condensation. Duration of dew condensation was fairly uniform for each test cycle, but current leakage varied depending on the conductor spacing and on difference in thermal capacity due to the size of the specimen. This indicates that specimen conditions greatly influence the quantity of dew condensation. Even when test temperature and humidity conditions are uniform, different results can be anticipated according to the dimensions of the specimen.

7-2 Substrate Board Surface Elements and Wettability

Current leakage showed a gradual decline during continuous dew cycle tests. Interrupting the tests and removing the specimen in the middle of the series caused somewhat of an increase in current leakage. These changes might be due to the wettability of the surface of the substrate board with water. We can also report that migration is not as likely to occur when using organic acid flux in the dew cycle test. We surmise that this effect is due to the loss of bonding strength between water molecules and the surface elements of the substrate board when organic material exists between water and the surface of the substrate board, causing lower wettability.

Moisture absorption characteristics of the substrate board are shown in Fig. 7. Changes in current leakage are thought to be related to moisture absorption of the substrate board, but that does not seem to contribute very much to leakage. Leakage seems to be caused mainly by the wettability of the substrate board.

Cycle	Absorption Coefficient (%)
0	0.000
2	0.018
6	0.021
11	0.025
44	0.032

• Absorption coefficient =

$$\frac{\text{weight after absorption} - \text{weight before absorption}}{\text{weight before absorption}}$$

Fig. 7 Absorption coefficient of the glass epoxy substrate board in the dew cycle test

7-3 Critique of the Method of Measuring Migration

In evaluation testing, measuring was rated in general as inadequate to measure insulation resistance for conductor spacing using tandem compound electrodes for high-temperature, high-humidity testing. However, a different method of measuring can be applied in the dew cycle tests. Continuous measuring of insulation resistance is possible with a high resistance test chamber applicable even to dew cycle tests. Because of severe leakage when dew condensation is on the substrate board, measuring is limited to periods when dew condensation has evaporated. A crucial means of evaluation in the dew cycle test is to observe the growth of migration, especially up to the point that insulation resistance deteriorates. To make this observation, this specimen must be removed during the test.

8. Summary

The following observations were gleaned from this test.

(1) In technically examining the dew cycle test chamber to check migration caused by dew condensation, we found vital factors necessary for obtaining reproducibility.

(2) A tendency was noted for interdependency between quantity of dew condensation and current leakage from the tandem compound electrodes. This interdependency made possible a method of monitoring the dew cycle test.

(3) Using the dew cycle test makes it possible to cause migration to occur within a short time frame.

However, the effects dew condensation has on various conditions in the dew cycle test chamber are not fully understood, so technical matters are still under study and need to be clarified. In addition, further development of the sensor measuring the quantity of dew condensation by measuring current leakage is required to resolve instability in such areas as sensitivity, reproducibility, and sensor accuracy.

9. Acknowledgments

We would like to take this opportunity to express our gratitude for the great variety of advice we have received from everyone in the Quality Assurance Group, Quality Management Department at Matsushita Communication Industrial Co., Ltd. as well as everyone in the Electron Devices Division Device Functions Section, Electro Technical Laboratory, Agency of Industrial Science and Technology, Ministry of International Trade and Industry.

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Evaluation Method for Ion Migration Using Dew Cycle Test (Part 2)

Yuuichi Aoki[*1]/Hirokazu Tanaka[*1]/Shigeharu Yamamoto[*1]/Osamu Obata[*2]/Yoshiki Saito[*2]

Dew condensation has become a nemesis of the electronics field. It causes a number of problems, from ion migration to malfunction and breakdown of electronic equipment. Because of this, evaluation through dew cycle test has become indispensable for parts and products.

In the Part 1, we reported on stability and reproducibility in dew condensing test with the dew cycle test chamber. In this report (Part 2), we shall discuss how the test chamber has made possible abruptly raising the temperature from a normal temperature range (hereafter called low temperature) to a higher range of temperature and humidity (hereafter called high temperature). The test chamber has also made possible greater fidelity in reproducing the market environment in tests.

In addition, we have confirmed the relationship between the speed at which ion migration forms and the quantity of dew condensation forming in the test chamber when temperature and humidity conditions are changed.

