

JEITA

Standard of Japan Electronics and Information Technology Industries Association

EIAJ ED-4701/300-1

**Environmental and endurance test methods for
semiconductor devices
(Stress test I)
(Amendment 1)**

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Standard of Japan Electronics and Information Technology Industries Association

**Environmental and endurance test methods for semiconductor devices
(Stress test I)
(Amendment 1)**

1. SCOPE

Conforming to **EIAJ ED-4701/300** “ Environmental and endurance test methods for semiconductor devices (Stress tests 1) ” .

2. DEFINITION OF TERMS

Conforming to **EIAJ ED-4701/300**

3. PRECAUTIONS

Conforming to **EIAJ ED-4701/300**

4. TEST METHODS

Conforming to **EIAJ ED-4701/300**

Remarks : The Process of deliberation and technical description of each test methods are given to the test methods as Explanation.

COMMENTS

1. PURPOSE OF ESTABLISHMENT OF THE AMENDMENT 1

It was recondite where the latest test methods was entered, it was resulting the confusion of users. So establishment of new numbering system that was easy to use both users and manufacturers was decided, and the standard has been established as **EIAJ ED-4701/300** “ Environment and endurance test methods for semiconductor devices (Stress test) ” in August, 2001.

The change of a technical matter is needed in the test methods in part, we decided after that to publish only the test methods of requiring change as the Amendment. However, every three years it will be established as not the Amendment but the latest version of the standard “ Environment and endurance test methods for semiconductor devices (Stress test) ” that includes the whole test methods of **EIAJ ED-4701/300**.

2. EVOLUTION OF THE DELIBERATIONS

The evolution of the deliberations is conformed to the explanation of each test methods.

3. DELIBERATING MEMBERS

Deliberation of this standard has been made by “ Sub-Committee on Semiconductor Devices Reliability ” of the Technical Standardization Committee on Semiconductor Devices/Semiconductor Devices Reliability Group.

Below are listed the members of deliberation of this standard.

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APPENDIX

TEST METHOD 301 A

RESISTANCE TO SOLDERING HEAT FOR SURFACE MOUNTING DEVICES (SMD)

1. SCOPE

This standard provides for the method to evaluate to soldering heat of SMD used in electronic equipment for consumer application and industrial application in general. This standard is also applicable to both Sn-Pb solder paste and Pb free solder paste.

2. APPARATUS

2.1 High temperature furnace

The high temperature furnace must be capable of keeping temperature specified in Sub-clause 4.2 for long time.

2.2 Moisture chamber

The moisture chamber must be capable of keeping temperature and relative humidity specified in Sub-clause 4.3 for long time. The material composing the chamber must not react under high humidity conditions. Water to be used in the tests must be distilled water or deionized water, with pH from 6.0 to 7.2 and resistivity of 500 Ωm or more at 23°C

2.3 Infrared reflow soldering/Convection reflow soldering furnace

The infrared and the convection reflow soldering furnace must be capable to meet the temperature profile specified in Sub-clause 4.4(1). The temperature profile is specified in terms of the temperature of top surface of the specimen placed on the holder (refer to Sub-clause 2.7). The temperature at the top surface of the specimen shall be measured as shown in **Figure 1**. However, in the case of area array package such as BGA, the temperature can also be measured as shown in **Figure 2(a)** or **Figure 2(b)**.

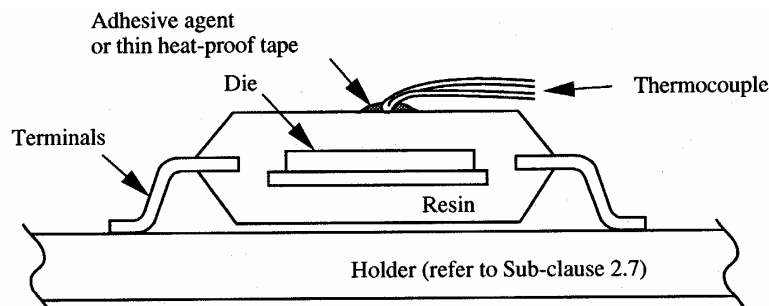


Figure 1 Method of measuring the temperature profile of a specimen

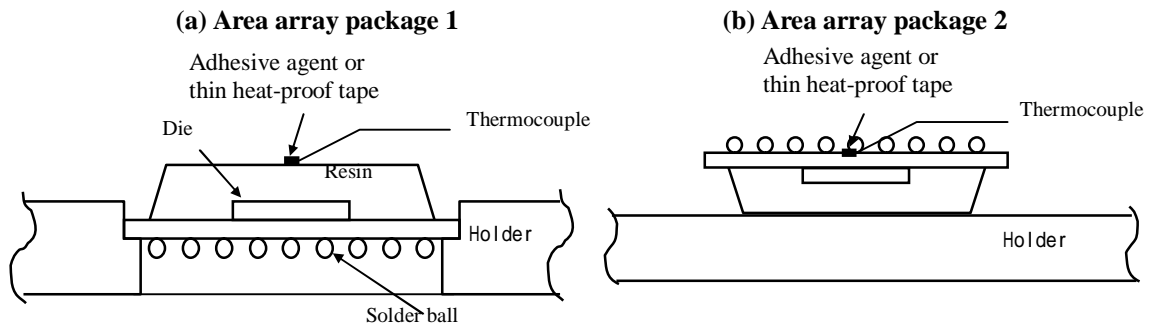


Figure 2 Method of measuring the temperature profile of a specimen (area array package)

2.4 Vapor phase reflow soldering furnace

The vapor phase reflow soldering furnace must be capable to meet the temperature profile specified in Sub-clause 4.4(2). The temperature profile is specified in terms of the temperature of top surface of the specimen placed on the holder (refer to Sub-clause 2.7). The temperature at the top surface of the specimen shall be measured as shown in **Figure 1**. However, in the case of area array package such as BGA, the temperature can be measured as shown in **Figure 2**.

2.5 Wave soldering furnace

The wave soldering furnace must be capable of keeping temperature of molten solder during the solder heating specified in Sub-clause 4.4(3). The molten solder must always be flowed. The preheat conditions in Sub-clause 4.4(3)(b) are specified in terms of the temperature at the top surface of the specimen as shown in **Figure 1** or **Figure 2**.

2.6 Solder bath

The solder bath should have capacity enough to keep the temperature of molten solder within the prescribed values even during the solder heating described in Sub-clause 4.4(4). The dipping equipment should be capable to control the dipping depth and the dipping time of the terminals in the molten solder as specified in Sub-clause 4.4(4)(c).

2.7 Holders

Unless otherwise specified, the material of the holder, which the specimen is to be placed on during the solder heating in the reflow soldering and the wave soldering furnace, should be made from glass-reinforced epoxy resin, polyimide, or alumina substrate

3. MATERIALS

3.1 Perfluorocarbon

Use Perfluorocarbon (perfluoroisobutylene) or equivalent in vapor phase reflow soldering furnaces.

3.2 Solder

Solders to be used in this test should be those ones specified in H60A, H60S, H63A of **JIS Z 3282** (SOLDER) or in **APPENDIX B of JIS C 0050**. Unless otherwise specified in the relevant specification, solder paste of Sn-Ag-Cu is used.

3.3 Flux

Flux to be used in this test should be 2-propanol (**JIS K 8839**) or ethanol (ethyl alcohol, **JIS K 8101**) solution of rosin (**JIS K 5902**) (the concentration should be from 10% to 35% of rosin in terms of mass ratio, and 25% unless otherwise specified) or the material specified in **APPENDIX C of JIS C 0050**.

4. TEST PROCEDURE

4.1 Initial measurement

In accordance with the relevant specification, the electrical characteristics of the specimen shall be measured, and the visual inspection for cracks and the other defects of the specimen shall be made with the assistance of a magnifier capable of giving 40 magnifications. The initial appearance for cracks and delaminations of inside of the specimen shall be inspected using scanning acoustic tomography (SAT) if necessary. (refer Sub-clause 4.6)

4.2 Baking

Unless otherwise specified in the relevant specification, baking under conditions of $125\pm 5^{\circ}\text{C}$ for 24h or more shall be performed if moisture soaking specified in Sub-clause 4.3 will be performed.

4.3 Moisture soaking

Moisture soaking specified in (1) or (2) of this Sub-clause shall be performed if the specimen is type of resin encapsulated SMD. The baking treatment specified in the relevant specification shall be performed instead of the moisture soaking if the baking before real soldering of electronic assembly process is specified in the relevant specification. Unless otherwise specified in the relevant specification, the solder heating specified in Sub-clause 4.4 shall be started within 4h^(Note 1) after finishing this moisture soaking.

Note: Longer time than 4h can be specified in the relevant specification if the specimen is a thicker SMD because it does not affect the moisture absorption and the drying.

(1) Moisture soaking for dry packed SMD

a) Baking not performed before dry packing

The first stage moisture soaking corresponded to the worst atmospheric condition for long storage of SMDs in the dry pack (the worst case is 30°C , 30%RH) shall be performed, and subsequently, the second stage moisture soaking corresponded to the allowable maximum storage condition after opening the dry pack (Floor life) shall be started within 4h after finishing the first stage moisture soaking. The temperature tolerance must be $\pm 2^{\circ}\text{C}$ and the relative humidity tolerance must be $\pm 5\%$. In case of moisture density of a package for one time soaking is more than the density of amount of the first and the second stage moisture soaking, the first stage moisture soaking can be omitted.^(Note 2)

b) Baking performed before dry packing

In case of the worst atmospheric condition for long storage of SMDs in the dry pack is guaranteed less than 30°C , 10%RH because of baking performed before dry packing, the first stage moisture soaking can be omitted.^(Note 3)

Remark 1: If 30°C , 30%RH for 1 year in the dry pack is specified as the worst atmospheric condition, conditions of the first stage moisture soaking can be made by rising temperature from 30°C to 85°C as shown in **Table 1** because moisture soaking speed can be accelerated by rising temperature. **Table 1** shows performing the first stage moisture soaking at 85°C , 30%RH, for 168h^(Note 4) and the second stage moisture soaking at 30°C , 70%RH, for 168h.^(Note 5)

Note⁽²⁾: The moisture density means the density at boundary of a structural object (i.e. chip, die paddle etc.) and resin. The one time soaking is a substitute way of the first and the second stage moisture soaking, and the data of the first and the second stage moisture soaking precede the data of the one time soaking.

Note⁽³⁾: The baking before dry packing must perform both of SMDs and IC-trays, because IC-trays are also absorbed moisture.

Note⁽⁴⁾: When the specimen is a thin SMD and the first stage moisture soaking reaches enough

saturation, its soaking time should be shortened below 168h. On the other hand, when the specimen is a thick SMD and the first stage moisture soaking does not reach saturation, their soaking time shall be extended to over 168h.

Note⁽⁵⁾: Conditions of the second stage moisture soaking should be determined corresponding to storage conditions between opening dry pack and the final soldering process.

Table 1 Example of moisture soaking conditions for dry packed SMDs

Item	Moisture soaking conditions	Expected storage conditions	Remarks
First stage moisture soaking (Moisture soaking corresponded to long storage in the dry pack)	85°C, 30%RH, 168h (perform until saturation of moisture absorption)	30°C, 30%RH, 1year (Worst atmospheric condition in the dry pack)	If expected storage conditions in the dry pack are different from this case, moisture soaking conditions shall be changed into suitable conditions. The first stage moisture soaking can be omitted when the atmosphere in the dry pack is less than 30°C, 10%RH.
Second stage moisture soaking (Moisture soaking corresponded to storage after opening the dry pack)	30°C, 70%RH, 168h	30°C, 70%RH, 168h	

(2) Conditions for non-dry packed SMDs

The moisture soaking conditions shall be selected from **Table 2**^(Note 6). Unless otherwise specified in the relevant specification, the soaking time of 168±24h should be selected for the condition A.^{(Note 7)(Note 8)}

Remark 1: Storage time for non-dry packed SMDs can be assumed as 1 year as upper limit because of some reasons such as degrading solderability.

