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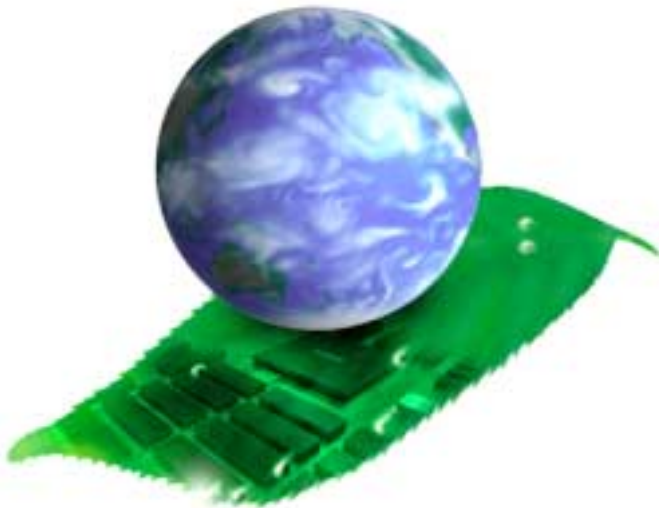
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Our Philosophy

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, 2000) |
| Chairman: | Eiichi Koyama |
| President: | Kiyoshi Shimazaki |
| Senior Managing Director: | Yoshinobu Yamada |
| Managing Directors: | Susumu Nojii Toshikazu Adachi Nobuyoshi Shin Shigemi Suzuki |
| Directors: | Eishiro Hizukuri Yoshio Nakai Hiromichi Fukumoto |
| Regular Auditor: | Katsuyuki Kakihara |
| Auditors: | Shoichiro Yoshioka Takuichi Omura |
| Employees: | 589 (plus 58 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)

Measurement Evaluation Systems

Ion Migration Evaluation System
PWB Conductor Resistance Evaluation System
Environmental Test Chamber Network, E-Bus

Burn-in Test Systems

Wafer Burn-in System
Dynamic/Monitored Burn-in System

Automated Production Equipment

Automatic Clean Cure System
High Speed Clean Oven for Glass Sheet

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.

Safety analysis methods and applications at the design stage of new product development —Introducing the FMFEA and S-H Matrix Method—

Hiroshi Wada*

Safety analysis requires a thoroughly methodical investigation—more so than even Reliability analysis. Such analysis must include the ability to deal with problems involving human error. This report will introduce the FMFEA (Failure Mode Factors and Effects Analysis) and the S-H (Software and Hardware) Matrix Method. These safety analysis methods serve as one part of the design review process in the design stage of new product development. Problem areas can only be discovered using analytical methods, but at the same time the approach must be efficient. This report will also include a review of the key application points for these methods.

1. Introduction

Product safety design is based on inherent design technology that starts from a consideration of reliability and progresses by applying reliability design methods.

When processes that can result in a lack of safety are spotted, a specific phenomenon (e.g., component failure or administrative or handling error) can usually be linked to personal injury through specific conditions or through a cause-effect relationship. Safety analysis methods must be able to follow these processes that create safety risks and determine in advance whether they will result in a lack of safety in product design.

First, we shall look at two safety analysis methods created by the author based on the widely used FMEA (Failure Mode and Effects Analysis) and FTA (Fault Tree Analysis). Specifically, we shall examine in detail the requirements for applying these analysis methods effectively.

2. Developing safety analysis methods

2-1 FMEA, FTA and ETA

FMEA and FTA are typical reliability analysis methods that are widely used. ETA (Event Tree Analysis) was developed in the US in 1974, and has since spread all around the globe, although this method is still not well known in Japan.

The FTA and ETA reliability analysis methods can be applied to safety analysis by limiting the phenomena to which they are applied. Table 1 shows a comparison of the features of these methods.

Table 1 Features of typical analysis methods

| Item | FMEA | FTA | ETA |
|----------------------------|-------------------------------------|------------------------------------|-------------------------------------|
| Purpose of analysis | Reliability | Reliability, Safety | Safety, Reliability |
| Starting point of analysis | Component failure mode | Product failure, Injury | Component failure mode |
| Direction of analysis | Components → Product (Bottom up) | Product → Components (Top down) | Components → Product (Bottom up) |
| Qualitative/Quantitative | Qualitative analysis | Both | Both |
| In advance/After the fact | Advance analysis | Both | Both |
| Printed form | FMEA table | FT diagram | ET diagram |

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2-2 Crucial elements in safety analysis

Safety analysis methods must possess the following three elements.

- (1) The ability to analyze even factors with scarce probability of occurrence
- (2) The ability to systematically develop complex failures and processes, not simply a single failure effect
- (3) The ability to illuminate the relationship between man and machine (e.g., misusing the product)

2-3 Designing safety analysis methods

FMEA analyzes failure of the relevant components that are selected according to the overall composition of the product, and so this method can be broadly applied. However, the method is not well-suited to investigating types of causes and effects systematically.

In contrast, FTA and ETA are much better at making systematic investigations. However, these methods suffer from a limited range of analysis.

Table 2 shows the strengths and weaknesses of each of these methods for safety analysis.

By judiciously combining these methods, we should be able to obtain a more satisfactory safety analysis method.

Table 2 Evaluation of adaptability for use as safety analysis methods

| Item | FMEA | FTA | ETA |
|---|---|---|--|
| Width of range | Applicable components selected from function block diagram ○ | Limited to top event (for analysis target) × | Limited to initial event (for analysis target) × |
| Ability to detect potential problems | Insufficient effects analysis (limited to single failure) △ | Cause analysis done logically and systematically ◎ | Effect analysis done logically and systematically ◎ |
| Analysis of safety in misuse | None × | None × | Applicable to misuse at initial event (limited) △ |
| Flexibility (simultaneous use for reliability) | Reliability only × | One or the other × | One or the other × |

Evaluation symbols: ◎: Optimum ○: Suitable △: Marginal
×: Not suitable

FMFEA¹⁾ was developed in 1995 to handle items (1) and (2) in section 2-2.

The S-H Matrix Method²⁾ is a safety analysis method developed in 1988 to handle item (3) in section 2-2, and is now widely used.^{3), 4)}

3. FMFEA

3-1 Application of FMFEA

3-1-1 Summary of FMFEA

FMFEA is a safety analysis method used to analyze factors and effects of failure modes of structural components. This method utilizes a combination of FTA and ETA. (Refer to Fig. 1.)

This method is able to both discover and predict problems using a systematic progression of detailed analysis. In addition, safety (preventing personal injury) and reliability (preventing product failure) can be analyzed simultaneously.

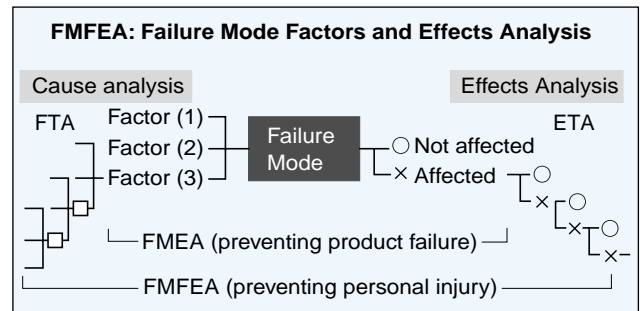


Fig. 1 Concept of FMFEA

Table 3 presents a comparison and evaluation of the differences between FMEA and FMFEA. Fig. 2 shows a printed form for FMFEA with an example of use.

Table 3 FMFEA vs. FMEA

| Item | FMFEA | FMEA |
|---------------------------|--|--|
| Components covered | New crucial* functional units are selected from a function block diagram. | Components are selected from a function block diagram. |
| Failure mode | Takes up a single failure mode with a basic and proper function obliterated. ◎ No individual differences. ○ Doesn't require a lot of time. | Determined by activities such as brainstorming to leave nothing out. (If something is overlooked, it interferes with analysis.) ↓ The failure mode and its factors are mixed together disjointedly (unequal order). ▲ Something could be left out. △ Takes time. |
| Cause analysis | Utilizes FTA. ◎ Systematic and logical △ Takes time. | ▲ Does not investigate deeply. |
| Effects analysis | Utilizes ETA. ◎ Systematic and logical △ Takes time. | ▲ Does almost none. |

Evaluation symbols: ◎: Excellent ○: Good △: Poor
▲: Unacceptable

* Crucial here must be defined in advance, e.g., having safety functions, or controlling something else.

| FMFEA | | Product name (Model number) | Component name | Function | Failure mode | Investigators | Day, month, year | Approved | Drafted | Page |
|--|--|--|---|--|--|---|---|--|---------|------|
| 5-dimensional | 4-dimensional | 3-dimensional | 2-dimensional | Effects analysis | 2-dimensional | 3-dimensional | 4-dimensional | 5-dimensional | | |
| Counter-measure 2 Error proof at design stage Pinhole Coating flaw Insulation degradation | Slit too shallow Slit too narrow Brush material Commutator surface too rough Brush attached backwards Holder pressure too great Brush sintering Layer short Coil winder tension too great | Commutator clogging Brush wear (0.2φ) Coil wire broken Leader line broken | Defective brush/commutator contact Electrical wire broken | Heater Not cooling (overheating) Electrical system (no current) Motor Lock (overcurrent) Mechanical system (lock) | X - Overheat protector stays ON O - Turned OFF X - Body heat distortion O - No heat distortion X - Coil overheats O - Not overheating X - Spark from layer short O - No spark (only open circuit) | Counter-measure 1 Thermal fuse test X - Stand-by mode Upper outlet O - Lower outlet X - Above body ignition point O - Below ignition point X - Thermal fuse stays ON O - Turned OFF X - Ignition on end plate O - No ignition | X - Thermal fuse stays ON O - Turned OFF X - Ignition at body O - No ignition X - Exceeds coil insulation heat resistance temperature O - Within heat resistance temperature X - Flashpoint at body O - Doesn't reach flashpoint | X - Mica doesn't block heat ⇒ A O - Heat is blocked X - Sintering continues O - No sintering X - Coil layer short ⇒ B O - No layer short X - Sintering continues O - No sintering | | |
| Counter-measure 3 Coil winding process check | Insufficient slack in wire Claw clasping too strong Broken line at claw edge Bearing sintering defect Bearing oil impregnation insufficient Shaft surface rough Brush wear dust Bearing off center Shaft bent Ferrite chipping Foreign matter from opening Rotor coating dust Ferrite adhesion U-separator off Sintering roundness precision | Insufficient slack in wire Claw clasping too strong Broken line at claw edge Bearing sintering defect Bearing oil impregnation insufficient Shaft surface rough Brush wear dust Bearing off center Shaft bent Ferrite chipping Foreign matter from opening Rotor coating dust Ferrite adhesion U-separator off Sintering roundness precision | Electrical system (no current) Motor Lock (overcurrent) Mechanical system (lock) | X - Overheat protector stays ON O - Turned OFF X - Body heat distortion O - No heat distortion X - Coil overheats O - Not overheating X - Spark from layer short O - No spark (only open circuit) | X - Stand-by mode Upper outlet O - Lower outlet X - Above body ignition point O - Below ignition point X - Thermal fuse stays ON O - Turned OFF X - Ignition at body O - No ignition X - Exceeds coil insulation heat resistance temperature O - Within heat resistance temperature X - Flashpoint at body O - Doesn't reach flashpoint | X - Mica doesn't block heat ⇒ A O - Heat is blocked X - Sintering continues O - No sintering X - Coil layer short ⇒ B O - No layer short X - Sintering continues O - No sintering | | | | |
| Counter-measure 4 Ferrite process check | Ferrite adhesion U-separator off Sintering roundness precision | Ferrite deviation | Checks and Countermeasures 1. Thermal fuse test (e.g., position mode gap, time, temperature, and blow-out condition during operation) 2. Investigate error-proof design for preventing backward attachment of brush. 3. Check winding process (e.g., jigs, winding tension, clasp strength of commutator claw). 4. Check ferrite sintering process (e.g., roundness and adhesion) | Person in charge | Date | | | | | |

Fig. 2 FMFEA printed form with example

3-1-2 Failure mode selection

When using FMFEA, the analysis begins with the components being investigated and their failure modes, making selection and sampling crucial. FMFEA follows the procedure listed below. (Refer to Fig. 3 and Table 3.)

