JEITA

Standard of Japan Electronic and Information Technology Industries Association

JEITA ET-7409/202

Surface mount technology - Environmental and endurance test methods for solder joint of lead terminal type device Part 202: Creep strength test

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Standards of Japan Electronics and Information Technology Industries Association

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Introduction

The solders used in production are being switched from tin-lead eutectic solder to lead-free solders in many production lines from the recent request to reduce negative environmental impact. In order to use new solders in production of electronic equipment, standards are necessary to evaluate reliability of the joint strength of a soldered joint using lead-free solder such as by creep strength test. This document provides the necessary information for the creep strength test.

1 Scope

This standard specifies the creep strength test to evaluate the strength of solder joint between the lead of an insertion type component and land when connected using lead-free solder. This is also applicable to such a device whose leads can be cut off from the device itself without any force applied to a joint. A lead-frame or the lead material (wire) itself can be substituted if leads terminal cannot be cut off from the device.

The test evaluates the durability of a soldered joint until break when connecting the lead of an insertion type component to single-sided print circuit board by flow soldering while measuring the electric resistance of the joint by applying a specified weight to the lead in a thermostat chamber. Time to break is evaluated because resistance increases if solder joint breaks.

This test is basically a durability test for soldered joints and is not a strength test of a device itself and of the bonding strength of a lead to the device. Therefore, the temperature in the test chamber specified in this spec may exceed the guaranteed temperature range of the device.

The structure of the joint for evaluation in this test is illustrated in **Figure 1**.

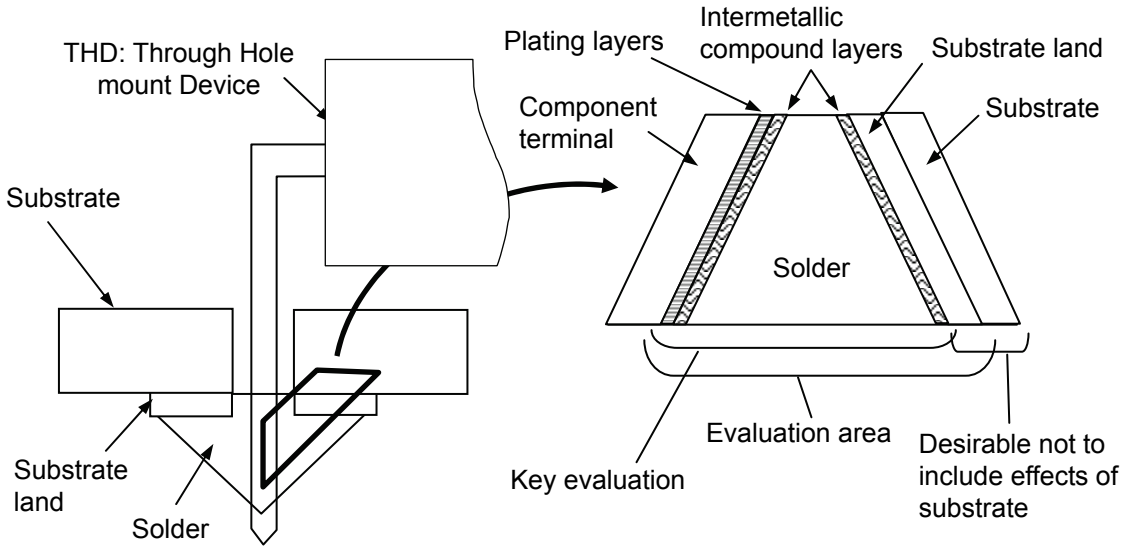

Figure 1 – Schematic illustration of the pull strength of a soldered joint

Note The reason why the test board is limited to a single-sided board is that the test using a double-sided board with through-holes results in break of the leads from a component before a soldered joint breaks. It is also important that minimal stress is to be applied to a soldered joint when a lead is cut-off from a component.

The mechanical strength test of the effect of self-heating of equipment and of environmental heat condition in use to a soldered joint of a lead and a land of a board is given in **JEITA ET-7409/201**, the creep strength test.

We have **JIS C 60068-2-21** for the tests for the connection strength of a lead to a component. This standard includes the following tests for lead strength but they are not the test for a soldered joint.