Note⁽⁶⁾: Condition A should be selected from **Table 2** when SMD is stored in room in Japan (Mean temperature and humidity are below 30°C, 70%RH). Condition B should be selected from **Table 2** when SMD is stored in atmosphere of higher humidity (Mean temperature and humidity are below 30°C, 85%RH). When condition A is selected and the average temperature and humidity exceeds 30°C, 70%RH even if transportation period, SMD should be dry packed.

Note⁽⁷⁾: Unless otherwise specified in the relevant specification, the soaking time of condition A should be selected as 336h when the moisture soaking does not reach the saturation level as thick SMDs.

Note⁽⁸⁾: When moisture soaking of below 168h can make saturation, soaking time of condition A and B can be shortened as within the saturated time as thin SMDs.

Table 2 Moisture soaking conditions for non dry packed SMDs

Condition code	Temperature (°C)	Relative humidity (%)	Soaking time (h)
A	85±2	65±5	168±24 or 336±24
B	85±2	85±5	168±24

4.4 Solder heating

In accordance with the relevant specification, solder heating method shall be selected from method I, II, III and IV in this Sub-clause. The test conditions are selected according to a kind of solder paste (Sn-Pb or Pb free). Unless otherwise specified, solder heating shall be performed twice. If another number of solder heating times may be required, the maximum repetition is 3 times and it shall be specified into the relevant specification. When second solder heating is performed, the specimen shall be cooled down below 50°C after the first solder heating. Unless otherwise specified, moisture soaking between the first and the second solder heating shall not be applied. If moisture soaking between the first and the second solder heating is applied, its conditions shall be specified in the relevant specification.

(1) Method I (infrared-convection or convection reflow soldering)

Solder heating by infrared-convection or convection reflow soldering shall be performed by the following procedures.

(a) Preparations

The specimen shall be put on the holder. Solder paste should not be applied on the holder.

(b) Preheat

The specimen shall be heated to a temperature between 140°C and 160°C for 90s±30s in the reflow soldering apparatus for Sn-Pb solder paste, and . between 160°C and 190°C for 110s±30s in the reflow soldering apparatus for Pb free solder paste.

(c) Solder heating

(i) In the case of SMD mounted by Sn-Pb solder paste

Following the preheat, the specimen shall be continuously heated to the peak temperature, and subsequently the specimen shall be cooled down. Heating conditions shall be selected from **Table 3**. Unless otherwise specified, condition I-I-A with peak temperature of 240^{+0}_{-5} °C and time within 5°C of actual peak temperature for 10s±3s shall be selected if volume of the specimen is below 2000mm³, and subsequently temperature of the specimen shall be lowered to room temperature as shown in **Figure 3**. On the other hand, if the volume of specimen exceeds 2000mm³, condition I-I-B with peak temperature of 225^{+0}_{-5} °C and time within 5°C of actual peak temperature for 10s±3s should be selected, and subsequently temperature of the specimen shall be lowered to room temperatures as shown in **Figure 4**.^(Note 9) If temperature of the SMD which reflects infrared rays is not raised, suitable conditions shall be specified in the relevant specification.

Note⁽⁹⁾: When many types of SMDs which have different volumes are soldered on the same printed circuit board at the same time, the temperature of larger SMDs whose volume is 2000mm³ or more rises slowly and their peak temperature do not reach 220°C because larger SMDs have higher heat capacity.

Table 3 Heating conditions of the infrared reflow and the convection reflow soldering

Condition code	Peak Temperature (°C)	Time within 5°C of actual peak temperature (s)	Remarks
I-I-A	240^{+0}_{-5}	10±3	Peak temperature: 240°C or less (refer to Figure 3)
I-I-B	225^{+0}_{-5}	10±3	Peak temperature: 225°C or less (refer to Figure 4)

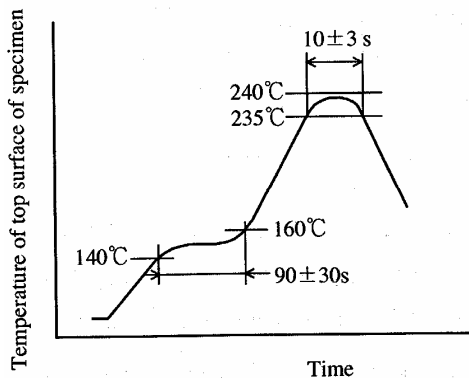


Figure 3 Temperature profile of infrared convection and convection reflow soldering (Condition I-I-A)

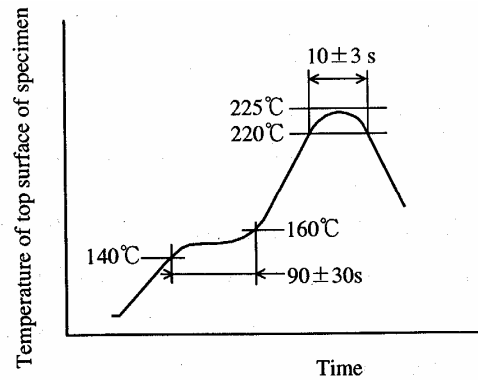


Figure 4 Temperature profile of infrared convection and convection reflow soldering (Condition I-I-B)

(ii) In the case of SMD mounted by Pb free solder paste

Pb free soldering such as using Sn-Ag-Cu solder paste needs higher mounting temperatures (more than 20°C), therefore next specification is specified.

Following the preheat, the specimen shall be continuously heated to the peak temperature, which is decided according to the package thickness and volume. The condition symbols have to be selected from **Table 4**. and the peak temperature is correspondingly specified in **Table 5** by each symbol. The time within 5°C of actual peak temperature is 10^{+6}_{-0} s for all symbols. Subsequently the specimen shall be cooled down. The package thickness has priority over package volume.

Table 4 Heating condition symbols of the reflow soldering for Pb free solder paste

Volume(mm ³) Thickness(mm)	Less than 350	350-2,000	More Than 2,000
Less than 1.6	I-II-A	I-II-A	I-II-A
1.6 ~ 2.5	I-II-A	I-II-B	I-II-C
More than 2.5	I-II-C	I-II-C	I-II-C

All BGAs belong to the symbol of I-II-A.

Table 5 Heating conditions of the infrared reflow and the convection reflow soldering

Symbol	Peak temperature °C	Time within 5°C of actual peak temperature s	Remarks
I-I-A	240^{+0}_{-5}	10^{+6}_{-0}	Refer to Figure 5
I-I-B	240^{+0}_{-5}	10^{+6}_{-0}	Refer to Figure 6
I-I-C	240^{+0}_{-5}	10^{+6}_{-0}	Refer to Figure 7

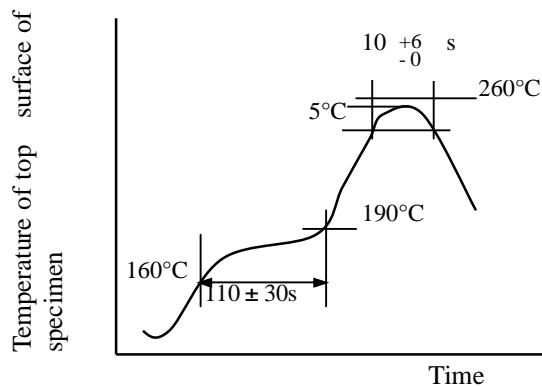


Figure 5 Temperature profile of infrared convection and convection reflow soldering (Condition I-II-A)

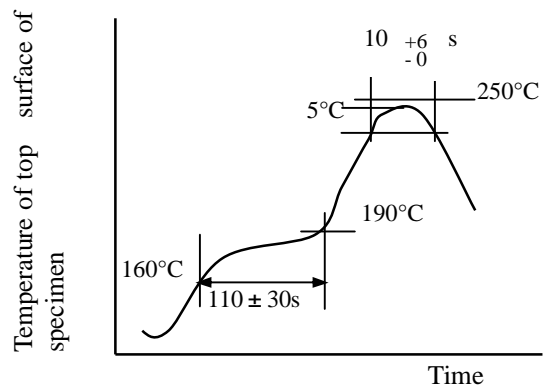


Figure 6 Temperature profile of infrared convection and convection reflow soldering (Condition I-II-B)

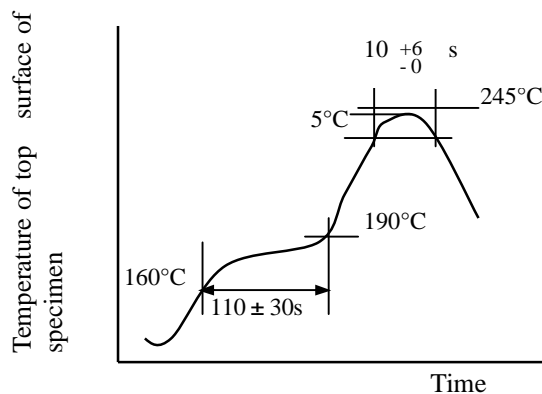


Figure 7 Temperature profile of infrared convection and convection reflow soldering (Condition I-II-C)

(2) Method II (Vapor phase reflow soldering)

When the specimens are heated by the vapor phase reflow soldering method, following procedure shall be applied. (Refer to **Table 6**, **Figure 8**) However, there is the case in which this method can not correspond to Pb free soldering.

(a) Preparations

The specimen shall be put on the holder. Solder paste should not be applied on the holder.

(b) Preheat

The specimen shall be heated to temperature from 140°C to 160°C for 90s±30s in the reflow soldering apparatus.

(c) Solder heating

Between 210°C and 220°C for 40s±4s as shown in **Table 6** and **Figure 8**, and subsequently the specimen shall be cooled down.

Table 6 Heating conditions of the vapor phase soldering

Condition code	Heating temperature (°C)	Heating time (s)	Remarks
II-A	210	40±4	refer to Figure 8

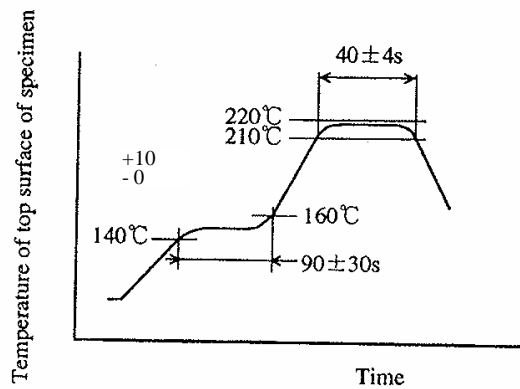


Figure 8 Temperature profile of the vapor phase reflow soldering (Condition II-A)

(3) Method III (Wave soldering)

(a) Preparations

Bottom surface of the specimen shall be adhered to the holder by adhesive agent in accordance with the methods and conditions of the applying adhesive specified in the relevant specification. Unless otherwise specified in the relevant specification, flux shall not be applied to the holder and the specimen. ^(Note 10)

Note⁽¹⁰⁾: Inhibiting the latent heat of evaporation of the flux from rising the temperature of the specimen, the flux should not be applied to the body of the specimen even if applying the flux to the specimen is specified in the relevant specification. If applying the flux to terminals of the specimen, the amount of the flux should be a minimum.

(b) Preheat

The specimen adhered to the holder shall be heated to temperature between 80°C and 140°C for 30s to 60s in the wave soldering apparatus.

(c) Solder heating

After the preheat, the holder with the specimen shall be immersed into flowing molten solder as shown in **Figure 9(a), (b)**. The immersion conditions shall be selected from **Table 7**, according to the real soldering process and conditions. The definition of the immersion time is from the part of the specimen starting immersion, as shown in **Figure 9(a)**, until the part of the specimen emerging from molten solder, as shown in **Figure 9(b)**. The package moving time to complete immersion into the molten solder or complete emergence from the molten solder shall be less than 2s.