- (1) Select as subject of the investigation a new unit with an important function. (Predefine “important”, e.g., having safety functions, or controlling something else.)
- (2) Check basic proper function of that unit.
- (3) Define a single failure mode with “failure = loss of function”.

Even when limited to a single failure mode, using this type of definition makes it possible to include such failure modes as secondary function failures and subordinate component failures in a follow-up analysis of details using FTA.

The problem areas and countermeasures obtained through focusing on important points are checked for other relevance, developed horizontally, and then standardized.

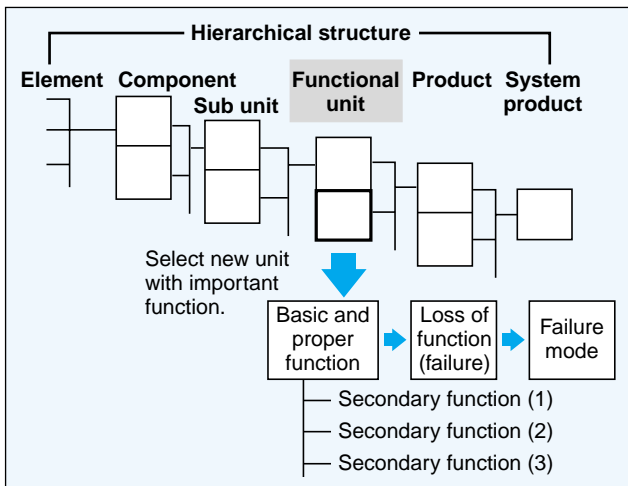


Fig. 3 Selecting the failure mode

3-2 Applying FMFEA — “Concurrent FMFEA”

3-2-1 Process FMEA

Process FMEA is used to prepare for new product manufacture, and constitutes an advance means of investigating and controlling production quality in production processes and assembly. This aim is achieved primarily by the production department.

Process FMEA differs in purpose from design FMEA (which is generally known as simply “FMEA”), but the printed forms used are almost identical. (Refer to Fig. 4.)

Table 4 compares the differences between the two.

Table 4 Differences between design FMEA and process FMEA

| Item | Design FMEA | Process FMEA |
|-----------------------------------|---|--|
| Purpose | Checking reliability design | Checking process control |
| Time period | Design stage (before design completion) | Production preparation stage (after design completion) |
| Department in charge | Design department | Production department |
| Starting point of analysis | Component failure mode | Manufacturing error |

The “process control table” serves the same purpose as process FMEA. (The “process control table” is also known as the “QC process table”. The printed form in Fig. 4 is one example.) All factories create these tables, regardless of whether they utilize process FMEA.

When used as the substance of advance investigations for new product quality assurance, these process control tables contain more detail than process FMEA, and this author believes that they are sufficient for that purpose.

3-2-2 “Concurrent FMFEA” practices

In Fig. 2 (an example of FMFEA), the cause analysis section on the left contains many controlling items related to processing, assembly, equipment, inspection and management. The effects analysis section on the right is related to product design.

When FMFEA is done at the design stage, process FMEA can be done concurrently. Process control for a new unit with an important function is performed from the design stage, and process design for the new product as a whole can be done using the conventional “process control table”.

This author proposes calling this new system “Concurrent FMFEA”⁽⁵⁾. Fig. 5 (next page) shows two flowcharts.

Concurrent FMFEA obtains the following results.

- (1) Production engineers obtain process information and they can be reflected in the design (improving design quality and completion rate).
- (2) From the early stages, design intention can be

| Process FMEA | | | | | | | | | | | | | |
|--------------|-------------------|--------------|----------------------------|-------------------|---------------------------|----------------------------|--------------------|---------|---------|-----------|-----|------------------|------|
| No. | Process flowchart | Process name | Name of equipment and jigs | Process functions | Manufacturing error modes | Manufacturing error causes | Effects on product | Ranking | | | RPN | Countermeasures | |
| | | | | | | | | Cause | Effects | Detection | | Person in charge | Date |
| | | | | | | | | | | | | | |

| Process control table | | | | | | | | | | | | | | |
|-----------------------|-------------------|--------------|----------------------------|--------------------------------|----------------------|-------------------|-----------------|------------------------|-----------|-------------------------|----------------------|--------------------|----------------------|-----------|
| No. | Process flowchart | Process name | Name of equipment and jigs | Component name; materials name | Process control item | | | | | Inspection control item | | | | |
| | | | | | Control points | Control standards | Control methods | Control specifications | Documents | Inspection items | Inspection standards | Inspection methods | Inspection equipment | Documents |
| | | | | | | | | | | | | | | |

Fig. 4 Printed form for Process FMEA and process control table

transmitted to the production process (improving process quality).

- (3) Factors causing production errors can be thoroughly investigated. Additionally, the relationship between production errors and product safety can be systematically analyzed (improving product safety assurance).

Process and design FMEA are carried out concurrently for secondary results, and this contributes to reducing the time required for new product development. This can also reduce the expense and loss of time accompanying product design changes. Concurrent FMFEA can contribute to management as a method of CE (concurrent engineering).

3-2-3 Development toward Design-In

The concurrent FMFEA system can apply not only to intra-manufacturer coordination (e.g., process and design departments), but also to inter-manufacturer coordination (e.g., component and product manufacturers).

FMFEA is utilized as a design-in tool for the component manufacturers to participate in design at the design stage of the product manufacturer. FMFEA is carried out jointly with the component manufacturers handling the cause analysis and the product manufacturer handling the effects analysis.

The responsibility of the component manufacturer is stated in the Product Liability Law as well, and the FMFEA serves as a link for the product safety assurance of the component manufacturers.

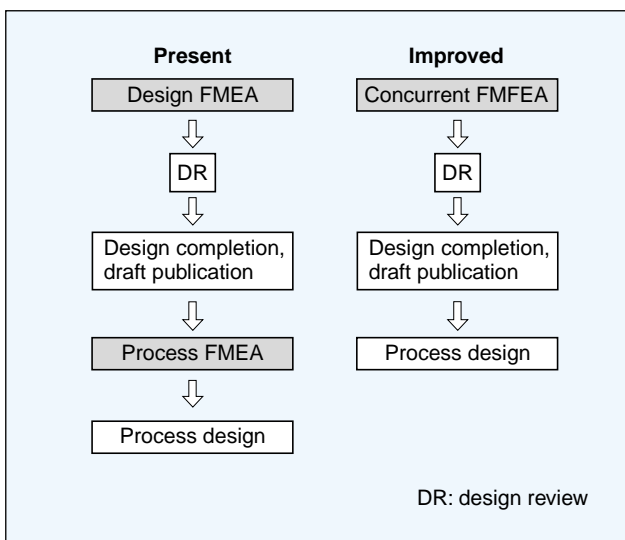


Fig. 5 Effect of concurrent FMFEA

4. The S-H Matrix Method

4-1 Utilizing the S-H Matrix Method

4-1-1 Misuse and product safety design

Uses and features of new products are determined at the planning stage, and so the manner in which the new product is meant to be used should already be conceptualized. The manufacturer must presume misuse and promote product safety design using the following notion. (Fig. 6)

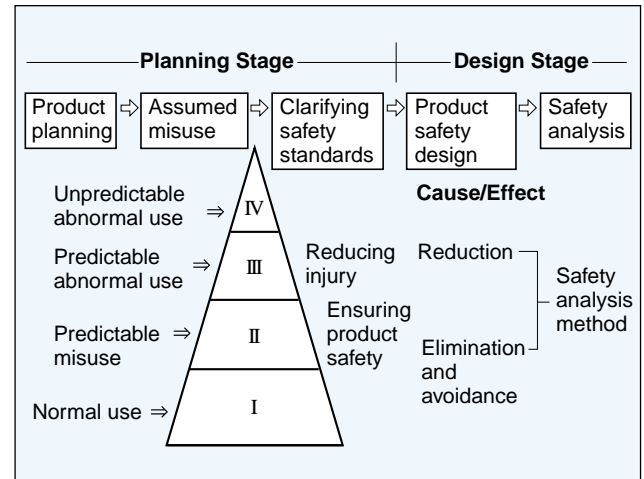


Fig. 6 Misuse and product safety design

Planning stage: What types of misuse are likely for this product? → Clarify safety standards and criteria.

Design stage: Create and evaluate safety in design, based on standards and criteria. → Apply safety analysis methods.

4-1-2 Summary of the S-H Matrix Method

Misuse causes additional stress to components, leading to failure. Such failure can result in a loss of safety or the misuse itself can be a direct safety hazard even when not resulting in failure. An example of the latter is “thoughtlessly” touching flammable material with a hot item and causing ignition.

A failure analysis method such as FMFEA overlooks this latter type of investigation. The S-H Matrix Method is an analysis method using a matrix to diagram the relationship between safety and misuse, and this method can cover the blind spots of unsafe misuse that does not lead to failure. Fig. 7 shows a model printed form, and Fig. 8 (next page) shows an example using a home appliance product.

| H | S | Normal use | | Misuse A | Misuse B |
|----------------------------|---|-----------------|------------------|----------|----------|
| | | Cause Detection | Effect Composite | | |
| All components normal | | | | | |
| Component (1) failure mode | | | | | |
| Component (2) failure mode | | | | | |

S: Software (method of use)
H: Hardware (component construction)

Fig. 7 Model printed form for the S-H Matrix Method

| S-H Matrix Method | | O: occurrence D: detection | | E: effects C: composite | | Evaluation | | Occurrences: promotion of failure mode, 3 pts Detection: ease of finding, 3 pts | | Effects: Severity, 5 pts Composite = Occurrence x effects x detection | | X, Δ: depending on the size of the evaluation countermeasure (No size for composite) | | Product name (model number) Automatic hot water function | | with built-in | | Performed (Year, month, day, member) | | Approved | | Checked | | Drafted | | Page | | | | |
|-------------------|----------------------|--|---------------------------------------|---|----|-------------------|-------------------|--|-------------------|--|-------------------|--|-------------------|---|--|-------------------|---|--------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|---|
| | | NO | NO | A | B | C | D | E | F | G | H | I | Countermeasures | | Person in charge | | | | | | | | | | | | | | | |
| Component NO | Component name | Safety functions | Failure mode | Kind of misuse | NO | A | B | C | D | E | F | G | H | I | Items for design investigation (1) Current leakage detector circuit (2) Overheating safety design review (3) Single cut-off relay → dual cut-off. (4) Inner cover detector | | Safety test performance (1) Wrong voltage (200 V) test (2) Current leakage test, tracking test (3) Supply water test (4) Connector loose test | | Date | | | | | | | | | | | |
| | | | | Probability of occurrence Safety standards Likelihood of occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | All functional units | — | Normal | Normal | 1 | O E D C | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| 2 | Heater | 800°C, 10 A, sheathed heater | Insulation degradation (pipe failure) | Normal | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| 3 | Heater thermistor | Overheating prevention, reversible type | Not operating (open) | Not operating (open) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| 4 | Water thermistor | Temperature adjustment from 45 to 95°C | Not operating (open) | Not operating (open) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| 5 | Thermostat | Overheating prevention, 110°C, backup for No.4 | Not operating (short circuit) | Not operating (short circuit) | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| 6 | Thermal fuse | 125°C, 15 A, backup for No.5 | Not operating (short circuit) | Not operating (short circuit) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 7 | Pressure switch | Detects use with no water. | Not operating | Not operating | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 8 | Relay | 15 A, single cut-off | Not operating (short circuit) | Not operating (short circuit) | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 9 | Seal mechanism | 3 used, Si rubber | Water leakage | Water leakage | 2 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | 2 3 4 | |
| 10 | Heater connector | SUS304, locking type | Overheating due to contact defect | Overheating due to contact defect | 2 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | 1 4 3 12 | |
| 11 | Grounding mechanism | Prevents electric shock. | Broken wire, left open | Broken wire, left open | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 12 | Lid SF switch | Won't start when open, prevents opening and releasing water while running. | Not operating (short circuit) | Not operating (short circuit) | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Fig. 8 S-H Matrix Method printed form with examples

4-1-3 Procedure

- (1) Make a list of items for S (misuses) and H (functional units).
- (2) Investigate in order the matrix formed by the S column and the H column.
- (3) Investigate each matrix column for the following four elements: probability of occurrence, severity of effects, detection and composite.
 - Probability of occurrence: the degree that misuse promotes component failure (ranked by the 3 point method).
 - Severity of effects: the degree of safety risk caused when misuse and components failure overlap (5 point method).
 - Detection: the degree of difficulty for the user to find the unsafety (3 point method).
 - Composite: Total of the three (Maximum $3 \times 5 \times 3 = 45$)

4-2 Points for effective utilization

4-2-1 Selecting S and H items

- (1) Misuse “S”
 - Limit items to those involving misuse specific to that product. Make a separate investigation according to the manual and design standards for misuse common to a product group.
 - Limit items to those involving misuse linked to components overheating (ignition) and insulation degradation (electric shock). Injuries, burns and other harm can be checked directly through separate safety tests.
 - Put items in groups and list only the representative items.
- (2) Subject components “H”

Select items using the same method as for FMFEA. (Refer to 3-1-2, (1).) However, when using the S-H Matrix Method, do not limit subject components to new items.
- (3) Investigating the matrix formed by S and H
 - The matrix diagram has the advantage of being the basis for an effective investigation even with only a small list of elements (S and H items). This approach provides for preventing omissions and checking relevance. Therefore, the problems can be found easily in the matrix.
 - On the other hand, when the relationship between misuse and unsafety is weak, the problem points do not become obvious even when listing a large number of elements. A long list in that case only makes the problem seem more complicated.