Test **Ua1** Tensile test
Test **Ua2** Thrust test
Test **Ub** Bending test
Test **Uc** Torsion test

2 Normative references

The following referenced documents are indispensable for the application of this document. For a dated reference, only the edition cited applies. For an undated reference, the latest edition of the referenced document (including any amendment) applies.

JIS C 60068-1:1993, Environmental testing - Electricity and electronics, Part 1: General and guidance

Note All the clauses referred to **IEC 60068-1**:1988, Environmental testing Part 1: General and guidance, and Amendment 1 are equivalent to the clause in this **JIS** document. **JIS C 60068-1**: 1993 is identical to **IEC 60068-1**:1988.

JIS C 60068-2-2:1995, Environmental testing Electricity and electronics Part 2 Tests, Test B: Dry heat

Note All the clauses referred to **IEC 60068-2-2**:1972, Environmental testing Part 2 Tests, Test B: Dry heat, and Amendment 1:1993 are equivalent to the clause in this **JIS** document.

JIS C 6484:2005, Copper-clad laminates for printed wiring boards - Epoxide woven E-glass laminated sheet of defined flammability

Note All the clauses referred to **IEC 61249-2-7**:2002, Materials for printed boards and other interconnecting structure - Part 2-7: Reinforced base materials clad and unclad - Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad and **IEC 61249-2-8**:2003, Materials for printed boards and other interconnecting structure - Part 2-8: Reinforced base materials clad and unclad - Modified brominated Epoxide woven fiberglass reinforced laminated sheets of defined flammability (vertical burning test), copper-clad.

IEC 61190-1-1:2002, Attachment materials for electronic assembly - Part 1-1 Requirements for soldering fluxes for high-quality interconnections in electronics assembly

3 Terms and definitions

The terms and definitions used in this document are given below.

3.1

flow soldering

a wave, drag or dip soldering process where the product is brought into contact with molten solder in to attach electronic components to the interconnecting surface of a board. It is often called also “wave soldering”.

3.2

through hole

the hole made on a board for mounting of components to a conductive pattern.

3.3

land

a portion of a conductive pattern usually used for the connection and/or attachment of components.

3.4

solder fillet

the form of solder after solidification, with a normally concave surface, at the intersection of the metal surfaces of a soldered connection.

3.5

creep strength

the maximum applied force to break the lead of a lead type SMD solder mounted and soldered from the copper land of printed wiring board using a jig to creep the lead.

4 Test equipment and materials

4.1 Flow soldering bath

The bath for flow soldering is a bath that can realize the temperature condition stated in **5**. An example of the temperature profile for flow soldering is shown in **Figure 2**.

4.2 Rapid temperature change chamber

The thermostat chamber is a chamber as specified in **JIS C 60068-2-2** and satisfies temperature conditions for the test. The chamber is capable of containing the creep test equipment that is described in **6.2**.

4.3 Creep strength test equipment

The creep strength test equipment shall be capable of realizing the test condition stated in **6.2**, having a power supply, resistor protector, monitor, (e.g., X-T recorder), a fixing jig of a test board in the chamber and a fixing jig of a lead with a weight as a load.

The entire system may be constructed into one instrument.

The weight for the load shall not give a transient overload to a lead and the load shall be applied smoothly to the direction of the axis of the lead.

4.4 Test board

Unless otherwise specified in the product specification, the testing board shall be of the following specifications.

a) Board material

The material of a testing board shall be epoxide woven E-glass copper–clad laminate of general purpose sheet laminated to single- or double sided board as specified in **JIS C 6484**.

b) Board thickness

The thickness of a test board shall be 1.6 mm ± 0.2 mm including the thickness of copper foil, or another thickness specified in **JIS C 6484**.

c) Size of the board

The size of a testing board shall be 140 mm × 45 mm.

Note This size of the board is for the board to be used in a test. The size of a board used in flow soldering process may be four times of this size but should be able to be divided into this size.

d) Thickness of the copper land

The thickness of the land of the board for shall be 35 μm to 45 μm including plating.

e) Diameter of a through hole

The diameter of a through hole is given in **Table 1**.

f) Diameter of a land

The diameter of a land is given in **Table 1**.