Table 7 Heating conditions by the wave soldering

Condition code	Temperature of solder (°C)	Immersion time (s)	Remarks
III-A	260±5	5±1	for single wave
III-B	260±5	10±1	for double wave

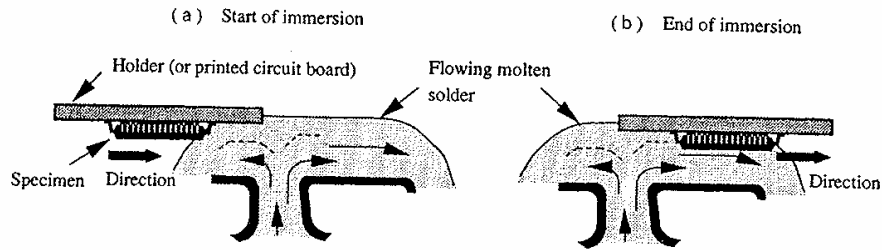


Figure 9 Heating method by immersion using the wave soldering

(4) Method IV (Dip of terminals into molten solder)

This test method, dipping the terminals of the specimen in molten solder simulates heat by the soldering iron.

(a) Dipping into flux

Dip the terminals of the specimen into flux at room temperature.

(b) Cleaning the solder surface

Clean the surface of molten solder by scraping it with a spatula made of stainless steel and the like.

(c) Dipping into molten solder

Dip all terminals of the specimens, one side at a time, perpendicularly into the molten solder surface according to the conditions of **Table 8** (refer to **Figure 10**). The dipping depth should be up to the flat portion for solder joint or up to the effective soldering portion of the terminals. The moving speed for dipping and removing should be 25mm/s. The duration for movement should not be included in the dipping time.

(d) Removing flux

Remove flux stuck on the specimens by washing it.

Table 8 Heating conditions for the dip of terminals into solder

Condition code	Temperature of solder (°C)	Dipping time (s)	Remarks
IV-A	350±10	3.5±0.5	

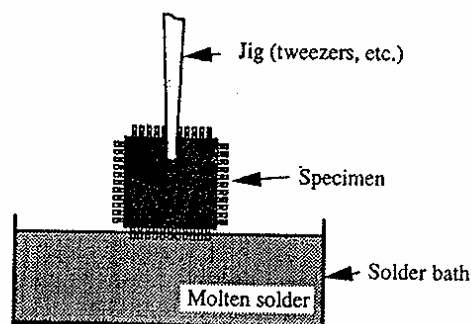


Figure 10 Method of the dip of terminals into solder

4.5 Recovery

If recovery is specified in the relevant specification, the specimen shall be stored under standard atmospheric conditions for the time given in the specification, after finishing the solder heating.

4.6 Final measurements

The specimen shall be judged by the results of electrical measurements, visual inspection of external cracks by 40X optical microscope, and internal cracks and/or delaminations by SAT according to the PASS/FAIL flow chart shown in **Figure 11**. The internal delaminations which come under Sub-clause **4.6.3** shall be judged by the results of the reliability test. A special package which can not apply to these test methods shall be judged by the relevant specification.

4.6.1 Electrical characteristic and visual inspection

A device is considered as a failure if it comes under any of the following:

- (1) Electrical failure
- (2) External cracks visible under 40X optical microscope
- (3) Expansion and/or distortion of the package shape under visual inspection

Remark 3: In the case that expansion and/or distortion of the package shape may cause assembly problems, it should be considered as a failure.

4.6.2 Inspection 1 by SAT

A specimen is considered as a failure if it comes under any of the following. If internal cracks are suspected based on SAT, polished cross sections shall be made to verify the suspected site.

- (1) Internal cracks that intersect a bond wire, ball bond, or wedge bond.
- (2) Internal cracks extending from any internal feature to any other internal feature (lead finger, chip, die attach paddle)
- (3) Internal cracks extending more than two-thirds (2/3) the distance from any internal feature to the outside of the package.

4.6.3 Inspection 2 by SAT

A specimen is considered as good if it does not come under Sub-clause **4.6.2** and any of the following: A specimen shall be judged by the results of reliability test if it exhibits any of follows, except for delaminations on the back side of the die paddle or die (lead on chip etc.)

- (1) Delaminations between the surface of die and the mold
- (2) Delaminations of any other internal feature
- (3) Internal cracks which do not come under Sub-clause **4.6.2**

4.6.4 Reliability test

The specimen shall be judged by the results of reliability test if it comes under item **4.6.3**.

Reliability test method referred to shall be Moisture soaking and soldering heat stress series test (**EIAJ ED-4701/100 test method B-104**) and specified the relevant specification.

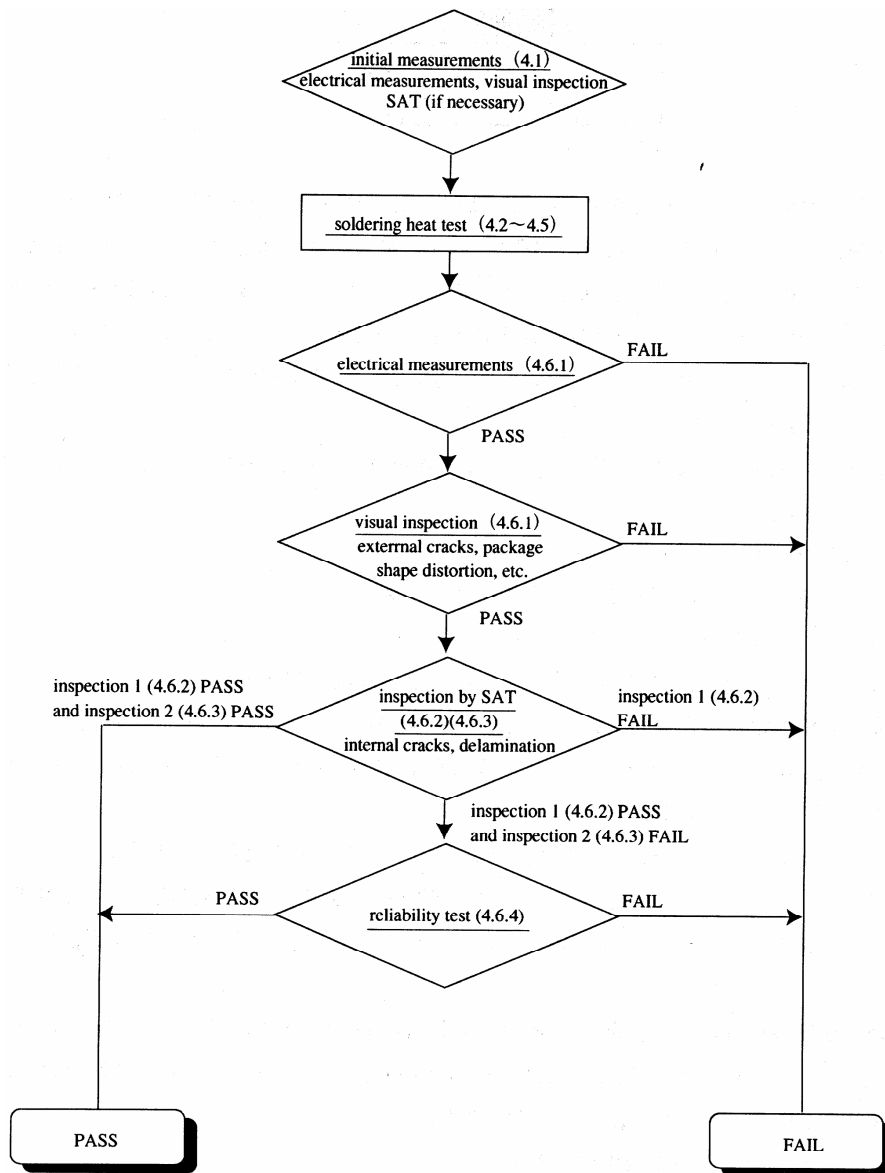


Figure11 PASS/FAIL flow chart

5. Storage limit from opening dry pack to soldering

The storage limit from opening dry pack to soldering classifies on 10 ranks. Baking before soldering is necessary if SMDs stores over the storage limit.

In case of baking performed before dry packing, the floor life should be included the time from end of baking to dry packing, and baking before dry packing must perform both of SMD and a tray.

When rank S is used, moisture soaking condition, storage condition after unpacking and storage limit after unpacking should be specified in the relevant specification.

Table 9 Rank of resistance to soldering heat

Rank	Moisture soaking condition * the second stage moisture soaking	Storage condition after unpacking	Storage limit after unpacking
A	85°C, 85%RH, 168h	<30°C, 85%RH	Unlimited
B	85°C, 65%RH, 168h	<30°C, 70%RH	1 year
C	* 30°C, 70%RH, 672h ^(Note11)	<30°C, 70%RH	4 weeks
D	* 30°C, 70%RH, 336h ^(Note11)	<30°C, 70%RH	2 weeks
E	* 30°C, 70%RH, 168h ^(Note11)	<30°C, 70%RH	168h
F	* 30°C, 70%RH, 96h ^(Note11)	<30°C, 70%RH	96h
G	* 30°C, 70%RH, 72h ^(Note11)	<30°C, 70%RH	72h
H	* 30°C, 70%RH, 48h ^(Note11)	<30°C, 70%RH	48h
I	* 30°C, 70%RH, 24h ^(Note11)	<30°C, 70%RH	24h
S	specified individually	specified individually	specified individually

Note: Acceleration soaking such as 85°C, 65%RH may be used if moisture density under acceleration soaking condition is confirmed over the moisture density under 30°C, 70%RH condition. The simulation results may be used for confirmation.

6. Information to be given in the relevant specification

- | | |
|--|---------------------|
| (1) Holder (When it is different from the specified ones) | [Sub-clause 2.7] |
| (2) Composition of the solder (When it is different from the specified ones) | [Sub-clause 3.2] |
| (3) Mixing ratio of flux (When it is different from the specified ones) | [Sub-clause 3.3] |
| (4) Items and conditions of the initial measurements | [Sub-clause 4.1] |
| (5) Baking (When required) | [Sub-clause 4.2] |
| (6) Moisture soaking conditions (When it is different from the specified ones) | [Sub-clause 4.3] |
| (7) Time period between the moisture soaking and the solder heating
(When it is different from the specified ones) | [Sub-clause 4.3] |
| (8) Allowable maximum conditions (temperature and relative humidity) in the dry pack and the first stage
moisture soaking conditions corresponded to their conditions | [Sub-clause 4.3(1)] |
| (9) Storage conditions of SMDs after opening the dry pack and the second stage
moisture soaking conditions corresponded to their conditions | [Sub-clause 4.3(1)] |
| (10) Selection of moisture soaking conditions for non-dry packed SMD | [Sub-clause 4.3(2)] |

- (11) Moisture soaking time of condition A for non-dry packed SMD [Sub-clause 4.3(2)]
- (12) Moisture soaking time when moisture absorption is saturated less than 168h [Sub-clause 4.3(2)]
- (13) Baking treatment conditions instead of the moisture soaking (When it is necessary) [Sub-clause 4.3]
- (14) Number of times of solder heating (When it is different from the specified ones) [Sub-clause 4.4]
- (15) Moisture soaking conditions between the solder heatings (When it is necessary) [Sub-clause 4.4]
- (16) Selection of solder heating method and conditions, or another conditions different from **Table 3**
[Sub-clause 4.4]
- (17) Adhesion method of specimen [Sub-clause 4.4(3)]
- (18) Application conditions of flux (When it is necessary) [Sub-clause 4.4(3)]
- (19) Time of the recovery (When it is necessary) [Sub-clause 4.5]
- (20) Items and conditions of the final measurements [Sub-clause 4.6]
- (21) Moisture soaking condition, storage condition after unpacking and storage limit
after unpacking if rank S used [Sub-clause 5]

REFERENCE

1. Purpose of establishment

At the beginning, SMDs (surface mounting devices) used to be soldered on the printed circuit board by hand work using soldering iron. At that time SMD did not present any problem in particular related to thermal stress during soldering. Since 1980's, SMD began to attract the attention in view of its advantages related to high density mounting, and such methods as vapor phase reflow soldering, infrared reflow soldering, convection reflow soldering and wave soldering, etc., that heating the whole component part and surface of the printed circuit board (overall heating method) become widespread in view of their merits related to batch soldering of the component parts.

