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ESPEC

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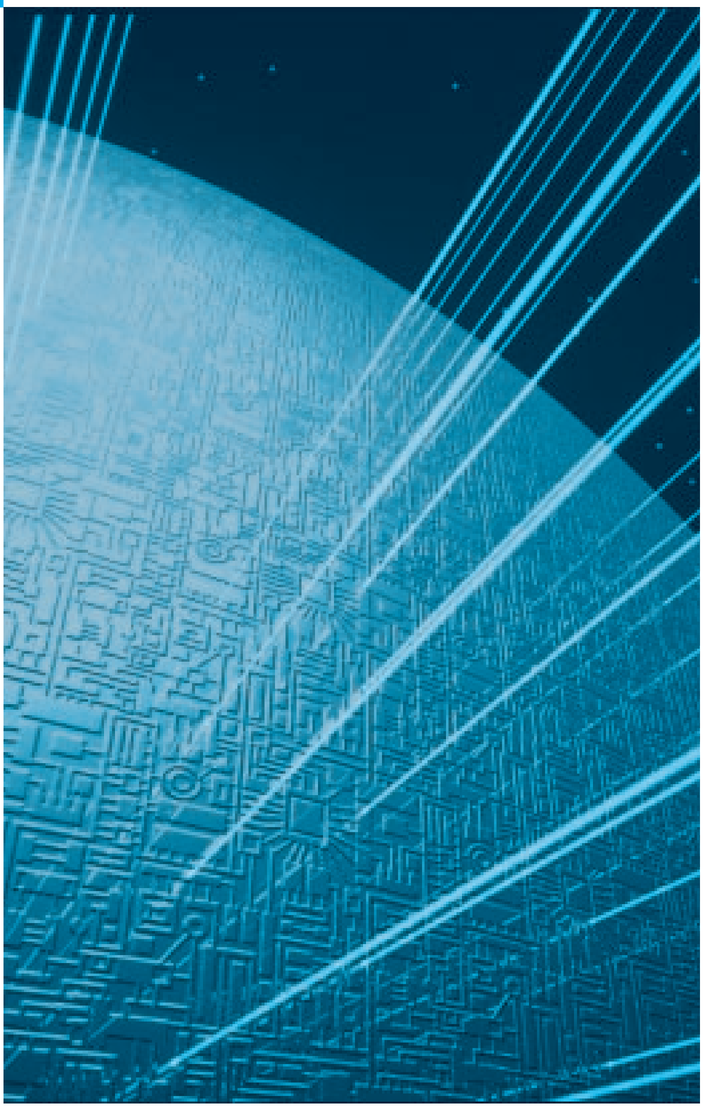
No. 6

Special issue: Evaluating Reliability and Burn-in



CONTENTS

TABAI ESPEC CORP.

Our Philosophy

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

ESPEC — our philosophy, our goal.

Corporate Data

TABAI ESPEC CORP.

Company Name:	TABAI ESPEC CORP.
Date founded:	July 25, 1947
Date incorporated:	January 13, 1954
Paid-up Capital:	6,778 million Yen (As of June, 1998)
Chairman:	Eiichi Koyama
President:	Kiyoshi Shimazaki
Senior Managing Director:	Yoshinobu Yamada
Managing Directors:	Susumu Nojii Toshikazu Adachi Nobuyoshi Shin
Directors:	Eishiro Hizukuri Yoshio Nakai Osamu Nakamatsu Hiromichi Fukumoto
Regular Auditor:	Katsuharu Nakano
Auditors:	Shoichiro Yoshioka Takuichi Omura Katsuyuki Kakihara
Employees:	577 (plus 61 temporary employees)

Product Guide

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

Measurement Evaluation Systems
- Ion Migration Evaluation System
- PWB conductor Resistance Evaluation System

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

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

Laboratory Chambers

Biomedical Chambers

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

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

Fundamental Concepts of Environmental Testing Techniques in Electricity and Electronics Part 3: Testing standards

Toshio Yamamoto*

In this issue, we are going to consider various items within public environmental testing standards. We shall take the IEC as an example, considering its structure and its process leading up to the establishment of testing standards, the characteristics of those standards, their current applications, and a summary of environmental classifications. We will not touch upon the details of individual standards, but we will be happy if this article serves as an aid in considering how to effectively apply the testing standards by understanding the process involved in their creation.

Contents

1. Introduction (positioning of testing standards)

In today's marketplace, industrial products are subject to an enormously wide range of environments that have become increasingly complex, making it impossible to apply uniform testing standards to all industrial products or to enforce common testing methods. However, the number of fundamental environmental factors is limited, and by combining these various factors and by selecting and combining their severity, we can create modified testing conditions that can be applied for individual testing. And yet, even within these conditions, average testing conditions do exist, and we must be able to show results quantitatively and be able to guarantee that anyone carrying out this testing based on the same standards will achieve similar evaluations and results. For these reasons, efforts to standardize test method are progressing on a global scope.

To consider this historically, GATT (the General Agreement on Tariffs and Trade Standard Code) came into effect in 1980 and set up various standardization agencies of the signatory nations to eliminate unnecessary barriers to mutual trade in regulations, standards, and systems of proof established in the field of technology. This approach promoted the establishment of international standards from the standpoint of promoting international free trade.

From 1990, this mantle was passed on to the WTO (World Trade Organization), leading to more importance being placed on international standards. The type of matters subject to review by this international body increased dramatically at that time, and evolved from being concerned merely with such fundamental matters as terms, basic standards, and product standards, to overseeing reliability management as well as safety and environmental problems.

Within this movement toward international standardization, the ISO9000 series enacted in 1987 had an especially pronounced effect on industry with its quality assurance system for industrial products. These standards are currently being adopted by more than 70 countries worldwide. In Japan as well, companies in a wide variety of fields, from industrial manufacturing to banks and securities firms, are enthusiastically rushing en masse to acquire the ISO9000 certification.

Within the arena of electrical and electronic industrial products, every country involved conforms to the IEC standards for domestic standardization of consumer products that are subject to these standards. The various countries of Europe in particular have been actively incorporating the IEC standards into their own domestic

*Technical Planning Department

standards from their inception. CENELEC (the European Committee for Electrotechnical Standardization) and ETSI (the European Telecommunication Standards Institute) have incorporated the IEC standards since 1994.

Since the toppling of the “Berlin wall”, the U.S. has stopped developing new MIL standards, and recently has been energetically promoting a variety of IEC activities.

In Japan, environmental testing was initially created mainly using the U.S. MIL standards as a model, but in coordination with the changes in the recent global situation, the Ministry of International Trade and Industry (MITI) has been promoting conformance between the JIS (Japan Industrial Standards) and international standards. Since 1993, work has been in progress to replace JIS standards, including both new and pre-existing standards, with translations of the IEC standards almost without changes to conform to the international standards.

In Part 3, we will look at the organization of the IEC and summarize the process of creating standards, focusing on how those activities are carried out. At this point, we will not touch directly on the details of individual standards, but we hope that each of you will independently take a look at the testing standards that affect you.

2. Structure for establishing testing standards

How are testing standards established and promulgated? Using the IEC standards as a model, we shall look at the organization and the process for establishing standards. The sequence explained here may not always be exactly the same for other public standards or industrial and private standards, but in general it can be assumed that most standards are enacted by going

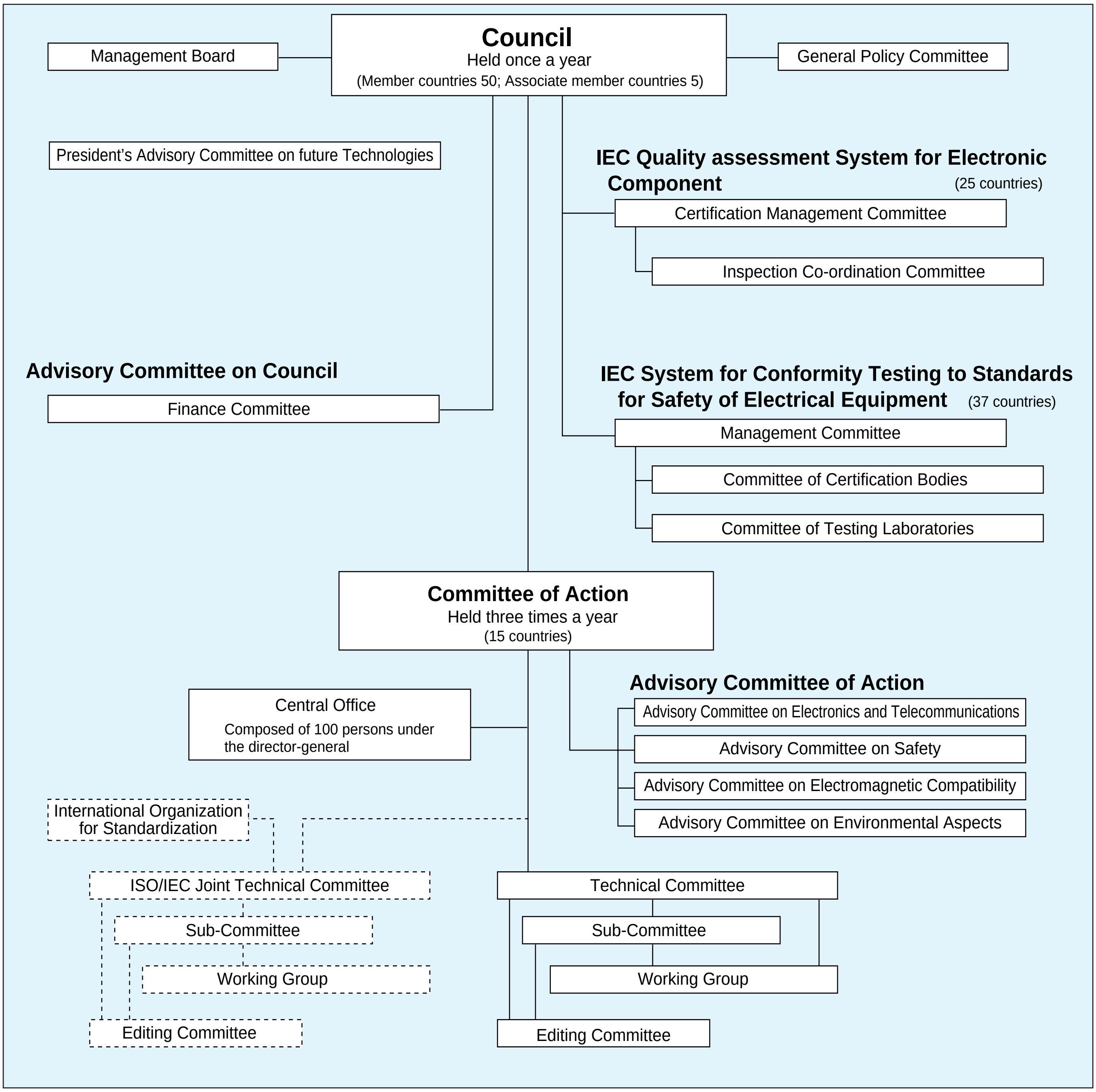


Fig. 1 International Electrotechnical Commission (IEC)

through the same type of process outlined here.

The duties of the IEC (International Electrotechnical Commission) are stated in their General Information as follows.

"The mission of the International Electrotechnical Commission (IEC) is to promote, through its members, international co-operation on all questions of standardization and related matters, such as the assessment of conformity to standards, in the field of electricity, electronics and related technologies. It therefore provides a forum for the preparation and implementation of consensus-based voluntary international standards, facilitating international trade in its field and helping to meet expectations for an improved quality of life."

These duties are achieved through the publication of materials (including international standards and recommendations in a form for international standards). When creating domestic standards, each country is asked to use the IEC standards as far as the domestic situation will allow. The IEC has no legal standing as a governmental organization, but rather is ranked as a corporation.

The IEC bureau was first located in London, England, a member country at the inauguration of the IEC, and then was moved to Geneva, Switzerland in 1947. In November 1967, the IEC and the ISO (International Organization for Standardization) formed a joint technical committee, leading to the close cooperation that exists today between the two organizations.

Within the present field of industrial products, the IEC retains control of standardizing the field of electrical and electronic products. In 1982 the IECQ (IEC Quality Assessment System for Electric Components) and in 1985 the IECEE (IEC System for Conformity Testing to Standards for Safety of Electrical Equipment) began to be used as assurance systems.

Member country to the IEC each forms a national committee which is required for representing its national electrical and electronics organizations (manufacturers, users, government agencies, academic societies, and industrial organizations). Each country is then authorized to have only one agency qualified as a committee member. In Japan, the JISC*1 (Japanese Industrial Standards Committee) is designated as the committee

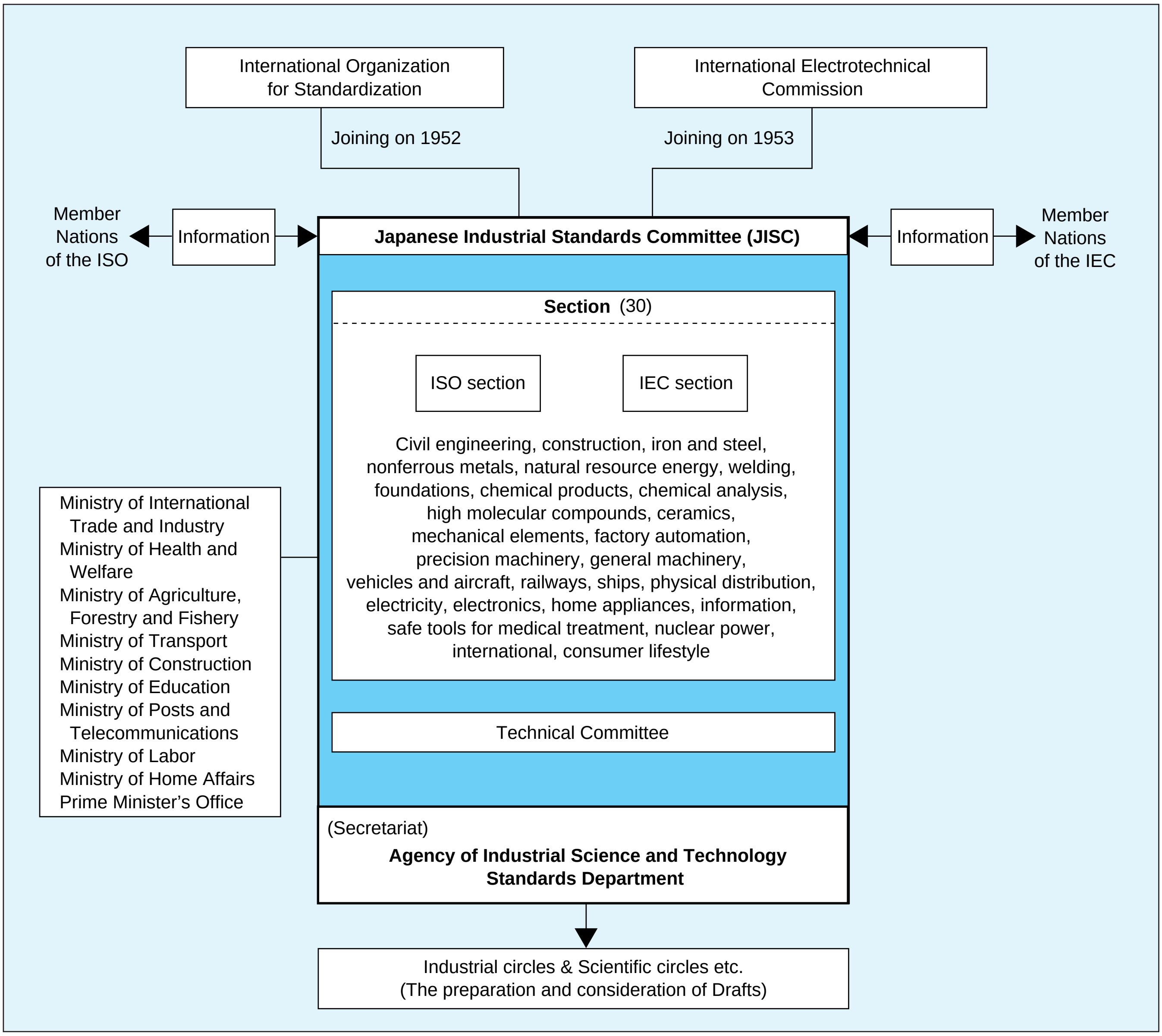


Fig. 2 The Organization for Standardization of Japan

member, and the Standards Department of the Agency of Industrial Science and Technology in the Ministry of International Trade and Industry, is in charge of the committee.