4-2-2 Utilizing this method at the planning stage

As discussed in 4-1-1, misuse should be hypothesized at the new product planning stage, and product design should start by clarifying safety standards. The S-H Matrix Method printed form (S column) should be used for these purposes, and these can be checked through a design review at the planning stage.

4-2-3 Combining with the FMFEA

Combining the merits of the S-H Matrix Method misuse analysis with the thoroughly systematic failure analysis of FMFEA can produce superior results. When product and component manufacturers cooperate to perform this type of analysis, they complement each other and create a more effective analysis. The framework for that process is:

[Product planning stage (before starting design)]

- (1) Forecast misuse and environmental conditions according to the uses and features of new products.
- (2) Create groupings of misuses, classify them, and put them in the S column.
- (3) Clarify the safety standards for (2).

[Detail design stage (before issuing drawings)]

- (4) Perform S-H Matrix Method investigation.
 - List important functional components and failure modes in the H column.
 - Investigate the S-H matrix in (2).
- (5) Select the key functional components based on the results of the S-H Matrix Method.
- (6) Perform the FMFEA investigation based on the key functional components thoroughly.

5. Conclusion

This report has introduced two new methods for analyzing safety, and discussed the main points for utilizing these methods.

The following points are key to regularly utilizing these safety and reliability analysis methods and linking them to the design review:

- When examples, experience and special methods are required → have the best specialist technicians participate in planning.
- When inference to find problem points are required → attach importance to hypothesis and verification.
- When elimination of waste and efficient practical use are required → concentrate on important points and then develop horizontally.
- When improvement methods appropriate to the product and purpose are required → establishing a “company style” method can be considered especially important.

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Easy-to-read “Features of environmental testing” (Part 1)

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This report is the first of a two-part series that, as the title indicates, is meant to cover the main features of environmental testing without getting bogged down in overly difficult aspects of the subject. Although intended to be easily read, we must be wary of simplifying the subject to the point of making it meaningless. Perhaps we could say that the level of this overview is “easy to read, with some difficulties”, and presented as a column. The discussion may seem at times to jump from topic to topic.

1. Introduction

Environmental testing is one type of reliability testing that has been developed as a method of predicting how the ambient usage environment will affect product functions and performance. In other words, environmental testing is used before the product is marketed to check the degree that the environment will affect the product. When product functions are affected, environmental testing is used to pinpoint the cause and to maintain proper reliability by creating measures to protect the product from such environmental effects. These tests have evolved well beyond their original aims, now being used to cover a wide variety of purposes, including research and development of materials and products, various checks in production processes, pre-shipping inspections, and post-shipping quality control. The tests may also be used for analyzing defects occurring in the field, as well as for a wide variety of applications focusing on the improvement of pre-existing products. The tests are very effective for improving methods of checking and maintaining reliability.

At first glance, it may seem logical to say, “Well, the test equipment happens to be free right now, so we’ll just slip some products in for testing,” but a wise engineer will never take this approach. Modern environmental testing must be done with logical measures in specific sequences capable of satisfying an independent observer. Proper testing does not consist of vaguely applying the label of “environmental testing”, but first requires clearly determining the purpose of the test from the outset. Next, the tester must be able to predict the results and estimate the required costs, and finally must draw up a complete test plan (written) of test requirements. Ideally, the tester will also be able to coordinate all of this.

To accomplish all of the above, the tester must be familiar with everything from product materials to production process details, and must consider both the product and the environmental features that the product will be exposed to in the field. The tester must predict what defects will occur under what circumstances, and create a test profile that can reproduce the failure

mechanism. These preparations result in the ability to grasp when tests can be handled simply and effortlessly, when large-scale testing projects are required, when relatively simple equipment can be used, and when high-level equipment is necessary for testing and measuring. Sometimes merely drawing up the plans and making the clarification studies obviate the need for testing. While not limited to environmental testing, the approach consists of first drawing up the plans, then making thorough studies, then constructing hypotheses, and finally carrying out the tests. Rushing into the test is simply not called for. The test should be seen as a means of verifying hypotheses.

2. Test preparations

Since the subject of the test is a manufactured product, the first step in making preparations must be to thoroughly clarify every aspect of the product in advance. While you may feel that you have a wealth of information related to the test product when approaching the test, this information is always from the standpoint of what you have already been able to find out. The main players in this drama are you and the product being tested. All tests begin from this point.

Now, let’s look at some points that will serve as references in the process starting from creating a test plan and going up to the point of actually carrying out the test.

2-1 Preparations

2-1-1 Gathering all information possible related to the product

The basic approach consists of obtaining in advance all technical data related to items such as the structure, functions, and capabilities of the product to be tested. Specifically, we need to obtain all information related to the materials used in the product, regardless of whether the product that we are looking at is electrical, electronic, mechanical, or a hybrid that combines any of these types. We must then investigate the specific physical properties of those materials. For example, these days, resins, which are chemical products, are being applied to a wide variety of mechanical products as well as electrical and electronic products too numerous to name. We must first collect

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information on such aspects in advance (including past in-house test reports). We must then investigate these aspects down to the atomic level, and that goes for conventional metal materials as well, and we must reconfirm their physical properties. (When materials are purchased from a new supplier, the composition may vary slightly due to differences in manufacturing processes even when the standards seem to be the same.)

2-1-2 Creating a “Life-Cycle Environmental Profile” of the product

At this point, we shall draw up a life-cycle profile that predicts all events the product will encounter from its manufacture to its use in the field until it is discarded. This profile will associate every aspect of these predicted events with the ambient environment that the product is expected to encounter. In other words, we must hypothesize the various environments to which the product will be exposed at every stage of its life. At the manufacturing stage in particular, we must get a firm grasp of conditions, including the environment for storage of materials and products as well as their handling and transfer. We must then investigate all possible details of each environment that the product will encounter at every stage after the product’s completion, and draw up a hypothetical profile (outline) of these environments. This profile should include packing methods and materials, shipping conditions and environments, pre-use storage, methods of handling from one operation until the next, local environments within the installation area as well as the overall geographical environments to which it will be exposed, and the environment of the main unit into which the product is placed. When creating this profile, obtaining the following information will increase the accuracy of environmental tests.

- (1) Conditions of the installation location and connections between the product and the main unit into which the product is placed
- (2) Conditions of the boundaries between the product and neighboring products
- (3) Details of the environment the product encounters and the absolute time period and the relative time period that these aspects are encountered
- (4) Probability that the intended environment will occur

Although some areas will overlap with previously mentioned items, the following items should also be grasped.

- 1) Carry out detailed examinations of the main structural parts and materials starting from the final acceptance inspection and continuing through storage period and conditions and every condition encountered in the manufacturing and assembly processes.
- 2) The environmental and stress conditions predicted to occur during the product life need to be put in time series, quantified numerically, and estimated statistically (if possible, displayed as a standard deviation).
- 3) When product defects appear, they are often generated by events occurring outside the technological domain of the product itself, such as in handling during shipping. These items should be thoroughly investigated and grasped, and it is important that the items of investigation be unified.

2-1-3 Understanding the limits of environmental testing

Environmental testing done in the test chamber cannot possibly reproduce the exact conditions of the field environment and employ all of the environment factors encountered in the field. Therefore, when creating the test conditions, the tester must select the appropriate environmental factors thought to have the greatest affect on the product. As a result, the test environment can only be an artificial environment far removed from equivalency to the actual environment.

In general, product defects are caused by (1) the concentrations and variations of materials, friction, wear, stress, heat, current, and electric field strength as these factors affect specific areas of the product, (2) factors due to product characteristics (materials, processing methods, and structural parts and materials and their manufacture) that are built into the product in design and production processes, and (3) stress from the peripheral environment of use. Therefore, test conditions must be set according to a specific product group test profile that is unique to that product group. When the product group being investigated is changed, naturally the test profile must also be revised.

2-2 Test sequence

The test sequence is crucial in environmental testing. Even in a single series of tests, changing the sequence can change the results. As noted above, we absolutely must not simply decide to change the test sequence for such reasons as “the test equipment was not being used”.

For testing in general, validity is assumed to be provided by following the same order of environments that the usage profile predicts will be actually encountered by the product at each stage, but this approach requires a large investment of time. In such cases, it seems more logical to follow the sequences considered to have the greatest affect on the product. This approach uses the technique of intentionally producing defects in the product within specific targeted boundaries. The following test methods can be useful for such cases.

- (1) An attempt is made to deliberately create a “trigger” in the initial test to produce the subsequent defect phenomenon. Then, the defects are promoted and expanded in the following tests.
- (2) When the number of test samples is extremely small, tests with the least amount of stress are run first to obtain a large amount of relevant data before the test items receive lethal damage.
- (3) To determine whether the product can withstand the most severe environment from the outset, priority is given to the most severe environment related to the actual environment.

For example, method (3) is appropriate when the samples are parts, the number of test samples is large, and the samples can be grouped according to test items. When there are a limited number of samples, method (2) is often used. Method (1) is used for a series of tests involving both parts and devices.

However, in that case, there are some points for which special care must be taken. Depending on the test sequence, items that show signs of defects in a previous

test may appear to be restored in subsequent tests, and so one must be careful especially when making a series of tests with the same samples. Furthermore, items showing functionally normal values may actually have physical defects revealed upon closer observation, and so multifaceted analysis and confirmation must be carried out. This means that the number of samples must be as large as possible, and samples thought to be free of defects must first be analyzed (non-defective item analysis), then after each subsequent test sequence, a small number of samples must be analyzed and taken apart, and finally a detailed analysis must be made of data and observations. Test planning and test item preparation with this type of margin is especially encouraged in environmental testing.

To supplement the above explanation, let's look at some specific hints using text examples involving parts.

For parts testing, the initial approach basically involves a series of tests using thermal shock. With parts, the functional part being tested is often sealed inside a mold or a case. When the sealing material for the functional part turns out to be unable to completely withstand the thermal stress (low or high temperature conditions), continuing testing beyond that point becomes meaningless.

(1) Further emphasizing defects

When specific purpose tests produce defects due to thermal shock, mechanical tests such as shock and vibration tests are then carried out to further emphasize these defects. These tests produce further expansion of cracking and sealing defects. Quite often the expansion of these defects leads to the appearance of some sort of internal functional variance caused by subsequent temperature and humidity testing, making it easier to detect incomplete functioning.

(2) Temperature and humidity cycle tests

During temperature and humidity cycle tests in particular, moisture often enters through the defective part, and it becomes possible to further emphasize defects using follow-up low-temperature endurance tests and depressurization tests. In other words, continuous temperature and humidity cycle tests cause a large amount of moisture to invade the defective part due to the breathing effect, enabling the tester to detect changes in functional characteristics.

(3) Constant humidity tests

Constant humidity tests are appropriate for investigating conditions of products left in moist air for long periods of time. These tests require a suitably long period of time, and so it is logical to leave these until after all other environmental test have been completed.

(4) Other tests

As a rule, tests for special items (e.g., solder characteristics tests, terminal strength tests, fire resistance tests, corrosion tests, falling and toppling tests, and sun exposure tests) are not a part of the test sequence, and instead are generally tested separately using separate test items.