However, in these methods, not only the terminals but also the body of the SMD are heated up to temperatures above the melting point of the solder, and it was found that package crack may occur in the case of plastic encapsulated SMD. When SMDs absorbing moisture during room storage are soldered, the package crack may be occurred by the high pressure water vapor generated internally due to the heat of the package during soldering. This problem tends to occur more frequently in IC and LSI containing large-sized dice, and is very rare in discrete semiconductors.

Then this test method was established by examining the problem of moisture absorption of SMDs during the storage and the conditions of the soldering.

2. Evolution of establishment

Since SMD for ICs and LSIs are more susceptible to soldering heat compared with other surface mounting components such as passive components, and they are more influenced by the effects of moisture absorption during storage before soldering, the provisional standards **EIAJ EDX-4701** (Test Methods for Resistance to Soldering Heat of Surface Mounting Devices for Integrated Circuits) were established on march, 1990. After that, the test method **A-133** in **EIAJ ED-4701** was established properly on February, 1992 by making partial modifications in **EIAJ EDX-4701**, so as to expand the scope of application to hermetic sealed SMD and discrete semiconductors.

And then, the test method **A-133A** was established on March, 1995 by revising the test method **A-133**, so as to correspond to the problem of storage after opening the dry pack and the problems which were found in infrared reflow soldering and wave soldering. And further, the test method **A-133B** was established on June, 1998 by revising the test method **A-133A**, so as to correspond to the problem of moisture absorption between plural times of soldering, classification of solder heating by the infrared reflow soldering and the convection reflow soldering depending on the package volume of SMD, and internal inspection method using by the scanning acoustic tomography (SAT).

In addition, the rank of resistance to soldering heat were added with consideration of JEDEC level and acceleration moisture soaking and revised as **A-133C** on October , 2000.

A classification reflow profiles for SMD mounted by Pb free solder paste were added to correspond to Pb free soldering, and revised as **EIAJ ED-4701/301 TEST METHOD 301A** on June, 2002.

3. Presetting the temperature conditions of the solder heating equipment

3.1 Presetting the temperature conditions of the reflow soldering method

Damages occurring in the SMDs during the soldering depend on the packaged body temperature and the moisture concentration at the first interface in package. (It will be explained in detail later on.) In the infrared reflow soldering, convection reflow soldering and vapor phase reflow soldering, when heating

conditions are preset by observing temperature of SMD terminals or atmosphere in these equipment, serious doubts about the repeatability of the test results occur because there are substantial differences of the packaged body temperature depending on such factors as the combination of temperature presetting conditions of the heating equipment and the speed conditions of the belt conveyor, types of the heating equipment, the type of the SMD, and material and size of the holder. Therefore, it is indispensable to specify the heating conditions in the reflow soldering method in terms of the temperature of the SMD body, (temperature of the top surface of the SMD) and the repeatability of the test results must be secured.

The solder heating conditions must be preset by measuring temperature of the top surface of the SMD that a thermocouple attached to its surface as shown in **Figure 1**, in the heating equipment according to the same steps of procedure as those ones of the test. A thermocouple must be attached to the SMD surface tightly with the adhesive agent or the thin heat proof tape. As long as the conditions are specified in terms of the surface temperature of the SMD, it is not necessary to specify the model of the heating equipment and to specified details of the holder.

Moreover, a thermocouple was attached to the top surface of the SMD by the adhesive agent in test method **A-133** and **A-133A**, however, the method of attaching a thermocouple to the package surface with the thin heat proof tape was added to the test method **A-133B**, because to be able to measure the temperature sufficiently with the thin heat proof tape was ascertained.

3.2 Presetting the temperature conditions of the wave soldering

The heating conditions related to the wave soldering are specified in terms of the molten solder temperature and dipping duration, because a quantity of heat conducted and conveyed from the molten solder to SMD is stable. However, the temperature conditions of preheat must be specified in terms of the surface temperature of the SMD.

4. Test procedure

4.1 Baking

When saturated moisture soaking conditions are assumed as a premise, the baking is not needed. However, since moisture soaking conditions specified in Sub-clause **4.3** are set for the almost saturated conditions, are not set for the perfect saturated conditions, and the test results may depend on whether the baking is performed or not. Therefore the baking is needed to heighten reproducibility of the tests.

4.2 Moisture soaking

It was found that package cracks during solder heating were induced by pressure of water vapor from the moisture contained in the resin near the bottom surface of die pad or near top surface of the die (hereinafter called the first interface). Such being the case, moisture soaking conditions must be specified in such a way that the moisture concentration at the first interface coincides with the moisture concentration after the actual storage of SMDs. Therefore moisture soaking conditions specified in Sub-clause **4.3** are specified in such a way that the moisture concentration at the first interface coincides with the moisture concentration of the allowable maximum storage conditions. Details related moisture soaking are explained below.

4.2.1 Method to obtain the moisture concentration of the resin at the first interface

Since the moisture concentration at the first interface can not be measured, the moisture absorption characteristics of the resin are analyzed by the fitting technique shown below, and the moisture concentration can be calculated from the numerical values of these characteristics.

In the first place, when a resin plate (having side areas as small as possible) with thickness d cm is stored under constant temperature and constant humidity conditions, moisture penetrates from the surface to the interior of the resin plate according to the diffusion law of Fick, given by the equation (1)

$$\frac{\partial C(x,t)}{\partial t} = D \frac{\partial^2 C(x,t)}{\partial x^2} \quad \square \dots\dots (1)$$

where $C(x,t)$: Moisture concentration (mg/cm^3) at the point x (cm) of the thickness coordinate having its origin at the center of the resin plate, and at the time t (s)

D : Moisture diffusion coefficient (cm^2/s) of the resin.

Assuming that immediately after the storage the surface of the resin reaches the saturated moisture concentration Q_s , the boundary conditions are given by the following equation.

$$\left. \begin{array}{l} C(x,t)=0 \quad \left(-\frac{d}{2} < x < \frac{d}{2}, t=0\right) \\ C(x,t)=Q_s \quad \left(x=\pm\frac{d}{2}, t>0\right) \end{array} \right\} \dots\dots (2)$$

and the equation (3) is obtained as a result.

$$C(x,t) = Q_s \left[1 - \frac{4}{\pi} \sum_{n=0}^{\infty} \frac{(-1)^n}{2n+1} e^{-\frac{(2n+1)^2 \pi^2 D t}{d^2}} \cos\left(\frac{2n+1}{d} \pi x\right) \right] \dots\dots (3)$$

On the other hand, given that area of the resin plate is S , amount of the moisture quantity $W(t)$ (g) of the resin plate will be given by equation (4).

$$W(t) = S \int_{-\frac{d}{2}}^{\frac{d}{2}} C(x,t) dx = S \cdot d \cdot Q_s \left[1 - \sum_{n=0}^{\infty} \frac{8}{(2n+1)^2 \pi^2} e^{-\frac{(2n+1)^2 \pi^2 D t}{d^2}} \right] \dots\dots (4)$$

Given Boltzmann factor k , absolute temperature T , pressure of moisture P , activation energy of moisture diffusion E_d , activation energy of moisture dissolubility E_s , coefficient D_0 , n and S_0 , the moisture diffusion coefficient D and the saturated moisture concentration Q_s can be obtained by equations (5) and (6).

$$D = D_0 e^{\frac{E_d}{kT}} \dots\dots (5)$$

$$Q_s = P^n S_0 e^{\frac{E_s}{kT}} \dots\dots (6)$$

By comparing equation (4) and the values of measured amount of the moisture quantity that the resin plate is stored under constant temperature and constant humidity conditions, E_s , E_d , D_0 , S_0 and n which are the moisture soaking parameters can be obtained by fitting technique. These moisture soaking parameters depend on the kind of resin. When these quantities are obtained, the moisture concentration at various places inside the resin can be obtained by equation (3). The moisture concentration at bottom surface of the die pad and top surface of the chip surface (first interface) can be obtained by substituting $x=0$ in the equation (the cos term becomes 1).

4.2.2 Characteristics of saturated moisture concentration of resin

The moisture concentration of resin at the saturation depends on the relative humidity clearly as shown in **Figure B1**. Although **Figure B1** is one of example, another type of resin has similar characteristics, too. So the condition of moisture soaking to be fit for the assumed storage environment can be obtained from **Figure B1**.

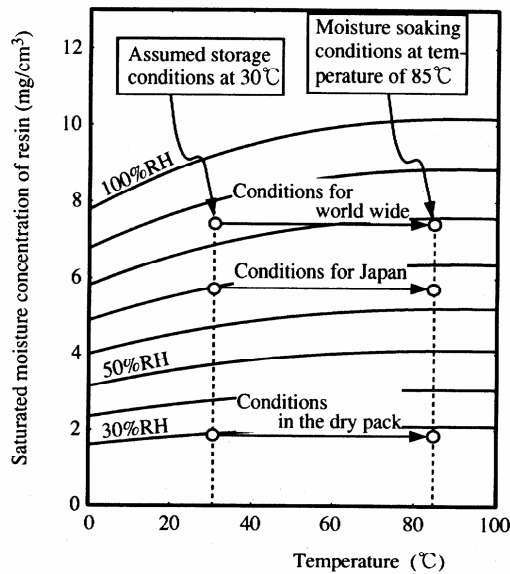


Figure B1 Examples of dependence, on temperature and relative humidity, of the saturated moisture concentration of the resin

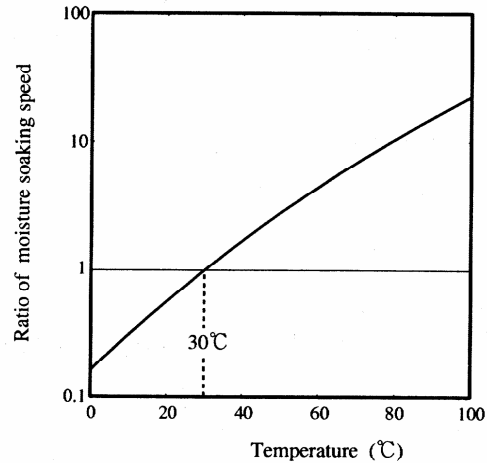


Figure B2 Example of moisture soaking speed depended on temperature (Speed at 30°C=1)

4.2.3 Moisture absorption speed

The moisture absorption speed in the resin is directly proportional to moisture diffusion coefficient D depended on temperature, therefore, the absorption speed increase according to temperature. When rising temperature from 30°C to 85°C, the absorption speed can be accelerated roughly to one figure as shown in **Figure B2**. By defining the resin thickness (length between surface of SMD to the first interface) as shown in **Figure B3**, the absorption speed at the first interface is inversely proportional to the square of the resin thickness ($d/2$ in the equation (3) corresponds to the resin thickness). Therefore the longer moisture soaking time is needed in order to saturate the moisture absorption of thicker SMDs. (refer to **Figure B4**)

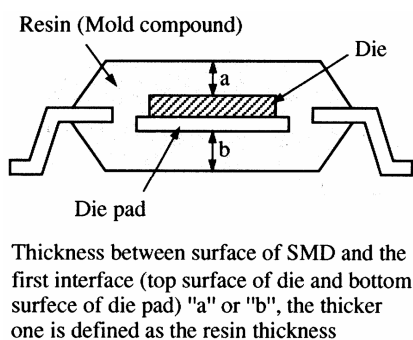


Figure B3 Definition of resin thickness

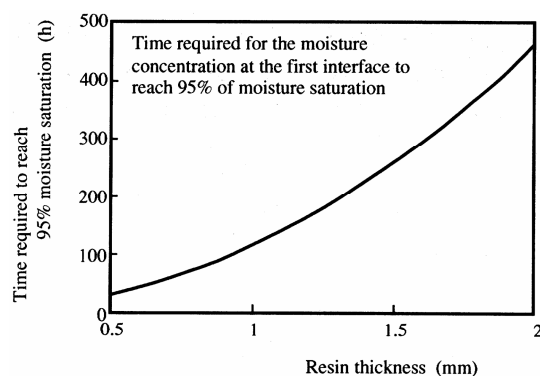


Figure B4 Example of dependence, on the resin thickness, of moisture soaking time at 85°C to reach moisture saturation

4.2.4 Necessity of saturated conditions of moisture soaking

Moisture sensitive SMDs can be stored for long term in the dry pack, and absorb moisture toward moisture saturation under conditions in the dry pack that atmosphere in the dry pack stored for long time is stabilized to lower humidity. The moisture concentration absorbed in the dry pack will be higher than that between opening the dry pack and the soldering when SMDs have medium and thicker thickness. Therefore, the first step moisture soaking corresponded to storage condition in the dry pack specified in Sub-clause **4.3(1)** must simulate the above moisture saturation.