1. Introduction

Currently no standardized testing method exists for dew cycle test. Different companies use a variety of testing methods. The lone exception to this lack of standardization are the JASO vehicle standards, which establish that the temperature and humidity conditions in which a vehicle is operated be considered in dew condensing test. Temperature and humidity conditions need to be set in accordance with the temperature and humidity encountered in each specific field for the specimen being evaluated.

Measurement can be made using one of two methods. In one, current is passed through the specimen, then the electricity is shut off and the specimen checked for evidence of ion migration. In the other, an external signal terminal is used to send current to operate the specimen while continuously monitoring and recording consumption of electricity. Continuous measurement during the test period is required because intermittent defective operation caused by dew condensation cannot be confirmed by a measurement that requires interrupting the test.

Dew cycle test can be carried out under a wide range of temperature and humidity conditions, depending on the type of equipment and the variety of environmental conditions in which the equipment is being used. Because of this, we shall report on testing performed to determine dew condensing quantity under a variety of temperature and humidity conditions.

Photo 1 Dew cycle test chamber

*1 Environmental Test Technology Center
*2 Product Design Department

2. *Determining Dew Condensing Quantity Through Differences in Temperature and Humidity Conditions*

The transition over time of the quantity of dew condensation forming, as we announced in the report part 1, can be postulated as in Fig. 1. We defined total dew condensing quantity as the integral value of the dew condensing time and quantity forming at rate time, then we measured quantity and duration of dew condensation. The equipment used in testing is as follows.

Test equipment:

Dew cycle test chamber DCTH-70, made by Tabai Espec

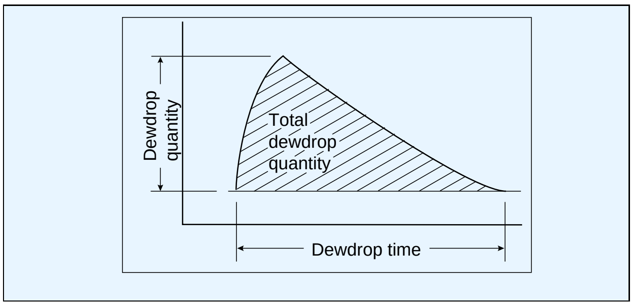

Fig. 1 Change in dew condensing quantity

2-1 Measuring Dew Condensing Quantity

2-1-1 Method of Evaluating Dew Condensing Quantity

We measured dew condensing quantity relatively from current leakage during dew formation. We used teflon to prevent the substrate board from absorbing humidity and plated the electrodes with gold to make it as difficult as possible for migration to form.

Then we applied alternating current. The resulting waveform of current leakage is not stable, but the peak value of current leakage showed the conditions to be reproducible. Taking this peak value as a representative characteristic of dew condensing quantity, we investigated the relationship between the peak value and each of the conditions, which we shall define. The method of measuring and the specifications of the substrate board are given in Table 1.

Table 1 Specimen specifications, prior processing, and method of measuring current leakage

Substrate board specifications	Board material: teflon. Tandem compound gold-plated electrodes corresponding to JIS type 2
Prior processing	First clean in alcohol (IPA) with ultrasonic wave, then hand wash in alcohol.
Measurement method	Apply 5V AC and measure the average peak value of current leakage.

2-1-2 Analysis of the Effect of the Temperature Difference (ΔT)

Because we felt that the quantity of dew condensation would change in relation to the temperature difference (ΔT), we examined the dew condensing quantity from the perspective of the temperature difference. We set the low temperature at a uniform +5°C and progressively changed the high temperature settings for humidity and temperature. Results are shown in Fig. 2.

The results show a temporary relationship between the temperature difference and the peak current leakage.

