Standard of Electronic Industries Association of Japan

EIAJ ED-7304

Measuring Method for Package Dimensions of Ball Grid Array (BGA)

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Measuring Method for Package Dimensions of Ball Grid Array (BGA)

1. Scope

This standard stipulates a method for measuring dimensions specified in the design guide of BGA which classified into Form D (ref. **EIAJ ED-7300**).

2. Definition of terms

The main terms used in this standard are as defined below and new terms are defined in the text.

(1)	**EIAJ ED-7300**	Basic standard for preparation of general dimensions rules of semiconductor device packages
(2)	**EIAJ EDR-7315**	Design guideline of integrated circuits for Ball Grid Array (BGA)
(3)	**JIS Z 8310**	General rules of drawing
(4)	**JIS B 0021**	Illustrating method of geometrical tolerance
(5)	**JIS B 0061**	Definition and display of geometrical tolerance
(6)	**ANSI Y14.5M**	Dimensioning and tolerating

3. History

External dimensions of packages for semiconductor devises are specified in the designguide and the individual standard. However, the specified external dimensions have been measured in a variety of methods by companies. As a result, measured results are so different that some trouble has occurred between semiconductor manufactures and users. Further, there are some dimensions specified in the designguide that are very difficult to measure. This standard is set up to make the definitions of the specified dimensions clear and to standardize the measuring method of them.

4. Definition of measuring method

The measuring method in this standard is defined for dimension values guaranteed to users on the basis of the following items.

(1) In general, measuring the dimensions shall be made with the semiconductor packages mounted on printed circuit board as the guarantee is made to user.

(2) In general, measurement may be made either by hand or automatically.

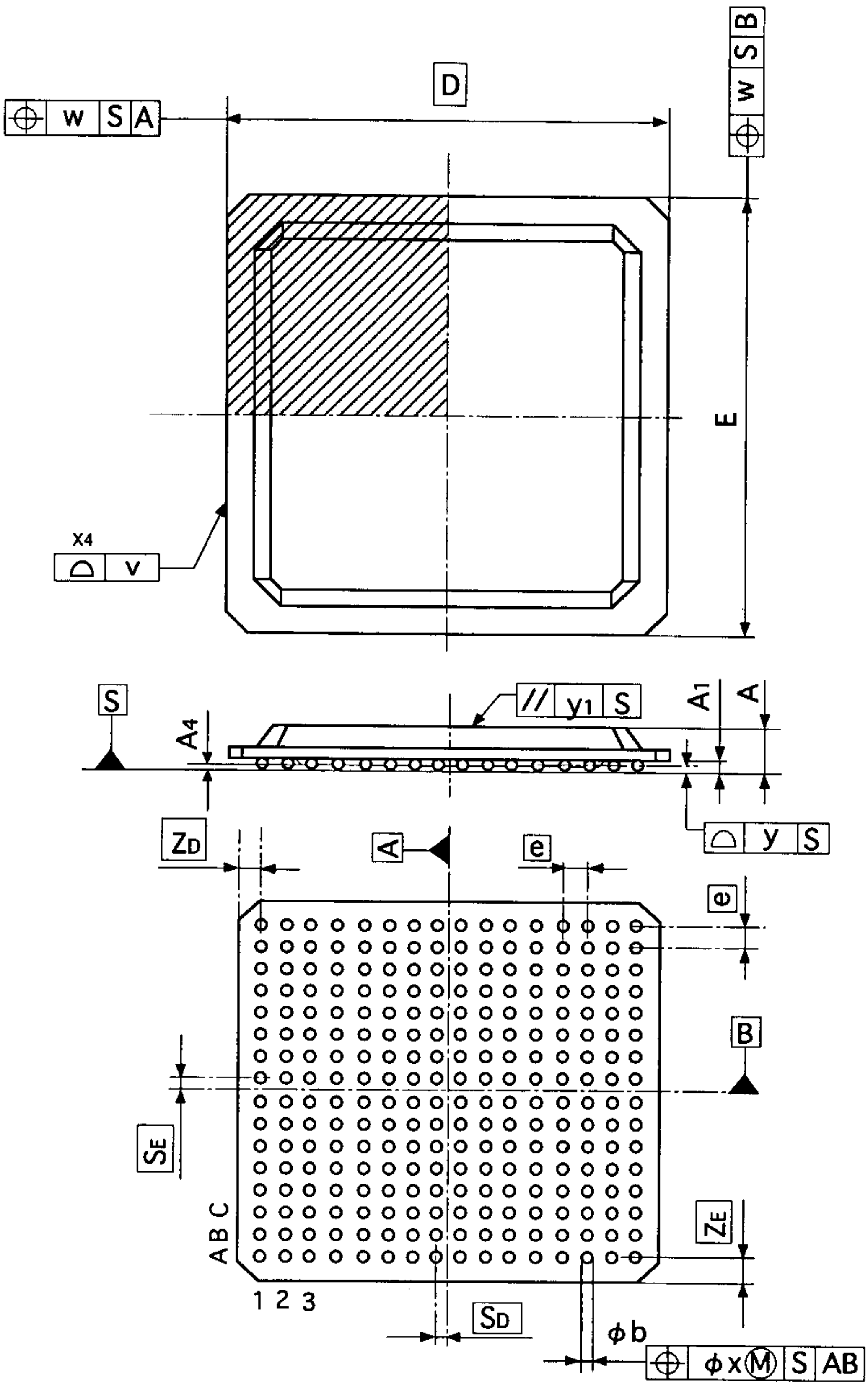
(3) If a specified dimension was difficult to measuring, the best alternative measuring method is defined as the formal measuring method.

(4) Even if a measuring method deviates out of the original definition of dimensions, it is defined as an alternative measuring method as long as it is equivalent in view of accuracy and can be used easily.

(5) The dimensions that cannot be measured unless the package is destroyed may be calculated from other dimensions or alternated by representative values.

5. Reference characters and drawings

Figure 1



6. Measuring method

6.1 Datum definition

(1) Datum S, Datum S as pertaining to ball coplanarity

(1-1) Definition

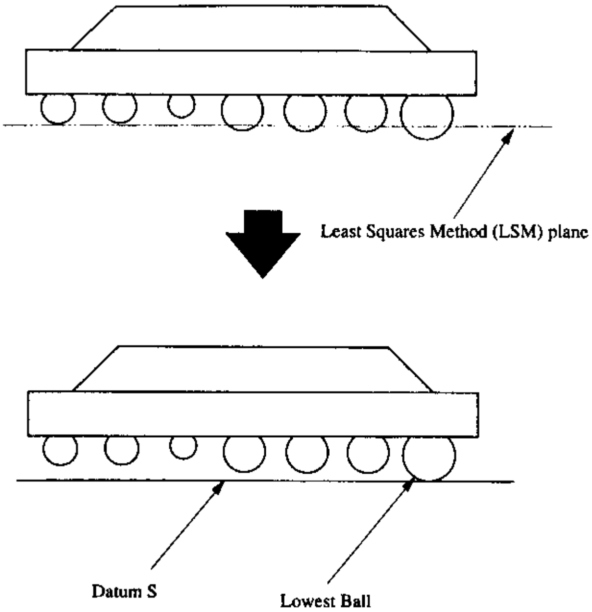
(a) The surface plane shall be Datum S (seating plane).

(b) Datum S calculated from the LSM plane applies to standoff A2,standoff A1,the ball center point and coplanarity.

Calculate a plane from each lowest point of all balls based on LSM.

Datum S shall be the LSM plane shifted to bottom of the lowest ball.

Figure 2



(2) Datum A, B

(2-1) Definition

Calculate 2(two) straight lines crossed perpendicularly from each center point of all balls based on LSM. Datum line A,B for a package shall be the 2(two) straight lines.

Figure 3

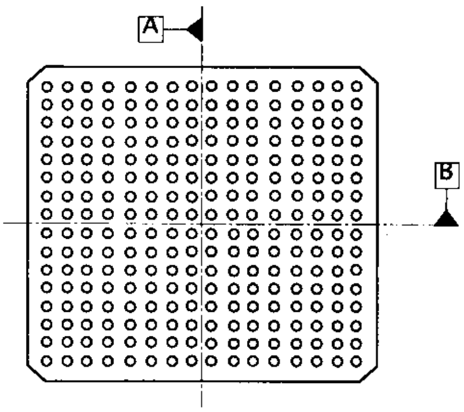
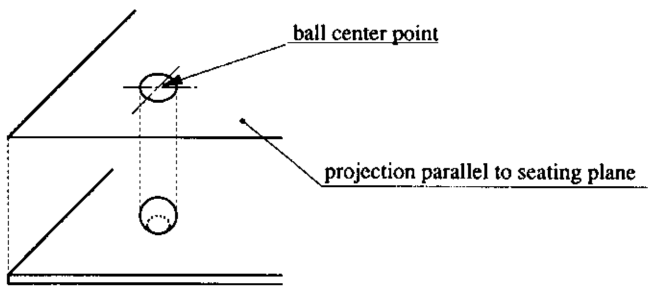