Table 1 – Nominal cross section of leads and diameters of through holes and lands

Nominal cross section(S), mm^2	Nominal diameter(d) of a round cross section type lead, mm	Through hole diameter, mm	Land diameter, mm
$S \leqq 0.10$	$d \leqq 0.35$	0.8	1.4
$0.10 < S \leqq 0.28$	$0.35 < d \leqq 0.6$	1.0	1.6
$0.28 < S \leqq 0.5$	$0.6 < d \leqq 0.8$	1.2	1.8
$0.5 < S \leqq 0.79$	$0.8 < d \leqq 1.0$	1.4	2.0
$0.79 < S \leqq 1.20$	$1.0 < d \leqq 1.25$	1.6	2.2

g) Solder resist

Solder resist is not applied.

h) Anti-rust treatment

Pre-flux is coated on copper land to prevent surface oxidation.

4.5 Solder

Unless otherwise specified in the product specification, the composition of the solder used shall be Sn96.5Ag3.0Cu0.5.

4.6 Post flux for flow soldering

Unless otherwise specified in the product specification, the flux specified in **IEC 61190-1-1** shall be used.

5 Preparation for mounting of component on board

5.1 Mounting of a specimen to a test board

Mounting of a specimen to a test board shall be in the following.

a) Insert the leads of a specimen into through holes of a board as specified in **4.4** using adhesive.

b) Coat the post flux as specified in **4.6** on the board surface on which a component is mounted in either the form of foam or by spraying.

c) Unless otherwise specified in the product specification, solder a component to a board by using a flow soldering bath specified in **4.1** and solder specified in **4.5** with the following condition. The temperature of preheating is 100 °C to 120 °C, the temperature of the soldering bath is 250 °C ± 5 °C with a dipping time of 3 to 5 s. An example of the temperature profile for flow soldering is shown in **Figure 2**. The position to measure the temperature is the land immersed into the molten solder.

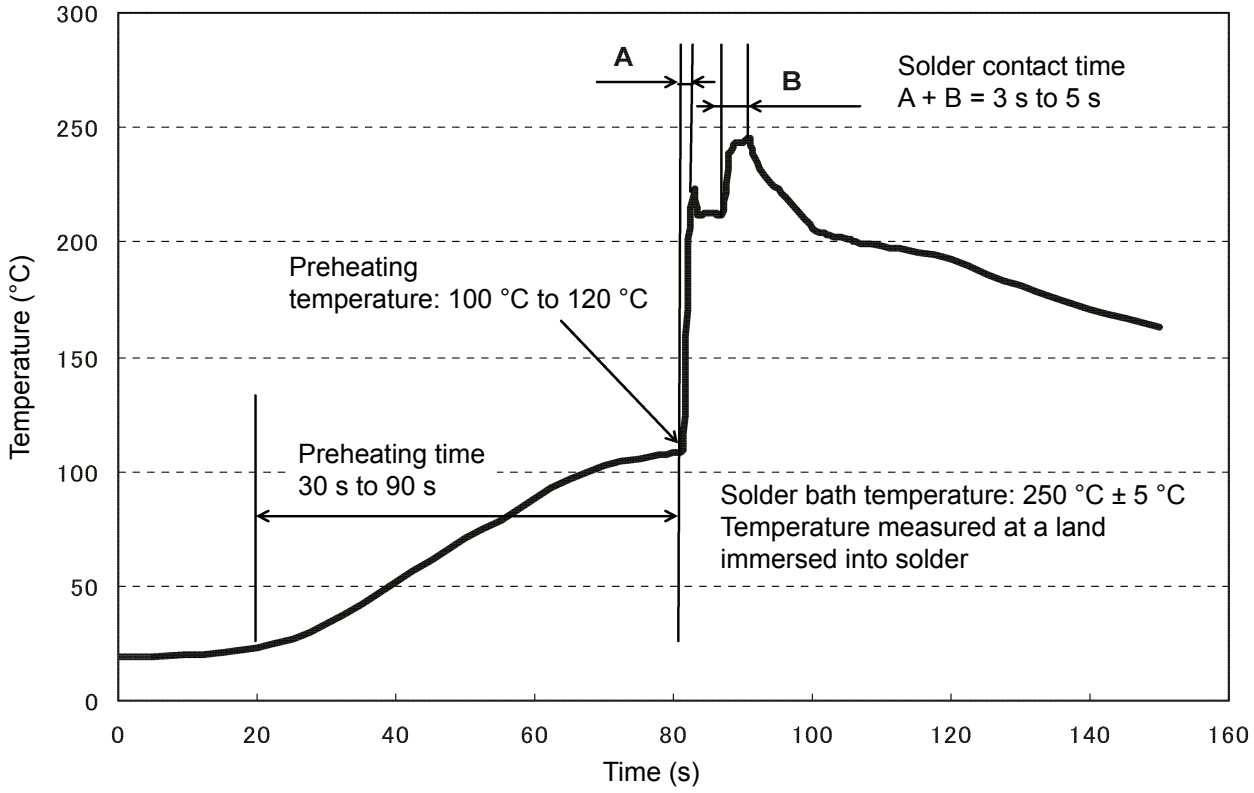

Figure 2 – Example of a flow soldering profile
(actual measurement for double wave soldering)