The revenue for the IEC comes from the annual share of expenses from each country, sales of publications, and other approved plenary sessions.

The official languages for activities of the IEC are English, French, and Russian, but in actual practice English is usually used, and standards and technical reports are currently drawn up in English and then translated into French for publication. In Russia, the Russian Federation National Committee independently publishes Russian-language editions.

The IEC is organized roughly as seen in Fig. 1, and the country currently holding the presidency is the United States of America. Currently, as of March 1998, there are 50 member countries. Within Japan, the Organization for Standardization is organized as shown in Fig. 2.

3. Process of creating IEC standards (Development of international standards)

Within the structure of the IEC, the groups directly concerned with creating testing standards are the TCs (Technical Committees) that handle technical matters. TCs are created for each specialized field, and there are now approximately 80 to 90 TCs. Within those committees, special SCs (Sub-Committees) are formed as needed. WGs (Working Groups) are formed as necessary to review pre-existing standards and create the drafts for new standards. Special ADs (Ad hoc Groups) are set up to handle limited problems.

Proposals for standards are drawn up within each committee (i.e., in the TC, SC, or WG) and these project stages are developed as shown in Table 1, and the order given in Fig. 3.

At this point, let’s look at the individual steps leading up to the creation of standards.

Table 1 Project stages and associated documents

Project stage	Associated document	
	Name	Abbreviation
0 Preliminary stage	Preliminary work item	PWI
1 Proposal stage	New work item proposal	NP
2 Preparatory stage	Working draft(s)	WD
3 Committee stage	Committee draft(s)	CD
4 Enquiry stage	Commitee Draft for Vote	CDV
5 Approval stage	Draft International Standard	FDIS
6 Publication stage	International Standard	

Preliminary stage

This stage is for handling the latest technology that doesn’t lie within the administrative range of the TC or the SC. Preparations are made at this point for technology that doesn't require immediate standardization.

Proposal stage

Proposals for New Work Items that currently lie within the administrative range of the TC or SC are begun at this stage. Proposals may be made by any of the following.

– Any national body
– The secretariat of that technical committee or sub-committee
– Another technical committee or sub-committee
– An organization in liaison
– The Technical Management Board or one of its advisory committees
– The Chief Executive Officer

Normally, most proposals are made by a particular country. In fact, the country proposing to create a standard will have already drawn up the gist of the details serving as the basis for the proposal, and then will submit the proposal to the appropriate TC or SC. A written form is sent to countries participating in that TC or SC asking whether they want to use the proposal. These voting sheets are collected within 3 months. If a majority of countries approve the proposal, and at least five countries participate in the work of drawing up the draft of the standard, the proposal is approved and is formally adopted. When necessary, a WG is formed and a target date is set for completing the working draft. Experts appropriate to the details of the proposal are recruited to serve in the WG from among member countries participating in the TC or SC.

Preparatory stage

The experts of each country hold WG meetings about twice a year and brainstorm the concrete points and specifics of the original draft. During this time, all matters are discussed in the WG, technical investigations are carried out, and meetings are held for further study of the data. Finally, the WG gets their working draft (WD) ready and submits it to the committee to which they are attached.

Committee stage

The WD received by the committee is sent on as the Committee Draft (CD). The countries participating in the TC or SC attach the opinions of their own country to the CD, which serves to express their approval or disapproval. However, at this point, there are still sections that concern domestic circumstances of each country as well as sections in the CD that are unclear, and pro and con opinions erupt in regard to individual items or even the contents of the entire proposal.
Ultimately, these opinions are sent through the committee to the WG that drew up the draft, and new discussions are requested as the WD goes back to the WG. Once again, the WG presents the revised draft based on the results of the WG discussions, and again it is sent on to each country. This cycle is repeated a number of times in creating the draft of the standard.

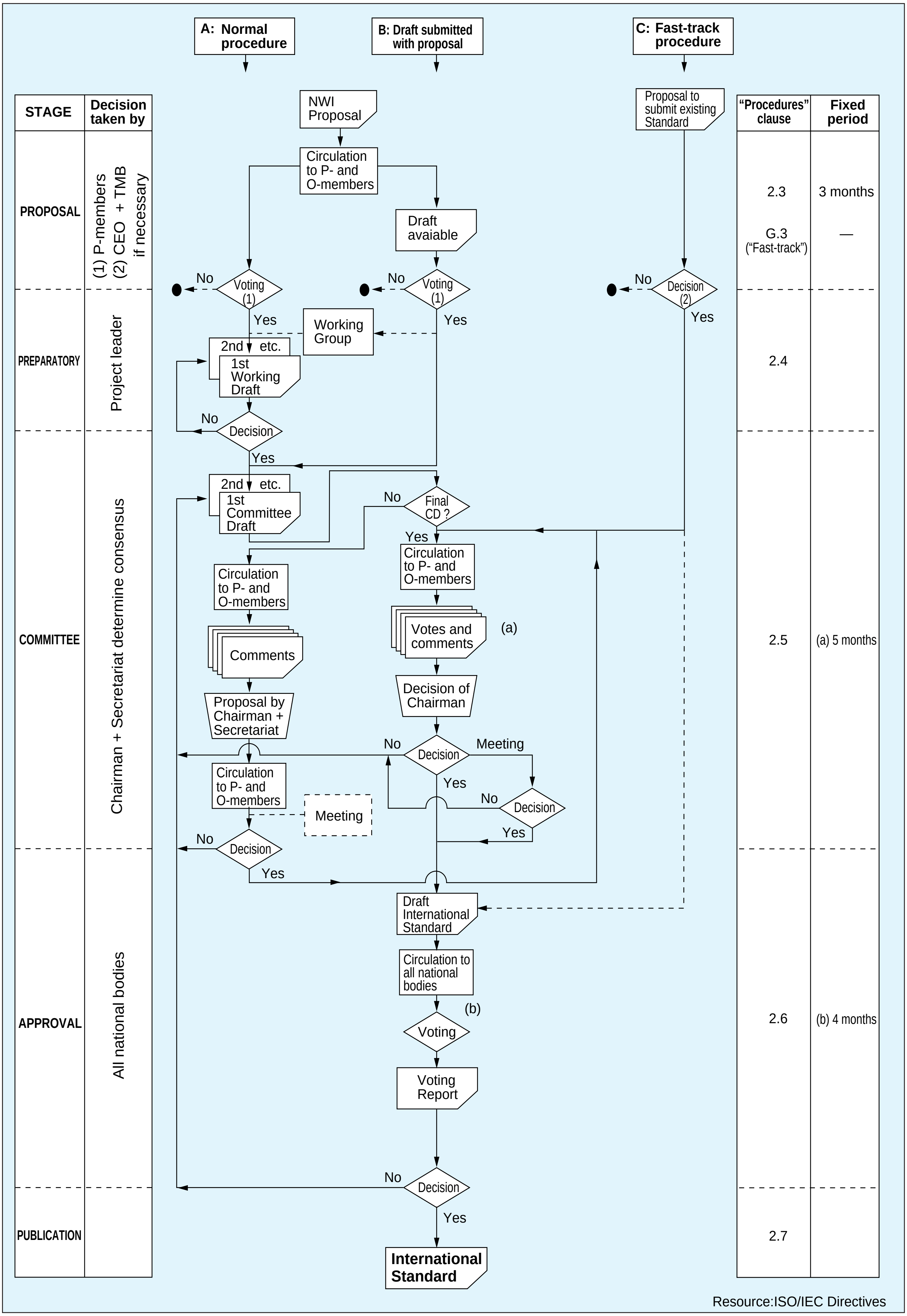


Fig. 3 Flowchart for development of an International Standard

Enquiry stage

Before moving to the Approval stage, the draft is sent to the P-member*2 countries of the TC or SC for the Committee Draft for Vote (CDV). Voting takes five months. The draft is approved by a two-thirds approval vote if the no vote doesn't exceed one-fourth. At this stage, voting countries can still express their opinions, but there is little probability that the opinions will affect the main character of the standard. If approval is attained, the revised draft is sent to the Central Office within four months. Here, the draft is used to create the final draft, called the Final DIS (FDIS), in accord with the standards form.

Approval stage

The draft that has become an FDIS is sent to each country to receive final approval in voting that takes two months. If nothing major comes up at this stage, the individual countries are not allowed to give their opinions on the contents of the draft. Comments are limited to pointing out problems in editing. Standards for approval or rejection are the same as in the Enquiry stage.

Publication stage

If the requisite majority approves the FDIS, authorization is given to publish the proposal as a formal international standard. The Central Office is in charge of administrative work up to publishing, and the form as an international standard is usually prepared within two months. The published standard is reviewed at least every five years by the TC or SC in charge. A majority vote of the P-members is required to continue the standard, revise it, or abolish it. If the committee decides to revise the standard, it becomes a new project and follows the same sequence as when creating a new standard. Other regulatory details exist for abolishing the standard. (In this way, other regulatory details exist for IEC administrative guidance.)

Within this sequence, the WG stage requires the greatest time and expense. In particular, when problems exist with each of the experts participating in the WG, they occur at the following two points.

Let's look at the economic problem first. We mentioned that the meetings are held about twice a year. Experts from normally participating countries currently attend the meetings on a voluntary basis. For members of participating countries who must travel a long way to where the meeting is held, this means a heavy financial burden from such expenses as travel fees and lodging. Meetings of the WG handling environmental testing matters are usually held in Europe, placing a financial burden on participating members from countries in Asia in particular. If the meetings were held in Asia, the reverse would be true. Very little aid is given from attached countries at the WG level, and at present most of the expenses of sending the experts abroad are borne by the corporations to which they belong. The current problem, therefore, is that most who are not employed by relatively affluent corporations cannot attend. Participation is possible as a corresponding member through such measures as letters and faxes, but it is difficult to transmit one's actual intentions, creating a rather large probability of a situation similar to trial in absentia.

The other problem is one of time. The CD, which is the WG draft that takes the most time, is sent to each country for a period of gathering opinions. If the details of the main points can be fully worked out in the WG, there will normally be few issues contended at the CD stage. However, even if the logic of the draft stands up well in interdisciplinary and logical terms, if it contains little of practical value, it will cause continuous objections, and generally will not win approval by the various countries no matter how much time is taken. Items exist which have been under consideration at the WG level for more than 10 years without being able to reach the final draft stage. If this state of affairs continues, it will not be unusual in this age of swift technological progress for the peak period for a technology to have already passed before agreement can be reached on the standard. Due to the tendency for this type of problem to occur, the IEC is trying to speed up the process at each stage, but so far has been unable to make much progress, due to the differing situations in the various countries.

4. Characteristics of standard testing methods

To begin with, public standards such as those of the IEC have a strong character of mutual agreement. However, seen as industrial standards, they also have the aspect of products with great compromises. Therefore, many sectors cannot really be said to purely scientific in their handling of technical problems. It seems necessary to see those items as reflecting the occasional international situation as well as the domestic governmental and economic situations of the various countries. Scientifically speaking, this type of situation leads to a number of points of contradiction at present.

The testing standards of the IEC present test conditions from a completely objective standpoint, and do not directly participate in any other purposes. In other words, they never touch on the individual products that are tested. That is why it cannot be guaranteed that the technical information was obtained according to the merits and demerits of the product as indicated through testing according to the testing conditions in the individual testing standards. Standard tests are simply tools to achieve specific purposes, and how those tests are used (e.g., including whether they are used a standard for determining product acceptability) is left up to the user. We must be aware that the standard itself was created with no relationship to the results of the tests.

The environmental testing methods standardized by the IEC are appropriate for handling most electrical and electronic consumer products, but when the products are subject to the effects of complex environments, severe problems crop up in combining tests, adding on, repeating, and in testing sequence. Contracts must be exchanged in advance based on mutual consent between the user and the supplier of the products and proper conditions must be set for how these test methods are used. (Giving priority to the test conditions required by individual products is also authorized within IEC standards.)

5. Current applications of testing standards

We have already stated that when deciding to carry out testing, the objectives of the test must be determined in advance. This is not all there is to it. It is also important to be aware of patterns obtained corresponding to various purposes in selecting the testing method. If we confuse the purpose with the result when carrying out a test, the test will serve no purpose at all. Of course, we must also be well aware of the limits of the test itself. (We cannot expect data for long-term guarantee of the product as it is used in the actual conditions within the marketplace environment.) However, “Fixed menu type” tests within the standards can be repeated as prescribed. If the complaint is made that the test doesn’t serve a useful purpose, it is because the ability of the testers themselves is being tested.

At this point, let’s classify tests according to their major purposes, which can be separated into the following categories:

(1) Finding and correcting technical problems,
(2) Determining or comparing product merits or demerits, and
(3) Seeking concrete reliability.

Standard testing methods can be used for numbers (1) and (3), but there is a high probability that in reality contents of the test would be extremely individual (or individualistic) based on independent conditions. Therefore, we would not expect the tests to have a common quality. Category (2) has the strongest relationship to standard testing. Representative tests in this category include all types of certification testing, acceptance testing, and tests for delivery and shipping. In other words, these tests are for accepting or rejecting and all are fixed-form (fixed menu style) and are performed to determine whether the product meets the standard level of quality. Determination of factors related to the standards and test conditions in general use for such tests such as the stress severity, time, and the number of samples removed should all be mutually agreed upon in advance via contract. If we take these tests as representative of the level of the greatest common denominator for transactions between users and manufacturers, then passing this test can provide wide public acceptance. However, we must be aware that this does not indicate individual product reliability.

At first glance, standard testing seems to have the possibility for wide public application, but when applying the tests strictly in the prescribed form, they are unexpectedly limited. At least in private corporations, at present these public standards are looked at from the corner of the eye while individually carrying out tests under independently determined test conditions. (In general, these conditions are much more severe than public standard tests.) In addition, each corporation maintains its own private standards based on its own policies, and such standards usually prescribe conditions with a much higher level of stress than do the public standards.

6. Environmental classifications in IEC standards

Up to this point we have looked at the structure and flow involved in establishing environmental testing standards, and also the current method of applying these standards. Now let’s see what type of classifications are made for the “environment” within the testing standards. Below is a brief outline.

In the IEC, the 60721 series standards contain the following overall divisions.

Part 1:
Types of environmental conditions and representative values

Part 2:
These standards explain natural conditions, classify environments based on over 10 years of meteorological data, and also give a general explanation of how the environments affect the products. Fire is also prescribed as a special condition environment.

Part 3:
Environmental conditions which the products encounter (e.g., storage, shipping, indoors, outdoors, vehicles, ships, carrying, and mines) are classified and given symbols.

Next is a list of the environmental conditions and factors covered.

(1) Meteorological conditions: temperature, humidity, pressure, wind, precipitation, radiation, and water other than rain.
(2) Biological conditions: flora, fauna
(3) Chemically active substances: NaCl, SO_2, H_2O, NOx, O_3, NH_3, Cl, HCl, HF
(4) Mechanically active substances: sand, dust, soot
(5) Polluting substances: all types of oil, electrolytes
(6) Mechanical conditions: vibration, falling, shock, inversion, acceleration, angular motion

Next, we would like to touch briefly on meteorological data, which of all these conditions has the strongest relationship to environmental testing.