Figure 4



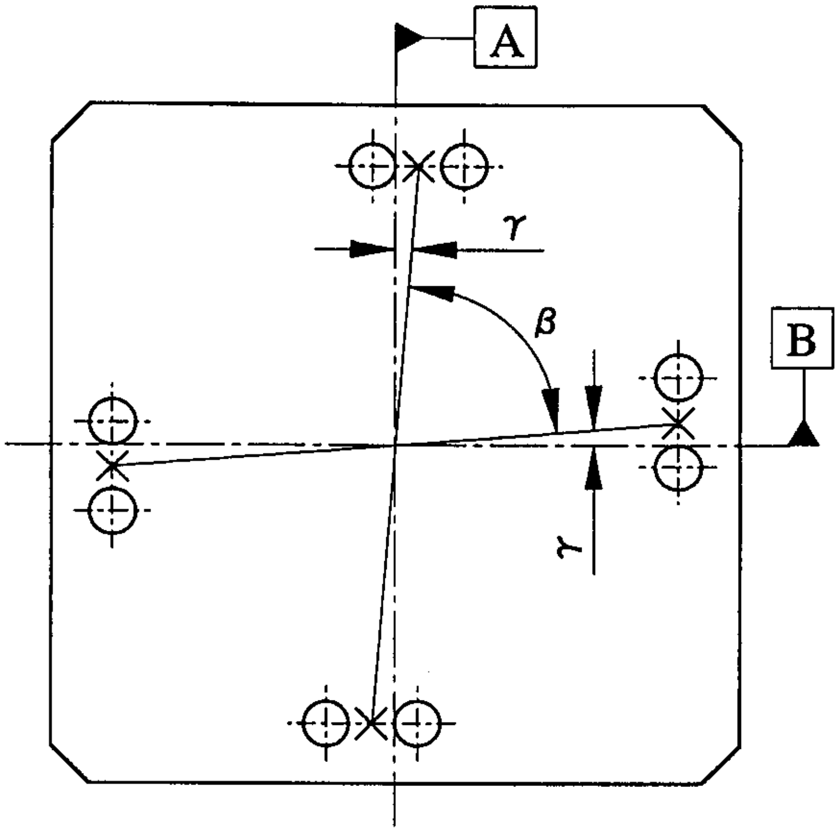
(a) **Definition of the ball center point**

The center of the image projected vertically from the seating plane by the ball shall be the ball center point.

(2-2) Datum A,B definition for quick measuring method

This definition should be defined as datum A,B for quick measuring method. Centers of opposite sides of a package, which are defined below, shall be connected together. An angle β subtended by the two crossing lines shall be obtained. A difference $|90^\circ - \beta|$ of the angle β from 90° shall be equally distributed to the sides to obtain orthogonal axes. The orthogonal axes are depicted as datum lines A and B of the package.

Figure 5



$$\gamma = \frac{|90^\circ - \beta|}{2}$$

Definition of the centers of sides

Figure 6

For an even number

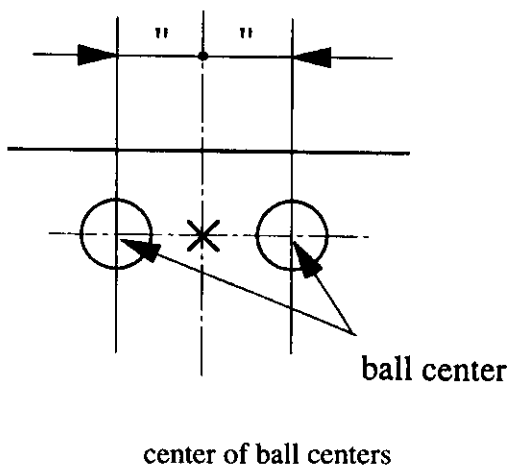
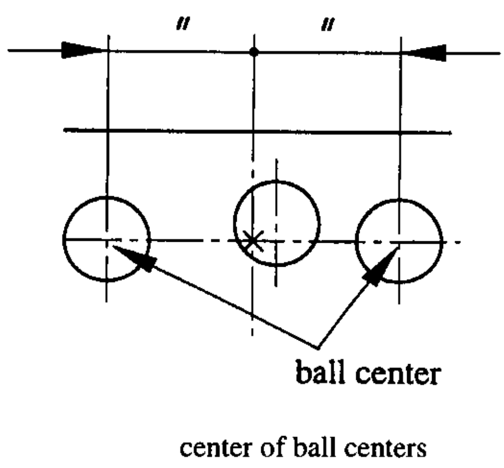


Figure 7

For an odd number



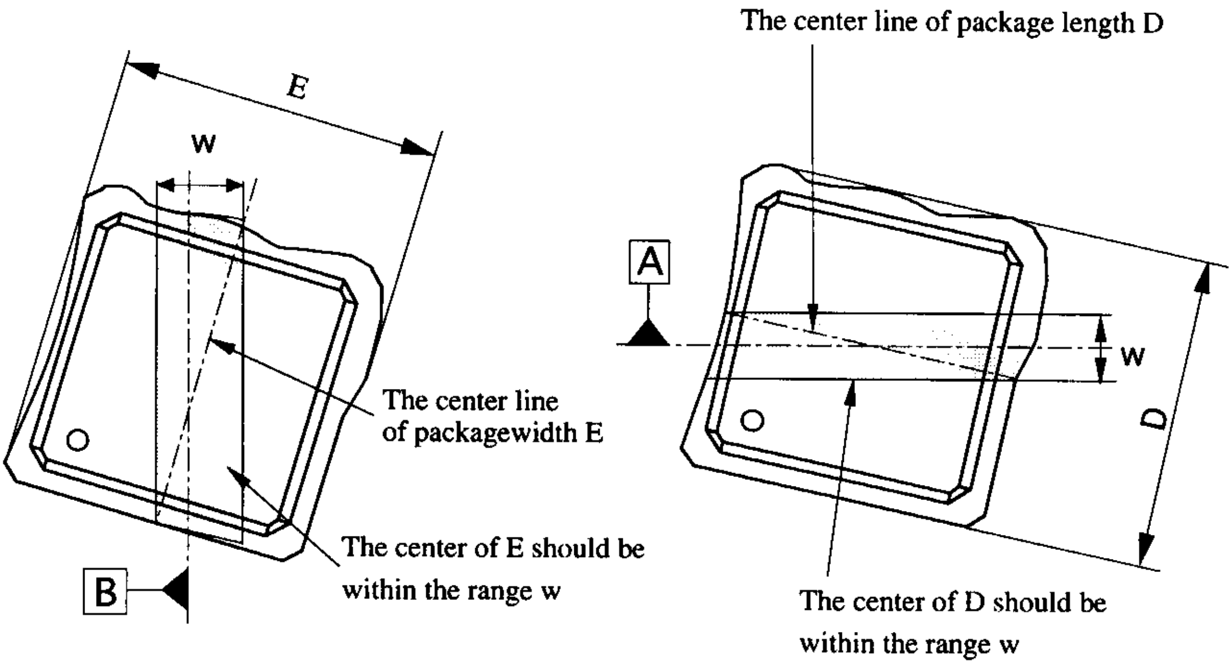
6.2 Definition of specified dimensions and measuring method.

(1) Tolerance w of the center position of Package length and width

(1-1) Definition

The package width and length should be defined as a distance between parallel tangent lined which touched package profile. And the center of Package should be defined as a center of these parallel. Tolerance w of the center position of Package length and width should be defined as tolerance of it.

Figure 8



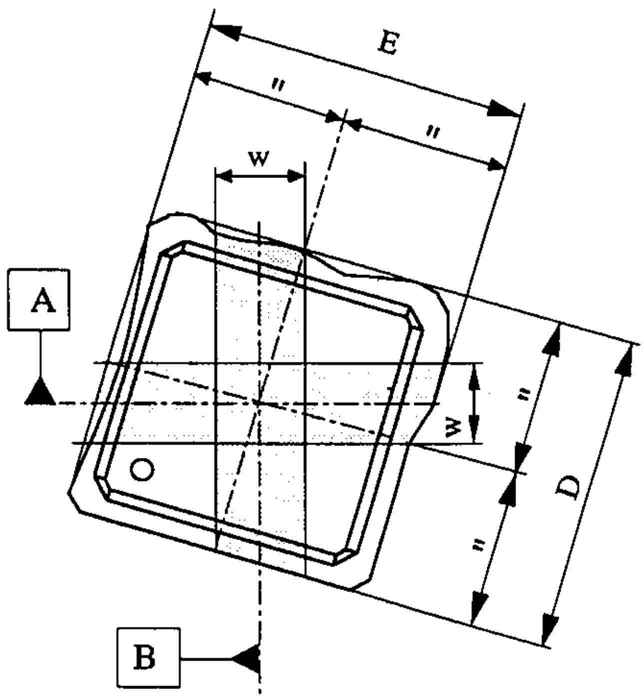
(1-2) Measuring method

(a) Put the package on the surface plate.

(b) The package width and length should be defined as a distance between parallel tangent lined which touched package profile.

(c) Make sure the center of it is within the range w centering on Datum A and B.

Figure 9



(1-3) Quick measuring method

(a) Flip the package over and place on the surface plate.

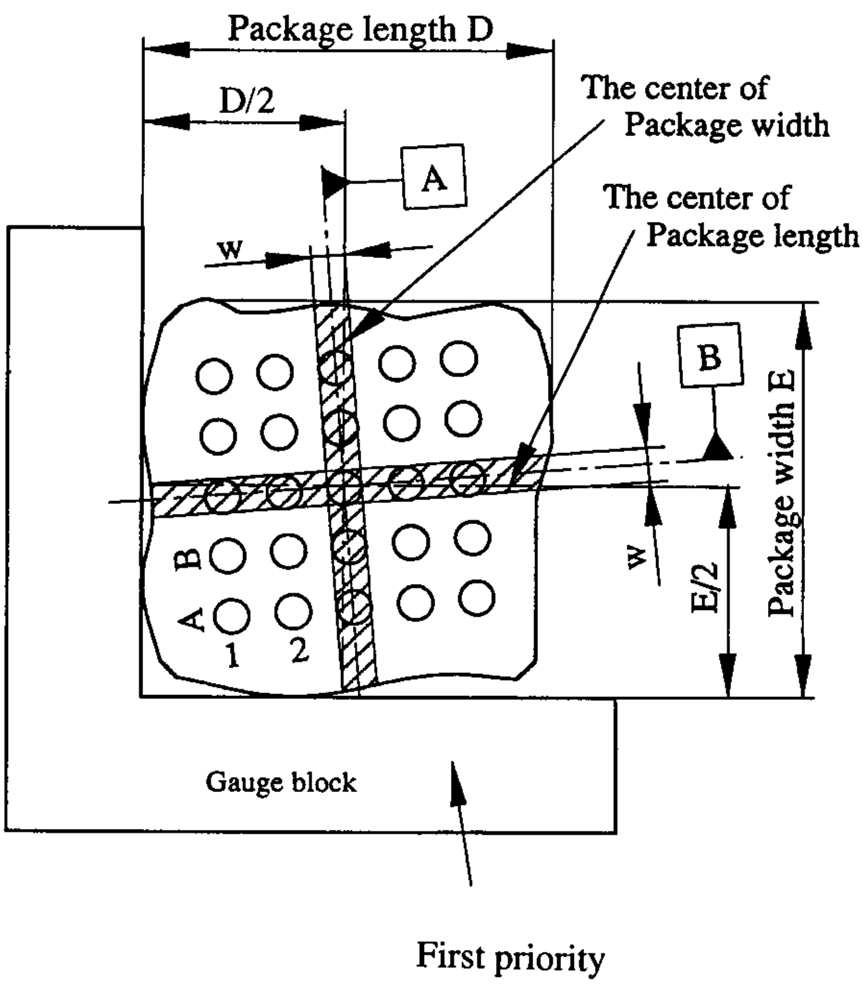
(b) At first, press the package side on which pin 1 is located against the bottom side of gauge block.

