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(JSNDI/JSA)

**Non-destructive testing—Ultrasonic
thickness measurement—Part 1:
Measurement method**

ICS 19.100

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard submitted by The Japanese Society for Non-destructive Inspection (JSNDI)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

Consequently **JIS Z 2355**:2005 has been withdrawn and partially replaced with this Standard.

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Attention is drawn to the possibility that some parts of this Standard may conflict with patent rights, applications for a patent after opening to the public or utility model rights. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying any of such patent rights, applications for a patent after opening to the public or utility model rights.

JIS Z 2355 series consists of the following 2 parts under the general title “*Non-destructive testing—Ultrasonic thickness measurement*”:

Part 1: Measurement method

Part 2: Method for evaluating performance characteristics of ultrasonic thickness measuring equipment

Non-destructive testing— Ultrasonic thickness measurement— Part 1: Measurement method

Introduction

This Japanese Industrial Standard has been prepared based on the first edition of **ISO 16809** published in 2012 with some modifications of the technical contents to facilitate smooth management of ultrasonic thickness meters based on the actual management in Japan.

The portions given sidelines or dotted underlines are the matters in which the contents of the corresponding International Standard have been modified. A list of modifications with the explanations is given in Annex JE.

1 Scope

This Standard specifies the thickness measurement method of metallic and non-metallic materials on the occasion of maintenance inspection or product inspection by the ultrasonic thickness measurement apparatus (hereafter referred to as measurement apparatus) utilizing the ultrasonic pulse.

NOTE : The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 16809:2012 *Non-destructive testing—Ultrasonic thickness measurement* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) listed below shall be applied.

- JIS B 0601 *Geometrical Product Specifications (GPS)—Surface texture: Profile method—Terms, definitions and surface texture parameters*
- JIS G 0431 *Steel products—Employer's qualification system for non-destructive testing (NDT) personnel*
- JIS Z 2300 *Terms and definitions of nondestructive testing*
- JIS Z 2305 *Non-destructive testing—Qualification and certification of NDT personnel*
- JIS Z 2353 *Method for measurement on ultrasonic velocity of solid by pulse technique using reference test piece*

JIS Z 2355-2 *Non-destructive testing—Ultrasonic thickness measurement—Part 2:
Method for evaluating performance characteristics of ultrasonic thick-
ness measuring equipment*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS Z 2300**, and the following apply.

3.1 residual thickness

value obtained by subtracting the reduced thickness (due to corrosion, erosion or wear) from the original thickness (thickness at completion of manufacture)

3.2 glycerol paste

couplant made of glycerol to which a small amount of surface active agent and thickener are added

3.3 display value

numerical value indicated on the display of thickness measurement instrument as a thickness

3.4 measured value

value adopted as a final measurement result

4 Measuring technique

As shown in Figure 1, the thickness of the test object is determined by measuring the time-of-flight required for an ultrasonic pulse to travel through the object, and using the value of time-of-flight and the known sound velocity of the material (see **JIS Z 2353**), according to the following formula.

$$d = \frac{1}{n} C \times t \dots\dots\dots (1)$$

where, d : thickness of test object (m)
 C : sound velocity of test object (m/s)
 t : time-of-flight of ultrasonic pulse through test object
 (s)
 n : number of transits through test object