Fig. 1 shows a general environmental test sequence for testing parts. This sequence is not presented as a standard recommended sequence, but should rather be understood as a sequence that can be varied depending on the

purpose, such as moving individual items up or back or eliminating individual items. Variations become even more likely when testing devices rather than parts.

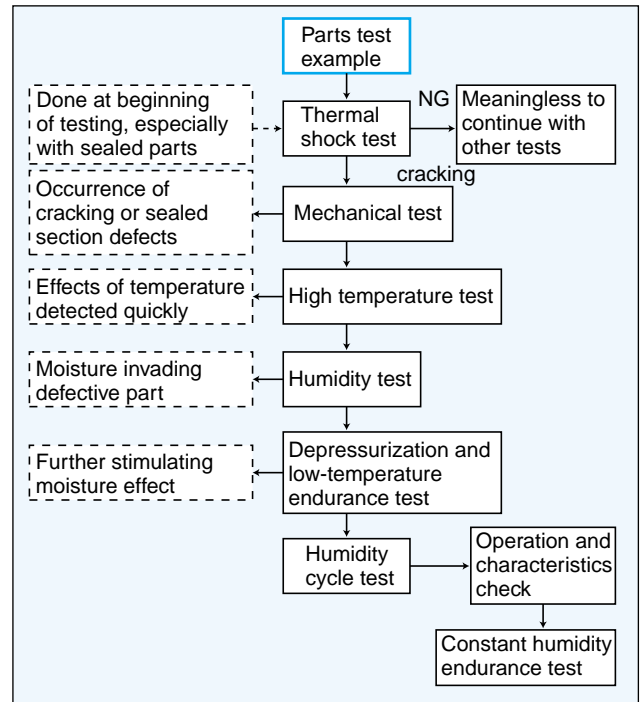


Fig. 1 General environmental test sequence for parts

2-3 Defining specific defects

Reliability (i.e., defects) must be defined for events encountered during the product life cycle. In other words, we must clarify what produces the determination that an item has a defect (or failure), and what are the “standard points” that serve as milestones of functional degradation.

Furthermore, we must assume that unpredicted situations will occur during the test (e.g., power outage, water shut-off, and test equipment failure), and we must determine in advance what our response will be to such emergencies (e.g., judgement standard of whether to continue or terminate the test). We must draft in advance a PERT (Program Evaluation & Review Technique) for test processes and not be left wondering what to do should such situations arise.

3. Effective method of creating field environments

Within environmental testing, some tests such as the paint coating exposure test, are carried out completely in a natural environment. However, at present most tests are carried out based on completely artificially-created environments using environmental test equipment completely removed from the natural environment, in a space that has been partially or completely sealed off. Therefore, making a mistake in selecting or combining environmental factors introduces the danger of creating an environment that greatly differs from the original purpose. At this point, let's look more closely at how to create an appropriate artificial environment.

3-1 Constructing an artificial environment and reviewing factors

Let's say we are testing electrical and electronic products. The environmental tests will be as shown in Fig. 2. In this example, test items are grouped as systems or parts, and a group in charge of each is set up, with another group established for the mechanical tests common to both systems and parts, and the test items are performed for the respective groups. This figure was downloaded from the NASA homepage, and processed and posted, and as you might expect it seems well-organized.

Naturally, these test constructions can also be considered appropriate for application to mechanical systems products as well. In fact, sometimes the same test name is used. However, one must be careful with these names, because the same name might be used in a specific field with quite different test contents, depending upon the industry to which the product belongs. (One example, while not of a test name, is the problem of the extent of corrosion [e.g., rust] in the field of electrical and electronic parts. In the field of shipbuilding, for some reason this is not referred to as corrosion.)

In any case, the test contents must be determined on their own. Because of this, the details of these individual test conditions are created by combining test factors as in Table 1. Then, the tester must decide whether to expose the specimens (for reference: in the field of environmental testing, items subject to testing are generally called specimens) to various levels of environmental conditions for specific periods of time, or whether to operate the products that are specimens at that time, or whether to simply let them set.

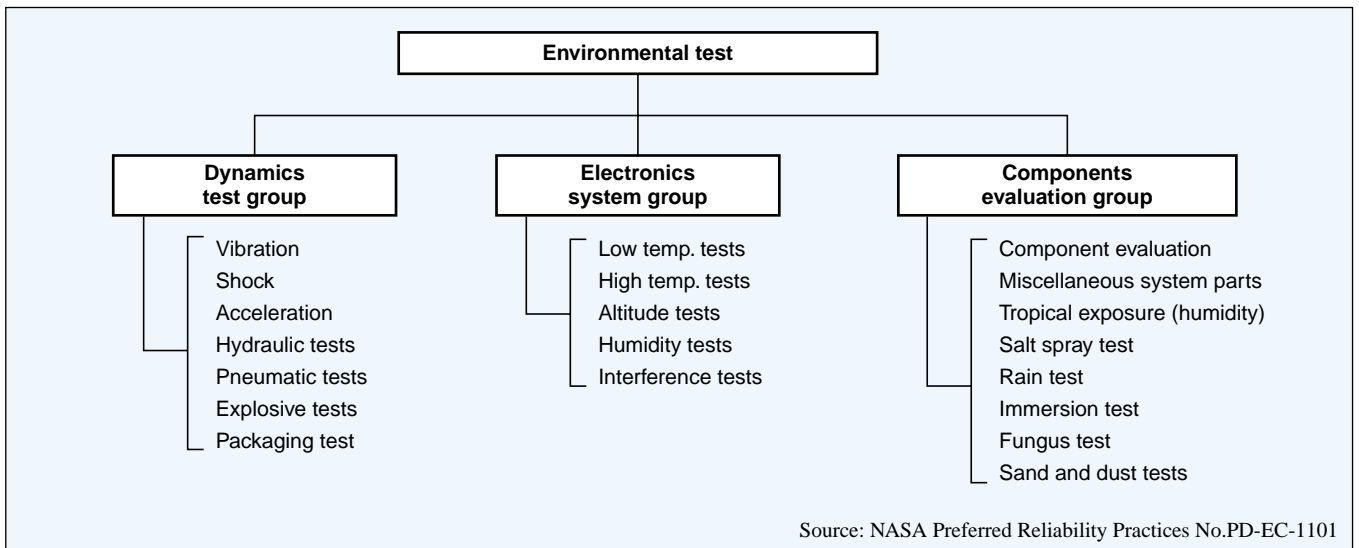
In general, environmental tests composed of only a single factor (e.g., temperature, moisture, pressure, vibration, shock, or a special substance such as salt) are called simple environmental tests, but it is actually very difficult to create this type of completely simple environment, and it isn't very realistic. On the other hand, single factors can be combined to create complex environments that are simultaneously reproducible. Most actual test environments consist of such complex environments, and the test name reflects the factor being emphasized within

the compound test conditions. For example, even when moisture is introduced, if the test involves high temperature and the moisture is not considered to have much effect on the products being tested, the test is called a temperature test, or a high-temperature test. Furthermore, humidity tests do not merely have environments with moisture, but have rather complex environments involving functions of temperature and moisture quantity.

Table 1 Typical appropriate environmental factors

| Natural factors | Induced factors |
|---------------------------|---------------------------------------|
| Planetary IR | Acceleration |
| Clouds | Chemicals |
| Electromagnetic Radiation | Corona |
| Electrostatic Discharge | Electromagnetic, Laser |
| Fog | Electromagnetic Radiation |
| Freezing Rain | Electrostatic Discharge |
| Frost | Explosion |
| Fungus | Icing |
| Gravity, Low, Hail | Magnetics |
| Humidity, High | Moisture |
| Humidity, Low | Nuclear Radiation |
| Ice | Shock, Pyro, Thermal |
| Ionized Gases | Space Debris |
| Lighting | Temperature, High, Aero.Heating, Fire |
| Magnetics, Geo | Temperature, Low, Aero.Cooling |
| Meteoroids | Turbulence |
| Pollution, Air | Vapor Trails |
| Pressure, High | Vibration, Mechanical, Microphonics |
| Pressure, Low, Vacuum | Vibration, Acoustic |
| Radiation, Cosmic, Solar | |
| Rain | |
| Salt Spray | |
| Sand and Dust | |
| Sleet | |
| Snow | |
| Temperature, High | |
| Temperature, Low | |
| Wind | |

Source: NASA Preferred Reliability Practices No.PD-EC-1101



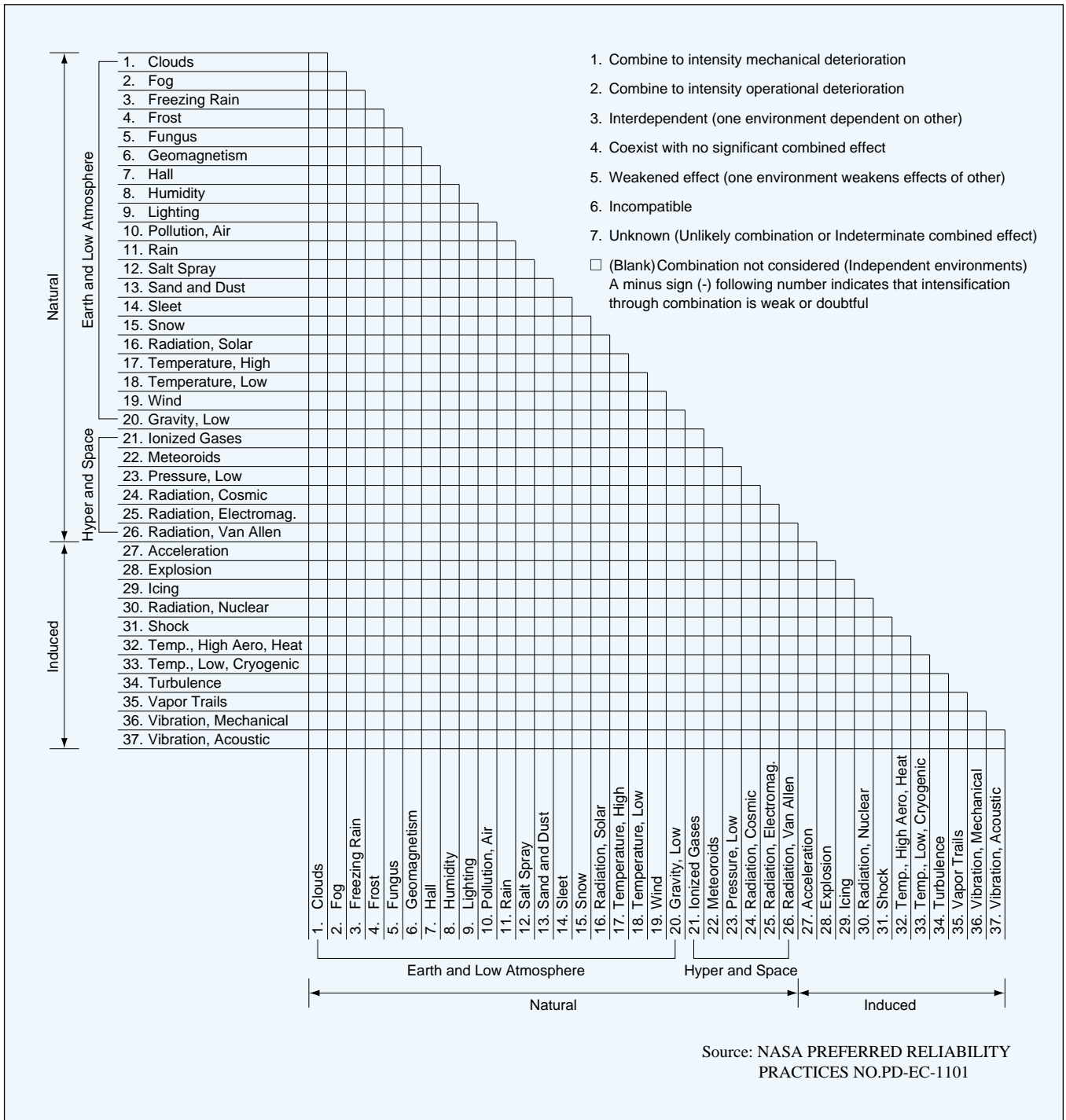
Source: NASA Preferred Reliability Practices No.PD-EC-1101

Fig. 2 Groups in charge and individual test items for environmental testing

3-2 Points for consideration when composing test environments

The complex environments that result from combining a large number of environmental factors (refer to Table 1) have a higher probability of complex effects on product reliability than environments with fewer factors. However, we must be careful when introducing mechanical factors, because it is quite possible to end up with a combination that is neither logical nor realistic. Therefore, when composing the test environment, we must fully

analyze and study the individual factors and the results of their combinations from a realistic and scientific viewpoint, and we must make very sure that the environmental conditions concur with the test purposes. Fig. 3 shows an example of a matrix check diagram that serves as a tool for studying the validity of compound environments when constructing an environment with representative factors. Table 2 presents effects of combining environmental factors of various types. These tables and figures can be used to roughly determine the validity of the effect.