(c) Move the package along the bottom side gauge and press it against the other side gauge.

(d) The center of package width and length should be defined as the center of a distance between the e gaug block and farthest point from the gauge block.

(e) Make sure the package center is within the range w centering on Datum A and B.

Figure 10

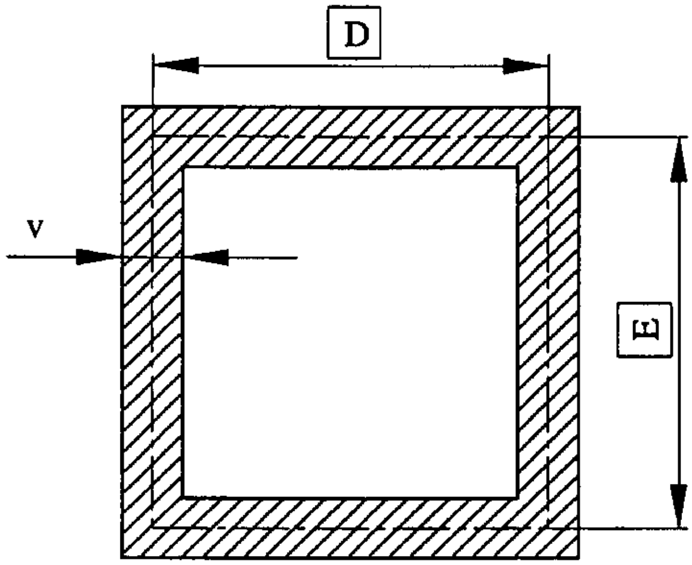


(2) Profile of a package edge surface v

(2-1) Definition

Profile of a package edge surface v should be defined as the range centering on the position which is a theoretically correct distance of D or E.

Figure 11



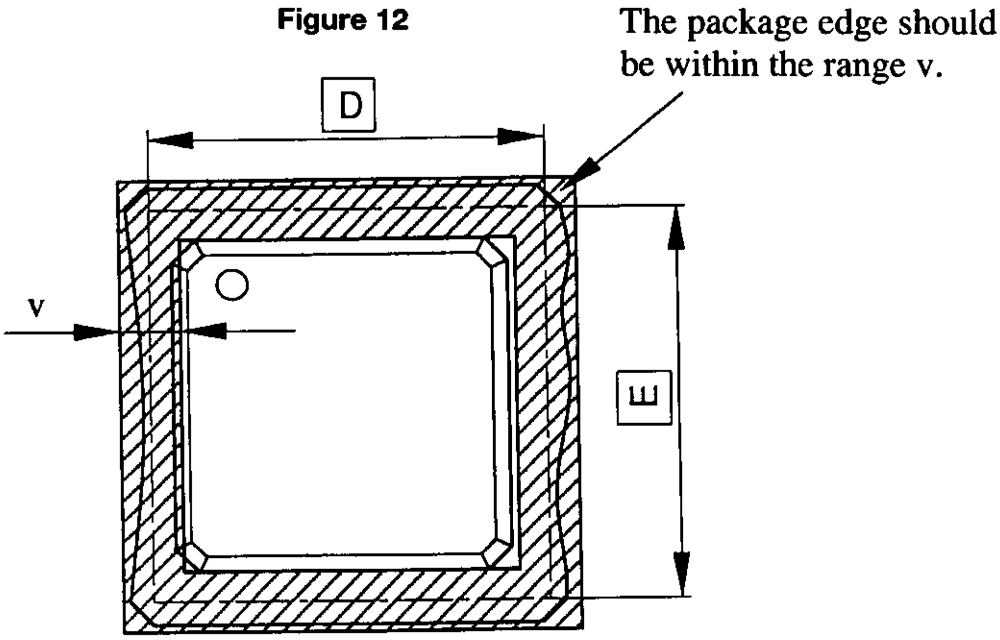
(2-2) Measuring method

(a) Fut the package on the surface plate.

(b) Make the range v centering on the position which is a theoretically correct distance of D or E.

(c) Make sure the package edge are within it.

Figure 12



(2-3) Quick measuring method

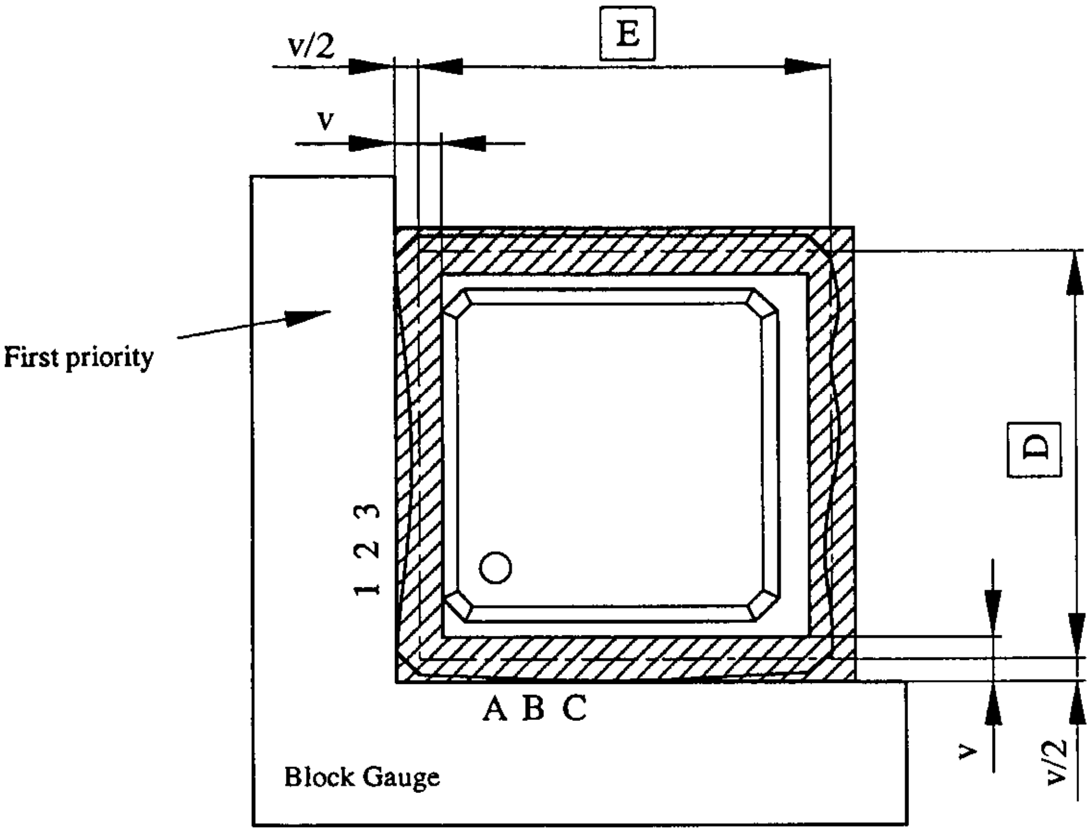
(a) Put the package on the surface plate.

(b) At first, press the package side on which pin 1 is located against the left side of gauge block.

(c) Move the package along the left side gauge and press it against the other side gauge.

(d) Make sure the package is within theoretically precise ranges of O to v, E to E+v, and D to D+v when measured from the gauge block.

Figure 13



(2-4) Remarks

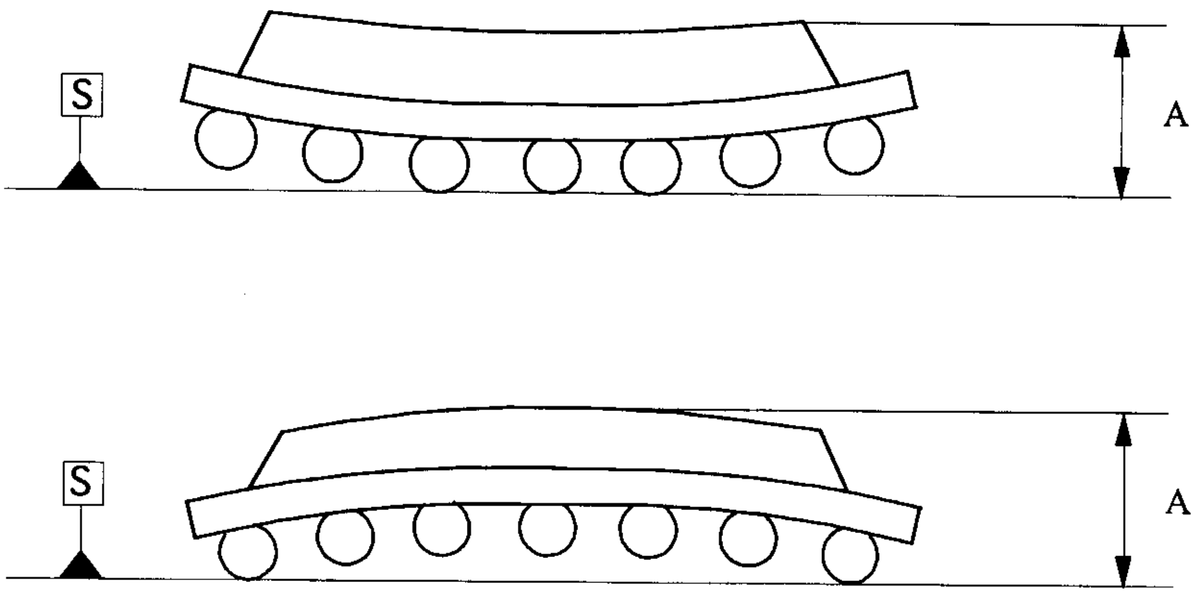
Except parts of chamfer.

