What is Environmental Testing?

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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.

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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.

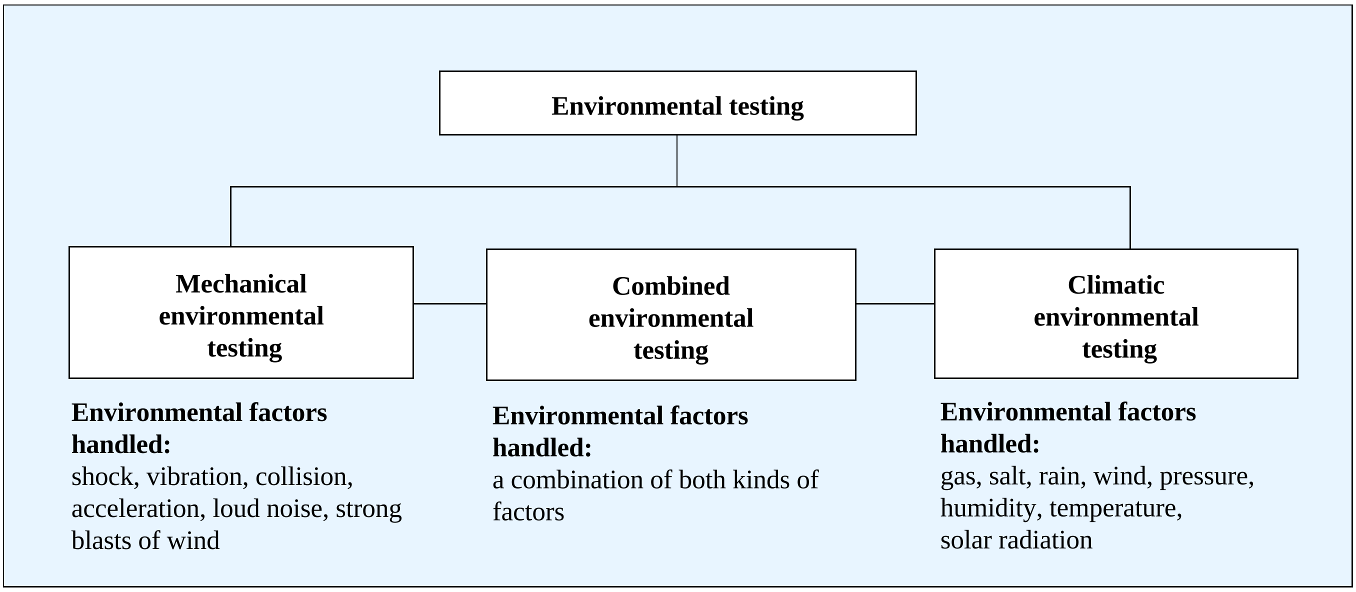


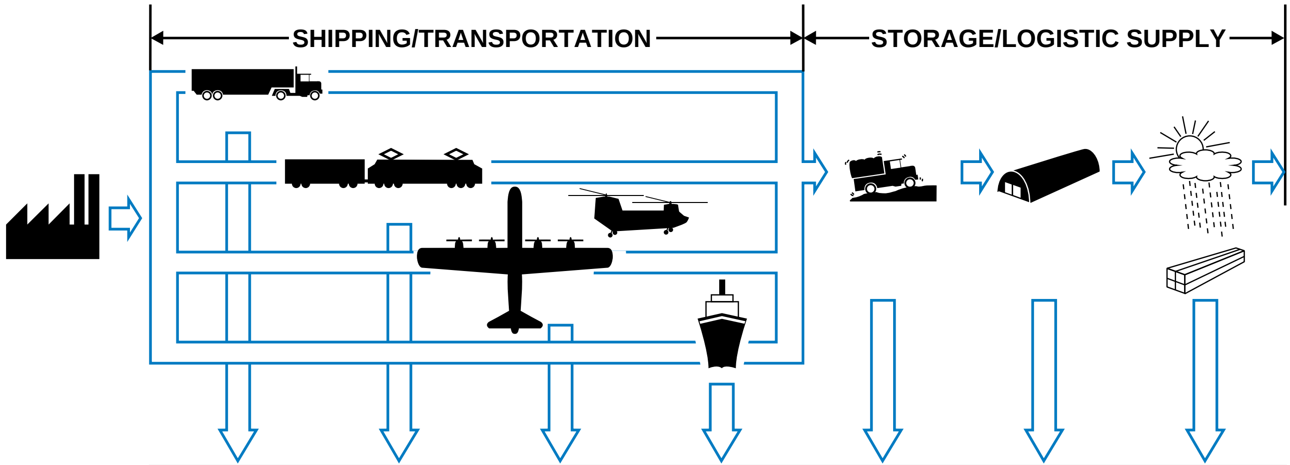
Fig 1 Types of environmental testing

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.