Moisture absorption of the non dry packed SMDs which is stored in the room is unstable, and does over again to absorb and dry. The non dry packed SMDs must be fit for long term storage under the worst condition of the average humidity in the storage atmosphere. So the moisture soaking which corresponds to the saturated moisture absorption of the worst condition is required.

4.2.5 Moisture soaking conditions for the dry packed SMDs and rank of resistance to soldering heat

Dry packed SMD absorbed moisture not only after unpacking but also in a dry pack. Moisture absorption in a dry pack is negligible when baking performed before dry packing, however humidity control is necessary from end of baking to dry packing. These absorption stages should be considered when absorption condition decides.

The manufacturer controls the moisture concentration of SMD before packing, and then, seal up SMD in the dry pack composed of a moisture proof bag and desiccants. But the dry pack is not perfect (the relative humidity in the dry pack is not 0%RH). SMDs, IC-trays, desiccants, etc. that are packed in the dry pack contain the moisture a little before the packing. The relative humidity in the dry pack differs in whether the baking of SMDs and IC-trays is performed before packing, how do the humidity control, how to treat the contents. However the moisture control is performed, there are the pinhole and the damage of the bag, the unsealing and resealing a bag in the shipping.

Generally the humidity indicator is enclosed in the dry pack. This indicator is an exclusive type or the blue beads to be mixed with the desiccant. Generally the sensitivity of the humidity indicator which the Japanese semiconductor manufacturer uses is about 30%RH, and it is requested user to confirm that the humidity in the dry pack is less than 30%RH just after opening the dry pack.

And generally, for the dry pack, it is permitted to store a long term with SMD in the cabinet which is controlled in less than 30%RH.

Besides, it can be considered that the moisture amount, which is absorbed in SMD during such operation for a short time as inspection or repacking of SMDs, can be recovered to the original condition if SMDs are sealed up in the dry pack or kept in the cabinet, which is controlled in less than 30%RH, after that operation.

As mentioned above, conditions of the first stage moisture soaking is 85°C, 30%RH, 168h (but, it should be saturated.) from **Figure A1** if the conditions of humidity in the dry pack or storage is controlled by 30%RH. However, **Table 1** is shown as a typical example as some of semiconductor suppliers specify other conditions from 30%RH. (In USA, EIA/JEP113-B specifies 20%RH for example.) The strict control, such as monitor of the weight gain of SMDs in the dry pack, will not be required, if the first stage moisture soaking conditions are set at the worst condition of humidity in the dry pack. On the other hand, the first stage moisture soaking condition less than 30%RH to be saturated can be applied when the humidity in the dry pack is controlled strictly. (For example, the specimen may be soaked by 85°C, 10%RH if it is controlled below 10%RH.) In this case, several limited conditions, such as execution of the weight gain monitoring of SMDs in the dry pack, or prohibition of opening and resealing of the dry pack, may be often required.

The maximum allowable storage conditions of SMDs between opening the dry pack and soldering are

different by the types of SMDs, which will be specified by semiconductor suppliers. So, conditions of the second stage moisture soaking should be specified in the relevant specification. Conditions of 30°C, 70%RH, 168h are used as the maximum allowable storage conditions of SMDs in Japan by many Japanese semiconductor suppliers. Accordingly, these conditions are shown in **Table 1** as the representative condition. (In Japan, 30°C of temperature is standardized, however, various conditions for humidity (60%RH to 85%RH) and soaking time (few hours to 336 hours) are applied).

The **Figure B5** shows comparison of the moisture calculation results between maximum allowable storage conditions and moisture soaking conditions shown in **Table 1**. Moisture absorption of all kinds of SMDs will be saturated not related with the resin thickness when SMDs are stored for a long term (1 year for example) in the dry pack. It is understood that the soaking condition of 85°C, 30%RH to be saturated (the first stage moisture soaking) can be applied. Besides, the soaking conditions of 30°C, 70%RH for 168h after the first stage moisture soaking can be applied to the case of that SMDs are stored under conditions of 30°C, 70%RH for 168h after the storage in the dry pack for a long term. Then, the soaking conditions of two steps are required independent of the kinds of SMDs due to correspond to the real storage conditions of SMDs.

The rank of resistance to soldering heat is laid down. The rank is included JEDEC's level. A comparison between JEDEC's level and EIAJ's rank is shown in **Table B1**.

The storage condition assumed 30°C, 60%RH in JEDEC's standard, and 30°C, 70%RH in EIAJ's. So the classification of resistance to soldering heat in EIAJ's is named "rank" and they have distinguished between JEDEC's level and EIAJ's rank. Furthermore, lead free soldering is also considered when the rank is fixed.

Figure B5 Comparison between moisture soaking conditions and assumed storage conditions for dry packed SMDs

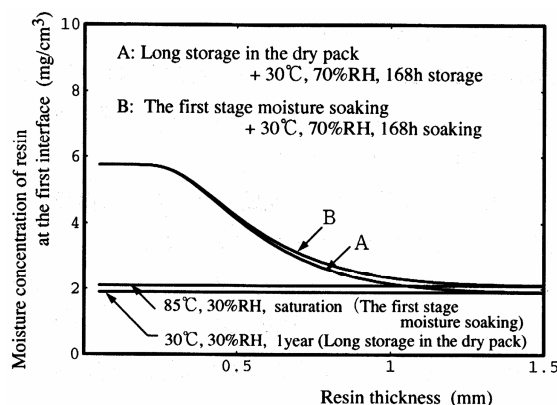


Table B1 Comparison between EIAJ's rank and JEDEC's level

EIAJ(ED-4701-4A-133C)			JEDEC(IPC/JEDEC J-STD-020A)		
Rank	Storage conditions	Storage time	Level	Storage conditions	Storage time
A	30°C, 85%RH	Unlimited	1	30°C, 85%RH	Unlimited
B	30°C, 70%RH	1 year	2	30°C, 60%RH	1 year
C	30°C, 70%RH	4 weeks	2a	30°C, 60%RH	4 weeks
D	30°C, 70%RH	2 weeks			
E	30°C, 70%RH	168h	3	30°C, 60%RH	168h
F	30°C, 70%RH	96h			
G	30°C, 70%RH	72h	4	30°C, 60%RH	72h
H	30°C, 70%RH	48h	5	30°C, 60%RH	48h
I	30°C, 70%RH	24h	5a	30°C, 60%RH	24h
S	specified individually	specified individually	6	30°C, 60%RH	TOL ⁽¹⁾

⁽¹⁾ TOL: Time On Label

Accelerated moisture soaking condition is studied since the test time of the two step moisture soaking is long. The one step moisture soaking can be substituted for the two step moisture soaking, if the moisture density under the one step moisture soaking is more than the density of the two step moisture soaking. The second step of the moisture soaking can be also accelerated moisture soaking. And a simulation result of moisture soaking is acceptable. In the case of rank E, the condition of the second step moisture soaking can be 85°C, 65%RH, 19h, and 85°C, 65%RH 38h for 1 time is also acceptable as shown in **Figure B6**. However the condition depend on the package type and a material of resin. Acceleration condition varies and the major conditions are as follows.

85°C, 65%RH

85°C, 85%RH

85°C, 70%RH

The temperature of acceleration condition does not exceed the glass transition temperature of a resin.

MET (Manufacturer Exposure Time) is not stated in this standard, because it makes the procedure complicated. The worst temperature and humidity condition in a dry pack is stated as an alternative plan.

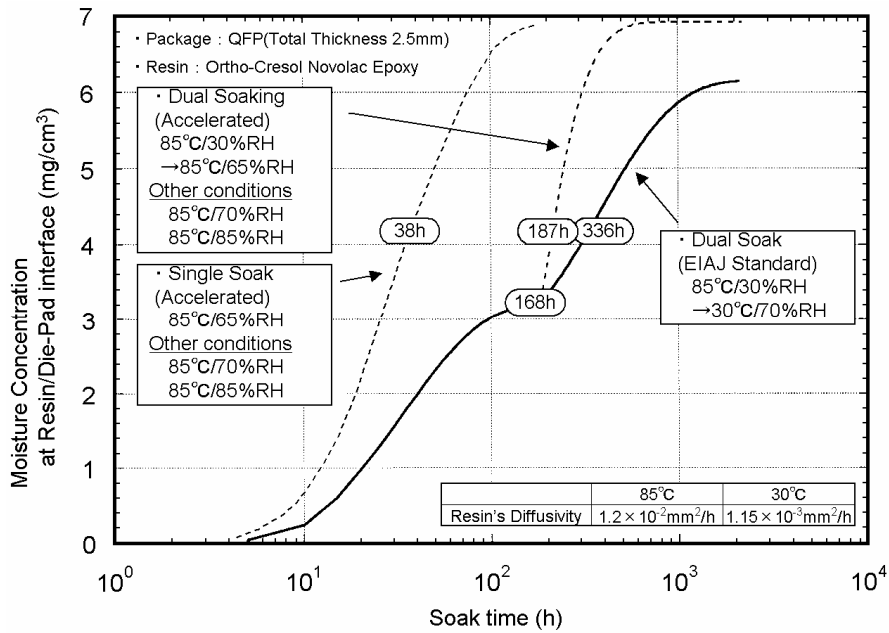


Figure B6 Example of accelerated moisture soaking conditions

4.2.6 Soaking conditions for non-dry packed SMDs

The moisture soaking conditions of 85°C, 65%RH to saturation is required for 30°C, 70%RH, which is the average value for several months (around five months) during summer season in Japan if SMDs are kept in a room such as store house. (Refer to **Figure B1**.) Generally 168h of soaking time is needed or 336h of soaking time is needed for thicker SMDs, which must be specified in the relevant specification.

However, the overseas environmental conditions should be considered because the case that electronic equipment is assembled at a foreign plant has increased recently. The average environmental conditions of 30°C, 85%RH will be enough for these cases, when SMDs are stored in a room. The conditions of 85°C, 85%RH, which is used for temperature humidity test generally, can be applied as the soaking conditions for this case. **Figure B1** shows that the soaking conditions of 85°C, 85%RH is corresponded to the storage conditions of 30°C, 90%RH. So, the conditions of 85°C, 85%RH for 168h, not to saturation, can be applied for almost of SMDs. (Refer to **Figure B7**.) The soaking conditions must be specified in relevant specification if a long soaking time is necessary for thick SMDs.

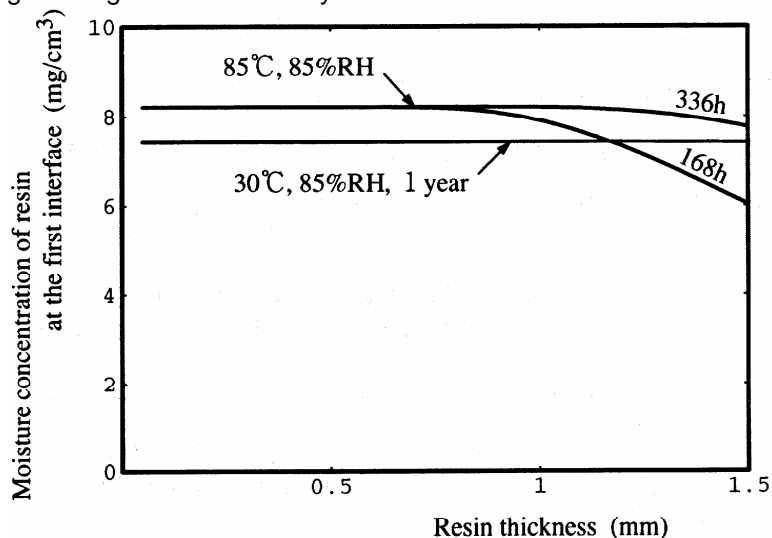


Figure B7 Example of comparison between storage of 30°C, 85%RH for 1 year and moisture soaking of 85°C, 85%RH

4.2.7 Case of that moisture soaking is not required

Moisture soaking is not required for hermetic packaged SMDs because moisture is not absorbed in them. And, in accordance with the relevant specification the moisture soaking can be omitted for plastic molded SMDs having a small die because moisture can not affect them.