(3) Mounting height A

(3-1) Definition

Let the height of a package from the seating plane to the top of the package be defined as the mounting height. The mounting height therefore includes inclination and warping of the package.

Figure 14



(3-2) Measuring method

(a) Put the package on the surface plate.

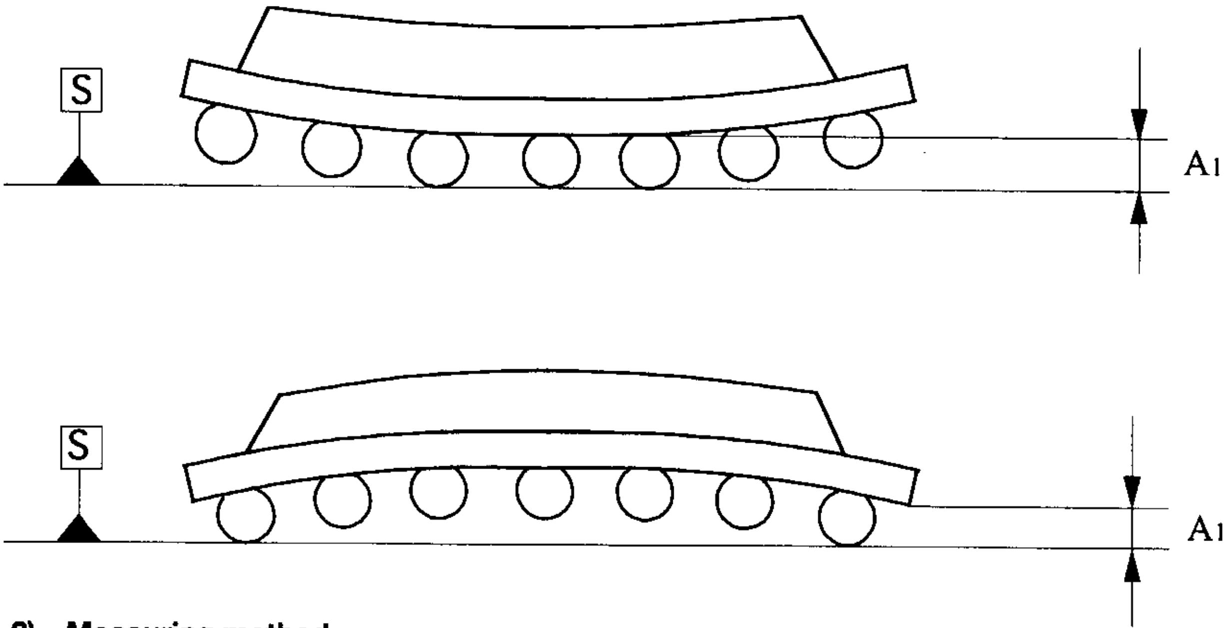
(b) From the top or side, measure the distance to the highest point. Let the distance be denoted as the mounting height.

(4) 1st. Standoff A_1

(4-1) Definition

1st. Standoff is defined as the distance from the seating plane to the lowest point of the package except the cavity.

Figure 15



(4-2) Measuring method

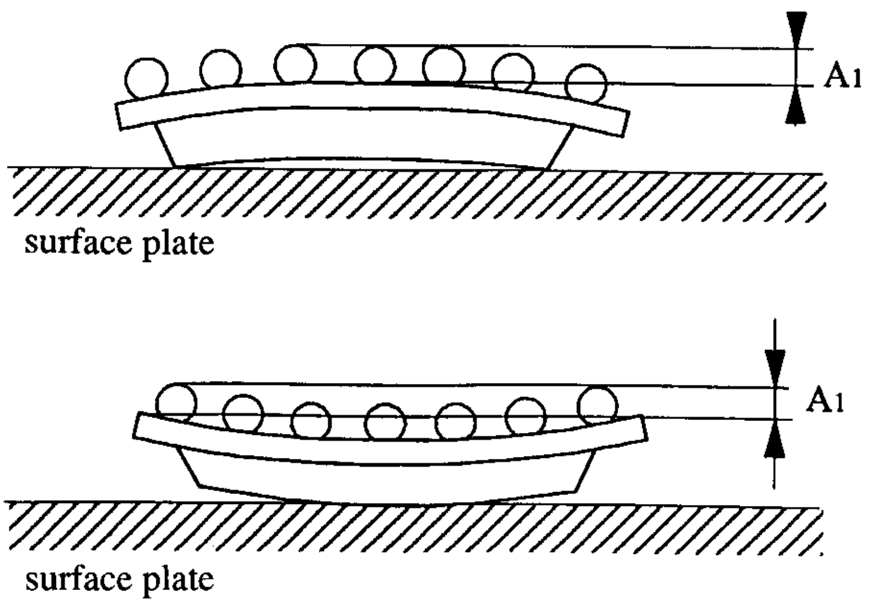
1st. Stand-off to be the distance measured from the calculate datum S based on least squares method (LSM) to the lowest point on the package except the cavity.

(4-3) Quick measuring method

(a) Flip the package over and place on the surface plate.

(b) From the side or top, measure the distance to the lowest point of the package except and the distance to the lowest ball. 1st. Standoff to be the difference between these values.

Figure 16

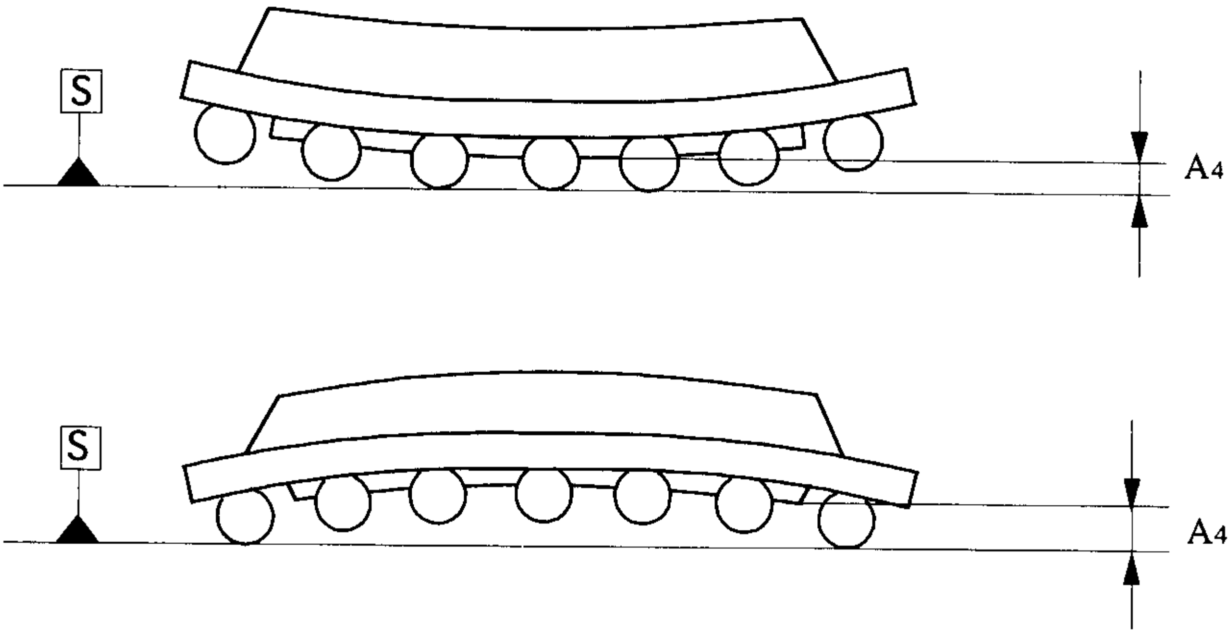


(5) 2nd. Stand-off A_4

(5-1) Definition

2nd. Stand-off is defined as the distance from the seating plane to the lowest point of the cavity.