Source: NASA PREFERRED RELIABILITY PRACTICES NO.PD-EC-1101

Fig. 3 Example of a matrix graph to study the creation of combined environments

Table 2 Combining various environmental factors

| Classification | Combined environmental factors | Effects of combining |
|-------------------------|---|---|
| High temperature | High temperature + humidity | High temperature tends to foster invasion by humidity. Normally, the humidity degradation effect is promoted by high temperature. |
| | High temperature + low pressure | The various factors of these environments display a synergistic effect. For example, a drop in pressure promotes the discharge of gas from the materials. Also, a rise in temperature fosters the discharge of gas. |
| | High temperature + saltwater mist | High temperature tends to foster corrosion due to the saltwater mist. |
| | High temperature + exposure to sunlight | When organic substances are mixed in, the effect is heightened. |
| | High temperature + bacteria | The growth of bacteria and minute organisms exists at favorable temperatures. Bacteria and minute organisms cannot multiply above 71°C. |
| | High temperature + dust | The level of corrosion promoted by dust is accelerated by high temperature. On the other hand, high temperature reduces invasion by dust. |
| | High temperature + (shock or vibration) | Environments in which both of these coexist affect the properties of most materials. They cause synergistic effects, and the level of effects changes depending of the strength of each factor. Except in the range that they don't coexist with extremely high temperatures, plastics and polymers are more sensitive to this environment than metals. |
| | High temperature + acceleration | This combination produces the same effects as high temperature + (shock or vibration). |
| | High temperature + explosive atmosphere | As merely a trigger for explosion, the temperature has a minimal effect. However, it does affect the air-gas component ratio. This problem merits serious consideration. |
| | High temperature + ozone | At above approximately 150°C, ozone reduction begins. At above approximately 270°C, ozone cannot exist at normally encountered pressure. |
| Low temperature | Low temperature + humidity | Humidity rises concurrent to the temperature drop. Low temperature induces water vapor to condense. If the temperature drops sufficiently, frost and ice form. |
| | Low temperature + exposure to sunlight | Low temperature tends to attenuate effects of exposure to sunlight. |
| | Low temperature + low pressure | This combination accelerates leakage of seals. |
| | Low temperature + saltwater mist | Low temperature reduces the degree of corrosion caused by saltwater mist. |
| | Low temperature + dust | Low temperature fosters the invasion of dust. |
| | Low temperature + bacteria | Low temperature slows the rate at which bacteria multiply. At sub-zero temperatures, bacteria hibernate. |
| | Low temperature + (shock or vibration) | Low temperature tends to aggravate the effects of (shock or vibration). However, this only becomes a problem at extremely low temperatures. |
| | Low temperature + acceleration | This combination produces the same results as the effects of low temperature and (shock or vibration). |
| | Low temperature + explosive atmosphere | As merely a trigger for explosion, the temperature has a minimal effect. However, it does affect the air-gas component ratio. This problem merits serious consideration. |
| | Low temperature + ozone | Low temperature attenuates the effects of ozone. However the ozone concentration increases as the temperature drops. |
| | Low temperature + saltwater mist | This combination is not expected to produce additional effects. |
| Humidity | Humidity + low pressure | Humidity promotes the effects of low temperature. In particular, this effect is striking with electrical and electronic appliances. |
| | Humidity + saltwater mist | High humidity reduces the salt concentration, and as a result widens the effective range of the salt, expanding the corrosion reaction. This causes an increase in conductivity. |
| | Humidity + bacteria | Humidity aids the growth of bacteria and minute organisms, but has no other effect. |
| | Humidity + dust | Dust has a natural affinity for water. This combination promotes degradation. |
| | Humidity + exposure to sunlight | Humidity strengthens the degradation effect due to exposure of organic substances to sunlight. |
| | Humidity + vibration | This combination increases the chances for destruction of electrical and electronic materials. |
| | Humidity + (shock or acceleration) | In general, the length of time of shock and vibration is too short to promote the effects of humidity. |
| | Humidity + explosive atmosphere | Humidity is not an effective trigger for explosion. However, high humidity reduces the pressure of an explosion. |
| High humidity | High humidity + ozone | In the presence of water vapor, ozone creates hydrogen peroxide. The effects of this combination are more severe than the sum of the individual effects on the degradation of plastics and elastomers. |

(Cont.)

| | | |
|-----------------------------|--|---|
| Low pressure | Low pressure + saltwater mist | This combination does not occur. |
| | Low pressure + exposure to sunlight | This combination is not expected to produce additional effects. |
| | Low pressure + dust | This combination only occurs when small dust particles are carried at a high altitude by a pungent storm. |
| | Low pressure + vibration | This combination affects all kinds of equipment, including most electrical and electronic devices. |
| | Low pressure + (shock or acceleration) | These combinations are only important in environments linked to high temperature. |
| | Low pressure + explosive atmosphere | At low pressure, electrical discharge is more likely to occur. However, it cannot easily serve as a trigger for explosions. |
| Saltwater mist | Saltwater mist + bacteria | This combination is unlikely to occur. |
| | Saltwater mist + dust | This combination produces the same effects as the combination of humidity and dust. |
| | Saltwater mist + vibration | This combination produces the same combined effects as humidity + vibration. |
| | Saltwater mist + (shock or acceleration) | These combinations are not expected to produce additional effects. |
| | Saltwater mist + explosive atmosphere | This combination is thought to be incompatible. |
| | Saltwater mist + ozone | This combination is similar to humidity + ozone, but is even more corrosive. |
| Exposure to sunlight | Exposure to sunlight + acceleration | The result of exposure to sunlight, this combination probably produces the same effects as the combined effects of high temperature and bacteria. Furthermore, direct exposure to ultraviolet rays acts as a bactericide. |
| | Exposure to sunlight + dust | This combination probably produces high temperature. |
| | Exposure to sunlight + ozone | This combination fosters oxidation of materials. |
| | Exposure to sunlight + (shock or acceleration) | These combinations are not expected to produce additional effects. |
| | Exposure to sunlight + vibration | Under conditions of vibration, exposure to sunlight has a high ratio of causing degradation of materials such as plastics, elastomers, and oils. |
| | Exposure to sunlight + explosive atmosphere | This combination is not expected to produce additional effects. |
| Bacteria | Bacteria + ozone | Ozone destroys bacteria. |
| Vibration | Vibration + acceleration | The effects of this combination are promoted with the coexistence of high temperature and low pressure. |
| Dust | Dust + vibration | Vibration can promote the wear effects of dust. |
| Shock | Shock + vibration | This combination is not expected to produce additional effects. |

While this is related to drafting to the life cycle profile of the product, the environment and its variations must be thoroughly examined from the assembly process of the parts used, through the preliminary operation of the completed product, to the environment after the product is in the field and through every stage of use while the product lasts.

- 1) The stress on the product in the various processes such as parts assembly, inspection, testing, transportation (or transfer) has a marked impact on the reliability of the completed product. Because of this, the tester needs to thoroughly confirm every type of experience the main structural parts and materials encounter in the parts manufacturing and parts assembly processes from the final acceptance inspection through the assembly process, and including storage time and control conditions.
- 2) Many items are often overlooked, especially the stress pertaining to test operation of the completed parts and the load during inspection periods. In these processes, it is possible that from the intention to confirm the functional limits of the product that the product can be forced to an unnecessarily severe level of operations that in reality it would rarely ever meet.
- 3) In addition, the actual product could be exposed to environments more complex than it would actually encounter during transportation or during normal

operation (e.g., combined environments such as non-stable temperature, humidity, stress fluctuations, and shock and vibration). In particular, the probability of occurrence, the sequence, time, and severity of stress in the environment require thorough study before making a careful composition of the test profile. To give a realistic problem as an example, if there is no margin of error in the delivery period, a short-term transportation company may be used that handles the product roughly during transportation, but if there is enough margin of error in the delivery period, the manufacturer will actually select a company that handles the product carefully even though it takes more time.

We can see that the environments and stress predicted to occur during the product life need to be put in time series, quantified numerically, and estimated statistically (if possible, displayed as a standard deviation). The estimation data at this stage can be verified later at the various stages when the actual values are confirmed, and the results of that analysis will become valuable technical material for product design in the future. In particular, shipping and handling cannot be simply disposed of as not being directly related to product design. These areas must be thoroughly investigated and grasped and are essential to test planning and composition.

3-3 Test environment construction

The treatise on constructing test methods “For busy people in a hurry” presents various “Meals with fixed menu” style environmental test methods set up according to public test standards. Typical standards include IEC standards (60068 Series) and the JIS standards (C0010 Series) that are basically a Japanese translation of the IEC standards. Industrial standards include the EIA (Electronic Industries Alliance) standards and the EIAJ (Electronic Industries Association of Japan) standards. These test methods clearly establish test conditions, and so if the test objectives of your product coincide with these, you can use them just as they are. However, these standard tests cannot be expected to produce long-term warranty data for actual usage conditions in the field environment.

On the other hand, if the individual test conditions of the product are clearly established in the individual specifications of the product, you can then substitute those individual test conditions for the test conditions (severity) in the standards. (The IEC standards permit prioritizing the individual test conditions, and when it is possible to clearly establish the necessary test items, the IEC standards number may be used as is. However, such use is based on the condition that the details of the substitution be clearly displayed in the test report.)

On the other hand, when there is a strong need of creating individual test conditions, you can select an appropriate standard test method from among the above-named standards. At present, making such revisions and combinations is more logical on every account than creating a test entirely from scratch.

3-4 Supplements to test environment construction

At this point, we will supplement material about three tests to item 3-3.

3-4-1 Climate tests

As previously noted, it is basically impossible to recreate the various phenomena of the real natural world within a limited space, that is to say within the confines of the test chamber and the test equipment. To overcome these limitations and develop a realistic approach, environmental factors such as temperature and humidity are combined to create the individual test environments. The 60721 Series of the IEC standards present standards classifying environmental factors by individual product category. This is an invaluable aid in creating appropriate complex environmental conditions corresponding to product applications.

It is extremely difficult to recreate the variety of factors within various environments, and sometimes the recreation is unrealistic because of the complexity. As noted above, a large variety of test construction data appears elsewhere, and so the tester must carefully study and grasp in advance the degree that each factor affects the product when creating test conditions.

3-4-2 Sunlight exposure test

The IEC60068 Series does not deal with specific environmental test methods for general sunlight exposure. In most cases, a simulated sunlight spectrum is used in tests for sunlight exposure. However, as an actual problem, within the various restrictions (e.g., tests costs, equipment, required personnel, and preparation time) it is extremely difficult to simulate sunlight inside a common test chamber or inside test equipment. Because of this difficulty, one simple method requires creating a small-scale spectrum test separated into the three separate regions of infrared, visible light, and ultraviolet light. Then, the products are sorted according to their sensitivity to these individual conditions, and the appropriate test is carried out according to the purpose.

The following is presented as a reference for the three major phenomena caused by exposure to sunlight.

1) Chemical action and sunlight degradation

In most cases these effects are produced in the ultraviolet range of the spectrum. However, the same sort of effects are known to occur in the visible range, and so we must be careful. Typical of these effects is the fading of product surfaces and fogging of semi-transparent plastic. Usually tests to evaluate these effects can be performed on materials and parts, but it is also possible to perform the tests on completed products. For example, discoloration of color paint results from increased heat absorption that raises the temperature of the product itself.

2) Heat effect

To determine the induction capacity and failure mechanisms related to temperature, the following method can be used to evaluate individual products.