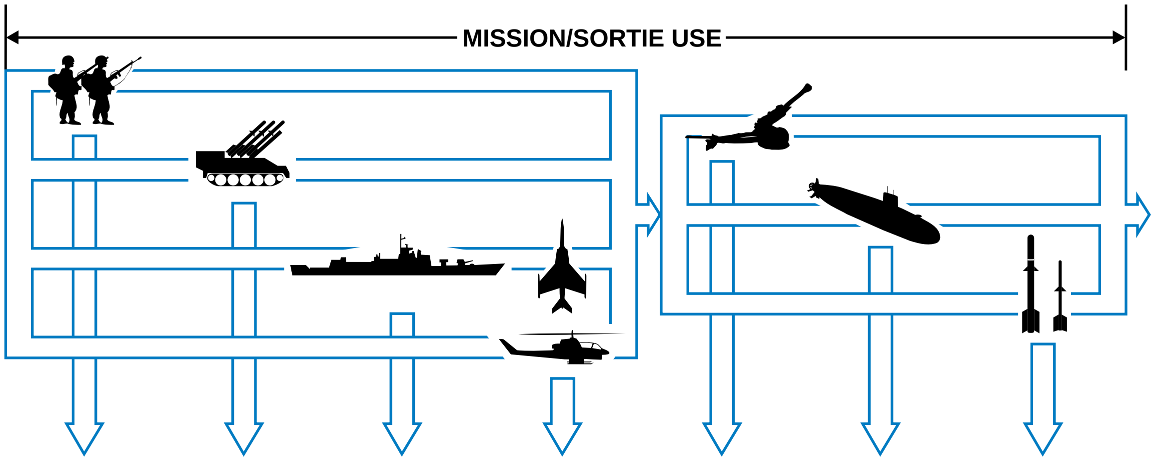
2.2 The environment that products encounter

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.

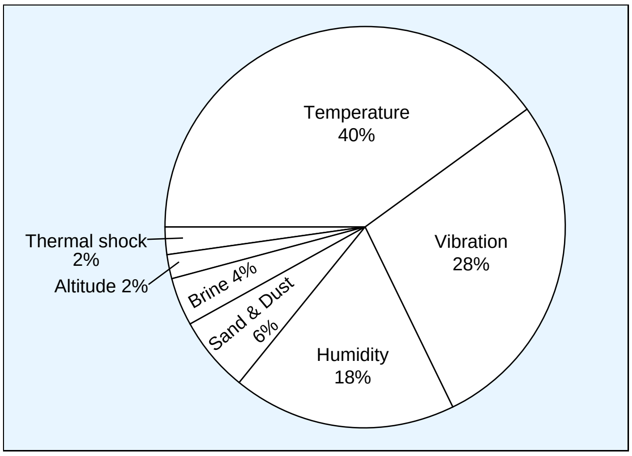


Fig. 3 Relationship between environmental factors and failure at Hughes Aircraft (USA)

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.