Figure 17



(5-2) Measuring method

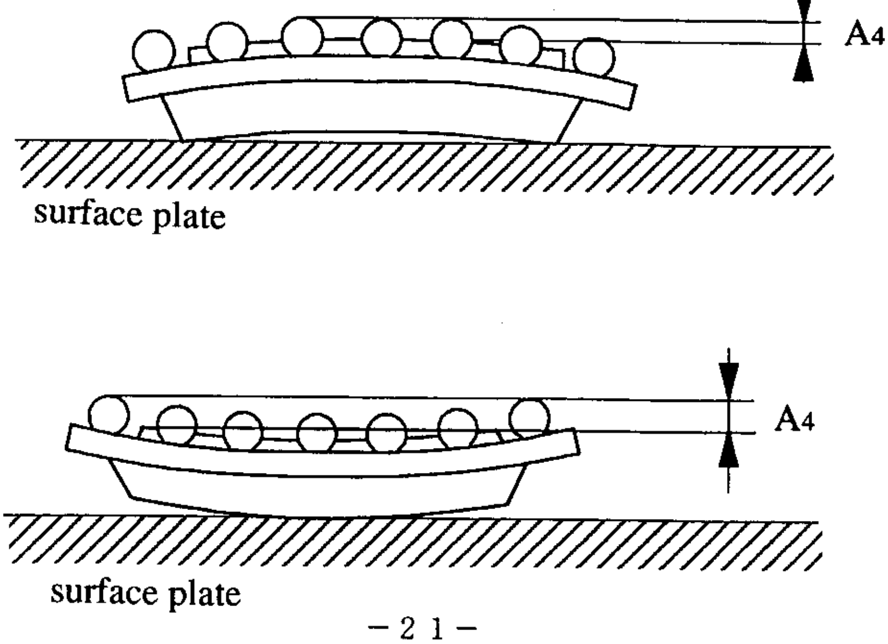
2nd. Stand-off to be the distance measured from the calculate datum S based on least squares method (LSM) to the lowest point on the cavity.

(5-3) Quick measuring method

(a) Flip the package over and place on the surface plate.

(b) From the side or top, measure the distance to the lowest point of cavity and the distance to the lowest ball. 2nd. Stand-off to be the difference between these values.

Figure 18

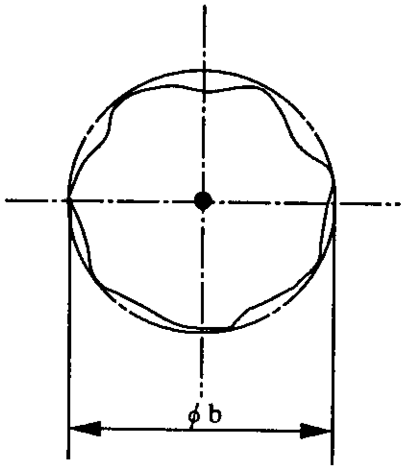


(6) Ball diameter b

(6-1) Definition

Ball diameter is defined as the diameter of a circle circumscribed about a vertical projection of the ball from theseating plane.

Figure 19



(6-2) Measuring method

(a) Make the calculate datum S based on least squares method(LSM) coincide with the measuring reference.

(b) Measure the diameter of a circle circumscribed about the ball.

(6-3) Quick measuring method

Put the package upside down on the surface plate and measure the diameter of the circle circumscribed about the ball.

(7) Ball center position x

(7-1) Definition

Based on datum A, B and S, determine the difference between the theoretically correct position of each ball's center and the actual position. That allowable distance to be the ball center position tolerance.

Figure 20

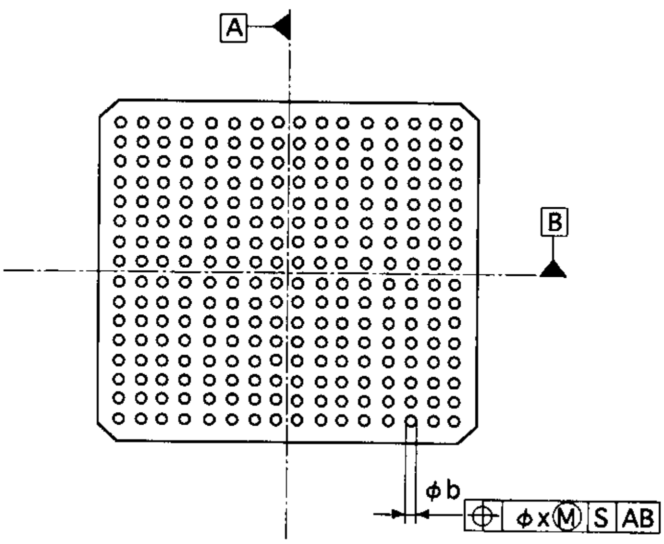
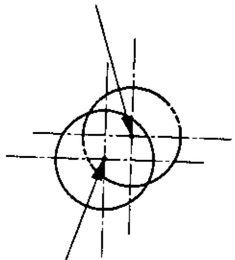


Figure 21



(7-2) Measuring method

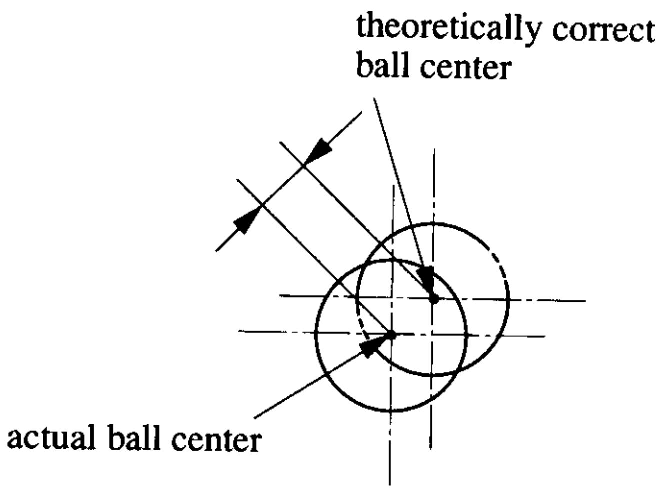
(a) Make the calculate datum S based on least mean squares (LMS) and datum A, B coincide and parallel with the measuring reference.

(b) Determine center of each ball.

(c) Determine distance to the theoretically correct ball center.

(d) Check if distance lies within the ball positional tolerance.

Figure 22



(7-3) Quick measuring method

Carry out above measuring method with package placed upside down on surface plate.

(7-4) Remarks

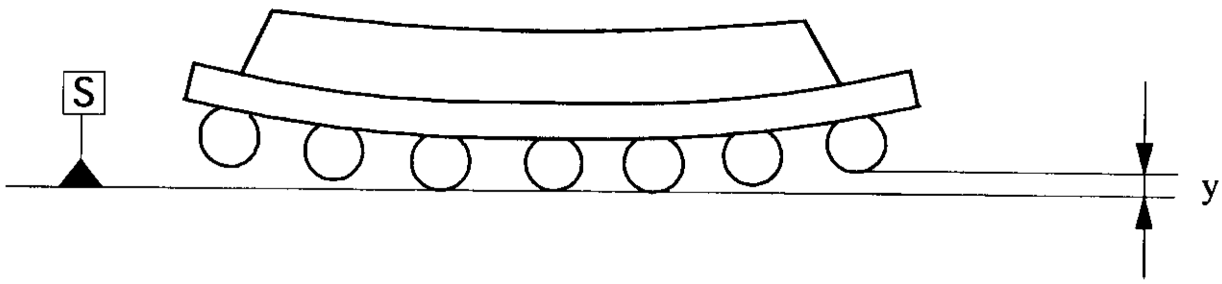
See **explanation 3.2** in detail.

(8) Ball coplanarity y

(8-1) Definition

Coplanarity y is defined as the distance from the lowest point of the top ball from the seating plane measured in the direction perpendicular to the seating plane.

Figure 23



(8-2) Measuring method

(a) Measure the distance from calculate datum S based on least squares method(LSM) to the lowest point of every ball.

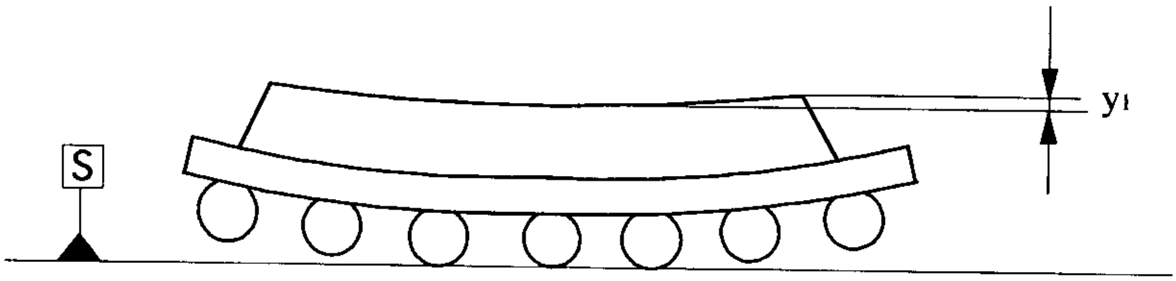
(b) Ball coplanarity y to be the maximum value.

(9) Package top flatness y_1

(9-1) Definition

Package top flatness is defined as the difference between the distance from seating plane to the highest points of the package top and the distance to the lowest points.

Figure 24



(9-2) Measuring method

(a) Put the package on the surface plate.

(b) From the side or top, measure the distance to the highest and lowest points of the package top. Package top flatness to be the difference between those values.

(9-3) Quick measuring method

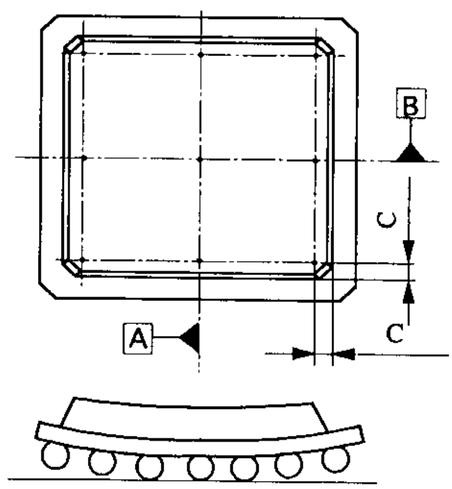
(a) Put the package on the surface plate.

(b) Determine 9 points based on intersection of datum A, B and lines based on positions distance C from the top side of the package (molded side).

(c) Measure the distance from the points determined in (b), or an area in the neighborhood of the points, to the surface plate.

(d) Package top flatness to be the difference between the minimum and maximum distances from surface plane.