5.2 Preparation of specimen

The lead for the pull strength test is cut off from the Through Hole mount Device. Care shall be made not to apply any force to the soldered joint. In a case that the lead terminal to be tested cannot be fastened to the fastening jig, other methods of fixing the lead to the jig (e.g., welding) may be used. A fixing method shall be selected that there is no ambiguity in judgment of the joint failure is anticipated.

6 Test condition

6.1 Pre-treatment

Unless otherwise specified in the product specification, the specimen shall be kept in a standard environment specified in **JIS C 60068-1**, **5.13** for more than 4 h.

6.2 Test procedure

The test shall be made in the following procedure using the equipment described in **4.3**.

a) The specimen shall be visually inspected after having the pretreatment specified in **6.1**.

b) Connection is made for the conduction test to a pattern connected to the land but apart from it more than 10 mm as a positive terminal and the weight jig to hold the lead as a negative terminal.

c) The test board is fixed to the creep test equipment.

Note When the test board is fixed to the equipment, the lead to be tested shall be positioned to the center of the lead fixing jig as to the lead terminal is in line to the lead fixing jig.

d) Unless otherwise specified in the product specification, fix the test board as specified in **4.2**. The temperature of the thermostat chamber shall be at the temperature specified in relevant standards.

Note 1 The temperature specified in relevant standards shall be lower than the heat resistant temperature of the board.

Note 2 Care shall be paid not to induce an excessive chemical, thermal, or chemical load to the joint of the lead and the land.

Note 3 Record the method of fixing the test board and also the relative position of the fixing jig and the testing joint.

e) A schematic illustration of the test is given in **Figure 3**.

f) Apply the force specified in the product specification to the lead terminal. A predetermined weight to the jig is used to apply the force to the lead. The accuracy of the force to the lead shall be less than ±1 %.

Note 1 Care should be paid to prevent the lead terminal and the weight touch the jig and other subjects in the chamber.

Note 2 Care shall be paid not to apply any dynamic force to the test board when a weight is added to the loading jig.

Note 3 In selecting an appropriate force (mass of the weight), it is efficient to start a test from a rather large Force (e.g., 90 % of pull strength of the joint) considering the results of a pulling test and of the creep strength to break. Use of a log-log plot of force to creep strength to break for extrapolation to select a weak force is desirable by reducing the force along the line in the graph.

g) Switch on the power supply and the monitor and start measurement.

h) Record the time from the start of loading the weight to the lead and the time the joint breaks.

i) Record the position and the failure mode as the joint breaks.

Note 1 Confirm the operation of the equipment, presence of circuit noise and open of the measuring circuit prior to the creep strength test by performing a conduction test before the loading of a weight without applying any external force to the joint.

Note 2 It is desirable to limit the estimated life within one order of magnitude when the life of a joint is extrapolated from experimental data.