- Temperature rise

The sunlight load produces a markedly higher temperature at the surface of the product and in the nearby air temperature than in the ambient temperature. There are two methods of simulating this temperature rise. The first, for example, involves using the 15°C rule (the predetermined temperature rise value calculated through experience).

The second method involves using a calorescent lamp to raise the temperature at the required surface of the test product and nearby.

- Heat gradient

The characteristics of sunlight exposure are related to the single direction from which the rays come, and so thermal effects in the natural environment are not equal overall, but are related to the direction of exposure. Therefore, exposed products suffer different thermal effects in different areas. This localized heat rise expands the common differences within the product and causes localized swelling of materials, causing defects in sealed functions and creating such problems as variations in performance of miniature parts in specific locations. To handle the problems of simulating the directional radiation heat source in a small test chamber, the tester must take measures to avoid causing an unrealistic heat rise in other sections of the product by maintaining appropriate air circulation.

3-4-3 Mechanical environment tests

In most cases, mechanical environments are more often induced or artificial environments rather than natural environments. In other words, these environments occur due to artificial transportation and equipment operation. Therefore, the tester must create and carefully analyze a life cycle profile for each element of which the product is composed. This profile should combine the phenomena resulting from exposure to the surrounding natural environment with the environment generated by the product itself, such as noise, shock, and vibration.

1) Vibration tests

The sine wave sweep vibration test is restricted by the measurement results and the test limits, but it is comparatively easy to control the test equipment and analyze the results. This test has historically been applied to most products. The test can be applied, for example, to a product that involves rotation while operating in a comparatively fixed position such as an airplane propeller or a rotor. At present, the test is limited to investigating sine wave resonance.

On the other hand, random vibration involves determining the gravity force according to power spectrum density and vibration time, providing a more realistic phenomenon. Nowadays, when we talk about vibration tests, we are generally referring to random vibration tests.

2) Shock tests

Shock tests are applied to products exposed to comparatively rare conditions encountered in non-repetitive situations encountered during product operation, transportation, and use. (All product packages are used to handle product fragility in these environments, and so there are various ways of using these tests.)

Typical effects of shock include:

- a) Permanent damage caused by excessive load
- b) Sudden damage or fatigue to materials
- c) Failure caused by friction or variations in impedance between the products.

3-5 Specifications of environment test equipment

Test contents for individual products are determined by developers, designers, and testers. Rather than presume to understand these individual contents, at this point we will create a format of required specifications for environmental test equipment based on the standpoint of supplying test equipment corresponding to your tests, assuming you are performing general environmental tests involving temperature and humidity. From the standpoint of supplying test equipment, this format will enter somewhat into the individual tests contents of all of you who are users, but by using the format we can create a framework for test equipment that will create the required test environment conditions.

Test equipment suppliers propose specific forms of test equipment based on this framework.

Every type of test equipment that actually creates the test environments currently includes measurement systems. Therefore, compared to 20 to 30 years ago, using pre-existing equipment and procuring new equipment is

amazingly easy. (However, the high cost of environmental test equipment compared to its functions still presents a problem.)

On the other hand, the simpler types of test equipment could be created using do-it-yourself methods. You should be aware, though, that recently in some cases self-manufacture actually raises the overall cost. Because of that, from the aspect of reliability of test results, sometimes the test environment cannot be precisely controlled, and concerns for safety arise during continuous operation and automatic operation, and so we must be very careful on these points. If you are still determined to go ahead with the do-it-yourself approach, the above details must be carefully studied before attempting to design and manufacture the equipment.

The most important thing is to take sufficient care at the beginning of any endeavor. The same holds true for environmental testing. This report has taken up the issue of reliability testing (ignored perhaps because its importance is taken for granted), but we have attempted to address a variety of fundamental issues. For newcomers to the field, the report probably contains many new concepts, but the discussion may have been old hat for experienced technicians. In either case, we will be happy if reviewing the background for handling the daily duties of carrying out environmental tests has been of service.

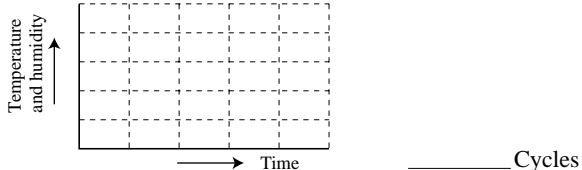
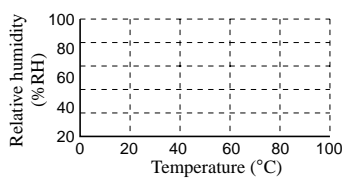
In our next issue, we shall take a closer look at some key points of environmental testing taken from the aspect of applications.

Table 3 Checklist of required specifications for environmental test equipment

| Check item | Required specifications |
|--|--|
| 1. Check of main contents of test | |
| 1.1 Test purpose (Which of the following apply to the test being planned?) | <input type="checkbox"/> Testing within the range of upper limits and lower limits of the application environment established for the product (testing within rating) <input type="checkbox"/> Testing at harsh conditions outside the range of upper limits and lower limits of the application environment established for the product (testing outside rating) * The test contents will be explained in the next issue. |
| 1.2 Specimens (confirming the pieces to be tested) a. List of specimens by type and test contents b. Model type, dimensions, and rating c. Quantity and weight | Type _____ Contents _____ _____ Number of items _____ kg |
| 1.3 Test conditions (corresponding to main test contents) a. Standards on which test is based (e.g., public standards, in-house standards) b. Temperature and humidity range and distribution of permissible fluctuation range c. Required wind velocity (The wind velocity determines the stress on the specimens. In particular, the wind velocity is related to the humidity control method of the test equipment.) d. The load that the specimens generate on the test equipment (e.g., applied bias, whether operating, amount of heat generated) e. Test time (with cycle tests, time and number of cycles) f. Whether to cause dew condensation on the specimens or not (related to controlling temperature and humidity) | _____ _____ °C ± _____ °C _____ %RH ± _____ %RH _____ m/s _____ Cycles _____ min. <input type="checkbox"/> Caused or <input type="checkbox"/> Not caused |
| 2. Checking installation site for test equipment (putting the required infrastructure in order) | |
| a. Space for facilities b. Load resistance of floor c. Test site height, temperature, and humidity (when air conditioned, confirming whether air conditioning operates at night and on holidays), whether in direct sunlight d. Whether combustible gas or corrosive gas is generated (avoiding unnecessary external disturbance) e. Power capacity and voltage fluctuations (avoiding unnecessary external disturbance) f. Water supply and drainage facilities (nowadays, from the standpoint of protecting the global environment) g. Whether there is an earth contact point (avoiding external disturbances on control and measurement) h. Route and loading entrance for equipment and specimens (related to size and construction of doors for test equipment) | W _____ mm × H _____ mm × D _____ mm Within _____ kg Height _____ m _____ °C _____ %RH Direct sunlight <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Yes <input type="checkbox"/> No AC (or DC) _____ V <input type="checkbox"/> 50 Hz <input type="checkbox"/> 60 Hz <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Yes <input type="checkbox"/> No |
| 3. The main point in drawing up specifications for test equipment that must be stored | |
| 3.1 Power (including whether power supply to the specimens is required) | <input type="checkbox"/> AC (or DC) _____ V ± _____ % _____ A ± _____ % <input type="checkbox"/> Single phase <input type="checkbox"/> 3 phase (3-line type or 4-line type?) <input type="checkbox"/> 50 Hz <input type="checkbox"/> 60 Hz |
| 3.2 Ambient temperature (particularly when cooling equipment is used, maximum water temperature in summer) a. Range of equipment operation b. Range of performance maintained | Air temperature _____ °C Water temperature _____ °C _____ °C |
| 3.3 Temperature and humidity control method | PID control (at present, this method is almost always used) |

(Cont.)

(Cont. from the previous page)

| | |
|---|---|
| <p>3.4 Details of test standards used (related to specimens)</p> <p>a. Public standards</p> <p>b. In-house standards or standards from user</p> <p>c. For programmed test, contents of each cycle and number of cycles</p> | <p>_____</p> <p>_____</p>  |
| <p>3.5 Performance</p> <p>a. Confirming required performance</p> <p>b. Temperature and humidity range</p> <p>c. Humidity fluctuation range</p> <p>d. Temperature and humidity distribution</p> <p>e. Temperature heat-up range and pull-down range</p> <p>f. Setting precision of temperature and humidity controller</p> <p>g. Indication accuracy of temperature and humidity controller</p> <p>h. Permissible temperature load</p> | <p>Ambient temperature _____ - _____ °C</p> <p>(Maintain the following performance when setting the specimens in place.)</p> <p>_____ - _____ °C _____ - _____ %RH</p>  <p>± _____ °C at ± _____ %RH</p> <p>± _____ °C at ± _____ %RH</p> <p>Heating from _____ to _____ °C for _____ min</p> <p>Cooling down from _____ to _____ °C for _____ min.</p> <p>_____</p> <p>_____ °C at _____ %RH, Max. _____ W</p> |
| <p>3.6 Internal and external dimensions, load resistance, weight</p> <p>a. Volume inside test chamber</p> <p>b. Load resistance of shelf for specimens</p> <p>c. External dimensions</p> <p>d. Overall weight</p> | <p>W _____ mm × H _____ mm × D _____ mm _____ Levels</p> <p>_____ kg × _____ (Number of shelves)</p> <p>W _____ mm × H _____ mm × D Within _____ mm</p> <p>Within _____ kg</p> |
| <p>3.7 Other incidental items (directly related to how the test is performed)</p> <p>a. Has observation window?</p> <p>b. Has cable port?</p> <p>c. Has voltage impression terminals?</p> <p>d. Has timer?</p> <p>e. Signal connection terminals</p> <p>f. Computer connection terminals</p> <p>g. Other</p> | <p><input type="checkbox"/> Yes <input type="checkbox"/> No</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ φ × _____</p> <p><input type="checkbox"/> Yes</p> <p>(withstand voltage _____ V × _____ (Number of pieces) <input type="checkbox"/> No</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No</p> <p>Specifications _____</p> <p>Specifications _____</p> <p>_____</p> |
| <p>3.8 Safety devices (in particular, contents determined by in-house standards)</p> <p>(When safety equipment is legally required, the requirement usually falls on the test equipment manufacturer.)</p> | <p>_____</p> |

Trends in IEC environmental testing standards for LCD

Fumio Sokawa*

International standards contained in IEC publication 61747-5 (Environmental, Endurance and mechanical test methods) for use in environmental testing of Liquid Crystal Displays (LCD) have now been published. These standards were deliberated and enacted by international committee IEC TC47/SC47C/WG2 based on a Japanese proposal. These new standards integrate standards for mechanical environmental testing such as shock and vibration tests, atmospheric environmental testing such as temperature and humidity tests, and these standards have been combined with pre-existing visual inspection standards.

This report will discuss the background, details and contents of these newly-enacted standards, focusing on atmospheric environmental testing in particular.

1. IEC activity in creating LCD standards

The IEC (International Electrotechnical Commission) enacts international criteria and standards related to electrical and electronic matters. This organization is composed of Technical Committees (TC), Sub-Committees (SC), and an International Special Committee on Radio Interference (CISPR).

International standards are actually drafted within Working Groups (WG) composed of specialists gathered from around the world. The WG, which write the initial drafts, are subordinate to the various TC and SC.

Currently the IEC TC start with TC1 (Terminology) and go to TC106 (Testing Instrumentation and Methods for Measuring Electric and Magnetic Fields Associated with Human Exposure). LCD is deliberated by WG2, connected to SC47C, which itself belongs to TC47. In establishing standards, the WG study the proposals in comparison with standards from other TC.

Committees with items related to LCD include TC1 (Terminology) and TC25 (Quantities and Units, and Their Letter Symbols), which deal with items describing LCD standards and specifications. In addition, the multimedia field of TC100 is strongly connected to color management problems. LCD also has a strong relationship to TC104, which received jurisdiction of IEC environmental testing series that was transferred from TC50.

Fig. 1 shows the TC/SC/WG related to LCD standards.

IEC standards first go through the following seven stages, then are enacted and published: Preliminary stage, Proposal stage, Preparatory stage, Committee stage, Enquiry stage, Approval stage, and Publication stage. (Table 1)

As you can see, an item must pass through a large number of deliberations and votes before being published. At least three years are required from the time the theme is set until a standard can be published. Average items require about five years, and some can take more than 10 years.