Figure 25



surface plate

(9-4) Remarks

(a) Index mark and ejector pin to be ignored.

(b) C value should be minimized.

Explanation

1. Purpose

This standard is aimed to provide the common measuring method of dimensions that have been defined in the design guideline of integrated circuit package.

2. Background

This measuring method has been established only for QFP package in May, 1995, in order to prevent the difference of the measured dimensions between user and supplier. For BGA, the measuring method was discussed by the "BGA package WG" that was constituted in April 1994, as a substructural organization of the Semiconductor Package Special Committee, re-discussed by Outer Dimension Measuring Method Project Group, finally determined by the Semiconductor Common Standard Sub-Committee, and officially approved and determined to establish and issue the document by Semiconductor Package Standardization Committee in January, 1997.

To standardize the measuring method to be provided herein, that is the purpose of the standard, this document attempts to include the figures and symbols as possible and to avoid complicated expressions. Some complicated and difficult methods that were suggested in the process of discussion have been converted into easier ones if the measuring accuracy is within the allowable limit.

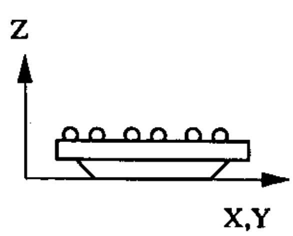
3. Major Contents

3.1 Datum

(1) While datum S (mounting surface) is basically the fixing panel surface, it is difficult for standoff, terminal center position and terminal bottom surface to measure properly from the fixing panel surface using the existing measuring method. Therefore, the surface calculated using the least square method has been applied as datum S. For using virtual plane, it was discussed to create a plane consisting of three bottom points. However, it was found that the errors occurred when measuring with microscope, image process, laser and any other devices and greatly influenced the error in operation, therefore, the least square method is considered as the best method to calculate a plane stably.

The calculation with the least square method is as follows:
If the minimum square plane is z = a + bx + cy and the measuring value of terminal bottom points to be calculated is indicated as xi, yi and zi:

Figure 1



$$S(xx) = \Sigma(xi - x)^2$$
$$S(yy) = \Sigma(yi - y)^2$$
$$S(xy) = \Sigma(xi - x)(yi - y)$$
$$S(xz) = \Sigma(xi - x)(zi - z)$$
$$S(yz) = \Sigma(yi - y)(zi - z)$$

$$a = z - bx - cy$$

$$b = \frac{S(xz)\,S(yy) - S(yz)\,S(xy)}{S(xx)\,S(yy) - S(xy)^2}$$

$$c = \frac{S(yz)\,S(xx) - S(xz)\,S(xy)}{S(xx)\,S(yy) - S(xy)^2}$$

The surface defined through the formulas a, b and c shall be "least square plane".

(2) For datum A and B, it was discussed to calculate based on a specified terminal center position. In this case, it is required to select a terminal with the least offset to prevent the terminal offset from influencing the center positions (x) of other terminals. However, it was found that terminals of BGA randomly cause each position offset. (See section 4.) Therefore, it was determined to calculate datum A and B by applying the least square method for all of the terminal center positions.

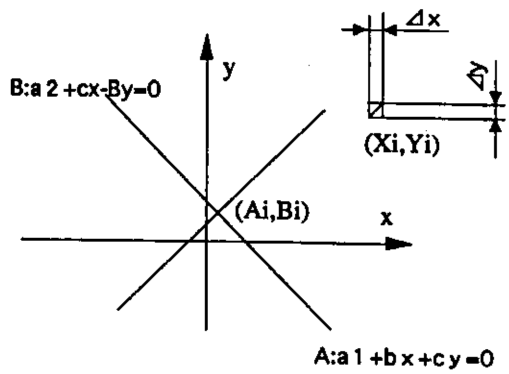
The calculation with the least square method is as follows:

Find the difference ($\triangle xi$, $\triangle yi$) between the accurate terminal center position (xi, yi) and the measured center position (Ai, Bi) depending on datum A and B. Then find a1, a2, b and c where the sum of the differences $\Sigma(\triangle xi^2 + \triangle yi^2)$ can be minimum. Finally, the following formulas show datum A and B.

$a1 + bx + cy = 0$

$b2 + cx - by = 0$

Figure 2



3.2 Allowable Value of Terminal Center Position

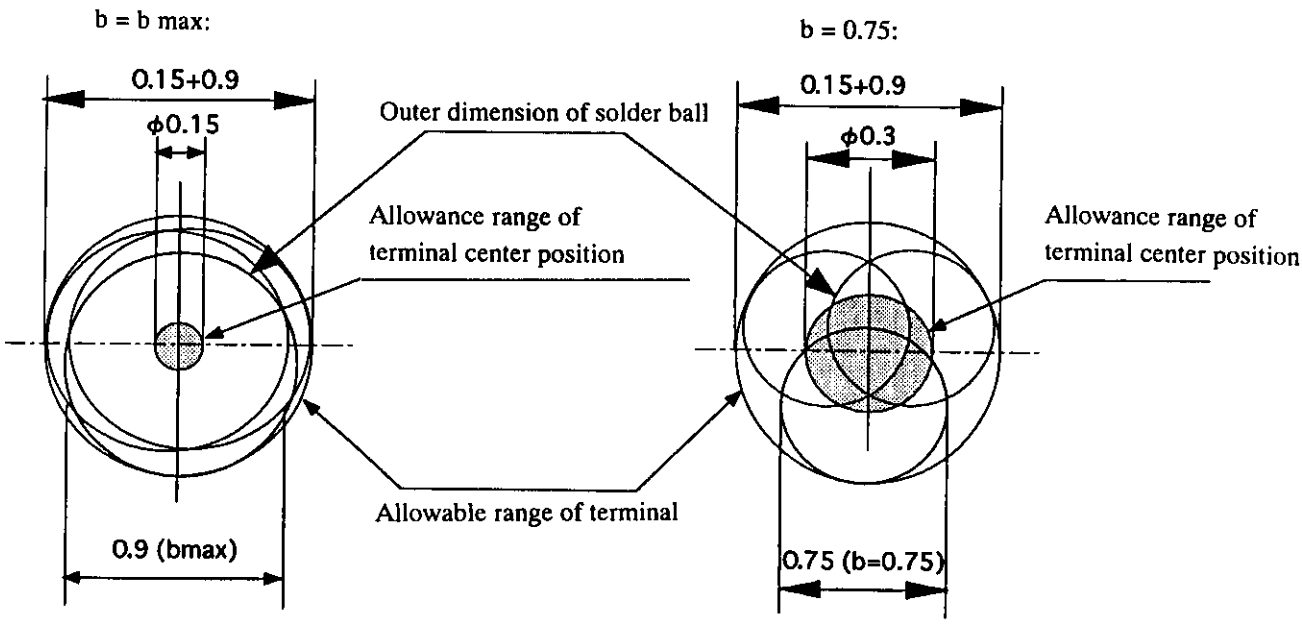
This allowable value of terminal center position is defined through the maximum stereoscope tolerance method. This method is designed for calculating the allowable value when the terminal diameter is maximum. If the diameter is below the maximum limit and within limit, the tolerance changes accordingly.

Example

If ϕ x = 0.15, b = 0.75$\pm$0.15 is provided in the standard, ϕ x = 0.15 is applied for b max. When the terminal diameter is not b max, for example, 0.75:

Allowable value of terminal center position = (0.15 + 0.90) - 0.75 = 0.3

Figure 3



3.3 Allowable Value of Package End

The allowable value of package end is determined by applying the specified method based on the contour tolerance, considering adjustment with JEDEC. For its measuring method, it was judged general to find each contour simply from projected images, therefore, the method to find straightness of contour line from projected image was provided.

3.4 Parallel Level of Top Surface of Package

The parallel level of top surface of package is defined excluding index mark and ejector pin. This value is calculated based on the representative value measured around the periphery and center, that is considered as a convenient measuring method.

4. Result of Terminal Position Accuracy Measurement

4.1 Background

It is likely to use balls for positioning BGA if fine pitch is applied in the future. Therefore, it was determined to use balls for BGA datum. To define the ball datum, there are two possible methods: one is to define by using all balls and the other is by using specified number of balls for simplicity.

4.2 Purpose

The purpose is to measure packages actually and check if the sufficient accuracy is maintained even though the datum is determined by using only specified number of packages.

4.3 Measuring Condition

(1) Package Sample

BGA-352-3535 (for 1 company) BGA-256-2727 (for 2 companies)

(2) Number of Samples

5 packages each

(3) Measuring Device

Laser system; Repeatability: 10 μ m (actual value); Measuring accuracy: 20 μ m (actual value)

4.4 Result

The ball offset was caused randomly. The maximum amount was approximately 90 μ m. For details, refer to Figure 4 to 6.

4.5 Conclusion

The stable and distortion-free positions were not obtained due to the random occurrence of ball offset. The datum for test calculated from the terminal row of the center part was compared with the result calculated with the minimum square method. As a result, the maximum difference was 20 μ m, that is not too large. (See Figure 7.) However, it was determined to define the datum by using all balls and the minimum square method as long as there is any possibility to cause difference to be large enough.