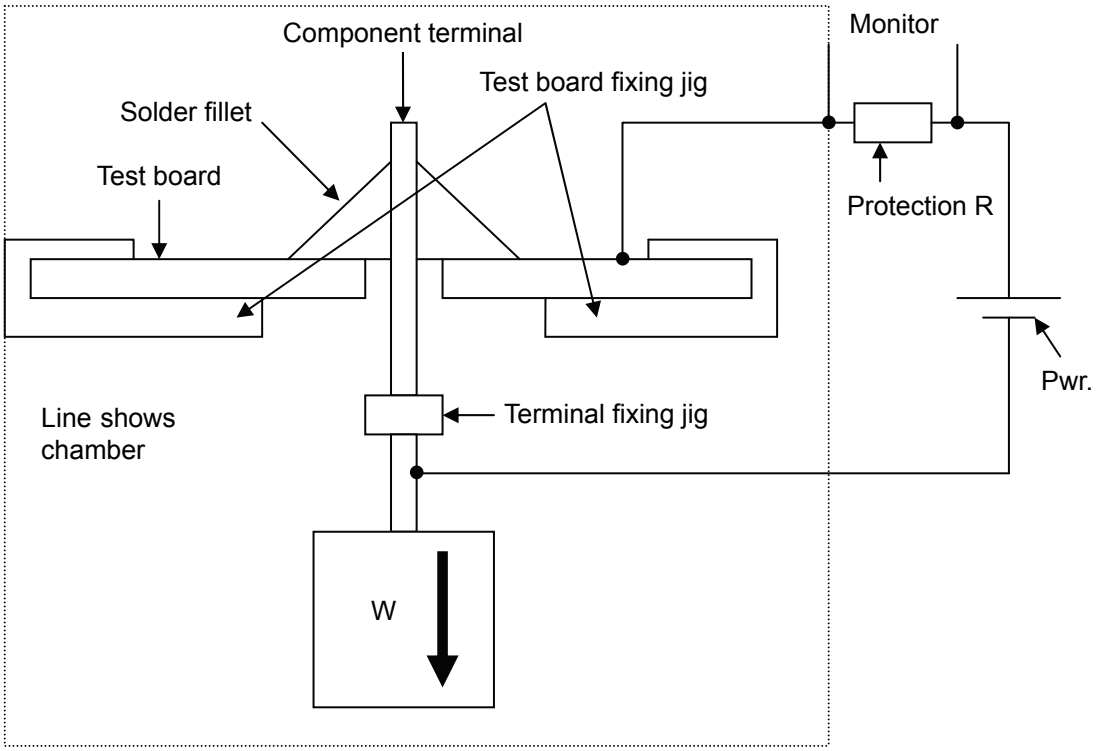

Figure 3 – Illustration of creep strength test equipment

7 Items to be included in the test report

The items shall be selected from the following list as agreed between user and supplier and recorded in the test report of this creep strength test.

a) Date of the test
b) Name of the test laboratory, or venue of the test
c) Name, type, and dimensions of the component tested
d) Material, presence or not of metal plating, and the material of plating of the leads
e) Material and dimension (size and thickness) of the board
f) Diameters of the land and the through hole on the test board
g) Diameter (or cross section) of the lead and electrolytic plating if any
h) Types of solder and flux used
i) Temperature profile of reflow soldering
j) Type of creep strength test equipment used
k) Temperature within the thermostat chamber
l) Mass of the weight
m) Creep strength
n) Failure mode of creep break of the joint

8 Items to be stated in the product specification

a) Material, thickness and size of the test board, thickness of copper foil of the land, diameters of land and of a through hole and solder resist if used (**4.4**)
b) Solder (**4.5**)
c) Post flux for flow soldering (**4.6**)
d) Dipping time to flux (**5.1 b)**)
e) Temperature profile in flow soldering (**5.1 c)**)
f) Pre-treatment (**6.1**)
g) Condition of creep strength test (test temperature and creep speed) (**6.2**)
h) Items to be recorded in the test report (**7**)

9 Related standards

JEITA ET-7409, Surface mount technology - Environmental and endurance test methods for solder joint of surface mount device or lead terminal type device: Selection of the test methods

JEITA ET-7409/201, Surface mount technology - Environmental and endurance test methods for solder joint of lead terminal type device Part 201: Pull strength test

JIS C 60068-2-21:2002, Environmental testing - Part 2-21: Tests - Test U: Robustness of termination and integral mounting devices (MOD).

Note All the items referred to **IEC 60068-2-21**:1999, Environmental testing - Part 2-21: Tests - Test U: Robustness of termination and integral mounting devices (MOD) are equivalent to **JIS C 60068-2-21**.

Surface mount technology - Environmental and endurance test methods for solder joint of lead terminal type device Part 202: Creep strength test Additional information

The information given here describes items of interest related to the descriptions made in this standard and in the Annex and does not consist of a part of the standard.