Table 1 Project stages and related documents

| Project stage | Related documents | |
|---------------------|--|--------------|
| | Name | Abbreviation |
| 0 Preliminary stage | Preliminary Work Item | PWI |
| 1 Proposal stage | New Work Item Proposal | NP |
| 2 Preparatory stage | Working Draft | WD |
| 3 Committee stage | Committee Draft | CD |
| 4 Enquiry stage | Enquiry Draft | |
| | Draft International Standard (ISO) Committee Draft for Vote (IEC) | DIS CDV |
| 5 Approval stage | Final Draft International Standard | FDIS |
| 6 Publication stage | International Standard | ISO/IEC |

Source: "Outline of IEC Activities", Japan Standards Association (March 1998)

*Appollomec Corporation

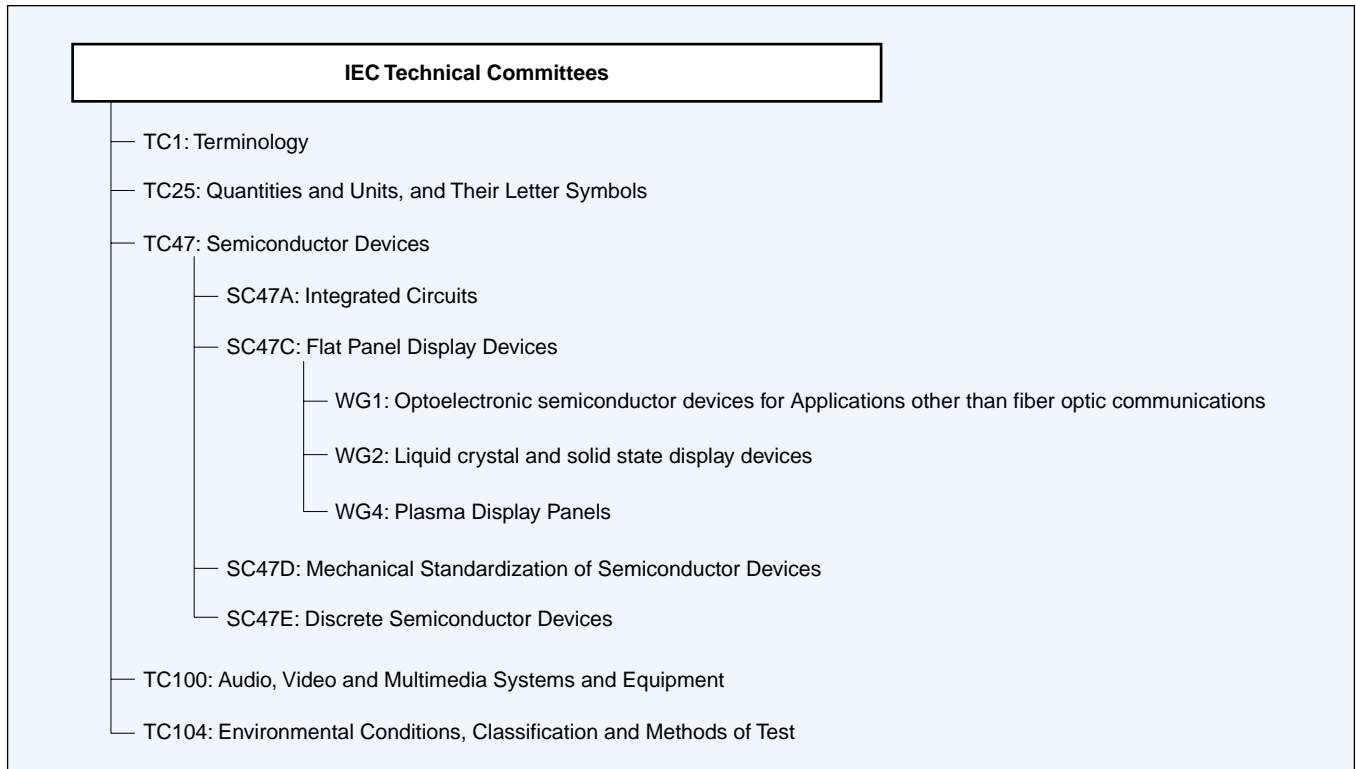


Fig. 1 IEC/TC/SC/WG related to LCD

2. IEC environmental testing standards for LCD

2-1 Details of enacting standards

Along with the growth in LCD production has come the establishment of the “Technical Committee on Electronic Display” and its attached “Subcommittee on Liquid Crystal Displays” in 1990 by the EIAJ (Electronic Industries Association of Japan). These groups were set up to strengthen standardization activity in Japan, and have initiated studies of EIAJ standards for all matters related to LCD.

The first standards enacted by this committee were related to environmental testing methods, and were published in 1992 as EIAJ ED-2531A “Environmental testing methods for Liquid Crystal Display devices”.

Since its inauguration by the EIAJ in 1990, this committee has been sending members to the IEC, and the committee has become the site of deliberations in Japan for IEC standards related to LCD. The name of the committee has now been changed to the “Technical Standardization Committee on Electronic Display Devices” (renamed from the “Technical Committee on Electronic Display”), “Liquid Crystal Display Group” (renamed from the “Sub-Committee on Liquid Crystal Displays”).

The English translation of EIAJ ED-2531A served as the proposal submitted to IEC/TC47/SC47C/WG2 by Japan, and after a series of deliberations and votes, the measures have been enacted as IEC 61747-5 (Environmental, endurance and mechanical test methods). The new proposal (NP) of February 1993 resulted in a committee draft (CD) approximately a year and a half

later in July 1994, and the proposal finally was approved for publication as an international standard in April 1998. Actual publication took place two months later in June 1998, requiring a total of five years and four months for the entire process.

The initial year and a half constitute the core activity within this process, and after that the time is spent on formal procedures consisting of comments, revisions, and votes. This process is hardly suited to our current rapid pace of technological progress, and so the IEC is currently conducting internal studies on methods of speeding up the standards enactment process.

2-2 Outline of standards

As previously discussed, a draft of EIAJ ED-2531A was deliberated, but when the items reached the publication stage, they became integrated into IEC 60747-5 (Semiconductor devices: Discrete devices and integrated circuits-Part 5: Optoelectronic devices) and compiled as an amendment concerning visual inspections.

These visual inspections are not closely related to environmental testing, but this organization can be understood as a result of the structure of the IEC standards system.

Table 2 shows the table of contents for IEC 61747-5.

2-3 General

The section titled “1. General” covers the area of purpose and applications, as well as making provisions for standard conditions. The standard reference temperature used for general electronic parts is usually 20°C (IEC 60068-1). These measures prescribe 25°C as the standard reference temperature, the same as the temperature for semiconductor device standard reference temperature (IEC 60749).

Table 2 Table of contents for IEC 61747-5

| | |
|---|---|
| <p>1. General</p> <p>1.1 Scope and object 1.2 Normative references 1.3 Terms, definitions and letter symbols 1.4 Standard atmospheric conditions 1.5 Visual examination and verification of dimensions 1.6 Electrical and optical measurements 1.7 Electrical operating conditions</p> <hr/> <p>2. Mechanical test methods</p> <p>2.1 Robustness of terminations 2.2 Soldering 2.3 Vibration (sinusoidal) 2.4 Shock 2.5 Acceleration, steady state 2.6 Bond strength test</p> <hr/> <p>3. Environmental and endurance test methods</p> <p>3.1 Change of temperature 3.2 Storage (at high temperature) 3.3 Storage (at low temperature) 3.4 Low air pressure 3.5 Damp heat, steady state 3.6 Damp heat, cyclic (12+12-hour cycle) 3.7 Composite temperature/humidity cyclic test 3.8 Light exposure 3.9 ESD test</p> | <p>4. Miscellaneous test methods</p> <p>4.1 Permanence of marking 4.2 Scratch test (of face plate) 4.3 Life test</p> <hr/> <p>5. Visual inspection of monochrome matrix liquid crystal display modules (Excluding all active matrix liquid crystal display modules)</p> <p>5.1 General 5.2 Visual inspection of displays</p> <hr/> <p>6. Visual inspection of monochrome liquid crystal display cells (Excluding all active matrix liquid crystal display modules)</p> <p>6.1 General 6.2 Visual inspection of displays 6.3 Seal inspections (see figure 13) 6.4 Visual inspection of contact pad area (see figure 14) 6.5 Visual inspection for chipped material at the borders and edges of the support plates of cells</p> |
|---|---|

IEC 60068-1 sets 20, 23, 25, and 27°C for referee measurements and tests, but the new LCD standards sets 20, 25, 30, and 35°C for referee measurements and tests. This change is based on the greater susceptibility of the numerous LCD functional characteristics to be affected by temperature, and so reflects the opinions of LCD manufacturers concerning the necessity of using an extremely wide temperature range. (Because IEC standards publications have now become five digit numbers, the previous environmental test method 68 series has become the 60068 series, and the semiconductor-related 74X series has become the 6074X series.)

2-4 Mechanical testing

The second section is titled “2. Mechanical test methods”, and contains standards for robustness of terminations, solder heat endurance, vibration, shock, acceleration, and bond strength of flat surface terminals. Most of the items are borrowed from the IEC 60068 series on environmental test standards, and measures include the use of large glass panels in conditions for severity. Comparatively mild conditions are prescribed due to construction involving internally-injected liquid.

Furthermore, just as with the bond strength test for flexible flat cables, examples of actual tests used by LCD manufacturers were used for reference in setting original methods for items with no pre-existing standards.

2-5 Weatherability

The third section, titled “3. Environmental and endurance test methods”, prescribes test conditions related to Change of temperature, Storage (at high temperature and low temperature), Low air pressure, Damp heat, Composite temperature/humidity cyclic test, Light exposure, and ESD (electrostatic discharge) tests.

This section also borrows from the IEC 60068 series and the IEC 60749 series, and determines supplementary conditions appropriate to LCD characteristics.

Tables 3 and 4 show conditions for items related to temperature testing, with Table 3 showing the low test temperatures and Table 4 the high test temperatures.

The original Japanese proposal set the low-temperature range down to -40°C, but this was further lowered to -50°C based on opinions from the European committee members.

**Table 3
Low test temperatures**

| |
|-----------|
| -50 ± 3°C |
| -45 ± 3°C |
| -40 ± 3°C |
| -35 ± 3°C |
| -30 ± 3°C |
| -25 ± 3°C |
| -20 ± 3°C |
| -15 ± 3°C |
| -10 ± 3°C |
| -5 ± 3°C |
| 0 ± 3°C |

**Table 4
High test temperatures**

| |
|------------|
| +100 ± 2°C |
| +90 ± 2°C |
| +85 ± 2°C |
| +80 ± 2°C |
| +75 ± 2°C |
| +70 ± 2°C |
| +65 ± 2°C |
| +60 ± 2°C |
| +55 ± 2°C |
| +50 ± 2°C |
| +45 ± 2°C |
| +40 ± 2°C |
| +35 ± 2°C |
| +30 ± 2°C |

The IEC 60068 series dealing with general electronic parts, as shown in Tables 5 and 6, has a wider temperature range.

Table 5
Low test temperatures
(60068-2-1)

| |
|-----------|
| -65 ± 3°C |
| -55 ± 3°C |
| -40 ± 3°C |
| -25 ± 3°C |
| -10 ± 3°C |
| +5 ± 3°C |
| -5 ± 3°C |

Table 6
High test temperatures
(60068-2-2)

| |
|------------|
| +200 ± 2°C |
| +175 ± 2°C |
| +155 ± 2°C |
| +125 ± 2°C |
| +100 ± 2°C |
| +85 ± 2°C |
| +70 ± 2°C |
| +55 ± 2°C |
| +40 ± 2°C |
| +30 ± 2°C |

2-6 Other tests

The next section, “4. Miscellaneous test methods”, standardizes marking tests only.

This subject deals with testing the difficulty of fading of the display printed on the LCD device and so uses IEC 60068-2-45 (Environmental Testing, Part 2: Tests, Test XA and guidance: Immersion in Cleaning solvents) for reference. The standards proscribe the use of freon solvents.

2-7 Visual inspection

The final two sections are “5. Visual inspection of monochrome matrix LCD modules” and “6. Visual inspection of monochrome LCD cells”.

As noted above, these sections were taken from pre-existing LCD-related standards IEC 60747-5 (Semiconductor devices: Discrete devices and integrated circuits-Part 5: Optoelectronic devices) and were combined with these standards.