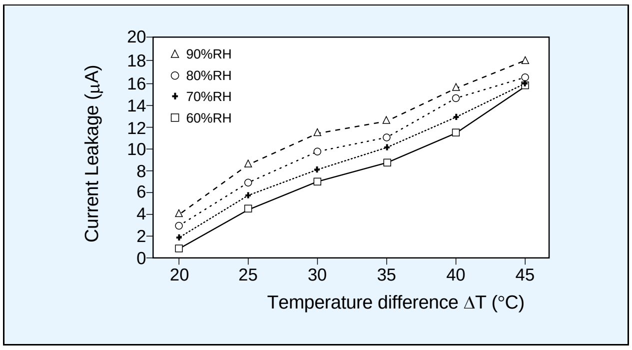

Fig. 2 Temperature difference (Δ) vs current leakage characteristics

2-1-3 Analysis of the Effect of the Difference in Temperature Settings

With the temperature difference (ΔT) between low temperature and high temperature set to a uniform 20°C, we looked for changes in dew condensing quantity when the temperature settings were changed. In addition, we set the high temperature relative humidity to a uniform 90%RH. Fig. 3 shows the results. The quantity of dew condensation varies in response to the temperature setting range. We were able to confirm that the higher the temperature range, the greater the quantity of dew condensation. This can be postulated as due to the higher the temperature range, the greater the saturation quantity of steam in the air, even when the temperature difference remains the same. (Refer to Fig. 2 and 3.)

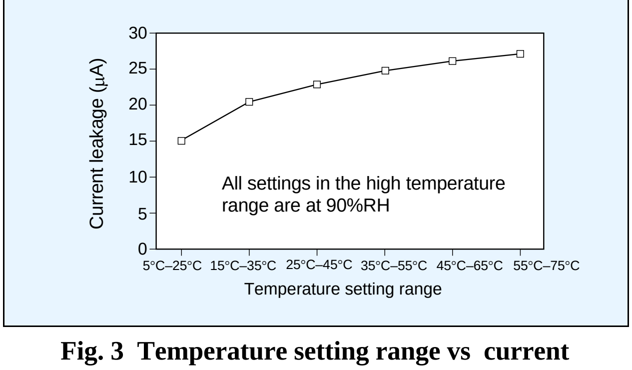

Fig. 3 Temperature setting range vs current leakage characteristics

2-2 Measuring Dew Condensing Time

Fig. 4 shows changes in specimen temperature occurring in the dew cycle test. The range ($t_0 \rightarrow t_1$) of temperature equilibrium at which dew condensation forms on the specimen shows wet-bulb temperature. In the next range ($t_1 \rightarrow t_2$), that of transit ion from wet-bulb temperature to dry-bulb temperature, the surface of the specimen can be assumed to be drying regionally. Because of this, we measured the time ($t_0 \rightarrow t_1$) charted for wet-bulb temperature of the specimen and used it to represent dew condensing time. Because this time varies according to the thermal capacity of the specimen, we used a 10 mm diameter steel ball as the standard specimen for this series of tests. The ball has dew condensation for at least half the high temperature exposure and dries within the time period.

Dew condensing time can be postulated as $t_0 \rightarrow t_2$, but since the condition is uncertain in $t_1 \rightarrow t_2$, we measured $t_0 \rightarrow t_1$ during which time the dew formation on the specimen can be assumed to be uniform.

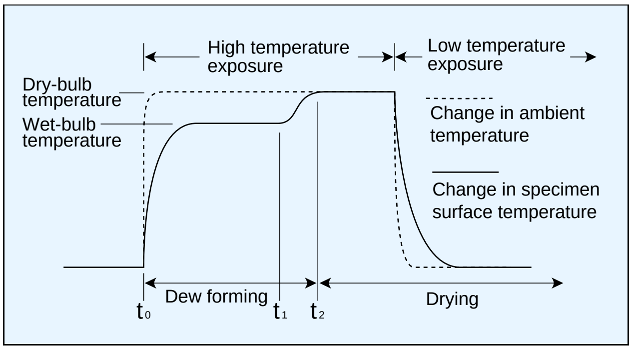

Fig. 4 Specimen temperature change in the dew cycle test

2-2-1 Method of Measuring

First, we measured the surface temperature of the steel ball. Next, through reciprocal comparison between the steel ball surface temperature and the time charted for the wet-bulb temperature in the chamber, we examined the changes in dew condensing time caused by humidity, temperature, and wind speed.

Table 2 shows test conditions. We set the temperature difference (ΔT) to a uniform 20°C for the temperature and humidity conditions, which we changed by 10°C at a time.