The IEC60721-2 series consists of technical data, indicating the influence each natural environmental condition has on products, and also presents worldwide meteorological data. In 1995 the IEC60721-2-1 standard was adopted as JIS standard. (JISC0111: Classification of environmental conditions. Part 2: Environmental conditions appearing in nature. Temperature and humidity) This standard contains statistical values of meteorological data from every region of the world. For statistical values of temperature, this standard presents absolute extreme values, average temperatures of extreme values for the year, and average temperatures for daily averages of extreme values for the year. In addition, the standard divides climate into four classifications and then classifies the regions of the world into nine forms based on the type of climate. (Refer to Fig. 4 and 5.) Further, the standard presents a geographical survey of open-air climates, which adds temperature and humidity factors to the above statistical values in each classification.

According to these classifications, the Japanese climates are moderate open-air climates (which include cold temperature, warm temperature, warm dry, and mild warm dry climates). The climate forms include cold temperature for Hokkaido, with the rest of Japan classified as either mild warm dry or warm damp. The new classification of tropical region has recently been added to meteorological conditions, and more revisions can be expected before long. The tropical regions are regions inside the tropical regression lines (the tropic of Cancer to the north and the tropic of Capricorn to the south). The meteorological conditions in these regions include moderate regions, dry desert regions, pluvial and damp regions, as well as high-altitude regions 4000 meters above sea level and up such as the Andes and Kilimanjaro. Those environmental classifications are extremely diverse.

Finally, we would like to present the recent trends in IEC activities related to environmental testing. From 1997, the previous TC50 dealing with environmental testing methods and the previous TC75 dealing with environmental classification were combined to form the new TC104*3, which will carry on the work of both prior TCs. Within the continued items, the relevant guidance will be completed for both the IEC60721 series of prescribed environmental conditions, and the IEC60068 series of prescribed environmental testing methods, and can be considered extremely useful for selecting testing methods.

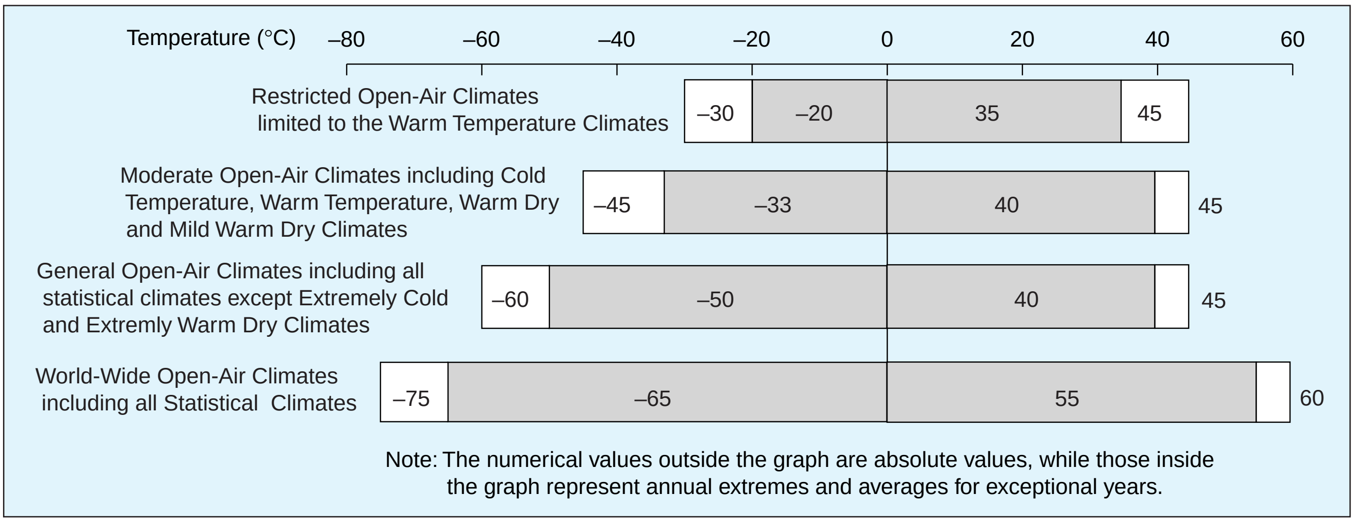


Fig. 4 Temperature conditions of climate groups

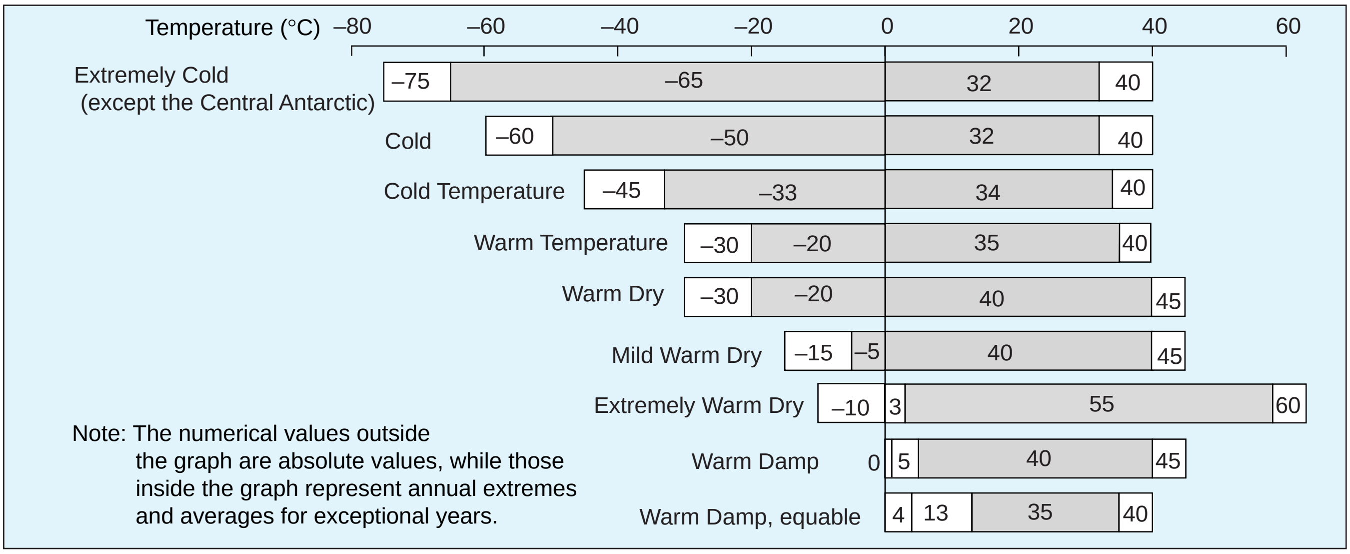


Fig. 5 Climate types and temperature conditions

Terminology

*1 **JISC**: Japanese Industrial Standards Committee
JISC is within the Ministry of International Trade and the Industry-Agency of Industrial Science and Technology, and is involved in investigative deliberations on establishing, revising, and abolishing Japanese industrial standards and specifying what items should display the JIS symbols. In addition, they are able to submit reports on suggestions to advise the related ministries on matters related to promulgating industrial standardization. This committee utilizes 29 sectional meetings and around 1,000 specialists and is composed of 240 committee members from academic backgrounds, and around 8,000 provisional members and specialist members.

*2 **P-member**
Participating actively in the work, with an obligation to vote on all questions formally submitted for voting within the technical committee or sub-committee and voting on drafts of International Standards, and, whenever possible, participating in meetings.

*3 **TC-104**
Environmental conditions, classification, and methods of testing

Report 1

Combined environmental testing for equipment used on automobiles — Overview and test approach —

Jyuro Izumi*

Automobiles of the 1990's face societal demands such as conserving energy, promoting recycling, and preventing pollution, while at the same time they must respond to purchaser desires for improved safety and greater comfort and convenience. The complex control systems employed to meet these demands can only be discussed in terms of car electronics. The continued development of vehicle electronic equipment has led to an age requiring diagnostic systems, serial data transmission control, and information displays as well as data transmission to navigational and other equipment inside and outside the vehicle. This burgeoning use of vehicle-mounted electronic equipment has led to a diversity of mounting environments, so that sometimes even when the environmental endurance of an individual part is well understood, the results could change when the equipment is actually mounted on the vehicle. Some mounting sites are within the relatively benign environment of the passenger cabin, but the majority of parts are used in harsher environments, such as outside in low temperatures, or subjected to the high heat and humidity and the mechanical vibration of the engine compartment. To maintain the rated safety and performance for the long term in the environments where the parts are actually used, combined environmental testing is carried out on electronic equipment mounted on many types of vehicles, as well as for the machinery built into the electronic equipment. In this article, I would like to present some examples of the approach of combined environmental testing in which temperature, humidity, and vibration are combined to create the environments in which the parts are presumed to be used in the vehicle.

1. Introduction

There is a strong trend toward incorporating electronic control to attain the high performance and high functionality of today's automobiles. The greatest efforts in technological development are being poured into this field, and the functions of every type of control system are growing increasingly complex. Within this situation, we can note that:

(1) Customers are demanding more safety and comfort features, and safety and comfort equipment such as four-wheel drive, braking control, and traction control are becoming standard on many cars.

(2) Fuel consumption and exhaust gas regulations are becoming stricter, while at the same time the customer is seeking improvements in both driveability and general driving features, all of which requires higher level control.

With vehicle control systems relying on ever-more-sophisticated electronics, the reliability of the electronic control equipment has a major impact on the overall reliability of the vehicle.

In general, the usage environment affects the durability and operating characteristics of electronic devices and units. Therefore, when studying the developmental design and application of the equipment built into these devices and units, the crucial problems have become how environmental test items should be set with regard to actual usage conditions, and how to maintain practicality and requisite performance while keeping costs reasonable.

*Sales Engineering Department

2. The usage environments of equipment mounted on vehicles

The vehicle usage environment includes such factors as temperature, humidity, vibration, rainwater, weatherability, voltage fluctuation, and surge voltage. When considering temperature, we find that the vehicle itself is a source of heat production, and the temperature in the engine compartment gets up to around 100°C, it goes over 65°C in the trunk, and can hit 100°C at sites such as the instrument panel in the vehicle interior. With humidity, we find it is not limited to high humidity caused by rainwater. Sudden changes in temperature cause dew condensation, which reaches a maximum of 95 percent humidity in the trunk at 38°C. Next, turning to vibration, we find that the body shake vibration occurring while driving receives 2.2 to 4.4 G's of acceleration, and the engine vibration generates 20 to 40 G's of acceleration that affects the engine compartment.

3. The affects of temperature and humidity environments on vehicle-mounted equipment

3-1 Vehicle heat sources (engine compartment temperature conditions)

The major sources of heat in the vehicle are engine heat and friction heat from the braking and automatic transmission systems. Temperature conditions in the engine compartment are particularly severe in hot weather when driving in traffic jams or going uphill. Newer model vehicles have smaller ventilation openings to reduce air drag while at the same time having to cope with greater heat output due to equipment such as DOHC and turbochargers. The increased heat combined with the reduced ventilation means that temperatures of 80 to 120°C must be handled. Table 1 gives maximum temperatures for different areas of the engine compartment.

Table 1 Maximum temperatures at different areas of the engine compartment

Location	Maximum temperature
Engine coolant	120°C
Engine oil	120°C
Transmission oil	150°C
Intake manifold	120°C
Exhaust manifold	650°C
Alternator air intake	130°C

Quoted from "Vehicle electronics and reliability"

3-2 Cabin temperature while car is parked

When the car is parked under a blazing sun and the passenger cabin is shut tight, the car becomes like a sun room. The temperature climbs to around 110 to 120°C in the vicinity of the front and rear panels, which are exposed to direct sunlight. The temperature of the headlining and the area of the front and rear seats reaches 65 to 85°C. Table 2 gives maximum temperatures for different areas inside the passenger cabin.

Table 2 Maximum temperatures at different areas of the passenger cabin

Location	Maximum temperature
Top of the front instrument panel	120°C
Bottom of the front instrument panel	71°C
Passenger cabin floor	105°C
Rear deck	117°C
Headlining	83°C

Quoted from "Vehicle electronics and reliability"

3-3 Vehicle humidity environment

Most cars today come equipped with air conditioning, and when the doors are opened and closed, high humidity outside air flows in and tends to cause dew condensation to form on air-conditioned equipment. To take vehicle-installed audio equipment as an example, when a car has been parked in a cold area such as at a ski resort, the car is started up and the heater is turned on, blasting hot air from the engine compartment onto the audio equipment installed on the exterior of the front panel. The sudden change in temperature creates a gap between the panel temperature and the temperature inside the passenger cabin. Table 3 shows maximum humidity for different areas inside the passenger cabin.

Table 3 Maximum humidity at different areas of the vehicle

Location	Maximum humidity
Engine compartment (around engine)	38°C, 95%RH
Engine compartment (dashboard)	66°C, 80%RH
Passenger seats	66°C, 80%RH
Around both side doors	38°C, 95%RH
Around front dash panel	38°C, 95%RH
Floor sheet	66°C, 80%RH
Rear deck	38°C, 95%RH
Trunk	38°C, 95%RH

Quoted from "Vehicle electronics and reliability"

3-4 Examples of demands on electronic equipment by temperature environments

Temperature environments require that vehicle-mounted electronic equipment meet the following conditions.

(1) Operate normally at high and low temperatures.
(2) Operate normally during severe temperature increase or drop within a short period.

The ability to meet these conditions becomes crucial in environments that include such factors as severe temperature fluctuations and vibrations from starting up or stopping.

Example 1:

Starting up after having been parked under a blazing summer sun requires the ability to operate safely at 80 to 120°C. After driving 10 minutes, the air conditioner lowers the temperature to 15 to 20°C, and then the car is parked again and returns to the high temperature.

Example 2:

Starting the engine in the early morning in the dead of winter in a northern climate (about –30°C) requires the ability for all functions simultaneously to operate normally. After driving for 10 minutes, the engine compartment reaches 80 to 120°C, and the heater warms the passenger cabin to 20 to 25°C, then the engine is turned off and the temperature returns to minus 30°C.

3-5 Environments that vehicle electronic sensors must endure

Electronics sensors in vehicles are subjected to severe usage environment conditions in regard to such factors as temperature, humidity, vibration, high voltage surges, and power fluctuations. Malfunctions could lead to highway accidents, and so the equipment must have high ratings in safety and reliability.

Requirements for electronic sensors for vehicles include the following.

(1) Precision requirements are not particularly severe compared to other fields.

(2) Reliability and environmental endurance requirements are much more severe than in other fields.

Table 4 shows specifications and environmental endurance requirements for sensors with various applications.

The newest applications for sensors include measurements by two axis acceleration sensors to control the chassis, and measurements by three axis acceleration sensors to operate air bags.

4. Types of vibration and vibration characteristics that affect vehicle-mounted equipment

Noise and vibration in the passenger cabin come from many different sources of vibration. Fig. 1 gives an outline of the mechanisms that generate noise and vibration inside the passenger cabin.

These vibration sources can be classified according to the generating conditions and frequency bands. The broad classifications include engine vibration, gear noise, road noise, tire noise, and wind noise. Also, low frequency vibrations that become problematic with spring expansion and spring compression are mainly road vibrations. Vibrations can be considered random vibrations or shock vibrations (road bumps or sharp drops).

4-1 Vehicle noise that occurs while driving

(1) 1 to 2 Hz vibration (spring expansion body pitching and bouncing vibration)

During the large undulations on the express highway, or just after driving over a bump or a sharp drop, the body makes a continuous soft floating vibration. The oscillation frequency is determined by the natural frequency of the spring expansion.