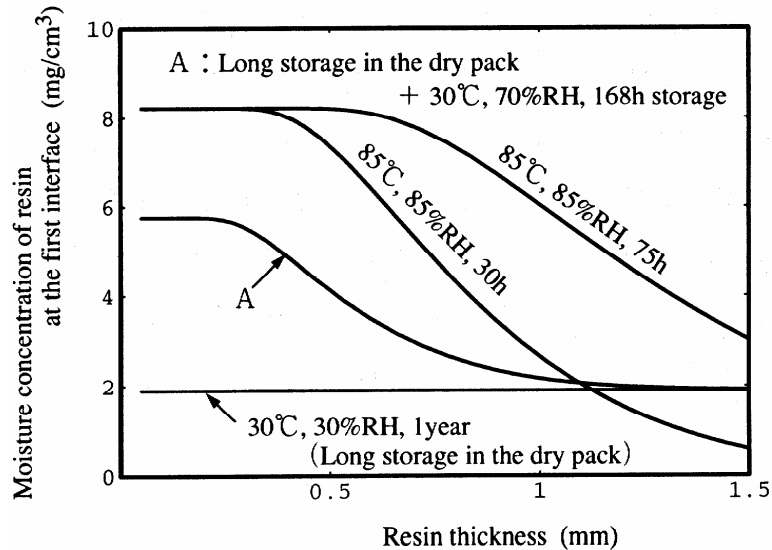


Figure B8 Comparison between single stage moisture soaking and assumed storage condition

4.2.8 Other soaking conditions

Other conditions, 85°C, 85%RH for a short time, such as 30h or 75h, etc., were proposed during establishment of **EIAJ EDX-4701**. In these unsaturated conditions, thin SMDs are soaked excessively and thick SMDs are soaked insufficiently as shown in Figure B8 because the first stage moisture soaking is omitted. The moisture concentration at the first interface after moisture soaking become lower than that after real storage if SMDs are thicker. Accordingly, these conditions had not been adopted.

4.2.9 Moisture soaking condition in USA

In USA, moisture soaking conditions and storage conditions (Floor life) were specified in standards of **JEDEC-IPC/J-STD-020**, **IPC-SM-786A** and **EIA/JEP113-A** before 1999. A maximum allowable relative humidity in the dry pack that is 20%RH was specified in standards of **IPC-SM-786A** and **EIA/JEP113-A**, and further, it was specified that SMDs after opening the dry pack can be stored for a long time into the condition of 20%RH. And then, moisture soaking conditions and storage conditions in the above standards were classified into 6 levels as follows.

(1) LEVEL-1 and LEVEL-2

LEVEL-1 of moisture soaking conditions requires 85°C, 85%RH, 168h for long term (limit free) storage at 30°C, 85%RH. And LEVEL-2 of moisture soaking conditions requires 85°C, 60%RH, 168h for long term (1 year) storage at 30°C, 60%RH. LEVEL-1 is almost corresponds with Condition B given in **Table 2** of Sub-clause 4.3. But as **Figure B7** shows, there is a case that some SMDs are short of moisture soaking time for long term storage at 30°C, 85%.

(2) LEVEL-2a to LEVEL-5

LEVELs 2a to 5 stipulate moisture soaking conditions to cover storage time at 30°C, 60%RH after opening the dry pack (it is defined as floor life and is classified into five parts of storage time). These levels require 24h for Manufacture's Exposure Time (MET) between bake and bag plus the maximum time allowed out of the bag at the distributor's facility. LEVEL-3 is for SMDs to solder by 168h after opening the dry pack (it is mean that floor life is 168h) and moisture soaking condition is 30°C, 60%RH, 192h (floor life plus MET(=24h)) after baking of 125°C, 24h. LEVEL-4 requires moisture soaking time of 96h for floor life of 72h and LEVEL-5 requires soaking time of 48h or 72h for floor life of 24h or 48h, in the same way as LEVEL-3.

As stated above, these moisture soaking conditions are based on conditions that relative humidity in the dry pack is 0%RH because these consist of the baking, the MET and the floor life. Therefore SMDs, IC trays and other materials in dry pack must be completely baked just before packing into the dry pack by semiconductor suppliers.

On the other hand, in **IPC-SM-786A** and **JEP113-A**, their permissible relative humidity in the dry pack was 20%RH, and further, it was specified that SMDs can be stored for long a time (limit free) after opening the dry pack when relative humidity is below 20%RH. Therefore LEVEL-2a to 5 did not correspond with the conditions of **IPC-SM-786A** and **JEP113-A**.

Figure B9 shows comparison of moisture soaking conditions of LEVEL-3 and storage conditions (A: 0%RH in the dry pack, B: 20%RH in the dry pack). This figure shows the following. If SMDs are stored in the perfectly dried dry pack for long a time (assumption: MET=0), moisture soaking condition of LEVEL-3 can cover floor life of 30°C, 60%RH, 168h after opening the perfectly dried dry pack. But when relative humidity in the dry pack become 20%RH, moisture soaking condition of LEVEL-3 can not cover the floor life of 30°C, 60%RH, 168h. In addition, it can not cover the floor life of thick package that relative humidity in dry pack becomes 10%RH.

As stated above, moisture soaking conditions of LEVEL 2a to 5 were based on ideal conditions that the contents in dry pack were dried completely and can not cover long time storage at permissible relative humidity 20%RH being stipulated by IPC-SM-786A in dry pack.

Therefore moisture soaking conditions of LEVEL 2a to 5 were not adopted at this committee because these conditions did not fit real assembly environment because they can not guarantee relative humidity of 0%RH in the dry pack as follows.

- (a) We do not have humidity indicator to correctly guarantee 0%RH in the dry pack
- (b) It is very difficult to completely dry and pack all contents in the dry pack
- (c) We do not have system to control packing the dry pack and temporary opening the dry pack in distributor's facility.
- (d) We can not supply pinhole free or scratch free dry pack.

In addition, moisture soaking conditions of EIAJ can cover one of customer's requirements that SMDs are stored in dry cabinet controlled humidity (below 30%RH) instead of dry pack. On the other hand, the upper relative humidity limit in a dry pack was changed to 10% and revised as **J-STD-020A, JEP-113-B** following the discussion of JEDEC/EIAJ Joint Meeting. A little lack of moisture soak may result as a thick package with 10% of relative humidity. However it is conceivable that there is no contradiction in the moisture soak condition when the strength of a package is considered.

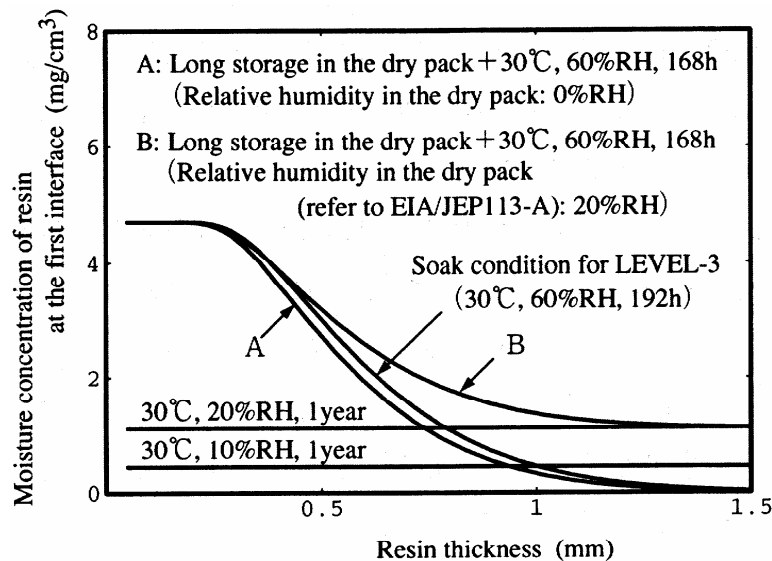


Figure B9 Comparison between moisture soaking conditions and assumed storage conditions for JEDEC Floor Life LEVEL-3

(3) LEVEL-6

This standard specifies that those SMDs which should be soldered within TOL (Time on label) after baking, shall be stored at 30°C, 60%RH for 6h.

4.2.10 Moisture soaking between plural solder heating

Moisture soaking between plural solder heatings, a new proposal on moisture soaking conditions, as shown in **Figure B10 (B)** was given during discussion of revising this test method because SMDs absorb moisture between real plural soldering process and it is practical as shown in **Figure B10 (A)**.

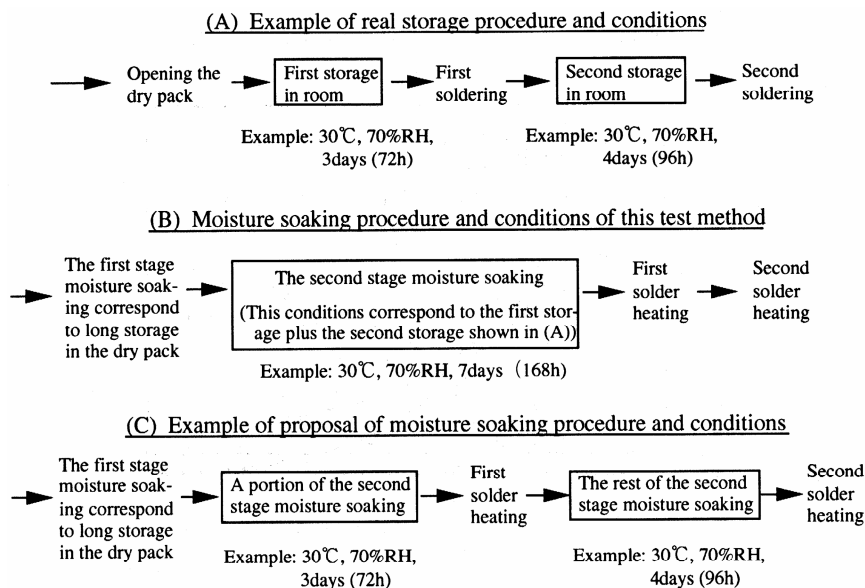
Moisture soaking of Sub-clause **4.3 (1)** is performed as shown in **Figure B10 (B)** that the first stage moisture soaking corresponding to long storage in the dry pack is performed and subsequently, the second stage moisture soaking corresponding to the full amount of storage between opening the dry pack and final soldering is performed. Therefore real storage conditions after opening the dry pack, the full amount of storage between opening the dry pack and final soldering, must be controlled within conditions of the second stage moisture soaking.

Our committee members made experimentations that the second stage moisture soaking of this test method mentioned above and the new proposal as shown in **Figure B10 (C)**. And the assumption of these experimentations is that conditions of the second stage moisture soaking coincide with the sum of soaking conditions between the first stage moisture soaking and final solder heating of the new proposal.

Consequently, two kind of experimentation results are obtained, on the hand moisture soaking of this test method is severer than new proposal, on the other hand the new proposal is severer than moisture soaking of this test method, it is understood that these experimentation results are depended on structure of the SMDs.

In the new proposal, the second stage moisture soaking must be divided into two conditions, but semiconductor user have various storage conditions. Therefore the ratio of dividing the second stage moisture soaking can not be specified.