Table 2 Temperature and humidity conditions and wind speed for measuring dew condensing time (○ : indicates condition enforced)

Temperature and humidity conditions	Wind speed		
	MIN. (0.9m/s)	MID. (1.4m/s)	MAX. (1.9m/s)
5°C 90%RH↔25°C 90%RH (20 minutes each)	○	○	○
15°C 90%RH↔35°C 90%RH (20 minutes each)	○	○	○
25°C 90%RH↔45°C 90%RH (20 minutes each)	○	○	○

2-2-2 Test Results

Fig. 5 shows test results. When a uniform temperature difference was maintained, the higher the temperature setting, the shorter the dew condensing time. In addition, the higher the wind speed, the shorter the dew condensing time. Both these results and the dew condensing quantity results in item 2-1-3 show that the dew condensing quantity increases at the high temperature conditions, and drying can also be assumed to be faster. We can also assume that the higher the wind speed, the faster the drying time.

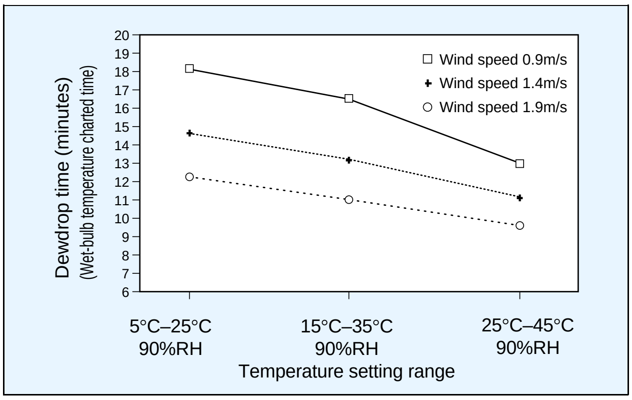

Fig. 5 Steel ball dew condensing time characteristics

3. The Relationship Between Temperature/Humidity Conditions and Migration

3-1 Test Method

The main conditions influencing the speed at which migration occurs are temperature, humidity, and electrical field. We can also report that for dew condensation, ion shift time varies according to the way drops of water adhere. However, the relationship between migration and temperature and humidity conditions in the dew cycle test is not well understood, so we examined migration occurring in response to each of the temperature and humidity conditions.

Table 3 shows test conditions.

3-2 Test Results

Fig. 6 shows test results. Photo 2 shows the migration that formed. The higher the range of the temperature setting, the more quickly migration formed and the less time elapsed before failure. The results, as seen in Fig. 7, indicate that the speed at which migration forms is more strongly related to dew condensing quantity than to dew condensing time.

Table 3 Dew cycle test conditions for confirming migration

Temperature and humidity conditions	(1) 5°C↔25°C 90%RH (20 minutes each) (2) 15°C↔35°C 90%RH (20 minutes each) (3) 25°C↔45°C 90%RH (20 minutes each)	
Test cycles	80 cycles	
Specimen	Material	Glass epoxy substrate board
	Pattern	Tandem compound electrodes corresponding to JIS type 2 (spacing 0.318 mm)
	Sample number	n = 15
	Substrate board dimensions	50 mm x 120 mm
Prior processing	No coatings such as flux or resist Ultrasonic cleaning in alcohol (IPA)	
Bias	DC 5V applied	
Measuring method	External observation by intermittent removal each 10 cycles	
Judgment method	Even one occurrence of migration in pattern results in failure	