1 The purpose and history of establishing this standard

At the issue of the EU RoHS Directive, experts in the academia and industry organized a three-year program as a NEDO (New Energy Development Organization) project to investigate problems to be anticipated in the reliability of a lead-to-land joint under the joint effort of ex-**EIAJ** (Electronics Industry Development Association of Japan), now **JEITA** (Japan Electronics and Information Technology Association) and **JEIDA** (Japan Electronics and Information Development Association - later joined with **EIAJ** to form **JEITA**), and started their activity in 1998 including people from other organizations. One of the fruits of the study resulted in standardization of the test methods of mechanical strength of a soldered joint of a lead and a land made using lead-free solder. A new NEDO three-year project was organized in 2001 of the New Joint Technology Standardization Committee, and the Durability Test Methods of Joints Sub-committee, (sponsored by the METI - Ministry of Economics, Trade and Industry of Japan from the second year) was formed to develop a pulling strength test method together with other durability test methods.

A Sub-committee was organized in the Assembly Technology Standardization Committee of **JEITA** to study types of lead-free solders, printed wiring board itself and circuit design, electrolytic plating of lead terminals, soldering conditions, and the relation of these factors to the strength of a soldered joint. The present standard was developed by this Sub-committee.

2 Items of special interest in developing this standard

The following items were presented.

a) If the weight used can reflect the physical strength of a joint in a creep strength test,

b) Effect of types and thickness of a board.

3 Description of Each Clause

3.1 Title of this document

This document is a standard in the area of surface mounting technology, especially of the test method to evaluate the strength of a soldered joint of the lead of an insertion type component and a land, and also the durability of such a joint. The title of this document was determined as to “Surface mount technology - Environmental and endurance test methods for solder joint of surface mount device with leaded terminal device - Part 201: Creep strength test”.

3.2 Introduction

It is stated that we did need a document providing the standard for reliability of the joint strength of a soldered joint using lead-free solder in responding to the environmental request.

3.3 Scope (**1** of the main text)

This standard specifies the creep strength test of the soldered joint of the lead of the insertion type device and a land using lead-free solder for the evaluation of durability of the lead. There is a pull strength test to check the joint strength under the effect of self-heating and of the continuous thermal load to the device from the using environment.

The test method described in this standard is to confirm the creeping strength between a lead of an insertion type device and a land of a board. This is an effective method to evaluate changes in production process prior to production such as electrolytic plating of a lead, of board itself and of circuit design, and of the soldering process in production process and the process actually used.

The reason a test board is limited to single-sided is the strength of a soldered joint made to a through-hole is much stronger than the strength of a lead itself.

3.4 Normative references (**2** of the main text)

IEC 61190-1-1 is added to the list of normative references as explained in **3.6** of this information. The **JIS** numbers of environmental tests have been changed from the old numbers to the new five-digit **JIS** numbers to comply with the respective **IEC** document. The numbers of the following standards have been changed.

e.g. **JIS C 0010** → **JIS C 60068-1**
JIS C 0021 → **JIS C 60068-2-2**
JIS C 0051 → **JIS C 60068-2-21** (relevant standard)

3.5 Terms and definitions (**3** of the main text)

The definitions of those terms specifically used in this standard are listed. A term “creep strength test” is added to the list.

3.6 Test equipment and materials (**4** of the main text)

The key materials in this clause are the test board, solder and flux.

It is known that the board material, thickness and land design affect considerably to the strength of an interface of a soldered joint. It is recommended to use the test board specified in **4.5** of the main text when various factors for the board are required to be the same but not specified in a product specification. The solder specified in **4.6** is chosen for the test if it is not specified in a product specification, however, it is allowed to use the solder actually used in the production line.

The standard flux to be used in solder paste was carefully reviewed by the committee. The discussion made among flux manufacturers was that flux used in soldering process had been developing day-by-day in a sense and not suitable for standardization yet. Manufacturers were reluctant to disclose the detailed flux information. We decided to use the flux specified in **IEC 61190-1-1**.

Discussion was made, however, if the flux used for flow soldering might be specified as to the mixture of 25 g of colophony (rosin), 75 g of 2-propil alcohol specified in **JIS K 8839** or ethyl alcohol specified in **JIS K 1501**, and 0.39 g of di-ethyl ammonium chloride. If this flux was not appropriate for this type of test, addition of di-ethyl ammonium chloride (reagent class) of chlorine content of (shown as free chlorine to the content of colophony) up to 0.5 mass %” may be used.

3.7 Mounting of component on board and preparation of specimen (**5** of the main text)

The temperature profile of a soldering furnace considerably affects strength of the interface of a soldered joint. A typical temperature profile without indication of temperature is shown in this document as actual specific temperatures depend strongly on each furnace used. Specification of the cooling after soldering was also discussed but not specified in this document.