As mentioned above, our committee have decided that the new proposal, which can be adopted if required by the relevant specification, is not adopted.



**Figure B10 Examples of real storage conditions and moisture soaking conditions
in the event that twice soldering are performed**

4.3 Solder heating

4.3.1 Plural solder heating

Number of times of the solder heating of this test method is twice. However real soldering process has possibility of three times of soldering, therefore three times of the solder heating can be applicable as the maximum times when it is specified into the relevant specification. In this case, if soldering temperature during rework is lower (temperature of SMD's body is below 200°C, or heating by the soldering iron), adding its number of times to that of the solder heating may be not needed.

The moisture soaking of this test method corresponds to the moisture soaking from opening the dry pack to the final soldering of the real soldering process. Therefore, moisture soaking is not carried out between plural solder heatings (see Sub-clause 4.2.10).

When the solder heating is carried out twice or more, the heating procedures specified in Sub-clause 4.4 must be repeated. For example, when solder heating of Method II at 215°C for 40s is repeated twice, heating of 215°C for 40s is made, subsequently, temperature must be cooled down to below 50°C, and temperature must be raised by the same conditions again. Substitute conditions such as 215°C for 80s are not appropriate though duration time is equal to twice of 40s.

4.3.2 Temperature profile method I (Infrared reflow, Convection reflow soldering)

Since the purpose of soldering is to connect SMDs to the printed circuit board, measuring temperature of the terminals of SMDs is an ideal for the soldering heat test. However, SMD's resistance to soldering heat depends on the surface temperature of the body. If conditions of the solder heating are defined by temperature of the terminals, test results will be unstable as mentioned in Sub-clause 3.1. Therefore, in order to ensure test repeatability, conditions of the solder heating for reflow methods could not be help defining temperature of the body surface. Further, as temperature profile of these methods are unstable, temperature of SMD's body surface must be measured for each time of soldering heat test.

The maximum temperature at the body surface during solder heating depends on heat capacity, heat resistance of SMDs. Therefore each members of this committee conducted experiments in correlation between surface temperature at the time of soldering, and body thickness and volume using various SMDs, which indicated a good correlation between volume of SMDs and body surface temperature. With considering circumstance mentioned above, it is decided that the heating condition I-I-A (peak temperature: from 235°C to 240°C) shown in **Table 3** is applied to small of medium size SMDs whose volume is less than 2000mm³, and the heating condition I-I-B (peak temperature: from 220°C to 225°C) is applied to large size SMDs whose volume is over 2000mm³.

For getting good solder junction, SMD terminals should be heated up to at least 210°C (Sn-Pb solder paste). When various SMDs having differ in volume are soldered on the same printed circuit board, the larger the device volume is, the lower its peak temperature of terminals becomes. Therefore, soldering conditions must be set in terms of the terminal temperature of the largest SMD at least 210°C.

When terminal temperature of the largest SMD is set from 210°C to 215°C, body surface of larger SMDs having over 2000mm³ in volume on the same printed circuit board do not reach 220°C, and that of small SMDs having less than 2000mm³ on the same printed circuit board reach over 220°C. Therefore applying solder heating conditions are decided as mentioned above.

This test method had adopted solder heating condition I-A. In this case, if this condition is applied to large SMDs, temperature of the printed circuit board reaches from 250°C to 280°C and foul smell is generated from heated printed circuit board, because power of reflow furnace must be increased in order to heat large SMDs having tendency that raise speed of temperature is slower. Therefore condition I-I-B was added to this test method as a corrective action against this problem, and can be selected one of two conditions.

To examine the Pb free soldering conditions, each members of this committee conducted experiments in correlation between surface temperature at the time of soldering, and body thickness and volume using various SMDs, which indicated a good correlation between volume of SMDs and body surface temperature. With considering circumstance mentioned above, the peak temperature conditions with 3 levels were decided according to the matrix of package thickness and/or volume. An end point of 350mm³ was added in package volume to correspond to temperature rise of 20°C due to an introduction of Pb free soldering.

Moreover, this value of 350mm³ is adopted in the JEDEC specification.

Temperature range was introduced to peak temperature to clear the peak temperature definition.

4.3.3 Temperature profile of method II (Vapor Phase Reflow)

Because that the upper temperature limit, which is the property of perfluorocarbon, reaches 210±5°C, the period while the upper temperature limit is to be kept should be longer, and **IEC-749** second edition adopted the period of 40s, the period is decided to 40s.

4.3.4 Method III (Wave soldering)

A test method that the entire of the specimen are immerse into molten solder as shown in **Figure B11** was specified in **EIAJ EDX-4701** and **ED-4701**, **IEC-749** second edition.

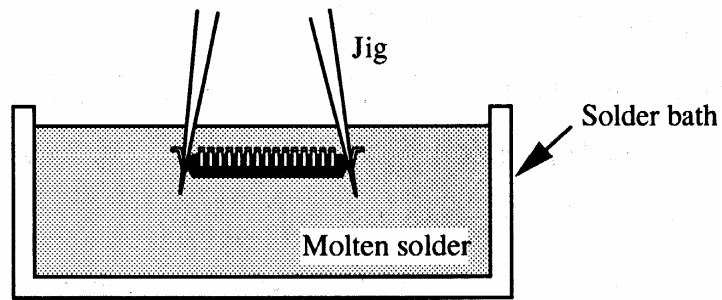


Figure B11 Whole immersion method into molten solder

However, it is reported that the conventional method shown in **Figure B11** becomes too severe as a test method, because the entire body of SMD is immersed in the molten solder and the temperature of SMD itself goes up to higher degrees than that of actual soldering. Meanwhile, when the wave soldering method is used, the temperature of the inside of the package goes up slowly because only one side of SMD is immersed into the flowing molten solder, and the radiation effect from the other side of SMD is also recognized. Consequently, the peak temperature of the inside of the SMDs is lower than that during immersing entire of SMDs into solder bath.

Accordingly, the conventional method was abolished when the test method **A-133** was revised, and the new method, immersion into the flowing molten solder after the SMD is temporarily fixed on the holder as shown in **Figure 9**, was introduced in order to match the actual soldering condition.

The heating conditions were decided as Condition III-A (260°C, 5s) and III-B (260°C, 10s), corresponding to the single-wave and the double-wave soldering.

If flux is applied to the specimen, the flux vaporizes quickly during the immersion. At this time, the latent heat is deprived, which prevents the temperature of SMD from rising. Therefore, it is desirable that the flux is not applied. When the flux is applied, only a small amount should be applied to the terminals and the body of SMD should be avoided. More, when this method is used, the molten solder must be flowed all the time. The static solder bath should not be used because the temperature of the part of solder which the specimen contacts lowers.

4.3.5 The method IV (Terminal immersion into solder bath)

As the SMD is soldered by soldering irons in some cases, the method is provided as Condition IV-A.

4.3.6 Solder heating condition for the Pb free soldering process

Pb free soldering is still now under development stage, however, spreading gradually into the industrial field. Therefore, several kinds of reflow profiles become intensive. With considering these circumstances, JEITA standard on classification reflow profile for Pb free soldering was established comparing with JEDEC standard as reference.

Recently, so called hat type reflow profiles with relatively low temperature (less than 240°C) flat peak region are using. An example of hat-type profile is shown in **Figure B12**. An examination of classification reflow profile for these hat-type profile is considered to be necessary.

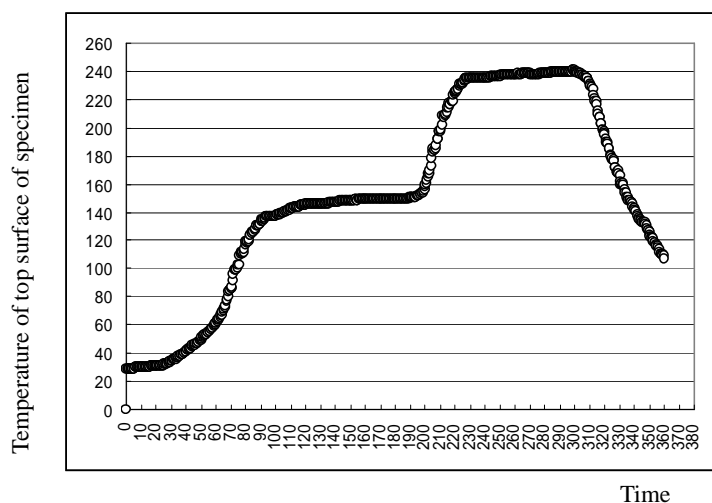


Figure B12 Example of hat type reflow profile

5. SAT (Scanning acoustic tomography)

5.1 Background

EIAJ decided to include SAT criteria in the test method because IEC and JEDEC have been studying SAT criteria for resistance to soldering heat and Japanese semiconductor companies have already started using SAT.

5.2 Conformity to JEDEC SAT criteria

EIAJ and JEDEC have discussed test methods in order to conform to the JEDEC standard in 1996/Sep. and 1997/Oct.. JEDEC suggested considering the specimen to be a failure if it should be an electrical failure, or has external cracks and internal cracks defined in item 4.6.2. And to be judged by the results of reliability tests if it should have delaminations as given in the JEDEC SAT criteria (**J-STD-020A**)

5.3 Criteria

The committee considered the opinion survey results of 16 companies (shown in **Table C1**) for JEDEC criteria. Although there were many opinions to consider the specimen to be a failure if an entire delamination of the die surface should exist, the committee has decided that the delamination shall be judged by the results of reliability test with a view to conforming to JEDEC standard, because the entire delamination does not always cause reliability failure. Also, the committee has decided to match internal cracks criteria in EIAJ to JEDEC criteria.

Table C1 Opinion survey results of EIAJ reliability sub committee for JEDEC criteria

Inspection items	FAIL	PASS	Judged after reliability test
Electrical measurements	16	0	0
External crack	16 (1)	0	0
Internal crack 1 intersect wire, bond	16	0	0
Internal crack 2 to other feature	14	0	2
Internal crack 3 distance >2/3	12 (2)	0	4
Delamination 1 on die surface	12 (3)	1	5 (4)
Delamination 2 on wire bond surface	4	2	10
Delamination 3 (5) Polymeric film	0	3	13
Delamination 4 (6) die attach region	3 (7)	3	10
Delamination 5 (8) feature > entire length	1	1	13
Other delamination back side of die paddle	0	1	1 (9)
Other delamination PBGA: mold and PCB	1	0	0
Other: cracks (10) small internal cracks	1	0	0
Other: cracks (11) wire bond	1	0	0

Each opinion below was from one of sixteen companies.

(1) Visual inspection

(2) More than 2/3 distance shall be needed to discuss

It should be FAIL if it would be YES

(3) It should be FAIL if it would extend to AI PAD

Entire delamination shall be judged FAIL

Small delamination shall be judged PASS

Partial delamination shall be judged by reliability test

(4) Small delamination does not reach AI PAD

(5) No criteria

(6) Die attach delamination shall be eliminated from SAT criteria because it is difficult to measure die attach delamination

(7) It should be FAIL if cracks would be measured

Standard package results shall be referred

It should be FAIL if delamination more than 70% in thermal enhanced package would be measured.

(8) No criteria

(9) It should be FAIL if delamination would cause cracks

(10) Small internal cracks visible by SAT

(11) Internal cracks 3 toward wire

TEST METHOD 307A THERMAL SHOCK ⁽¹⁾

1. SCOPE

This standard provides for the method to evaluate the endurance of the semiconductor devices when they are submitted to rapid changes in the temperature.

Remarks;

1. Initially, this test was designed by assuming the cleaning of semiconductor devices by means of heated solvents. Recently, however, the thermal shock test is being used in some cases as an alternative test substituting the temperature cycle test, but care must be taken when applying it because it may bring about failure modes that are impossible in the field. (Refer to REFERENCES).
2. The glass transition temperature point of resin has gradually become lower as packages become thinner and more compact, and a failure modes that dose not occur in the field may occur due to overshooting the glass transition temperature under a high-temperature test condition, in particular. It is, therefore, necessary to take such a failure into due consideration in case of the application.