Figure 4: Company A - 352 pin

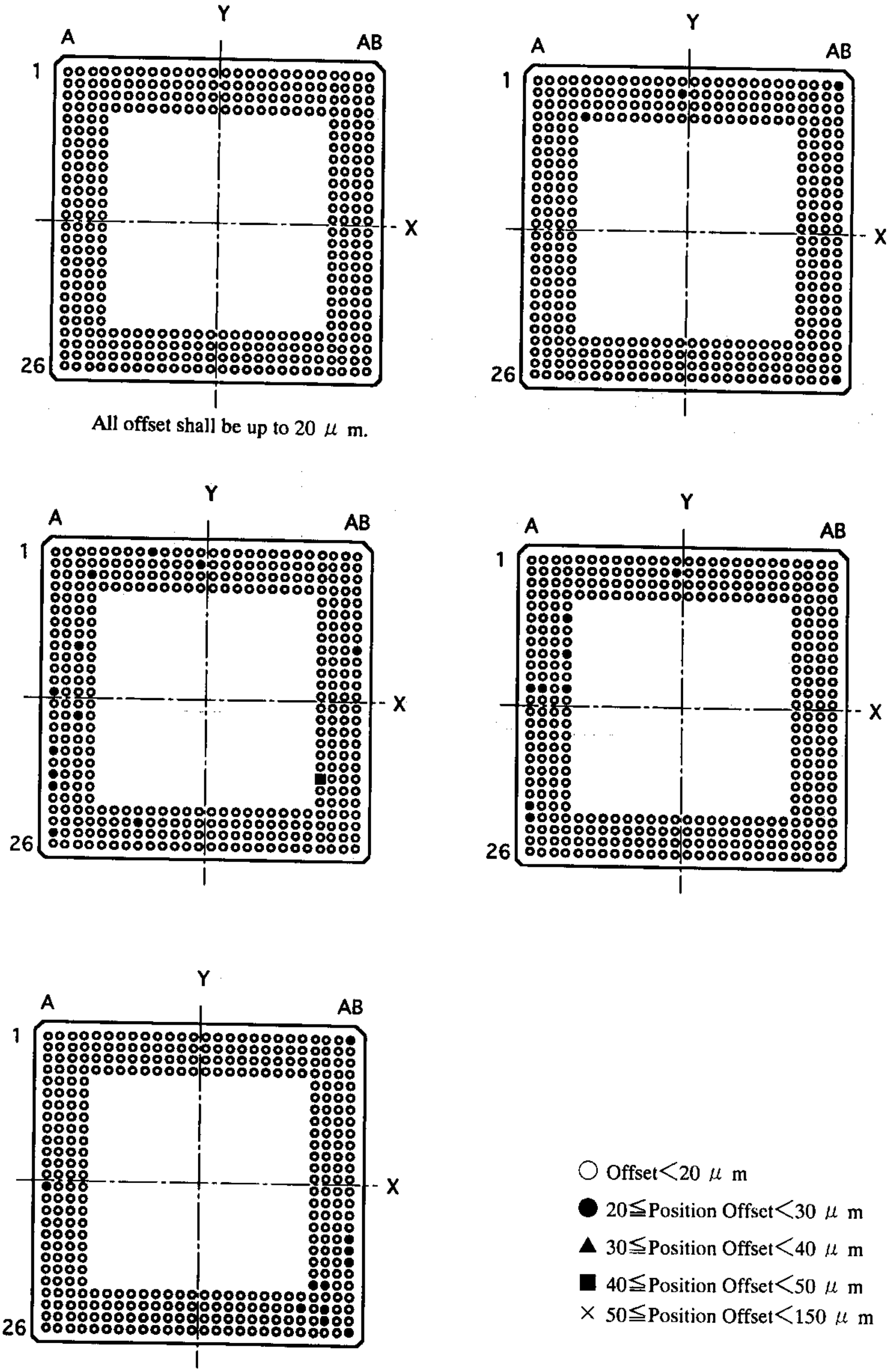
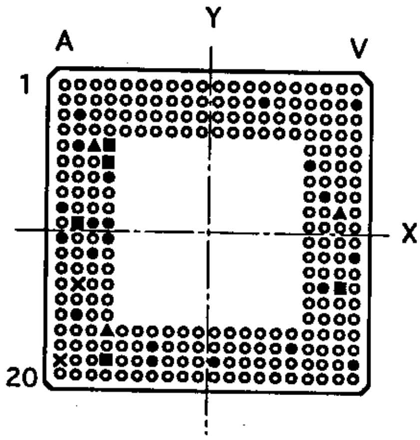
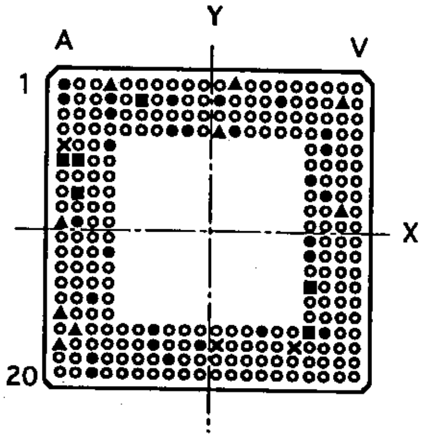
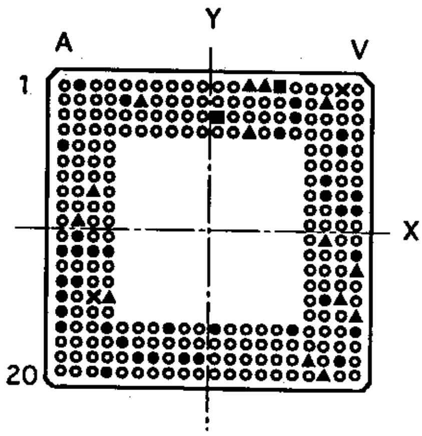
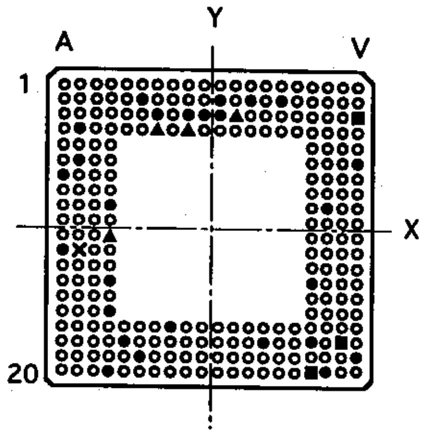