3.8 Test condition (**6.2** of the main text)

The creep strength test is a test to show the durability (life) of a lead-free soldered joint under a continuous applied force. Creep is a phenomenon that deformation is not induced at room temperature under a constant load to an object but deformation does occur at an elevated temperature though slow under thermal activation of the object. The temperature at which creep occurs strongly depends on it melting temperature. It is said that the creep temperature of a substance is generally $T > 0.4\ T_m$ (T_m is the melting temperature in absolute temperature). For most of lead-free solders, the room temperature is about $0.6\ T_m$, therefore, creep temperature of any lead free solder can be from -50 °C up to its melting temperature. One should also consider the body strength of an insertion type component and the degradation of the board on which the component is mounted. It is recommended that a creep test for a joint may better be made over a temperature range of room temperature to up to 125 °C. A higher temperature may be employed for a board having higher heat resistance temperature. The maximum temperature should be stated in the product specification of a component and/or of board. It is to be noted that the temperature for a creep test may be of a temperature at which a specific lead-free solder may degrade, and the temperature may exceed the rated temperature of the insertion type component used in a creep test.

Creep is a phenomenon of deformation of a material induced under a constant load. A test is made holding a specimen in a chamber and a constant load is applied. The force applied to a lead of an insertion type component may be set to an arbitrary value. A small load requires a long time to see any change. It is desirable to perform a preliminary test to find an appropriate force that the joint breaks in several minutes. The true test may start using a load force of about 90 % of the force obtained in this preliminary test., and then decrease the force for 3 to 5 load values as an efficient test.

It is possible to predict from a creep strength test the time to break of a joint but the prediction of the break time by extrapolation of test result should be limited to 10 times of the actually obtained experimental data. It is important to take into account of this consideration to predict a very long creep life by selecting an appropriate test condition that the predicted (extrapolated) creep life should not be out of the proper prediction. In a case the relation between creep break life and the applied force is known beforehand for the same composition of lead-free solder, it is possible to select a proper test condition from the analysis of the force per unit area obtainable from the total applied force and the area of a joint.

The details of the creep strength test is described in **6.2**. There was a discussion on the mass of a weight to be applied to a lead. First we used a 1.1 kg weight which was used in the preceding NEDO project. A comment was raised that the weight might be changed depending on the diameter of the lead. It was agreed that a smaller weight seemed to reflect the true situation at a joint and the use of a smaller weight is stated in the **Notes 1** to **3** in the main text.

The result we obtained in the NEDO project in 1999, “Evaluation of lead-free soldered assembly board”, is given below for information.

(Test and test condition)

Specimen: ϕ = 0.5 mm steel wire with Sn plating with Cu under coat. N=10

Board: 1.6 mm thick single sided board,

Land diameter; ϕ = 1.3 mm, Through hole; ϕ = 1.0 mm

Solder: Sn-3.5Ag-0.75Cu

Soldering condition: 250 °C

Conveyer speed; 0.0167 m/s (1.0 mm/min), Conveyer angle; 5 °

SCLS-2635H Solder bath, Double solder flow – pumping

Flux; CF-11VH-2A (Spray)

Thermostat chamber: 125 °C

Mass of the weight: 0.5 kg

Time to drop the weight was measured by continuous monitoring of electric conduction

Soldering		In Nitrogen	In air
Creep strength h	Maximum	3.67	5.17
	Minimum	2.67	2.00
	Average	3.10	3.87
	Standard deviation	1.25	3.79

3.9 Items to be included in the test report (**7** of the main text)

It is specified in this standard to include also the experimental results, the factors and conditions which are preferred to be included in a report of a test.

3.10 Items to be stated in the product specification (**8** of the main text)

The items to be specified in a product specification are described in this clause. These items are specified in this document with a statement that either “not specified in the product specification” or “as specified in the product specification”. Many of them are factors and test conditions which may affect the test result and are also included in the test report.

3.11 Related standards (**9** of the main text)

Though the related standards are not directly referred in this document but added to this document as related standards of **JEITA ET-7409/201** for the creep strength test of a lead-free soldered joint under continuous temperature load, and **JIS C 60068-2-21** in which a test for the lead strength to a component is specified. **JEITA ET-7409** is also included as it is necessary to select a test method suitable to a specific device.

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