(2) 2 to 15 Hz full body trembling up and down vibration

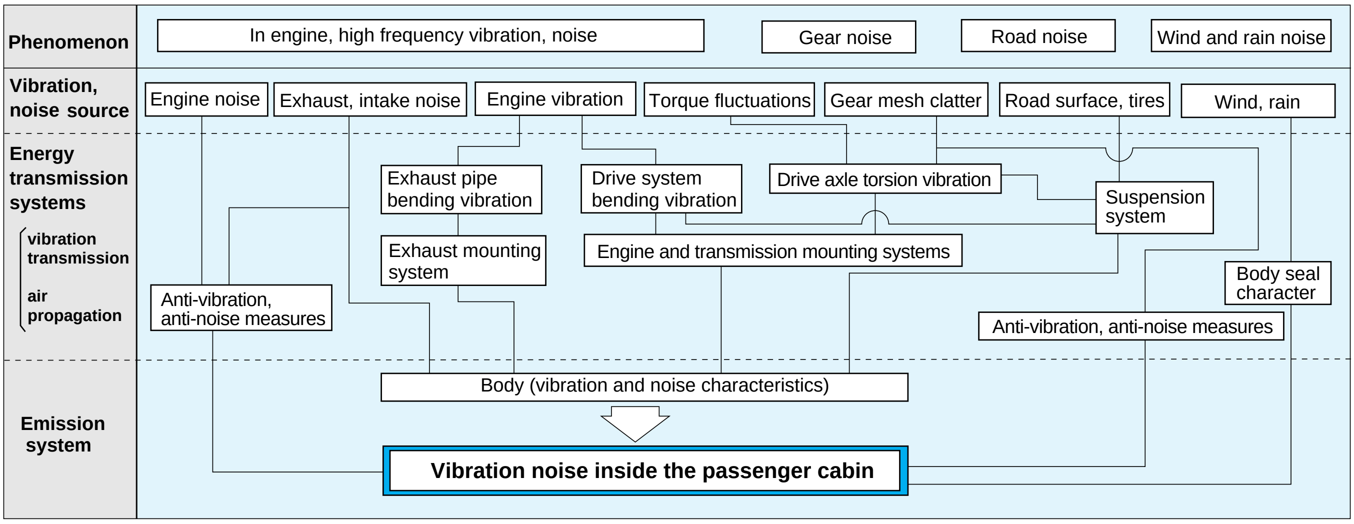
This vibration occurs when driving over a continuously uneven surface, or just after driving or a major bump or sharp drop. It is amplified by spring compression resonance, engine rigid body resonance, and body elasticity resonance, and transmitted to the seats, steering wheel, and the floor.

(3) 15 to 30 Hz rough vibration that is transmitted to the driver

When driving over a continuously rough road surface, the vertical and longitudinal road surface stimulation is transmitted without being dampened by the suspension system.

Table 4 Specifications and environmental endurance requirements for sensors with various applications

		Home use	Measurement use	Airplane use	Vehicle use
Precision		Several %	0.1 to 1%	0.1 to 1%	1 to several %
Environmental endurance	Operating temperature	–10 to 50°C	0 to 40°C	–55 to 70°C	–40 to 120°C
	Vibration	Up to 5G	1G	0.5 to 10G	2 to 25G
	Source voltage fluctuation	±10%	±10%	±10%	±50%
	Electromagnetic environment	Good	Good	Good to Worst	Bad
	Saltwater	No	No	Yes	Yes
	Water	Yes	No	Yes	Yes
	Muddy water	No	No	No	Yes
	Gases	No	No	No	Yes
Reliability (failure rate)		—	—	(Max. 10^{-9})	10^6 km (10^{-9})



Quoted from “Vehicle technology handbook tests and evaluation” chapter 6

Fig. 1 Diagram of mechanisms generating vibration noise inside the passenger cabin

4-2 Low-frequency engine vibration while driving

The vehicle engine suspension system has a rigid body resonance of 10 to 30 Hz. That vibration phenomenon is exhibited in various forms. Body vibrations occur when starting or idling, and shock and body longitudinal hiccup vibrations occur due to sudden changes in engine torque when accelerating or changing speeds.

(1) Engine shake (7 to 20 Hz)
Engine resonance and rigid body vibration of the body create low-frequency vibrations in the coupling system of the engine, body, and suspension. This is called engine shake.

(2) Idling vibration (20 to 50 Hz)
During idling, low-frequency vibration occurs in the floor, seats, and the steering wheel. Trembling up and down vibration causes 20 to 35 Hz low-frequency vibration with four cylinders and 30 to 50 Hz low-frequency vibration with 6 cylinders. Swaying up and down vibration occurs at 5 to 10 Hz due to uneven combustion. The main cause of swaying up and down vibration is engine roll vibration.

4-3 Vibration characteristics of the suspension system

The vibration characteristics of the suspension system differ from static characteristics. Anti-vibration rubber largely relies on displacement and frequency, and has poor vibration transmission characteristics at the high frequencies and low displacement that become a problem with road noise. With coiled springs, a steep peak appears at high frequency and the spring constant becomes high. At the shock absorbers, the characteristics become nearly the same hysteresis dampening as the anti-vibration rubber.

The suspension system transmits various types of vibration, but the main ones are as follows.

(1) Both perpendicular and horizontal vibration are caused at the tires by uneven road surface.
(2) Torque fluctuation occurs during braking at the braking friction surfaces.
(3) Rotation vibration occurs due to static and dynamic unbalance at the rotating sections, from the engine to the tires.
(4) High-frequency vibration of 400 Hz to 1 kHz occurs during gear meshing in the transmission and differential.
(5) High-frequency vibration from 1 to several kHz is caused by self-induced vibration of braking friction surfaces.

4-4 Vibration characteristics of the steering system

Just as in the suspension system, most vibration affecting the steering system does not act directly on the steering system, but is amplified in the tires and suspension system. Other vibration phenomena include power steering vibration, kickback due to uneven road surface, and dynamic unbalance of rotating parts such as the wheels and the braking system.

(1) Low-speed shimmy*1 is generated by self-induced vibration accumulating within the steering system, and occurs at the low vehicle speeds of 20 to 60 kilometers per hour. Displacement is large, and the shimmy has a greater tendency to occur in worn tires or tires with low air pressure.
(2) High-speed shimmy*1 is mainly caused by static or dynamic unbalance of the tires on the wheels. Other causes include disk wheel eccentricity, the wheel not being vertically plumb, and non-uniformity*2 of the tires. Unbalance of the tires on the wheels causes peak vibration in the vicinity of 10 Hz to 30 Hz. Displacement is small, but with worn tires or low air pressure in the tires, displacement becomes large.

*1 Vibration in the direction the steering wheel turns caused by unbalance or non-uniformity in the front tires is called “shimmy”.
*2 Unevenness in tire weight, internal rigidity, or dimensions is called “non-uniformity”.

(3) Kickback occurs when driving on a bad road surface causes both vertical and horizontal vibration to the drive tires. That vibration is transmitted to the tie rods, causing the steering wheel to turn suddenly. This vibration occurs in the drive wheels on front-wheel-drive cars, giving a greater tendency for longitudinal changes in force than with rear-wheel-drive cars.

(4) Tire vibration factors seen from the characteristics of static springs, include vertical springs, lateral springs, longitudinal springs, and torsion springs. Longitudinal stiffness is strongly related to actual vibration, and becomes harder roughly in proportion to the increase in air pressure. Natural tire frequency results from the fact that an elastic body filled with air has an individual vibration mode. The natural frequency of radial tires is around 90, 110, 135, and 160 Hz, while that of bias tires is around 140 and 155 Hz.

We have looked at suspension and steering systems in regard to vehicle vibration characteristics affecting vehicle-mounted equipment. Fig. 2 shows related vehicle vibration and noise classified according to source input and source frequency.

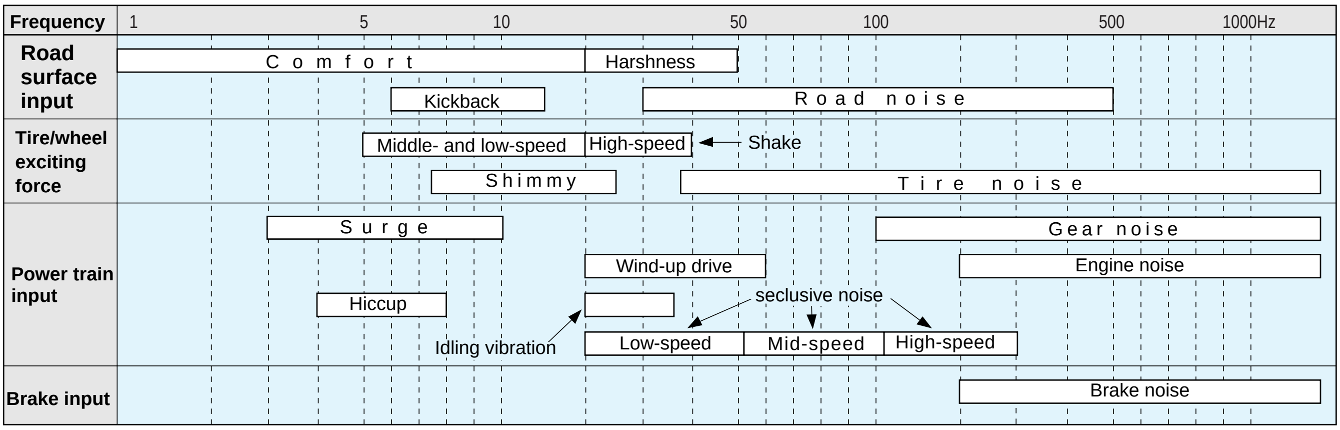


Fig. 2 Vibration sources and input to the suspension and steering systems

4-5 Elastic vibration and vibration noise of the vehicle body

Many types of vibration and noise can be sensed while driving. Vibration is transmitted to the passenger cabin from the controlling force generated by the engine drive and the power transmission equipment as well as vibration from the road surface while driving. Table 5 shows elastic vibration in the vehicle body and related vibration phenomena.

As we have seen, body vibration is related to many types of vibration and noise. Propelled by the movement for safer and lighter vehicles that can be recycled, developmental research for new synthetic materials and body construction is flourishing.

Table 5 Elastic vibration and vibration noise in the vehicle body

Vibration and noise phenomena	Elastic vibration in the body	Related vibration phenomena
Shake (front)	Body primary flexural resonance (5 – 30 Hz)	Rigid body vibration in the engine suspension system, front spring compression resonance, steering system vibration
Shake (lateral)	Body construction primary torsional resonance (30 – 50 Hz)	Tram road resonance of the rear chassis, lateral seat vibration
Idling vibration	Body construction primary torsional resonance (30 – 50 Hz)	Rigid body vibration in the engine suspension system, vibration in the exhaust pipe system
Hiccup vibration	Frame construction primary flexural resonance (– 10 Hz)	Torsional primary vibration in the drive system
Acceleration/ deceleration vibration	Body primary torsional resonance (5 – 30 Hz)	Rigid body vibration in the engine suspension system, primary and secondary vibration in the drive system
Low-speed seclusive noise	Passenger cabin floor body resonance (30 – 50 Hz)	Rear suspension wind-up resonance, pillar of air resonance
Mid-speed seclusive noise	Panel sectional vibration (50 – 100 Hz)	Elastic vibration in the rear suspension system, torsional fourth-level vibration in the drive system, pillar of air resonance
High-speed seclusive noise	Panel resonance (100 – 200 Hz)	Drive train vibration, pillar of air resonance
Road noise and harshness	Resonance from all of the above	Vibration in the tires and suspension system

4-6 Characteristics and nature of vibration and noise generated from the drive train

Table 6 shows the results of classifying vibration and noise in the drive train according to generating phenomena.

The sources of vibration include gear meshing, torque fluctuations due to angle, and unbalanced rotating parts in the power transmission system. The vibration wave pattern from the engine's dynamic unbalance and torque fluctuation due to operating conditions is classified as random wave, random on random, and sine on random. Testing vibration transmitted from the power transmission system requires a high-level vibration controller that can analyze and reproduce actual vehiclevibration.

Table 6 Phenomena generated by causes in the drive train and their characteristics

Vibration source	Phenomena generated	Frequency range
Engine torque fluctuations	Surge (vibration)	2 – 10 Hz
Clutch misalignment	Judder (vibration)	2 – 10 Hz
Driveshaft angle	Acceleration vibration (vibration)	10 – 20 Hz
Engine torque fluctuation	Wind-up (vibration, seclusive noise)	20 – 50 Hz
Unbalanced rotation	Wind-up (vibration, seclusive noise)	20 – 50 Hz
Engine torque fluctuation	Drive train torsion (seclusive noise)	50 – 80 Hz
Driveshaft angle	Drive train torsion (seclusive noise)	50 – 80 Hz
Engine complete rotation inertia	Power plant/driveshaft bending vibration (seclusive noise)	100 – 200 Hz
Hypoid gear meshing force	Power plant/driveshaft bending vibration (differential noise)	400 Hz – 2 kHz

5. Approach of combined testing for vehicle-mounted equipment

Reliability testing for vehicle parts and environmental endurance testing are fully considered and set according to the established JASO-D001 "General rules of environmental testing methods for automotive electronic equipment" of the Japanese Automobile Standards Organization. However, the diverse environmental conditions in which vehicle-mounted equipment is used, as represented by the recent boom in RV's and minivans, has brought a corresponding increase in the types of vehicles introduced to meet the many different user purposes, and so when the identical part is installed at a different location, operating conditions can undergo major changes.

Lately, the Environment Simulation Test (EST) has become more widely used. The EST uses MIL and IEC standards as references. Increasingly, combined environmental testing is being used to determine reliability and endurance of vehicle-mounted parts as well as to evaluate the parts. Combined environmental testing considers the effects of the temperature and humidity environments of the individual vehicle-mounted parts as well as the vibration and vibration characteristics of the vehicle type and the driving conditions.

5-1 Vibration excitation wave form of combined environmental testing

Below is a classification of vibration wave forms, which are necessary for reproducing and evaluating actual driving conditions. The vibration machine generally used is the electrodynamic single axis air-cooled type.

Excitation wave form

- Sine wave
  - Fixed frequency sine wave
  - Slow sweep frequency sine wave
  - Step sweep frequency sine wave
- Wide band wave
  - Steady wave
    - Random wave
    - Sine on random wave
    - Random on random wave
  - Non-steady wave
    - Classical shock
    - Shock on random wave
    - Shock response spectrum
    - Actual driving wave form

In evaluating excitation wave forms, sine waves have greater excitation energy, while random waves, if they are made in a qualified power spectrum, are closer to the usage environment. Control is usually achieved through digital control diffusion, permitting easy testing of sine, random, and shock waves. Usually, in slow sweep frequency sine waves, the acceleration level is fixed for the vibration frequency range and the frequency axis, and there are a number of patterns with two or three phase values changed. Fixed frequency sine waves are used for resonance point endurance testing, and random wave testing is beginning to be used for parts directly affected by engine vibrations and vibrations from the road surface when driving.

More recently, testing is changing from using single direction vibrations to three-way vibrations (vertical, longitudinal, and lateral), with a three axis vibration shaker sometimes being used. In reproducible evaluation testing for sound disruption of vehicle-mounted audio equipment, the simultaneous three axis vibration shaker is said to be effective in reproducing actual driving vibration wave patterns.

5-2 Representative examples of combined environmental testing

5-2-1 Random wave test conditions

Findings on vibrations induced at the installation site have shown that they are different from the three way total m/s^{2}rms value, they require vertical and horizontal testing, and they vary with different vehicle types. Combined testing is possible through simultaneously adding temperature and humidity conditions to these vibration test conditions.

Table 7 Representative examples of random wave testing

Vehicle type		Installation site	Vibration direction	Total value	Vibration frequency
12 V systems	**All**	Dash panel, floor, center console	Vertical Lateral Longitudinal	31.9 m/s^{2}rms 27.4 m/s^{2}rms 26.8 m/s^{2}rms	15 – 500 Hz
24 V systems	**All**	Dash panel, floor, center console	Vertical Lateral Longitudinal	21.5 m/s^{2}rms 6.5 m/s^{2}rms 15.9 m/s^{2}rms	

Testing time: 2h

5-2-2 Sine wave test conditions

Table 8 Representative examples of sine wave testing

	Vibration frequency	Cycle	Vibration acceler-ation	Vibration direction and time
12 V systems	15–60 Hz	20 min.	43.2 m/s^2	Vertical, 4 h Lateral, 2 h Longitudinal, 2 h
24 V systems	33 Hz	—	66.7 m/s^2 (3 mm)	Same as 12 V systems

All without current

Table 8 shows generally used official test patterns as vibration test conditions for spring expansion. In more recent vibration generating machines, the use of a longer stroke (100 mmp-p) and switching amps has increased the maximum vibration speed (200 cm/sec), making 43.15 m/s^2 (79 mmp-p) possible at 5 Hz, and testing has become possible at near the body resonance point. Combined environmental testing can be performed by simultaneously adding temperature and humidity conditions from both inside and outside the passenger cabin to these vibration conditions.