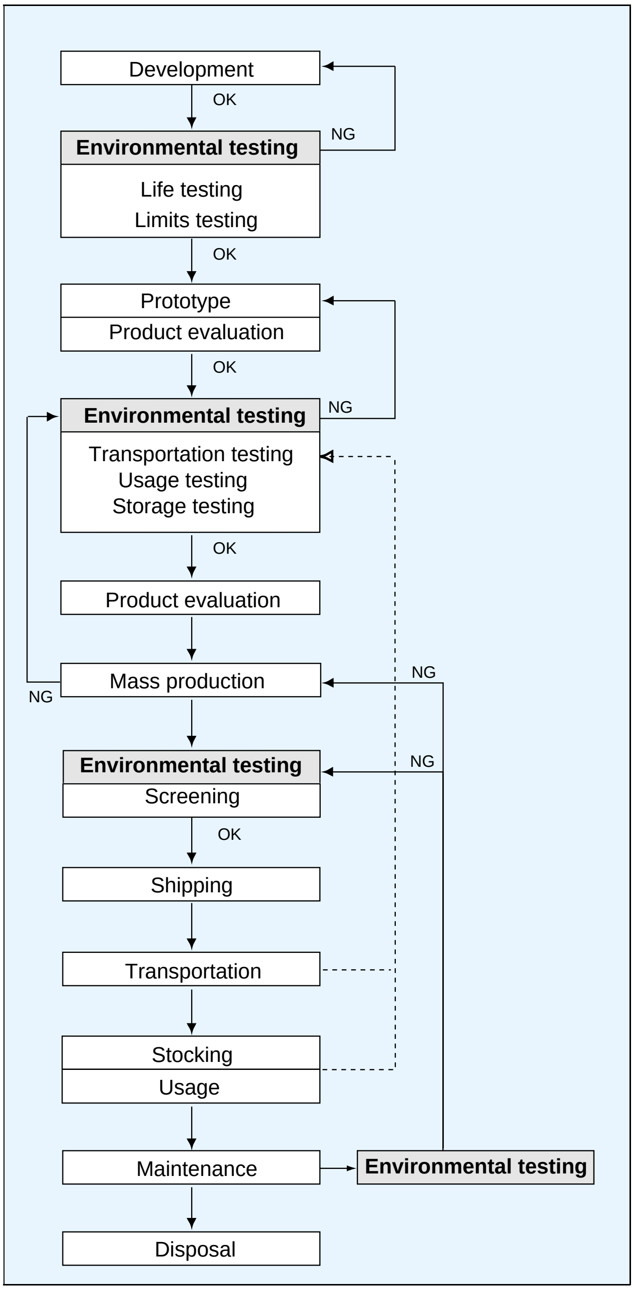


Fig. 4 Relationship between environmental testing and life cycles and processes of products

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.

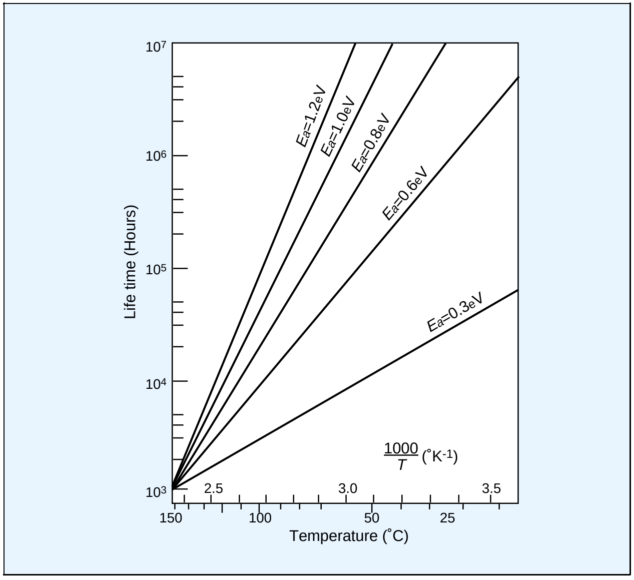


Fig. 5 Relationship between temperature and life

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

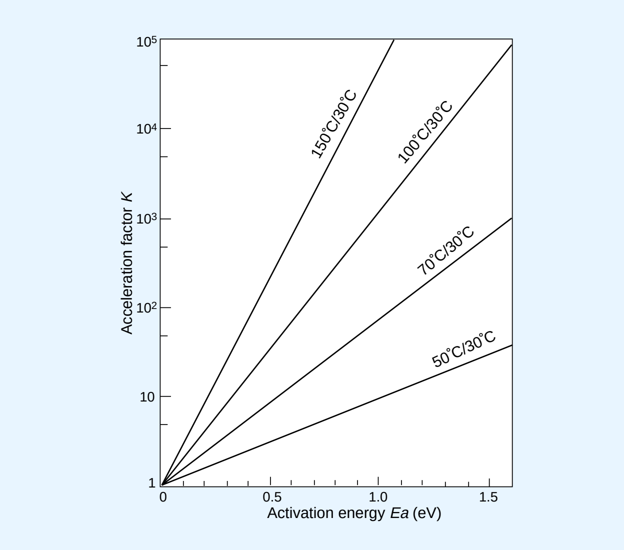


Fig. 6 Relationship between activation energy and acceleration factor

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.

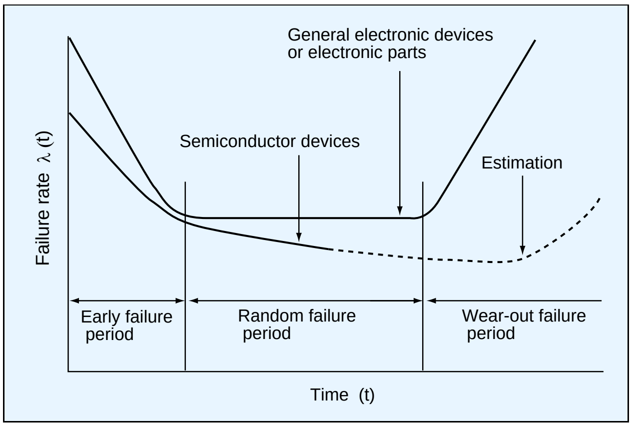


Fig. 7 Failure rate curves lines for typical electronic devices or parts and for semiconductor devices

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.