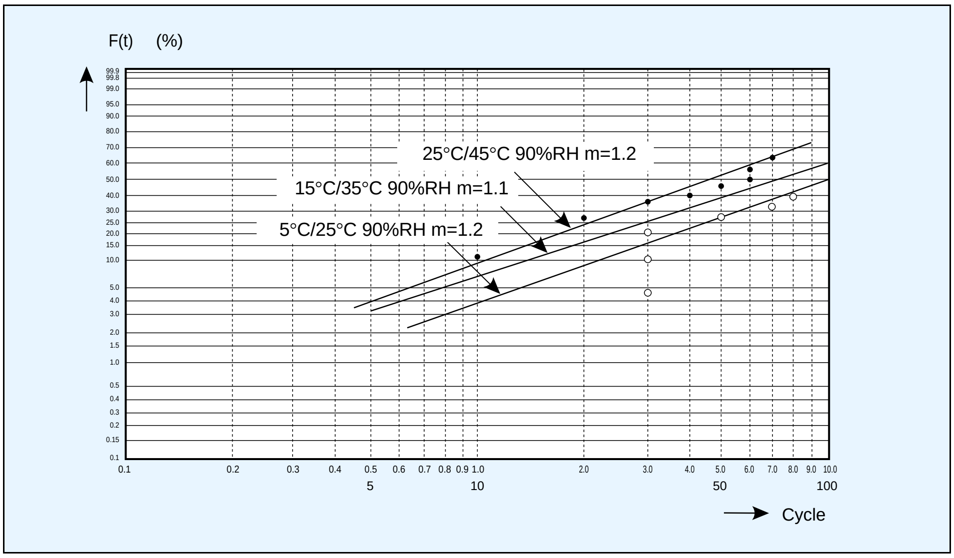

Fig. 6 Weibull probability plot data on dew cycle test results for migration

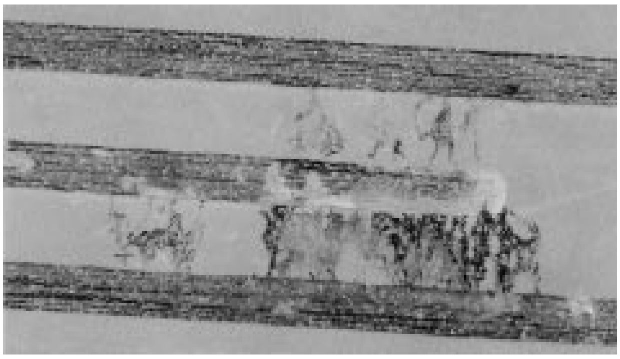

Photo 2 Migration formed in the dew cycle test

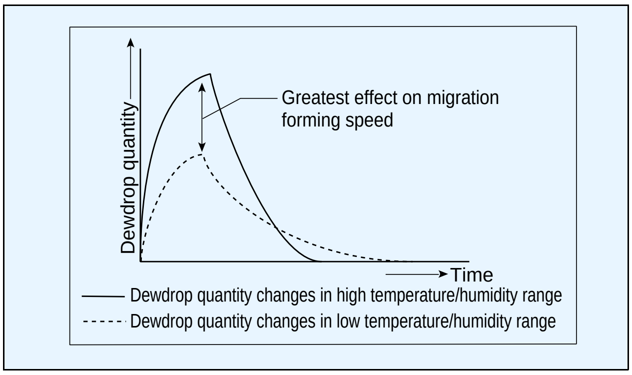

Fig. 7 The relationship between dew condensing time and quantity

3-3 Examining migration caused by dew condensation

At temperature and humidity conditions with a uniform temperature difference, the profile parameters all resulted in similar values (m = 1.2) regardless of conditions set. Failure caused by ion migration can be postulated to be the same at the various temperature and humidity conditions at which these tests were performed. The average life was approximately proporational to the temperature range set. We surmise that this is due to the strong influence of the different saturation level of steam in each temperature range.

In this type of dew cycle test with changes in conditions set, the difference in dew condensing quantity due to the different saturation level of steam for each temperature can be postulated to increase the speed at which migration forms. However, when evaluating marketplace products, we must keep in mind that materials come in a variety of shapes for both high temperature and low temperature use, making the causes more complex. Therefore, we must consider more than the dew condensation. We need to create tests that account for changes in materials. Accordingly, we must take great care to examine and select the characteristics of the test specimen.

4. Summary

These tests revealed the following points.

1. The greater the temperature difference (ΔT) in the dew cycle test, the greater the quantity of dew condensation.
2. When the temperature difference (ΔT) is uniform in the dew cycle test, higher temperature also produced more dew condensation, but duration is shorter.
3. The greater the wind speed, the shorter the dew condensing time.
4. Migration forming speed is strongly related to the peak time of dew condensing quantity and is influenced by the saturation steam quantity of the setting temperature.

The next tests that need to be carried out are an examination of the relationship between cycle acceleration characteristics and failure reproducibility in market products.

In addition, recently cases involving the use of specialized insulation resistance measurement systems have been increasing. This type of measurement method makes it possible to continuously monitor changes in insulation resistance. This seems as if it would be an effective method for collecting data for the dew cycle test.

5. Acknowledgments

We would like to take this opportunity to express our gratitude for the advice in putting together this report that we received from everyone in the Quality Assurance Group, Quality Management Department at Matsushita Communication Industrial Co., Ltd.