3. Conclusion

The development of LCD technology is making rapid strides. With new applications continually being developed for the technology, the market is growing rapidly. The need to maintain product reliability during this time of growth is beyond question.

Assuring international clarity presents a major problem for the domestic market, and as a result, these international standards should merely be mimicked for domestic standards. In that sense, international standardization activity can be considered to be increasingly vital to Japan as well as to the rest of the world.

For copyright reasons, detailed contents of the standards have been omitted. For such details, please refer to the reference literature listed.

[Bibliography]

- 1) “EIAJ IEC Activities '98”, Electronic Industries Association of Japan
- 2) IEC 60068-1 Environmental testing. —Part 1: General and guidance
- 3) IEC 60068-2-1 Environmental testing. —Part 2: Tests. Tests A: Cold
- 4) IEC 60068-2-2 Environmental testing. —Part 2: Tests. Tests B: Dry heat
- 5) IEC 60068-2-45 Environmental testing. —Part 2: Tests. Test XA and guidance: Immersion in cleaning solvents
- 6) IEC 60749 Semiconductor devices —Mechanical and climatic test methods
- 7) IEC 61747-5 Liquid crystal and solid-state display devices. —Part 5: Environmental, endurance and mechanical test methods
- 8) IEC web site (<http://www.iec.ch>)

Topics

Ozone protection measures for Tabai products

Shinichi Enomoto*

1. Introduction

In response to the myriad global environmental problems, the destruction of the ozone layer may be the first example in which global cooperation has brought results. This report will introduce the ways in which Tabai Espec is working to protect the ozone layer.

2. Summary of regulations

The ozone protection regulatory programs began with the adoption of the 1985 Vienna Protocol, followed by the 1987 Montreal Protocol. A 1992 revision strengthening the regulations of that protocol brings us to the current situation. During this time, the use of Class 1 substances (CFC's*¹), which are responsible for a serious degree of ozone destruction, has been completely abolished, and regulations are under way on Class 2 substances (HCFC's*²) that are being used as substitutes for CFC's. (Fig. 1)

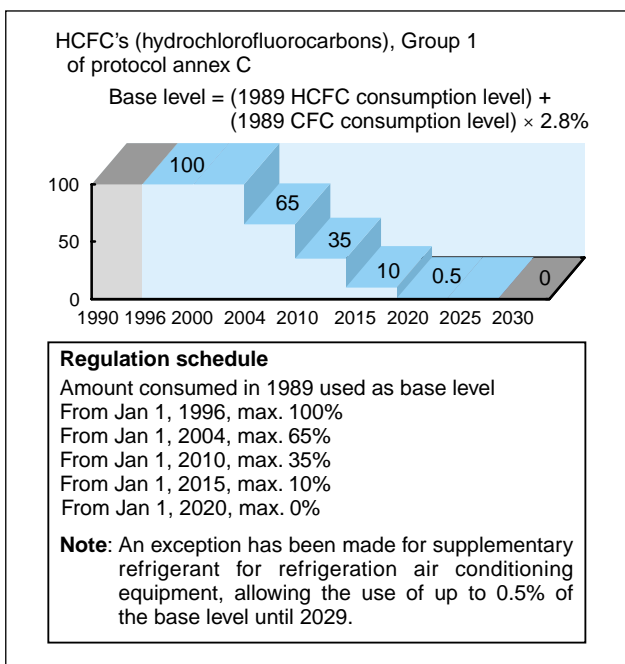


Fig. 1 HCFC elimination schedule according to the Montreal Protocol

In accordance with this schedule, the Japanese government has set elimination targets according to application type, and is providing guidance to the manufacturing industry. (Fig. 2)

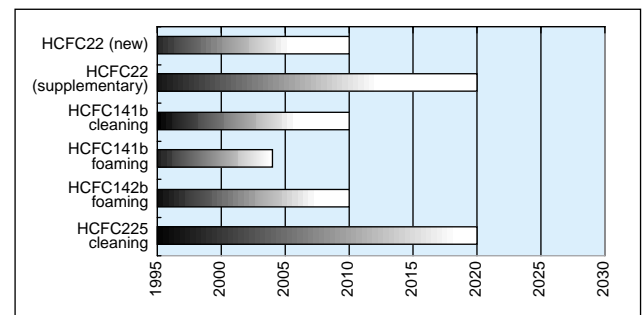


Fig. 2 HCFC elimination targets in Japan

3. Problems with fluorine substitutes (global warming measures)

HFC's*³ do not contain chlorine and so do not destroy the ozone layer, but since these are extremely powerful greenhouse gases, The Third International Conference on Pollution (COP3), held in December 1997, regulates these substances as greenhouse gases.

In order to eliminate substances (such as HCFC's) that are causing ozone layer destruction, which poses an urgent problem, we must continue to rely on HFC's at present. When used as refrigerants, HFC's are not discharged during product use, and can be recovered when products are repaired or disposed of.

In June 1998, the Japanese government formulated a system for handling HFC's based on the current system for recovering and disposing of CFC's.

*Technical Center

4. Espec elimination targets and basic policy

At Tabai Espec, we have obtained environmental management system certification (ISO14001). We have also produced “HFC measures for products” as one company-wide environmental management target, and we have promised to “completely eliminate the use of HCFC products by 2005”.

In response to these aims, our development department has formulated plans for creating products with respect for the environment, and has set the targets of “converting to HFC refrigerants for compression refrigerants for major products by the year 2000”, and “eliminating all HCFC’s (including retrofit technology) by the year 2005”. These targets are being developed, and conversion to HFC’s for major products has been completed.

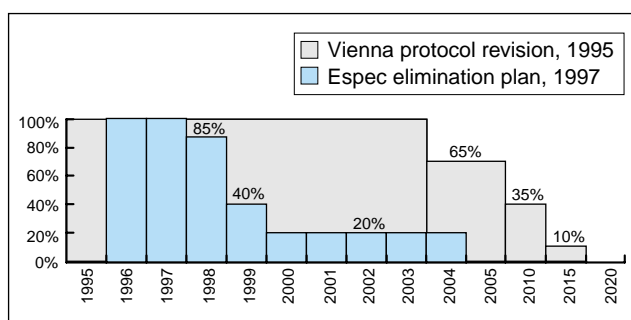


Fig. 3 Espec HCFC elimination targets

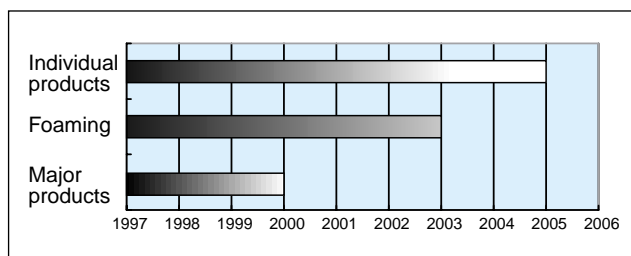


Fig. 4 HFC product conversion plan

5. Dealing with refrigerant applications

In accordance with 1995 protocol on the total elimination of CFC’s, we have converted to HCFC22, R509A, R412A, and HFC134a. With the exception of HFC134a, these will require reconversion to HFC’s, and we have used R404A as a substitute refrigerant.

Table 1 Comparison of substitute refrigerants

| Item | Regulated substances | | | Substitute substances |
|------------------|----------------------|------------------------|--------------------------------------|--------------------------------------|
| Refrigerant name | HCFC22 | R509A | R412A | R404A |
| Ingredients | HCFC22:100 | HCFC22:44 PFC116:56 | HCFC22:70 PFC218:5 HCFC142b:25 | HFC125:44 HFC143a:52 HFC134a:4 |
| ODP*4 | 0.055 | 0.02 | 0.04 | 0 |
| GWP*5 | 1700 | 6300 (calculated) | Unknown (min. 17,000) | 3300 |

The properties of R404A, a substitute for HCFC22, differ from the properties of HCFC22 in the following ways (Table 2), and requires changes in design.

The strategy adopted for changing refrigeration oil in particular will differ according to the compressor manufacturer, but most will change over to POE*6 oil, which is generally compatible with HFC refrigerants. However, this POE oil absorbs more moisture than conventional mineral oil and causes hydrolysis when absorbing moisture, and so POE oil requires strict supervision in processing.

Tabai Espec has been using HFC134a for one type of equipment since 1995, and we are already thoroughly familiar with the strict moisture control required by POE oil.

The compressor must be replaced for HFC compatibility, but due to the greater temperature range in environmental testing, the refrigerating equipment is exposed to much harsher operating conditions than is common in general applications. As a result, when selecting a new compressor, cooperation must be obtained from the compressor manufacturer to carry out reliability confirmation testing focusing on life testing.

Table 2 Technology issues when using R404A in compressors

| Item | Problems | Countermeasures |
|--|---|---|
| Has no chlorine | No extreme pressure effect, increased tendency to wear | • Change materials (compressor manufacturer) |
| Doesn’t dissolve in conventional refrigeration oil | Oil return defect | • Change refrigeration oil (compressor manufacturer) |
| High pressure | Higher pressure | • Reconsider design pressure • Improve condensation capacity |
| Cooling capacity | At lowest temperature conditions, capacity drops slightly | • Use rotating type (rotary scroll) • Reconsider system |
| Increased refrigerant circulation amount | Increased pressure loss in liquid tubing | • Reconsider tubing diameter |

6. Dealing with foaming applications

The Japanese government has targeted total elimination of HCFC141b, which is used in foaming agents, for specific applications by the year 2004.

The foam industry has selected HFC245fa as a substitute refrigerant, and the US company Allid Signal plans to begin supplying the substance in 2002. At present, the company manufactures the substance at a test plant, and improvements include optimizing foaming conditions and using additives to improve foaming.

A formula using cyclopentane is now being developed, but this substance requires special equipment to comply with the Fire Services Act because it is combustible and also has somewhat inferior adiabatic efficiency. With lower adiabatic efficiency, more capacity is required during operation, more power is consumed, and more carbon dioxide is discharged.

Tabai Espec is committed to completely eliminating HCFC from foaming applications by 2003.

Table 3 Comparison of foaming agent substitutes

| Foaming agent | HCFC141b | HFC245fa | Cyclopentane |
|-------------------------------------|----------|----------|--------------|
| ODP | 0.11 | 0 | 0 |
| GWP | 580 | 820 | 3 |
| Compression strength | 1.4 | 1.8 | 1.4 |
| Coefficient of thermal conductivity | 0.0159 | 0.0164 | 0.0168 |
| Insulation performance | 100 | 97 | 95 |

Note: Form values for strength and coefficient of thermal conductivity correspond to panel density of 40 kg/m³.

7. Dealing with retrofits

As previously mentioned, refrigerants that are not discharged into the atmosphere will not affect the ozone layer and will not contribute to global warming. The supply of supplementary refrigerants will easily exceed the life of the equipment requiring it. The crucial matter is recovering refrigerants at the time of equipment maintenance or disposal. Tabai Espec Services include a refrigerant recovery site engaged in certified recovery.

On the other hand, we are also developing technology for converting to HFC refrigerants at such times as equipment overhaul. HFC refrigerants don't mix well with such substances as moisture, chlorine, and mineral oil, and so at present the entire set of refrigeration circuits must be converted. However, that represents a regression from the standpoint of preservation of resources and also presents added expense. We are now developing inexpensive conversion technology utilizing existing circuits.

8. Conclusion

We have presented an introduction to Tabai Espec's efforts to preserve the ozone layer. We shall continue to promote the development of products that have a consideration for the global environment and the usage environments.

Terminology

- *1. CFC's (chlorofluorocarbons)
These substances contain chlorine, and so have a major impact on ozone layer destruction.
- *2. HCFC's (hydrochlorofluorocarbons)
These substances contain chlorine, but they also contain hydrogen, and so have a much smaller impact on ozone layer destruction.
- *3. HFC (hydrofluorocarbons)
These substances do not contain chlorine, and so do not destroy the ozone layer.
- *4. ODP
This is a relative value for the coefficient of ozone layer destruction, setting CFC11 as 1.
- *5. GWP
This is a relative value for the global warming coefficient, setting CO₂ as 1 (integral period, 100 years), IPCC1995.
- *6. POE (polyol ester)
This is an oil that was developed for use in HFC refrigerants.

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