5-2-3 Combined test cycle

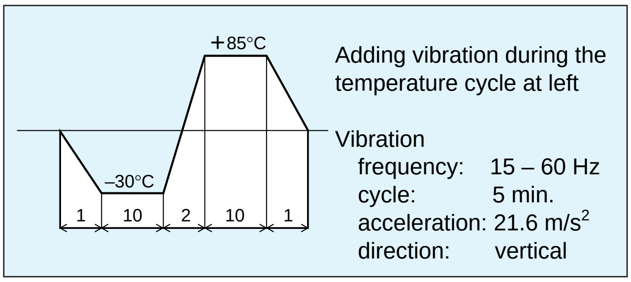


Fig. 3 Representative example of combined testing

Fig. 3 is a cyclic test that can be applied to test patterns for combined testing such as that used to test front panel displays and car navigation LCD displays used inside the passenger cabin. Combined testing of the air bag assembly unit inside the steering wheel and the front passenger side air bag unit adds RT (23°C) to longitudinal and lateral vibration testing. Vibration frequency is widened in the 5 to 100 Hz range, and the acceleration value is changed in each direction of vibration. In this way, for evaluation testing of vehicle-mounted equipment for new cars coming onto the market, by using the differences in vibration and vibration transmission characteristics during driving, combined testing is being performed simultaneously for vibration and temperature for equipment in three way installation conditions.

5-3 Degradation testing and accelerated stress testing at actual conditions of equipment mounted inside the passenger cabin

Reliability testing and endurance evaluation testing of electronic equipment for automobiles require long testing times. While maintaining conformity for developing electronic parts and developing vehicles for use in diverse areas, reducing testing time is vital, and means are being sought for accelerating stress testing. Accelerated stress testing consists of applying more severe stress than the conditions in the usage environment or than the maximum rating. This test combines two or more environmental factors and accelerates physical degradation in a short time to efficiently estimate the life of parts and products.

The specifics I would like to present here are the published results of collecting and investigating electronic equipment that was mounted on vehicles that had been scrapped by major domestic vehicle manufacturers. This report evaluates the life of the valuable solder joints.

(1) None of the electronic equipment had any problems at all with electrical contact, but visible cracking had occurred in the vicinity of the lead pin in one section, and the fracturing was a model of granulated thermal fatigue fracture.
(2) Areas with cracking were limited to those in close proximity to the lead pin and soldered fillet sections around substrate holes.
(3) Areas with cracking were not the result of peeling off from the lead pin interface, but rather occurred within the solder itself.
(4) To hypothesize the mechanism of degradation, stress is repeatedly applied to the soldered joints, tin (Sn) spreading occurs, and progressive roughening occurs in the α layer, with minute airholes developing in the crystal grain boundary in the interface between the Pb-rich α layer and the Sn-rich β layer, causing a decline in destructive stress.

From the details obtained from the above investigation, a field model type was used to measure life under actual conditions of use, and a method of evaluating the soldered joint life of vehicle-mounted electronic equipment was published. In the future, we anticipate promoting testing of single assembled parts due to the necessity of accelerated life testing stemming from the demand for reducing development lead time.

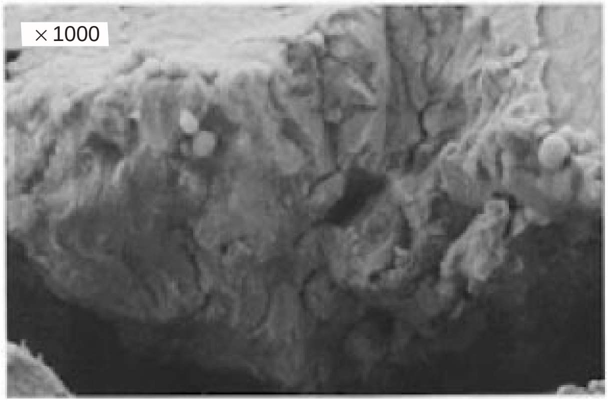


Photo 1 Cracking fracture

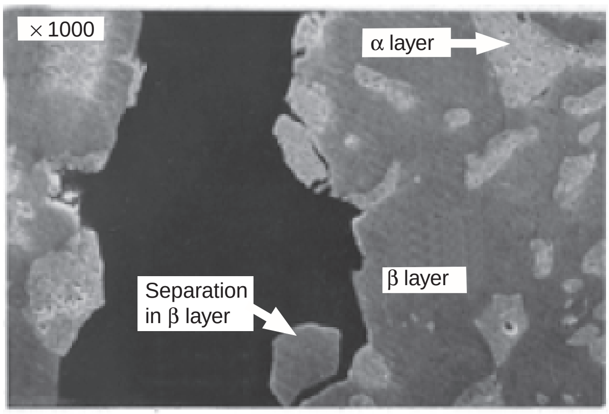


Photo 2 Magnified cross-section of cracking section

5-4 Test results at the vehicle test site and defect results in the market

In addition to environmental simulation testing indoors using combined environmental testing equipment, each manufacturer road tests vehicles for evaluation by actually driving them on a test course at the test site.

At this point, I would like to present examples comparing the results at the testing site with the actual failure rates in the market.

Fig. 4 shows a comparison of the defect rate in the market and the defect rate due to driving on bad roads at the test site. The failure rate in the body and steering systems is higher at the test site than in the market, but the failure rate for the engine, brakes, transmission, and electrical systems is much higher in the market than at the test site. Each test requires further analysis of the failure details.

Fig. 5 shows an example of looking for the correlation between the failure data in the market and the endurance test results at the test site. There is a uniform relationship between the failure rate and driving distance at the test site from 2700 miles to 30,000 miles, but in the market the relationship between the failure rate and the driving distance from 5,000 miles to 18,000 miles is lower than that at the test site, while above 20,000 miles it is higher. This seems to show that the endurance test methods at the test site require further study.

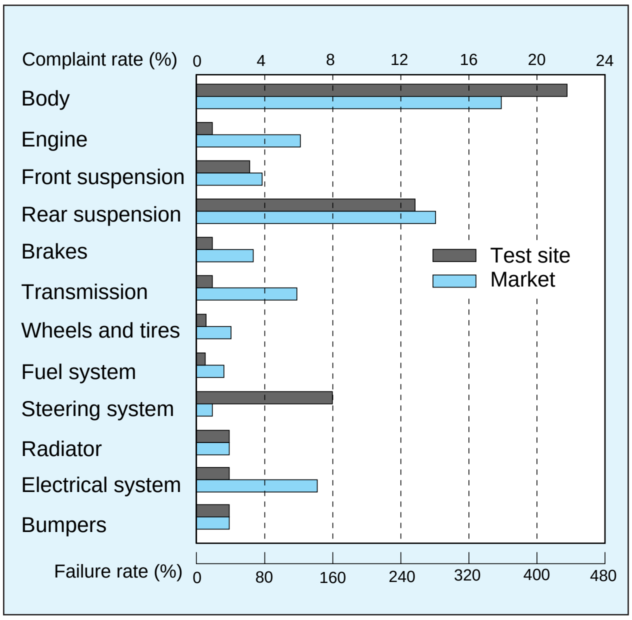


Fig. 4 Comparison of defect rates in the market and defects rates in bad road driving at the test site

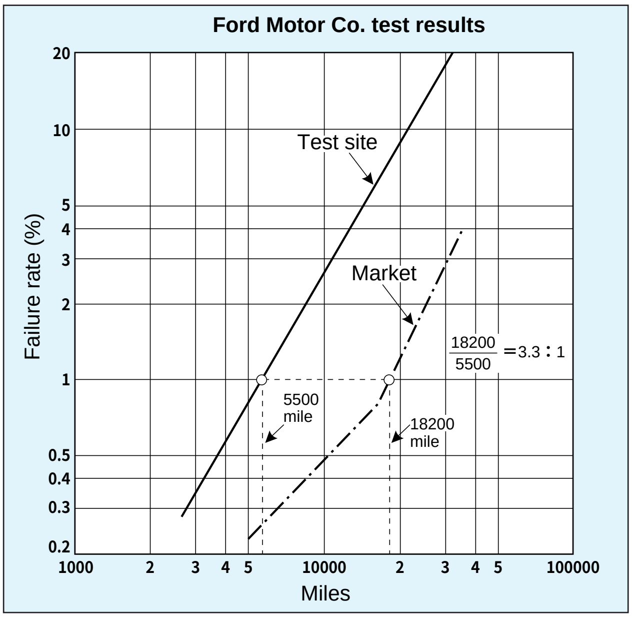


Fig. 5 Correlation between market failure data and endurance test results at the test site

6. In conclusion

In this article, I have discussed temperature and humidity conditions applicable to combined environmental testing for vehicle-mounted equipment and examined driving vibration and vibration characteristics. I have also presented test examples and discussed the most recent trends in testing.

Vehicle-mounted equipment now coming onto the market is facing demands for accelerated evaluation testing, including product life-cycle testing, to shorten the time period between the development and the marketing of a product. Both the past field data and the current evaluation data are used to carry out logical evaluation tests. However, to reproduce the defects that occur in the market, combined tests need to be based more closely on the types of applications for which the products are used.

Joining the combined test chamber with a single-axis vibration shaker makes it possible to create more test systems according to individual applications, but this does not completely satisfy the need for reproducing field data.

Advances in digital controllers have made it possible to reproduce a variety of unidirectional single-axis vibration wave forms on the vibration table, but the three axis vibration method comes much closer to reproducing the usage conditions in the field.

Progress has brought continued improvements in three axis vibration test equipment, and systems newly introduced to the market are now capable of reproducing the range of vibration frequencies to which vehicle-mounted equipment is subjected. However, a number of problems remain that need to be addressed to perfect combined three-axis vibration test systems.

Those problems include:

(1) Maintaining the moving construction for the vibration table inside the test chamber without three way restraint while attaining a perfect seal at the junction between the vibration shaker and the test chamber.

(2) Improving the work of placing and removing specimens on the vibration table in the test chamber in the limited amount of space and operating surface.

If the environmental test equipment manufacturers can solve the above problems in relation to combined multi-axis vibration tests while maintaining the performance of the single axis combined test, they will be able to introduce a combined three axis tester on the combined test market by combining temperature and humidity with three way vibration. This delivers new prospects for combined environmental testing.

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Wafer burn-in system

Isao Yano*

*Wafer burn-in is attracting attention as the most effective measure for reducing burn-in*1 cost and obtaining KGD*2 (Known Good Die) in semiconductor production. In this article I would like to discuss the merits and major themes of wafer burn-in, and present the wafer burn-in system developed by Tabai Espec.*

1. Introduction

Nowadays, burn-in is crucial to semiconductor production, and to DRAM production in particular. However, as memory capacity increases, more time is required for burning in, and efforts are under way to achieve a means of reducing test costs.

Entering the multimedia era has created a need for products able to process large quantities of data at high speed, leading to increasing demand for bare die*3 mounting such as the MCM (Multi-Chip Module) and the COB (Chip on Board). Because of this, the supply of bare die with verified reliability known as KGD (Known Good Die) has become vital.

KGD technology is already in use in the pre-existing Die Level method, but that method requires a special socket for testing and needs to have cost problems resolved.

In answer to the anticipation for a means of solving these problems, I would like to present the Wafer Burn-in, a burn-in done at the wafer level.

2. The merits of Wafer Burn-in

Burn-in at the wafer level has a variety of merits besides assuring KGD. At this point, I would like to present four merits of wafer burn-in for DRAM.

(1) **Reduced burn-in time**

For increasingly large-capacity DRAM, a major theme for burn-in has become reducing burn-in time and lowering the cost of testing.

Currently, burn-in time is almost exclusively for assuring cell reliability. Two problems stemming from this increased capacity are: (1) the increase in the length of the cell refresh cycle brings a corresponding decrease in the efficiency of applying stress, and (2) there is a limit to the pressure rise of word line potential when applying stress voltage that makes adequate voltage acceleration for peripheral circuits impossible with PKG (package) burn-in.

With wafer burn-in, special burn-in circuits are built into the wafer to resolve these problems, and burn-in time can be reduced by efficiently driving these special circuits.

(2) **Appropriate for all types of DRAM**

Currently new DRAM such as SDRAM and MDRAM are continually being developed that are difficult to access with PKG burn-in. While these types of DRAM have different access methods, they retain the same cell structure.

When the burn-in is done at the wafer level, direct contact can be made with the special burn-in pad. In this way, regardless of the type of DRAM used, effective stress can easily be applied to the memory cell.

(3) **Applying heat stress more accurately**

The hot plate of a prober*4 can apply heat stress directly to the wafer. This makes it possible to reduce heating up time and to accurately control junction temperature.

(4) **Improving yields**

Wafer burn-in is used in IC production processes such as shown in Fig.1. Based on the defect report from the wafer tester following burn-in, it may possible to improve yields by such measures as replacing the redundancy memory of the defective cell. In addition, the feedback this report provides to the previous process can lead to improved reliability by initiating immediate improvement of the production process.

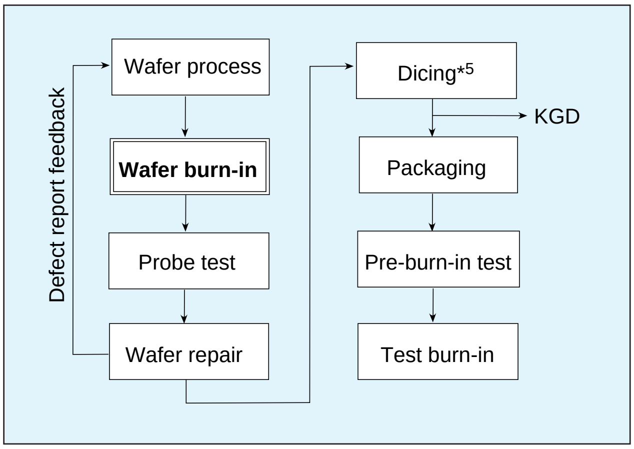

Fig. 1 IC production process

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3. Wafer burn-in problems

The merits of wafer burn-in are made available by solving the following two problems.

3-1 Achieving effective, economical burn-in circuits

Special burn-in circuits inside the wafer are required to apply efficient stress to the cell and to apply effective stress voltage to peripheral circuits. These circuits must make as little impact as possible with regard to die size and must be able to apply effective stress within a short time. Adding burn-in circuits without making special considerations can increase the cell surface area as much as five percent. The key to successful wafer burn-in is the ability to economically achieve effective burn-in circuits.

Proposals concerning these burn-in circuits are in the reference document[1)], and so I will present some reference circuits in Fig. 2.

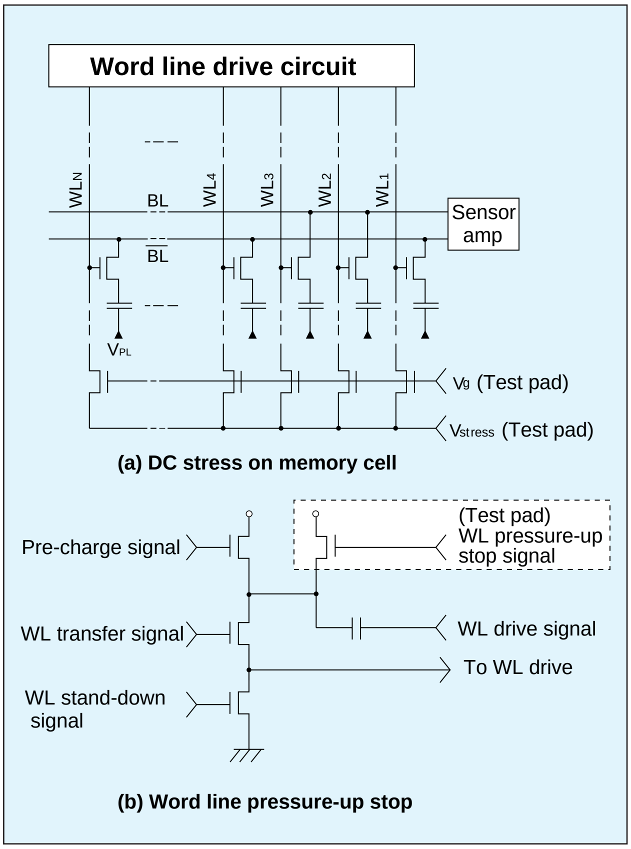


Fig. 2 Burn-in circuits

(1) **Applying DC stress to memory cells**

Transistors for applying stress are added to each word line and stress is directly applied to the word line from a special pad. In this way, stress can be applied without being affected by the refresh cycle.