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Topics

Introducing the Artificial Climatic-simulator

During the evolution of the human race, humans have been intimately linked to weather conditions. Today we must adapt to an even wider range of environmental conditions such as high altitudes, the ocean floor, and even outer space. The Artificial Climatic-simulator is able not only to investigate the effects of these environmental conditions on humans, but on equipment and materials as well.

At this point we would like to provide one example by introducing the Artificial Climatic-simulator that we provided to a Japanese construction company.

This Artificial Climatic-simulator can artificially reproduce not only temperature and humidity conditions, but also rain, snow, fog and sunlight. Our customer is using the simulator for research on how the natural environment affects construction materials and equipment and how it affects the performance of all types of system.

The simulator reproduces the effects of the natural environment on every area of construction materials.

The Artificial Climatic-simulator is a large installation, measuring 11.4 meters wide by 5.3 meters deep by 7.0 meters high. The construction is divided into three zones: zone 1 is a large zone comprising half of the simulator, while zone 2 is the upper part and zone 3 is the lower part of the remaining half. These three zones together can reproduce every type of condition encountered by construction materials in the areas of roofs, floors, and walls. Using two air conditioners, each with temperature and humidity controls, this simulator can reproduce a variety of natural environments.

For example, setting zone 1 as outdoor environment and zones 2 and 3 as interior environment causes the borderline between the zones to correspond to the conditions on construction wall surface material. Wall materials can then be tested by erecting materials such as aluminum sash or curtain walls. Experiments using settings such as this can provide major aid in research for solutions to such problems as dew drop and rainwater invasion into construction materials.

All of the operations can be controlled from the control console in the adjacent control room.

The multi-faceted applications of the Artificial Climatic-simulator have been brought about through the accumulation of high-level technology gained by aggressively responding to problems involving higher and higher levels of research. With this innovation, Tabai Espec once again proves to be the leader of creative technology for artificial environment.

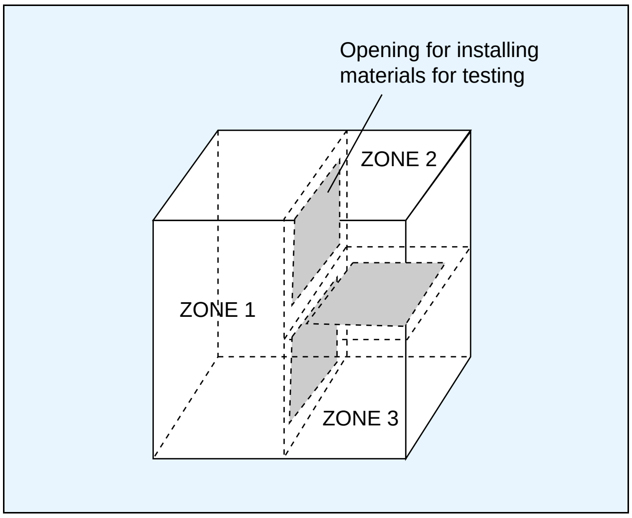

Fig. 1 Zones and locations for installing materials for testing

Photo 1 Snow drifts from snowfall system <Zone 1>

Photo 2 Solar radiation system <Zone 2>

Photo 3 Control console

Table 1 Capabilities of the artificial climatic-simulator

Air conditioner 1 (outdoor conditions) capabilities

Temperature range	–50 to +50°C <To zones 1, 2, 3>
Humidity range	30 to 90%RH <To zones 1, 2, 3>
Rainfall system	Rainfall volume 60mm/hr, 180mm/hr, 300mm/hr <To zone 1 only>
Fog system	Fog volume 0.03mm/hr, 0.06mm/hr <To zone 1 only>
Snowfall system	Snowfall volume average 200mm/day <To zone 1 only>
Solar radiation system	Solar radiation strength 0 to 860kcal/m^2 hr <To zones 1, 2>

Air conditioner 2 (indoor conditions) capabilities

Temperature range	+15 to +30°C <To zones 2, 3>
Humidity range	40 to 80%RH <To zones 2, 3>

ESPEC

TECHNOLOGY REPORT

Pub. Date: November 1, 1996 (biannual)

Publisher: TABAI ESPEC CORP.
3-5-6 Tenjinbashi, Kita-ku, Osaka 530, Japan

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