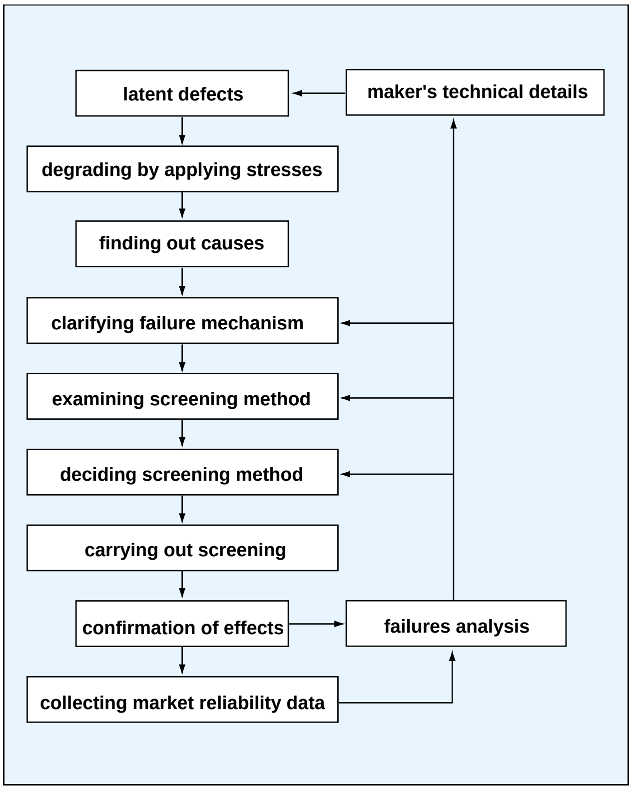


Fig. 8 Example of screening procedure

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

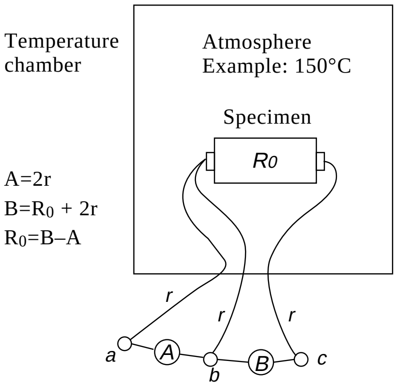
① Place specimen so that electrical inductance doesn't occur between specimen and so that specimen don't affect the heat of other specimen. Also, insure that specimen can easily be removed and replaced for measurement during testing.

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

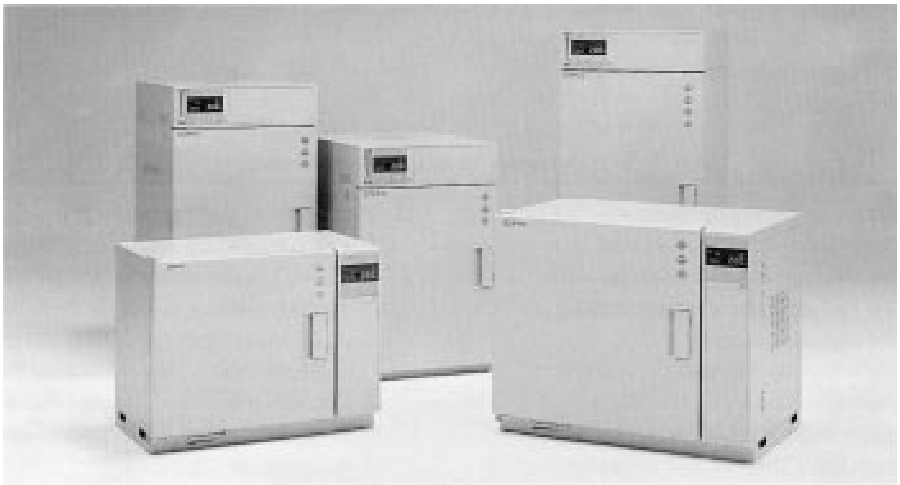


Photo 1 Temperature chamber

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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7) BS 4864 (1973)

8) ASTM D 2436 (1985)