(2) **Applying stress voltage to peripheral circuits**

When dynamic stress voltage is applied to peripheral circuits, word line pressuring up is stopped, and it becomes possible to apply high voltage stress to the peripheral circuits.

(3) **Automatic dynamic motion**

Designing circuits that automatically provide dynamic motion at peripheral circuits can make efficient burn-in possible.

This data is somewhat old, but it is reported that when giving these circuits to 4M DRAM, efficient burn-in can be achieved with DC stress applied for two minutes to the word line and dynamic stress applied for 3 minutes to the peripheral circuits.

3-2 Multi-probe card*6 reliability and economical operation

To reduce burn-in time, the ability to apply stress simultaneously to a number of die is vital. To do so, many have called for putting a large number of pins on the probe card. With a large number of pins, the key is how to achieve reliable and economical operation in spite of such problems as pin life, pin maintenance, getting the pins and the pads aligned, and pin misalignment caused by thermal expansion of the pins during heat stress. The vertical needle type and the membrane type are currently receiving a lot of attention for handling large numbers of pins, and there is great anticipation that these technologies will be developed soon.

The membrane type has received a lot of attention as a means of handling larger numbers of pins and higher speeds, but at present the vertical needle type is more practical. The vertical needle VCPC developed by the Japan Electronic Materials Corporation makes grid arrangement possible, and the pins are shorter with less dispersion in length. Tabai Espec recommends this VCPC.

4. The true state of wafer burn-in systems

Semiconductor manufacturers are highly interested in wafer burn-in. In response to market demand, Tabai Espec has developed a DRAM wafer burn-in system which we are now supplying to several manufacturers for evaluation. These systems were developed through technological cooperation and use a prober from Tokyo Seimitsu Co. Ltd., and a multi-probe card from Japan Electronic Materials Corporation.

The Tabai Espec wafer burn-in systems are crafted with care, from the system controllers, test heads, and full auto probers, to the design avoiding the necessity of taking up installation space in an expensive clean room. Connections for the test heads and multi-probe cards are made through insert ring pogo pins, providing a design in which reliable connections are made even with test heads opening and closing.

Photo 1 shows a wafer burn-in system, Table 1 gives the system specifications, and Fig. 3 shows a system block diagram.

Photo 1 Wafer burn-in system

Table 1 Wafer burn-in system specifications (WBD-02)

	(1) Prober **(2) Handling capacity** **(3) Mask functions for each die** **(4) Test temperature range**	UF200 (Tokyo Seimitsu Co. Ltd.) [Or, Tokyo Electron Limited (p-8).] 64 die simultaneous probing (maximum) Fail indication die interrupts power and clock. 50 to 130°C
Die power	**(1) Number of power sources** **(2) Voltage range** **(3) Power capacity** **(4) Protection functions**	1 2 to 7 V 150 mA/die OVP, OCP detection
Timing occurrence	**(1) Cycle Time** **(2) Resolution** **(3) Number of clocks** **(4) RTTC**	100 nS to 10 µS 10 nS 8 15
Clock driver	**(1) Number of clocks** **(2) VIH** **(3) VIL** **(4) Tr/Tf** **(5) Clock monitoring functions** **(6) Contact check functions**	8 ch/die 2 to 7 V, can be set for each clock 0 to 4 V, –2 to 0 V (CLK6), can be set for each clock 30nS/5V/50pF, 200µS/5V/2µF Window comparater Handles full clock
Measuring functions	**(1) V1 Supply amperage** **(2) Contact check pressure**	Measurement range, 0 to 250 mA Measurement range, 0 to –2 V
Dimensions	**(1) Size (mm)** **(2) Weight**	2344 (W) × 1416 (D) × 1834 (H) Approx. 950 kg

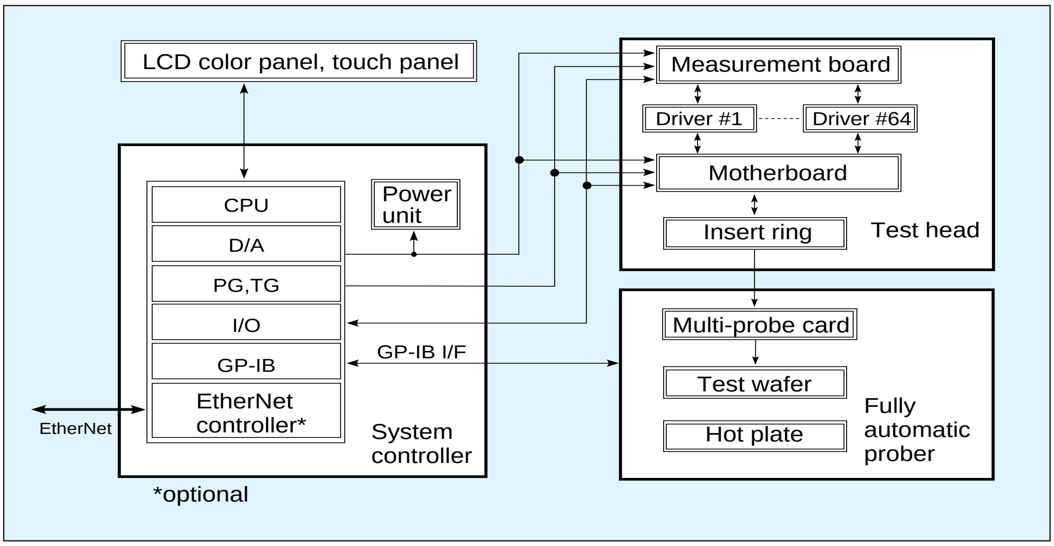


Fig. 3 System block diagram

This system boasts the following features.

(1) **Capacity for simultaneous burn-in of 64 die**

Contact can be made with 64 die at once for burn-in, so a typical 8-inch wafer can be completely tested with only 6 scans, providing high-speed management.

(2) **8-Channel clock driver**

An 8-channel clock driver provides burn-in control for high-capacity DRAM. This driver provides fine control through the ability to individually set VIH and VIL. The driver also provides the capacity to drive a 2µF load at 200µS Tr/Tf.

This equipment also gives the ability to add super drivers that can driver high-capacity loads such as word line.

(3) **Capacity for contact checking**

The clock driver prober can automatically determine whether proper contact is made with the wafer pad. This solves the problem of burn-in not being made due to defective contact.

As shown in Fig. 4, proper contact can be determined if Vf voltage can be detected within normal range when constant current incidentally generated by the diode is applied to the signal input pad.

The unit determines a short in the input pad when 0 V is detected, and determines that a circuit is open in the input pad when limit voltage is detected.

Multiple pads are generally used for power application pads and grand pads, so contact checking such as that used for signal pads cannot be used. Because of this, determination of proper contact is made when the power source is measured and found to be within the expected range. If the value is outside the expected range, defective contact (including test device problems) is determined.

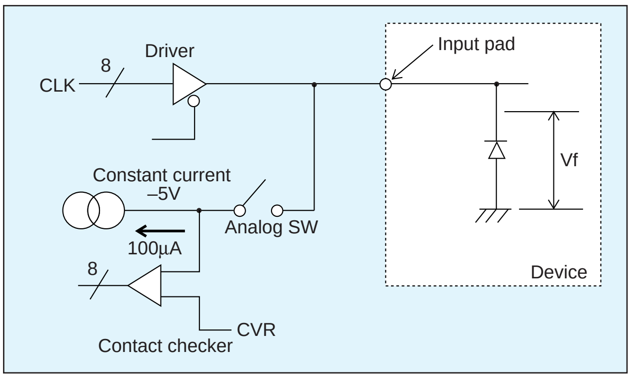


Fig. 4 Contact checking circuit

(4) **Mask functions for each die**

This system drives each die individually using 64 driver substrates. This provides individual control of each die.

When defective contact and abnormal current are detected, the die in which they are detected is not tested.

During the test, the system routinely for each die performs voltage OVP and source current OCP, and monitors the clock with the window comparator. If an error is detected, the hardware control immediately interrupts the current and the clock for that die only. As seen in Fig. 5, in a power line interrupt, the grand line can also be cut off by the relay.

This function prevents the defective die from affecting the normal die, and at the same time works to protect the system.

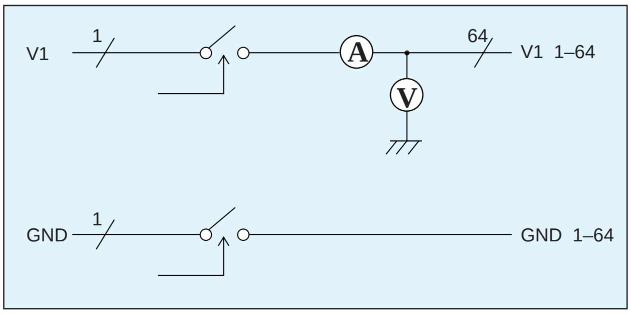


Fig. 5 Power circuits

(5) **Fail data indicator function**

As seen in Fig. 6, abnormal source current of OCP and OVP, defective contact, and clock monitoring failure can be displayed as bit information in the indicated shape of the wafer map. In this way, a defective die on the wafer can easily be recognized.

As Fig. 7 shows, the values for the measured source current can be displayed in the indicated shape of the wafer map.

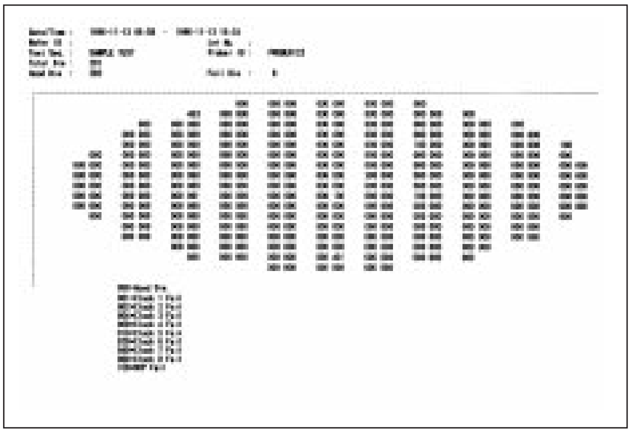


Fig. 6 Fail indication

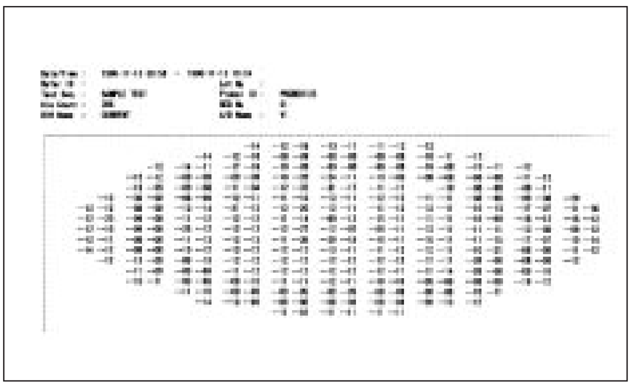


Fig. 7 Source cirrent indication

(6) **Testing based on test sequence**

As Fig.8 shows, burn-in can be carried out based on test sequence, in the form Test 1 to Test n. Sequences such as DC stress and dynamic testing can be carried out automatically for a fixed number of tests or for a specified time period. Fig. 9 shows a sequence setting screen.

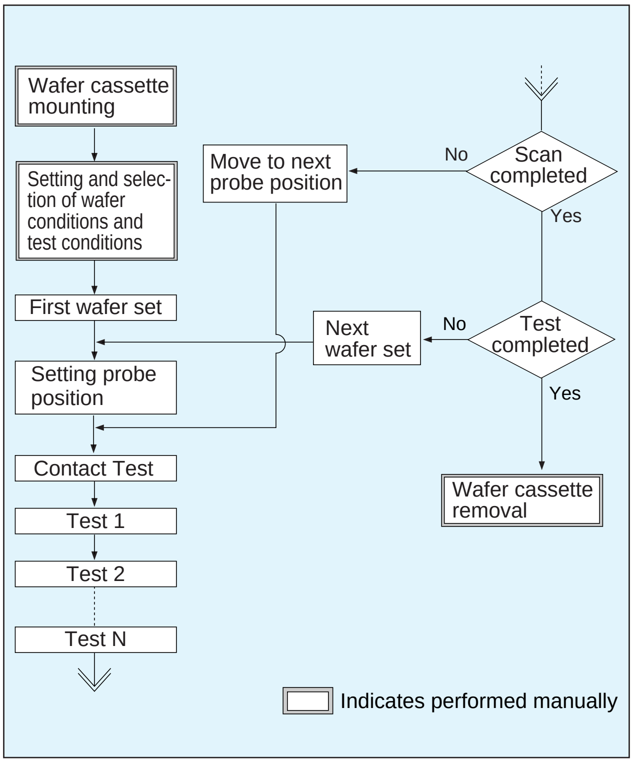
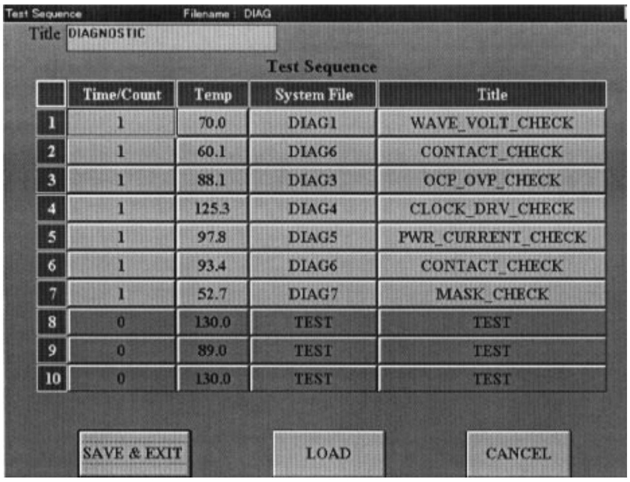


Fig. 8 Test sequence



Test Sequence　Filename : DIAG

Title DIAGNOSTIC

Test Sequence

	Time/Count	Temp	System File	Title
1	1	70.0	DIAG1	WAVE_VOLT_CHECK
2	1	60.1	DIAG6	CONTACT_CHECK
3	1	88.1	DIAG3	OCP_OVP_CHECK
4	1	125.3	DIAG4	CLOCK_DRV_CHECK
5	1	97.8	DIAG5	PWR_CURRENT_CHECK
6	1	93.4	DIAG6	CONTACT_CHECK
7	1	52.7	DIAG7	MASK_CHECK
8	0	130.0	TEST	TEST
9	0	89.0	TEST	TEST
10	0	130.0	TEST	TEST

SAVE & EXIT　LOAD　CANCEL

Fig. 9 Test sequence setting screen

(7) **Ease of operation using a touch panel**

Photo 2 shows a touch panel. The color LCD display sports a touch panel using the dialog method and the menu method for ease of operation. The control software runs as a Windows* application.

(*Windows is a registered trademark of the Microsoft Corporation.)

Photo 2 Touch panel

5. Outlook for wafer burn-in

5-1 Simultaneous burn-in

The wafer burn-in system introduced above can simultaneously burn in 64 die, and so requires 6 scans for an 8-inch wafer. Ideally, simultaneously burning in the entire wafer at once would cut burn-in time dramatically and reduce the cost of testing.