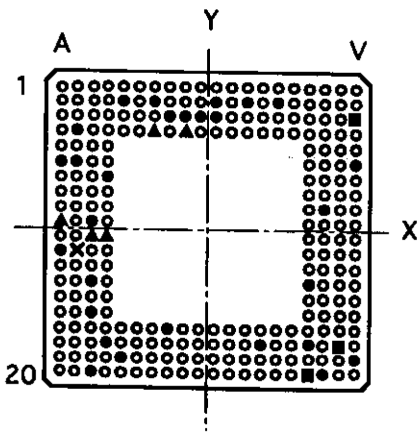
Figure 5: Company B - 256 pin











○ Offset<20 μ m

● 20≦Position Offset<30 μ m

▲ 30≦Position Offset<40 μ m

■ 40≦Position Offset<50 μ m

× 50≦Position Offset<150 μ m

Figure 6: Company C - 256 pin

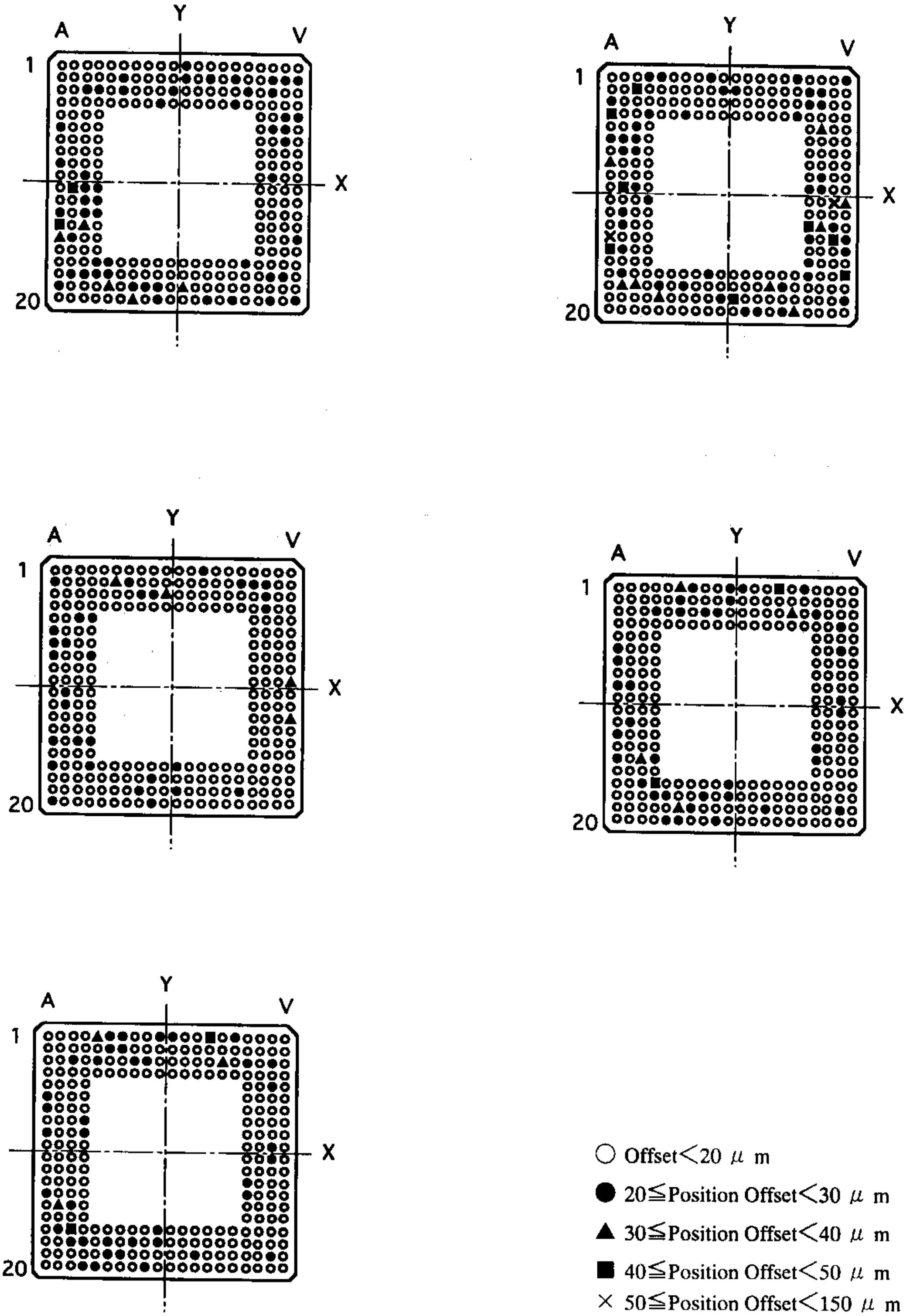


Figure 7: Company A - 352 pin

Datum Calculation: Minimum Square method

Datum Calculation: Applying only Center Part

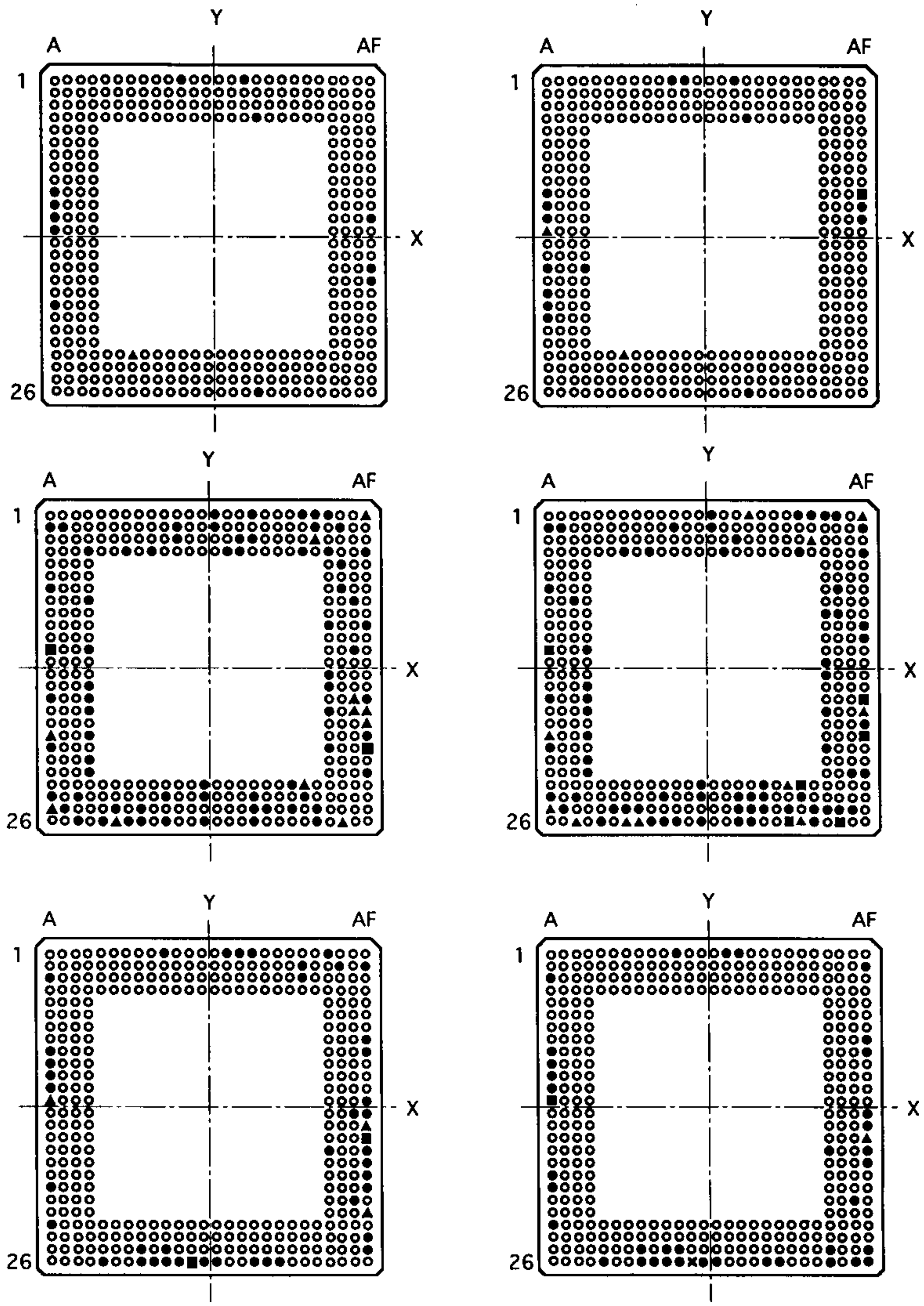
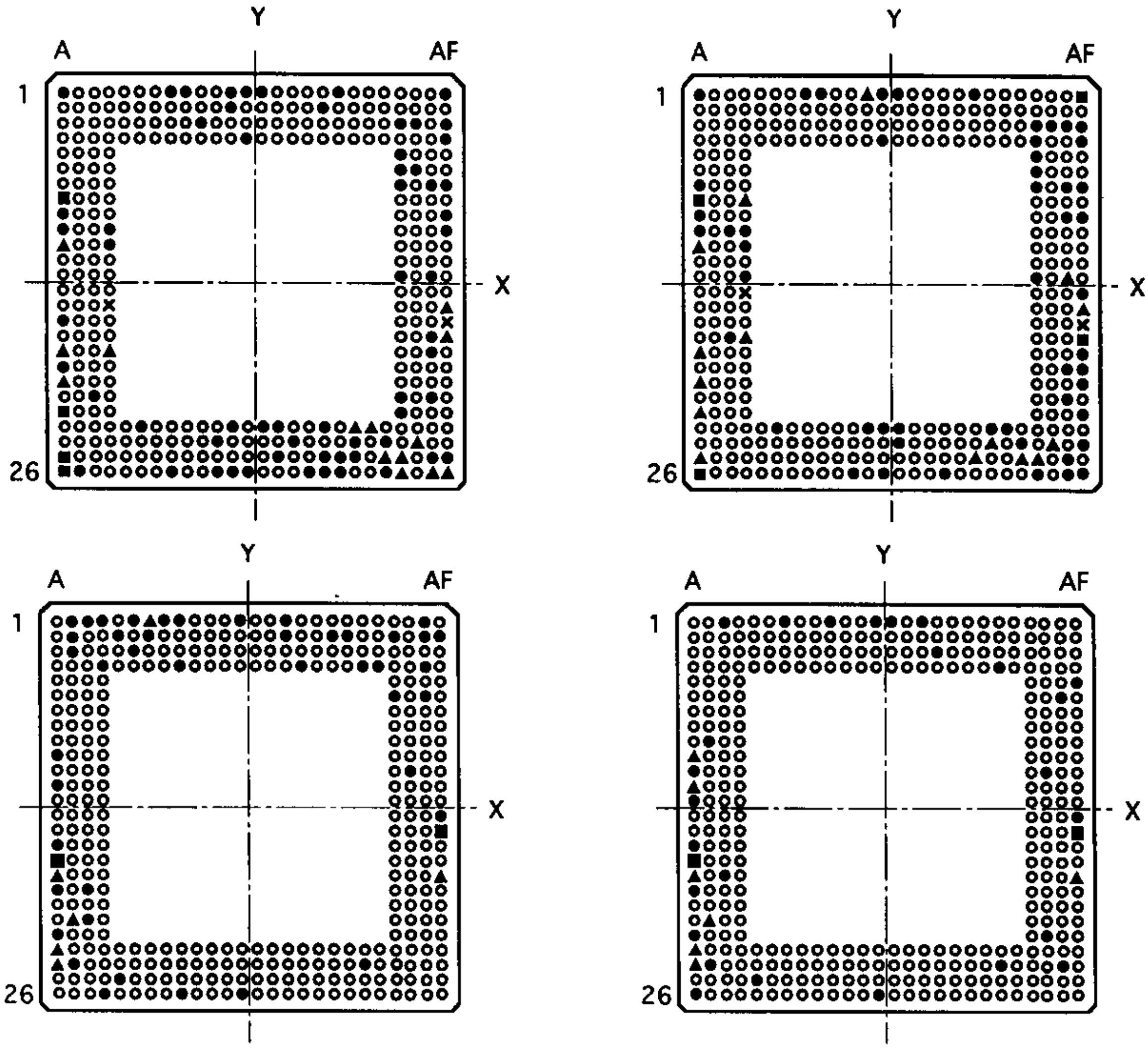


Figure 7: Company A - 352 pin (continued)

Datum Calculation: Minimum Square method

Datum Calculation: Applying only Center Part



○ Offset<20 μ m

● 20≦Position Offset<30 μ m

▲ 30≦Position Offset<40 μ m

■ 40≦Position Offset<50 μ m

× 50≦Position Offset<150 μ m

4. Committee Members

This standard was discussed mainly by Semiconductor Common Standard Sub-Committee of Semiconductor Package Standardization Committee and Semiconductor Package Outer Dimension Measuring Method Project Group. The members are as shown below.

<Semiconductor Package Standardization Committee>

Chairman	Toshiaki Shinohara	MITSUBISHI ELECTRIC CORPORATION

<Semiconductor Common Standard Sub-Committee>

Chief	Michio Sono	FUJITSU LIMITED

<Package Dimension Measuring Method Project Group>

Leader	Yasushi Otsuka	Sony Corporation
Sub-Leader	Tsuneo Kobayashi	IBM JAPAN, LTD.
	Eiji Mizutani	KOMATSU Ltd.
	Hideya Harukuchi	SHARP CORPORATION
	Hideo Taguchi	TOSHIBA CORPORATION
	Gohei Nanjoh	Nagase & Company, Ltd.
	Takahiro Naitoh	Hitachi, Ltd.
	Kenji Imamura	MITSUBISHI ELECTRIC CORPORATION
	Masahiko Fukuoka	YASUNAGA CORPORATION