2. TEST EQUIPMENT

Two chambers, capable to keep the fluid at the high temperature and low temperature conditions of **Table 1**, should be used. These two chambers must be installed adjacent to each other, so as to allow the transfer of the specimen within the transfer time specified in section **3.2.2**. The test condition should be monitored by the sensor and indicated by meter box or recorder. The monitored temperature under testing is measured by the sensor which should be set in the severest position, where monitored temperature is not steady or hard to approach specified temperature. The performance of equipment should be verified by worst temperature under maximum specimen loaded.

Remarks;

3. The sensor which is used for monitoring temperature is set at the position having a tendency not to be stable or approach the specified temperature, and also the sensor should be calibrated. The sensor's position is checked under maximum loaded state periodically.
4. The maximum loaded state means the maximum specimen's mass (or quantity) under the condition which equipment is able to keep the temperature and dipping time in specified section **3.2**.
5. The worst temperature is the temperature which is indicated by the sensor settled in specimen existing at the center of loaded specimens.

3. PROCEDURE

When the specimen is plastic-molded SMD, carry out the moisture soaking and soldering heat stress treatment specified in the TEST METHOD **104** (Moisture soaking and soldering heat stress test series) prior to this test.

3.1 Initial measurement

Carry out the initial measurements in conformity with the items and conditions specified in the relevant specifications.

Note ⁽¹⁾: This test corresponds to RAPID CHANGE OF TEMPERATURE: TWO-FLUID-BATH METHOD of the IEC standards.

3.2 Tests

3.2.1 Test Conditions

The temperatures in the two chambers and the fluids to be used therein should be selected out the conditions A, B, C, D and E of **Table 1**, or from within the range of the storage conditions (T_{stgmin} to T_{stgmax}) specified in the relevant specifications. The Conditions C should be applied unless otherwise specified.

Table 1 THERMAL SHOCK TEST CONDITIONS

Code of the test conditions		A	B	C	D	E
High temperature side		85 $+1_0^0$	100 $+1_0^0$	125 $+1_0^0$	150 $+1_0^0$	$T_{stgmax} +1_0^0$
Low temperature side		-40 -0_{-10}^0	0 $+2_{-10}^0$	- 55 -0_{-10}^0	- 65 -0_{-10}^0	$T_{stgmin} -0_{-10}^0$
Fluid used	High temperature side	Appropriate medium				
	Low temperature side	Appropriate medium				

Remarks;

6. Fluid used is recommended Perfluorocarbon or such a equivalent medium.

(These mediums are not subjected control of chlorofluorocarbon. It is necessary to take care with handle because of hazardous substance occurrence in high temperature ambient)

7. Ethylene glycol shall not be used as a thermal shock test fluid.

3.2.2 Test methods

The specimen should be dipped in the specified fluid of the low-temperature side for 5 or more minutes. After that, it should be dipped in the high-temperature side fluid for 5 or more minutes. The specimen should be transfer from the low-temperature side to the high-temperature side, or vice versa, within 10 seconds. Ten cycles should be repeated as shown in **Figure 1**, unless otherwise specified.

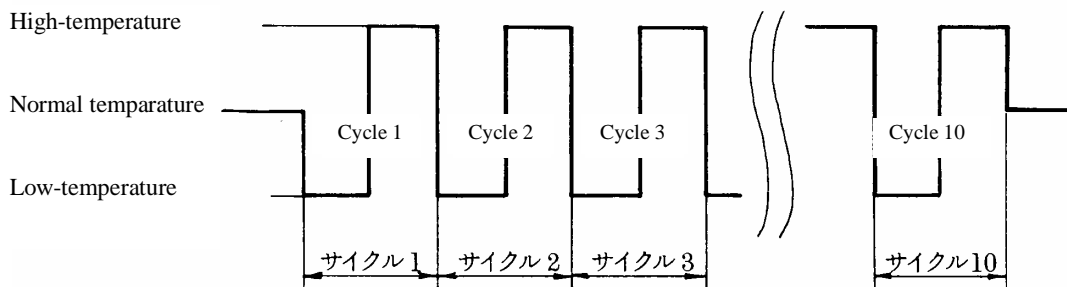


Figure 1 THERMAL SHOCK TEST PATTERN

3.3 Post treatment

Whenever required, wash the specimen with pure water (running water) or another appropriate fluid after finishing the last cycle, and then leave it standing under normal conditions from 2 hours to 24 hours.

3.4 End-point measurement

Carry out the end-point measurements in conformity with the items and conditions specified in the relevant specifications.

4. INFORMATION TO BE GIVEN IN THE RELEVANT SPECIFICATIONS

- | | |
|--|--------------------------|
| (1) Items and conditions of the initial measurements | [Refer to 3.1] |
| (2) Code of the test conditions (When using test conditions other than those ones of Conditions C of Table 1) or the test temperatures
(When using temperatures other than those ones of Table 1) | [Refer to 3.2.1] |
| (3) Fluid to be used | [Refer to 3.2.1] |
| (4) Number of repetition cycles (When executing the test with number of cycles other than 10) | [Refer to 3.2.2] |
| (5) Post treatment (When executing the tests with post treatment conditions other than the specified ones) | [Refer to 3.3] |
| (6) Items and conditions of the end-point measurements | [Refer to 3.4] |

REFERENCE 1

SUPPLEMENTARY INFORMATION ON THE TEST METHOD

1. TECHNICAL BACKGROUND

The thermal shock test is characterized by an extremely rapid shift from low/high temperature conditions to high/low temperature conditions, compared with the slow transition of the temperature cycle. The name "THERMAL SHOCK" of this test has been adopted in view of the extremely rapid temperature change. In general, the specimen is made of various materials with different thermal expansion coefficients, and stress occurs during the temperature cycle test due to the differential expansion and contraction extents of the various materials at the high and low temperatures, and failures related to deformation and rupture occur when the number of cycles is increased. On the other hand, peculiar failures induced by rapid temperature changes occur in the thermal shock test, in addition to failures similar to those ones of the temperature cycle test.

These peculiar failures consist of deformations and ruptures in the specimen resulting from stresses due to differential expansion and contraction extents at the inner and outer sides, caused by large instantaneous differential temperatures between the outer side of the specimen (directly in contact with the heat medium) and the inner side (not in contact with the heat medium). Since these failures may occur even when the specimen is made of a single material (same as a crack that occurs in a frozen glass cup when it is placed in hot water), they are distinguished from failures caused by temperature cycle.

As mentioned above, it may safely be said that the thermal shock test is a method consisting of composite conditions, in which there is repetition of transient states accompanying rapid temperature changes, in addition to the cycle repetition of high-temperature and low-temperature conditions.

2. ON THE SCOPE OF APPLICATION

The following cases related to actual conditions of practical use of semiconductor devices are presumed to be examples of environmental conditions corresponding to those ones of the thermal shock test, in which the semiconductor device is exposed to rapid temperature changes of the order of scores of degrees centigrade.

- Cleaning of the semiconductor device and printed circuit board using hot solvent
- Current applying test in hot inert fluid
- Thermal stress during solder mounting (The SOLDERING HEAT ENDURANCE TEST is specified for this stress), etc.

Since these cleaning and current applying tests may be carried out several times, the conditions of this thermal shock test are specified within a sufficient margin of safety related to temperature and number of times of repetition.

3. ON THE CORRELATION WITH THE TEMPERATURE CYCLE TEST

(1) Precautions related to the application

Temperature changes due to changes in the meteorological conditions and ON/OFF of the power are slow. The temperature cycle test is recommendable to apply with these temperature changes.

Recently, the thermal shock test is being executed in some cases as an alternative test method of the temperature cycle test with the object of shortening the test time. When the thermal shock test is executed, there is risk of inducing failures that are impossible in the actual environment, concurrently with rapid temperature changes.

When executing the thermal shock test as an alternative test method, it must be borne in mind that there is risk of occurrence of failures that are impossible in the field, and that the temperature cycle test is important.

(2) On the accelerability

During the discussion of this test method, some members of the committee mentioned that the thermal shock test has accelerability several times larger compared with the temperature cycle test. The difference is presumably attributable to the following fact. In the temperature cycle test using the hot gaseous medium, the temperature in the test chamber is unstable, and furthermore the specimen can not reach the specified high temperature and low temperature conditions because of its large heat capacity, and as a result the test in gaseous medium becomes more gentle compared with the thermal shock test in liquid medium. Other committee members mentioned that the same results as the thermal shock test could be obtained when the test conditions are preset by the temperature measured of the specimen itself.

4. PROPERTIES OF TEST FLUID

According to IEC standard, the physical properties of fluid used for test are required as shown **Table 2**.

Table 2 PHYSICAL PROPERTY REQUIREMENT OF PERFLUOROCARBON FLUIDS

Code of the test conditions		B	C	D
Boiling point ()		>100	>125	>150
High temperature side	Density at 25 (g/cm ³)	> 1.6		
	Dielectric strength (V/mm)	> 12000		
	Residue (X10 ⁻⁶)	< 50		
	Appearance	Clear, colourless liquid		
Low temperature side	Density at 25 (g/cm ³)	> 1.6		
	Dielectric strength (V/mm)	> 12000		
	Residue (X10 ⁻⁶)	< 50		
	Appearance	Clear, colourless liquid		

Remark; The perfluorocarbon used shall have a viscosity less than or equal to thermal shock equipment manufacturer's recommended viscosity at the minimum temperature.

COMMENTS ABOUT THERMAL SHOCK

1. Contents of discussion of revision and obtained issues

(1) Survey of test operation

In discussing the revision based on the compatibility with IEC, questionnaires were sent to the committee of each company for the review about the thermal shock test and test conditions, and the following results were obtained. (11 companies replied out of 17 companies)

Result of reply		
Items	Content	NO.of company*
Test purpose	Pretest under development product or Accelerate of temperature cycle test	7
	Customer requirement (not standard)	3
	Not testing	1
Test temperature	High 150 / Low -65	6
	High 125 / Low -55	6
	High 100 / Low 0	2
	Select from storage temperature (Tstgmin ~ Tstgmax)	4
Test cycle	10cycle	3
	100cycle	3
	Specified individually	2

Number of company has multiple reply.

(2) Summary of test condition

(a) The test temperature conditions were divided roughly in to the five conditions shown below.

-40 ↔ 85 , 0 ↔ 100 , -55 ↔ +125 , -65 ↔ +150 , Tstg.min ↔ Tstg.max,

(b) Number of actual test cycles was dispersed over a range of 10 ~ 100 cycles among the committee of these companies. Since the execution purposes of this test were not defined yet, the number of test cycles was noticeably dispersed among these companies as a result, because of the mixture of the number of test cycles for the product development processes, customers' demands, and other factors.

(3) Additional opinions from member of the committee

(a) Since the work for transferring semiconductor devices from a liquid bath to a liquid bath under the actual working environments requires only washing in the course of assembly, several test cycles (about 5 cycles) may be enough.

(b) In the conventional standard, the definition of the basis of the holding time specified by the unitary mass of samples is unclear. IEC standard requires temperature monitoring in actual testing and verifying the performance of equipment by measuring temperature in maximum loaded. It is necessary to incorporate IEC's points in this standard.

2. CONCLUSION

According to the results in paragraph 1, almost members of the committee were of the opinion that the revision is necessary, in particular, testing methods and conditions. The summaries of revision are as follows.

- (1) Test conditions are coordinated with IEC's condition(A ~ D) except condition E.
- (2) It is included that IEC's requirements which temperature in actual testing process must be monitored and verifying the performance of equipment by monitoring temperature under the maximum sample loaded.
- (3) The expression of test temperature tolerances are coordinated with IEC expression.(ex. 125 ± 5 to $125^{+1.0}_0$)
- (4) The dipping time and approaching time to specified temperature are coordinated with IEC condition, more than 2 minutes and less than 5 minutes, respectively.

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11, Kanda-Surugadai 3-chome, Chiyoda-ku, Tokyo 101-0062, Japan

TEL +81-3-3518-6434 FAX +81-3-3295-8727