A lot of suggestions have been made for various multi-probe cards to provide simultaneous contact, but at this point reliability and cost prevent them from being practical.

I believe that when these problems are solved, we will be able to provide a low-cost system that can simultaneously burn in the entire wafer.

5-2 Burning in various IC

This system is manufactured primarily for DRAM use. In the future, we plan to offer systems that handle many kinds of burn-in, including many types of memory such as SRAM and flash memory as well as various logic types such as ASIC and MPU.

5-3 Test burn-in

Test burn-in can be considered as the next step after dynamic burn-in. There is great demand for a low-cost test burn-in system that can achieve burn-in and function testing rather than high-performance, high-functionality, high-price wafer testers. The key to replacing the wafer tester is the ability to supply a system at low cost.

6. Summary

Burn-in at the wafer level is a new method rather than an established technology. However, it can be considered to be an effective approach to handle the supply of KGD and burn-in cost reduction.

The systems offered by Tabai Espec have been developed for evaluation as wafer burn-in systems. In the future, we would like to receive advice from all quarters so that we can strive for improvements to contribute to the establishment of test technology that achieves wafer burn-in on a practical level.

At any rate, the mutual cooperation and understanding of semiconductor manufacturers and equipment manufacturers is vital to the establishment of test technology using these systems.

Terminology

*1 **Burn-in**

Burn-in is generally used to mean exposing parts and equipment to temperatures and voltage that are higher than found in normal use.

The purpose is to immediately remove defects caused by the production process. However, with burn-in equipment, semiconductors are subjected to temperature and voltage stress during use in the field, accelerating defects. After that, products are tested with testers that measure electrical characteristics to remove defective products.

*2 **KGD** (Known Good Die)

A good bare chip that fulfills specifications. To improve the ratio of good MCM (Multi-Chip Modules), KGD must be mounted.

*3 **Bare die** (bare chip)

A bare chip that only cuts out wafers

*4 **Prober**

For mass production lines, fully automatic probers are used. These devices automatically perform the following series of movements with wafers: loading → auto alignment → auto probing → wafer unloading. Temperatures stress can be applied to the wafer using a hot plate. Devices capable of applying 180°C have been developed to handle the demand for high-temperature burn-in. In December 1997, a prober capable of handling 12-inch wafers was introduced at SEMICON JAPAN.

There is hope that if simultaneous burn-in can be achieved, the resulting simplification of the auto alignment function will bring costs down.

*5 **Dicing**

Cutting to divide the wafer into individual die.

*6 **Multi-probe card**

Inserting multiple probes into a substrate to apply power and test signals to the wafer pad.

Wafer probe cards can be divided into two major classifications: needle types and membrane types. The needle types can be further divided based on the shape of the pins into vertical needle types and horizontal needle types.

Multi-probe cards are quite expensive, and require maintenance, as they wear out.

Supplementary explanation of multi-probe cards

Here, I would like to introduce the vertical contact multi-probe card (VCPC) offered by Japan Electronic Materials Corporation.

1. Purpose of VCPC development

1) Handling diverse bonding pad layouts
- Handling diverse numbers of DUT and diverse DUT layouts in simultaneously measuring multiple memory modules.
- Handling diverse layouts of logic device bonding pads.

2) Create probe cards with short probes that can improve high-frequency characteristics
- Create the capacity for wafer tests of devices with actuating frequencies of 200 MHz.

In applying wafer testing to memory devices, emphasis is generally placed on increasing the number of items simultaneously measured, and so development focuses on technology for handling large items and unrestricted DUT layouts. In applying wafer testing to logic devices, attention generally centers on performance of high-speed operation tests, and so development focuses on technology for shortening probes.

2. VCPC features

1) Contacts the bonding pad due to stress based on buckling of the vertical probe.
2) The needles are located using a specially designed locator guide.
3) Makes smaller and neater probe marks than the cantilever type probe card.
4) Needle tip is more stable.
5) Can contact the bonding pad with fixed contact pressure (needle pressure), regardless of the number or layout of probes.
6) Probe location is less restricted.
7) Compatible for use with cantilever probe cards.
8) The type with improved electrical characteristics has shorter probes, and is suitable for wafer tests of high-speed devices.

3. VCPC specification

Table 2 gives VCPC specifications, and Photo 3 shows a VCPC.

Table 2 VCPC (Vertical Contact Probe Card) specifications

1	**Needle position precision**	±10 μm
2	**Needle tip height dispersion**	maximum 20 μm
3	**Minimum pitch**	150 μm
4	**Probe materials**	Tungsten, Tungsten impregnated with Rhenium
5	**Probe diameter**	80 μm
6	**Total probe length (from substrate connection to needle tip)**	15 – 20mm
7	**Tip diameter**	20 – 30 μm
8	**Tip length**	400 – 500 μm
9	**Needle tip shape**	Ball shaped (point contact) Flat (surface contact)
10	**Slip (with 75 μm drive)**	0 – 10 μm
11	**Operational temperature range**	20 – 100°C
12	**Maximum needle region**	120 × 120 mm angular
13	**Maximum number of probes**	2000
14	**Needle pressure (with 50μm drive)**	10 – 20g
15	**Contact resistance**	Maximum 1Ω
16	**Maximum current**	250 mA
17	**Maximum voltage**	50 V
18	**Capacity (substrate – probe)**	20 pF (standard value)
19	**Capacity (probe only)**	3 pF (standard value)
20	**Inductance (substrate – probe)**	65 nH (standard value)
21	**Inductance (probe only)**	10 nH (standard value)

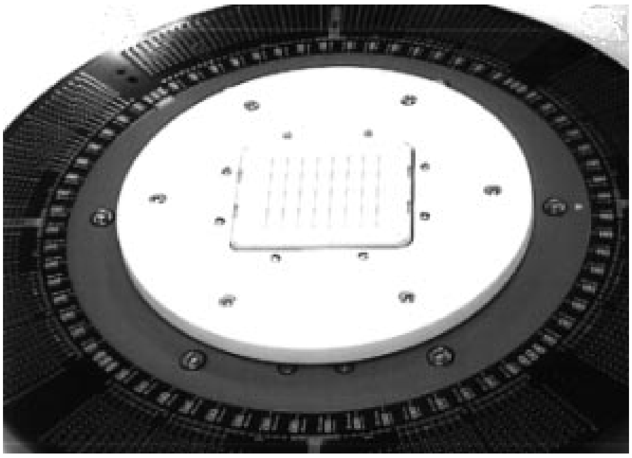


Photo 3 VCPC

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Topics

Introducing the automatic clean oven for LCD production

Yoshinori Kin*

1. Introduction

LCD panels have become quite popular these days for a variety of applications such as notebook computers and small TV screens. Behind the LCD popularity are a number of superb features such as low voltage drive, low power consumption, slim design and lightweight construction. As shown in Fig. 1, a number of ovens are used in the LCD panel production processes, including the color filter production process, the array process, and the panel assembly process.

Based on the high level of technology Tabai Espec has developed in manufacturing environmental testing equipment, we have achieved many solid results in developing ovens for LCD panel production processes.

At this time, I would like to introduce the features of ovens required by LCD panel production processes while presenting an outline of the equipment offered by Tabai Espec.

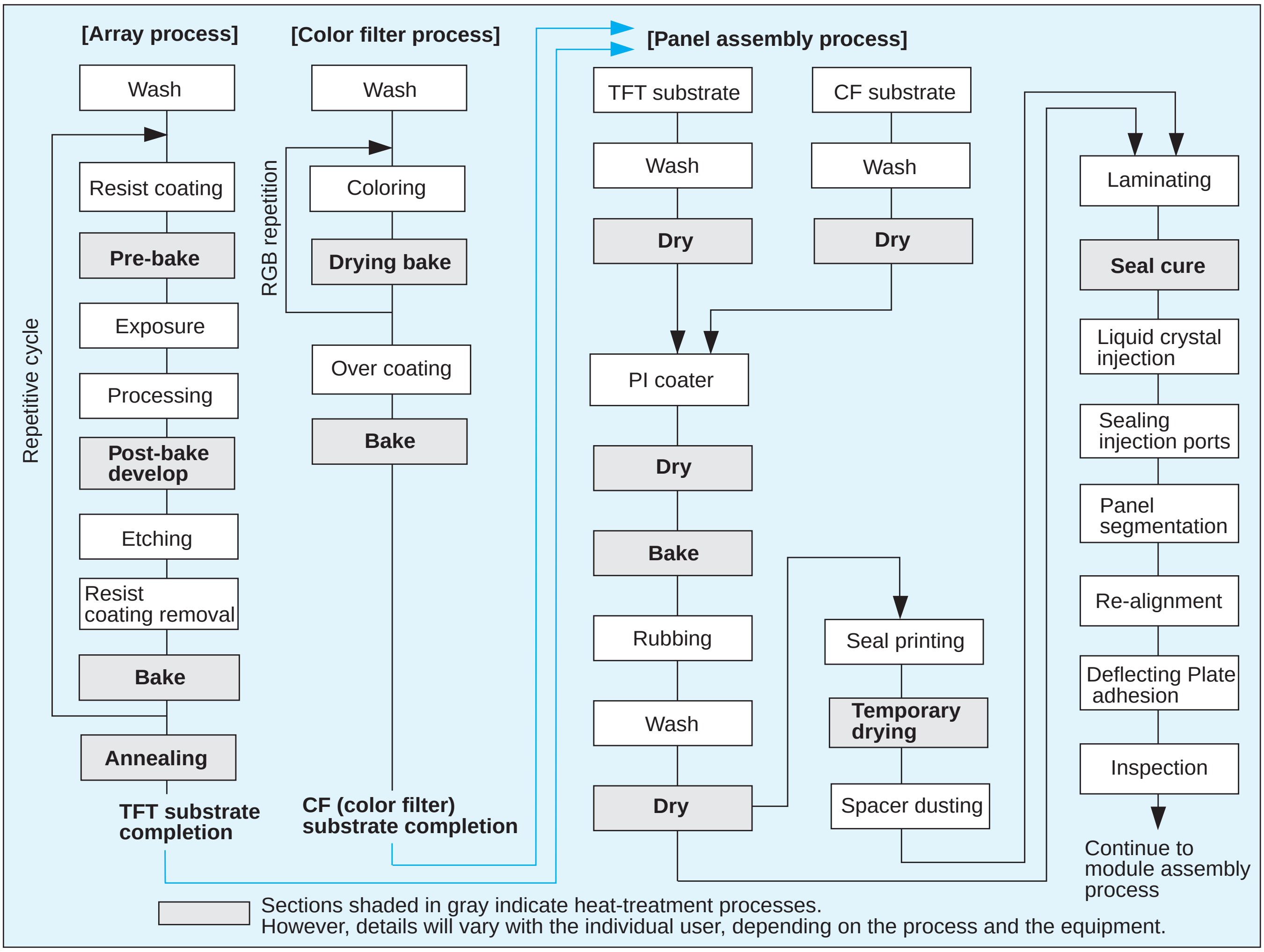

Fig. 1 Production processes of LCD panels

*Overseas Business Department

2. Features of ovens required by LCD panel production processes

Key features of ovens required by LCD panel production process are cleanliness, temperature uniformity, and glass supports for holding glass inside the oven.

2-1 Cleanliness

At this point, I would like to consider the filters used to maintain cleanliness inside the oven. The filter in general use is called the HEPA filter (High Efficiency Particulate Air Filter), which has a collection efficiency exceeding 99.97 percent for particles of 0.3µm. However, a normal HEPA filter emits a lot of particles from the filter itself due to temperature change, making it unsuitable for use inside ovens. Tabai has met this challenge by developing a special heat-resistant filter to suppress particulate emission from the filter during temperature change, and reducing harmful effects on glass.

Fig. 2 shows particulate emission during temperature change when using a normal HEPA filter, and Fig. 3 shows the emission when using the special heat-resistant filter. Tests were able to confirm a large quantity of particles emitted from a normal HEPA filter during a temperature change from high temperature to low temperature, but confirmed almost no particulate emission from the special heat-resistant filter.

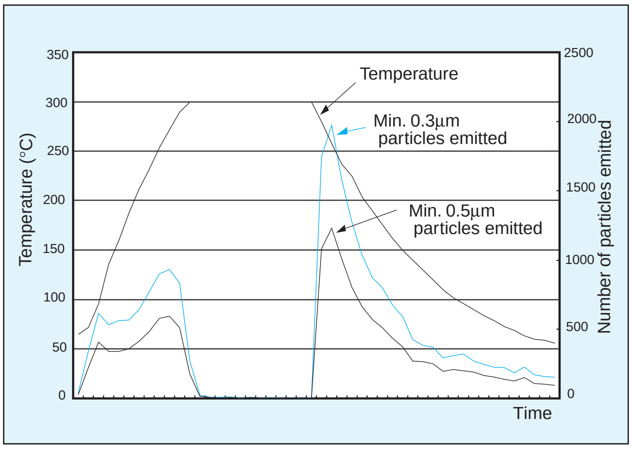

Fig. 2 Temperature change and particles emitted from a HEPA filter

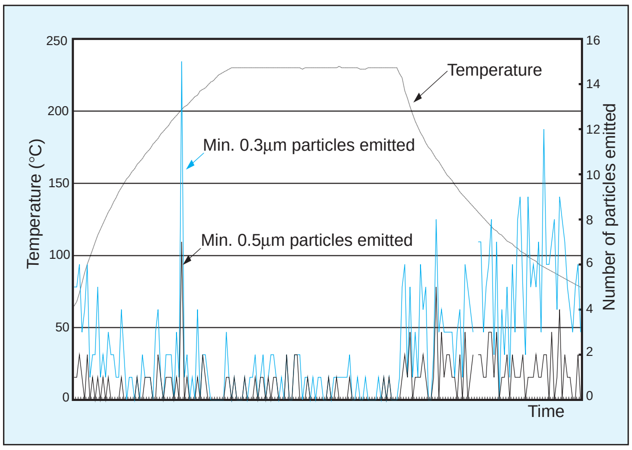

Fig. 3 Temperature change and particles emitted from the special filter

2-2 Temperature uniformity

Uneven temperature uniformity is linked to such problems as uneven color in the LCD panels, uneven brightness, and liquid leakage through defective seals, and so a high degree of precision in temperature uniformity is required within the ovens. With large glass surfaces, as well, an even temperature must be maintained across the entire surface.

With ovens using hot air circulation, temperature uniformity is closely connected to the quantity of air circulated. Temperature uniformity is also affected by such factors as the structure of the oven and the air velocity at the surface of the glass.

The following methods can be used to improve temperature uniformity.

- Increasing the amount of air circulated using fans
- Insuring an even air flow
- Increasing the wind velocity over glass surfaces
- Routing the circulation to reduce air resistance

However, selecting a fan that circulates a greater quantity of air can also cause problems. As seen in Table 1, the greater the wind velocity striking the filter, the greater the pressure on the filter, causing particles to be emitted from the filter as well as reducing the life of the filter.

Because of this, the filter used must have greater pressure resistance and less pressure loss.

Table 1 Comparison of surface wind velocity and heat resistance of different filters

	Rated surface wind velocity (m/sec.) at a pressure loss of 250 Pa (25.4 mmAq)	Heat resistance (at normal usage temperature) (°C)
HEPA filter	1.3	220
High temperature HEPA filter	0.36	350
Special heat-resistant filter (of Tabai Espec)	0.87	350

2-3 Glass supports

Specifications required for glass supports that come into direct contact with glass inside the oven are as follows.

- Must have high heat resistance.
- Must not scratch glass.
- Must have electrical conductivity to avoid charging the glass inside the oven.

Tabai Espec uses resins such as PI (polyimide).

3. Layout of the Tabai Espec oven and system

The Tabai Espec ovens used in LCD production processes can be broadly classified as either the “single loading plate processing” type or the “batch processing” type. The single loading plate processing ovens load and unload glass one sheet at a time, while the batch type ovens load and unload heat-resistant cassettes carrying the sheets of glass. The recent trend is to transport cassettes between several single loading plate processes rather than employing a single loading system between numerous continuous processes.

3-1 The single loading plate processing clean oven

Fig. 4 shows the construction of the Tabai Espec single loading plate processing oven. A gondola moves the glass up and down inside the oven, and the glass is loaded and unloaded through slits in the shutters built into the side of the oven. This gondola can hold 40 sheets of glass.

Main specifications

Takt time	Minimum 30 sec./sheet
Glass size	W 600 × L 720 mm (Max.)
Temperature range	+90 °C to +230 °C

Fig. 5 shows a single loading plate processing control system that uses the oven shown in Fig. 4.

This system has the following features.

- The glass is stacked vertically both in the oven and in the air-cooling stage, providing equipment with a smaller footprint.
- A modular design is incorporated for the oven, the robot, the air-cooling stage, the conveyor, and other sections, making it possible for the customer to put together a system layout based on individual needs.
- The oven can hold a maximum of 40 sheets of glass, but the number of sheets loaded in the oven can be changed to suit such needs as takt time and bake time.

This system performs the following movements.

(1) Glass is transported from the previous process loaded on a conveyor.
(2) The robot receives the glass.
(3) The robot corrects the alignment of the glass in the position received.
(4) The robot loads the glass in the oven.
(5) The glass is heat-treated inside the oven.
(6) After the heat-treatment is completed, the robot unloads the glass from the oven and then loads it into the air-cooling stage.
(7) The robot then loads the air-cooled glass onto an conveyor to the next process.

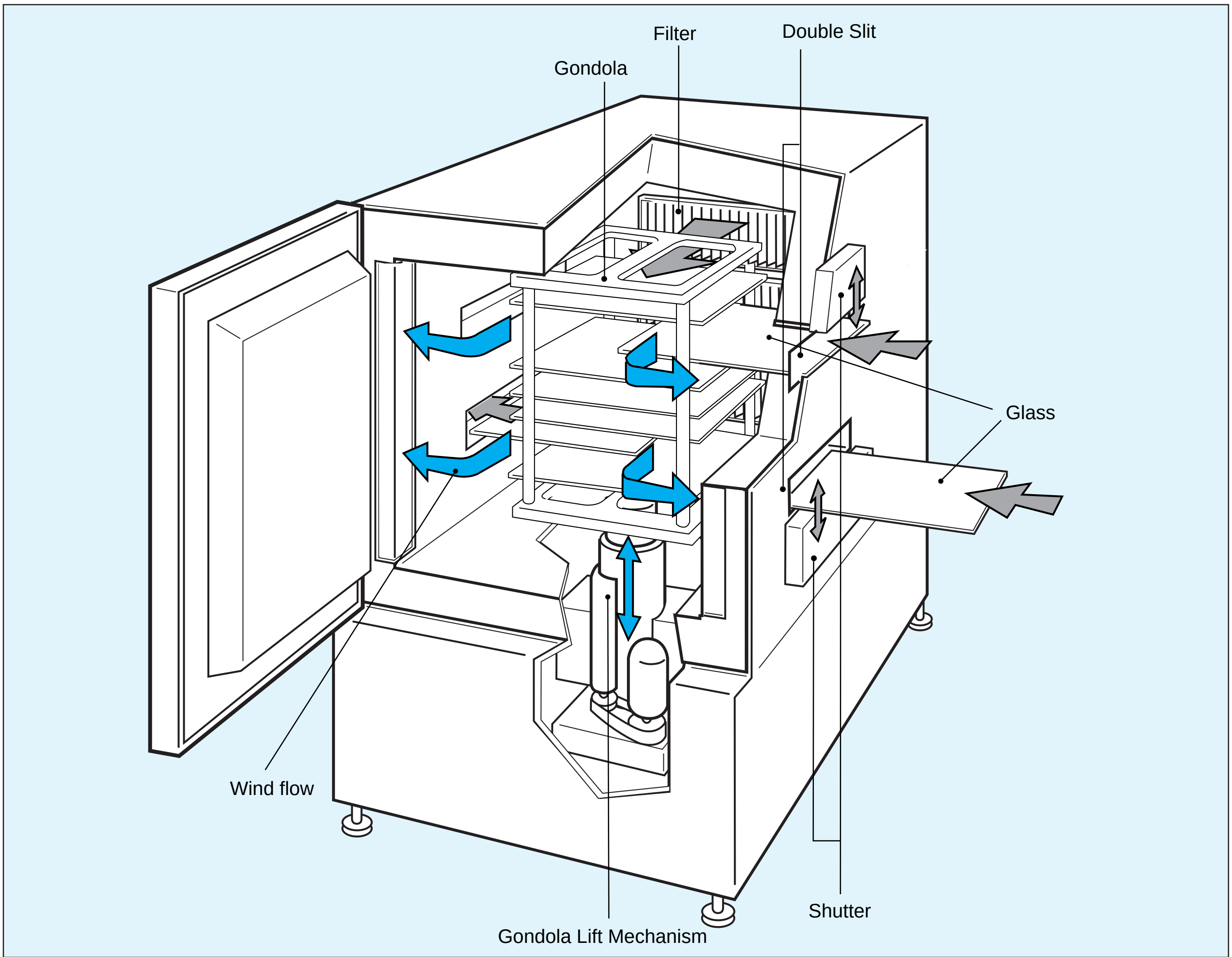

Fig. 4 Layout of single loading plate processing oven (Model HSC-4)

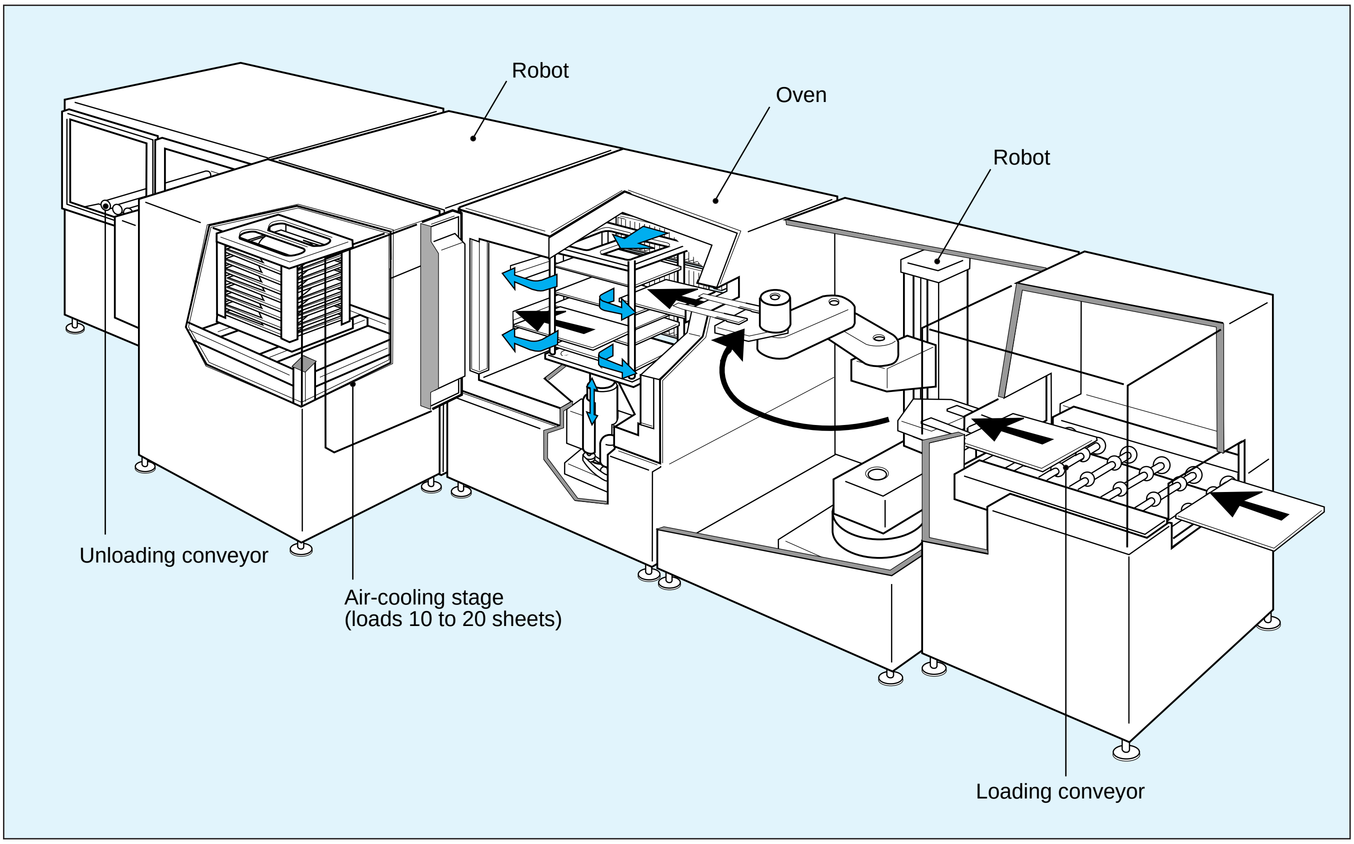

Fig. 5 System using single loading plate processing oven

3-2 Batch type oven with automatic doors

The batch type oven with an automatic door consists of a standard clean oven with automatic doors for loading and unloading cassettes.

To prevent oxidation of the glass during heat treatment, the oven is generally used with a non-oxidizing atmosphere created by introducing nitrogen gas.

Fig. 6 shows a batch processing oven system with automatic doors.

This system has the following features.

- A modular design is incorporated for the oven, the running robot, and the air-cooling stage, making it possible for the customer to put together a system layout based on individual needs.
- The number of ovens can be determined according to takt time and bake time.
- Heat treatment is possible in a non-oxidizing atmosphere.

This system performs the following movements.

(1) A heat-resistant cassette holding the glass is transported to the loader.

(2) A running robot loads the heat-resistant cassette into the oven.

(3) After the glass is loaded, the oven door closes and the oven heats up. (When using a non-oxidizing atmosphere, nitrogen gas is simultaneously introduced.)

(4) After the heat treatment is completed, the oven temperature is lowered, and the running clean robot transports the cassette to the unloader.

Main specifications

Takt time	Minimum 30 sec./sheet
Glass size	W 600 × L 720 mm (Max.)
Temperature range	+100 °C to +300 °C

4. Business trends

As cost competition becomes increasingly severe, LCD panel manufacturers are responding in the following ways.

- Using larger sizes of mother glass sheets and taking more panels from one sheet of glass.
- Reducing cost of equipment and materials.
- Improving yield.

4-1 Increased sizes of mother glass sheets

Mother glass sheet sizes have been increased from the initial 200 × 300 mm to 360 × 460 mm and again to 550 × 650 mm. Manufacturers are now calling for 1000 mm by 1000 mm.

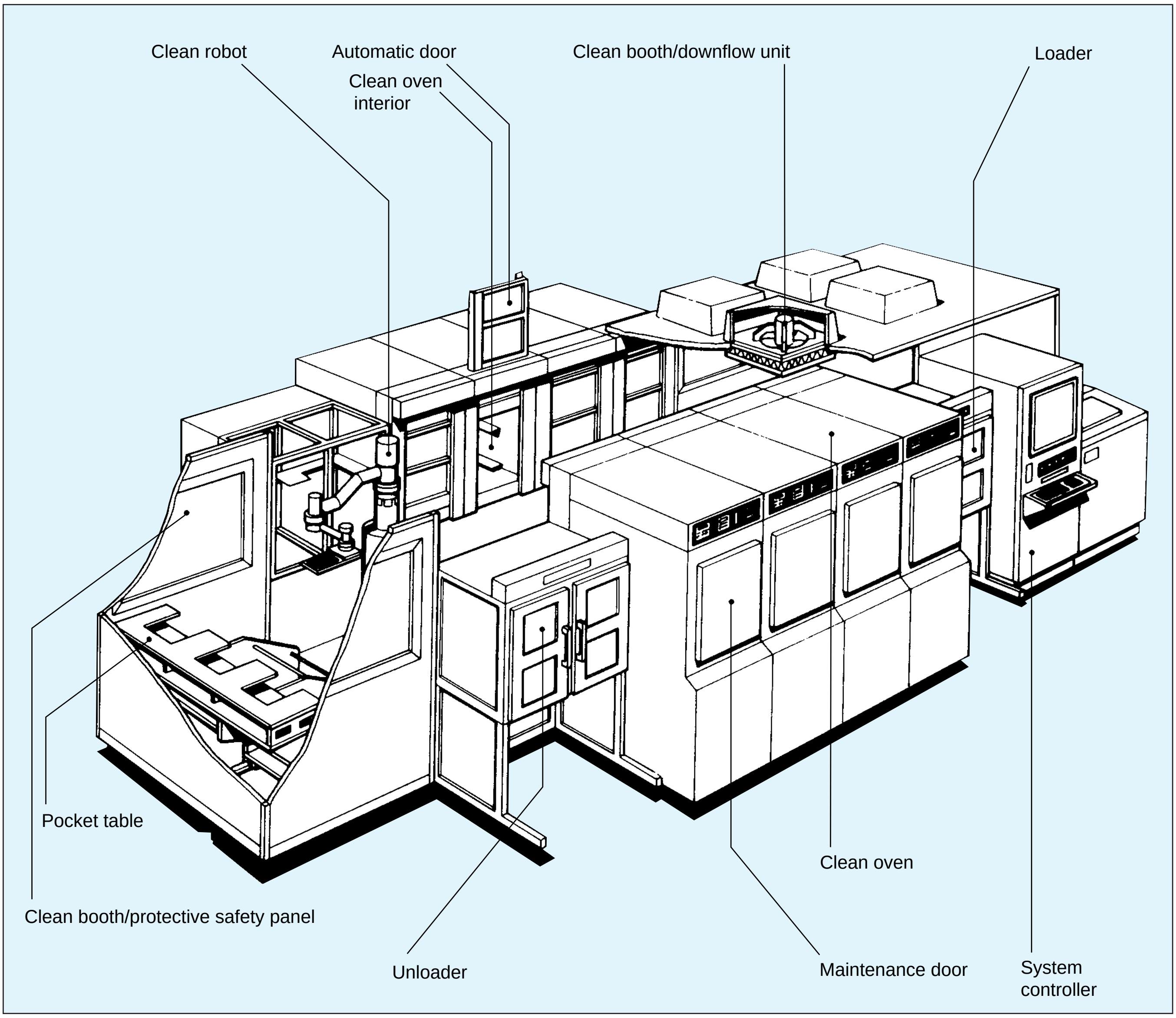

Fig. 6 System of a batch type clean oven

4-1-1 Improved temperature uniformity performance

The larger mother glass sheet sizes make it crucial to improve temperature uniformity inside the ovens. Not only does quality become a problem after completing heat treatment, but it also extends the total heat treatment time because of the increase in time required to eliminate the upwind/downwind temperature differential.

Larger mother glass sheet sizes require an oven with an air conditioning system that can reduce the upwind/downwind temperature differential during the temperature rise and temperature lowering periods.

4-1-2 Development of a clean robot system

With single loading plate processing ovens, increased glass panel sizes bring a corresponding increase in glass deflection, necessitating a greater glass pitch inside the ovens. If the vertical stroke of the robot can't be increased to handle the increase in pitch, the oven will be able to hold fewer glass sheets, resulting in a need to increase the number of ovens.

With batch type ovens, increased glass size brings a corresponding increase in cassette weight, causing problems with the conveyance weight capacity of the running robot.

Robots must be developed to meet the needs of both systems.

4-2 Reduced equipment cost

Commonly, the glass size of each LCD panel manufacturer differs by 5 to 30 mm.

If the glass sizes of the LCD panel manufacturers aren't uniform, the ovens and other equipment as well can't be standardized. This lack of standardization, has a major impact on cost and development time. Uniformity is needed in the LCD manufacturers' glass sizes.

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