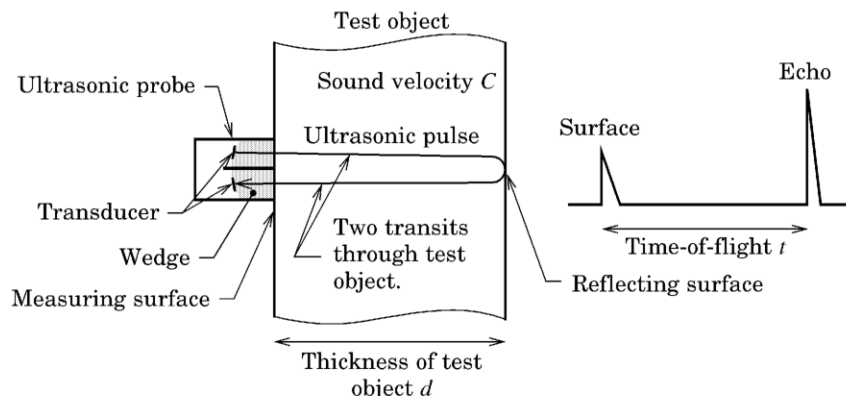


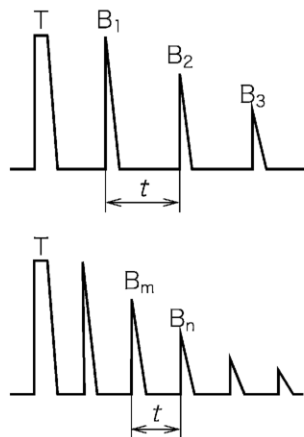
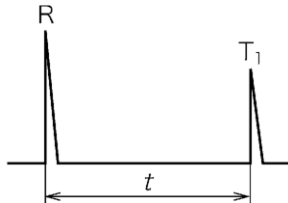
Figure 1 Principle for ultrasonic thickness measurement

The measuring techniques are classified as shown in Table 1.

Table 1 Classification of measuring techniques

	Measuring technique and example of probe	Type of echo	A-scan display
Technique 1	Zero point/first back wall echo technique (R-B ₁) technique Example of probe Double crystal probe	Set the zero point using the specified test piece and the probe. Obtain the thickness from the interval between this zero point and the first back wall echo (B ₁). The zero point is the time-base position corresponding to the surface of the test object.	The A-scan display for Technique 1 shows a horizontal time base. A vertical line marks the zero point (R). A subsequent peak represents the first back wall echo (B₁). The time interval between R and B₁ is labeled t.
Technique 2	Surface echo/first back wall echo technique (S-B ₁) technique Example of probe Double crystal probe Delay path probe Immersion probe	Obtain the thickness from the interval between the surface echo (S) at the measuring point and the first back wall echo (B ₁). ① Double crystal probe Obtain the thickness from the interval between the echo (S) from the surface of test object and the first back wall echo (B ₁). ② Delay path probe Obtain the thickness from the interval between the echo (S) from the surface of test object (bottom surface of material of delay path) and the first back wall echo (B ₁). ③ Immersion probe Obtain the thickness from the interval between the echo (S) from the surface of test object and the first back wall echo (B ₁).	The A-scan displays for Technique 2 show three different waveforms. Each waveform has a horizontal time base. A vertical line marks the surface echo (S). A subsequent peak represents the first back wall echo (B₁). The time interval between S and B₁ is labeled t. The waveforms are labeled T, S, and B₁.

Table 1 (concluded)

	Measuring technique and example of probe	Type of echo	A-scan display
Technique 3	Multiple-echo technique ① (B₁-B₂) technique Example of probe Single crystal probe <u>Immersion probe</u> Double crystal probe ② (B_m-B_n) technique Example of probe Single crystal probe <u>Immersion probe</u>	Obtain the thickness from the interval between two echoes among multiple echoes. Change the back wall echo according to the conditions. ① (B₁-B₂) technique Use this when B₁ echo is clear and sufficiently distinguishable from B₂ echo. ② (B_m-B_n) technique Use this when B₁ echo cannot be identified (n=m+1).	
Technique 4	Transmission technique Example of probe Single crystal probe	Obtain the thickness using pulses that have transmitted the test object. Useful for the measurement of high attenuating material from an echo can hardly be obtained.	

5 General requirements

5.1 Measurement apparatus

The performance of the measurement apparatus shall be indicated by the combination of the thickness measurement instrument and the probe shown below which satisfy the purpose of use.

5.1.1 Thickness measurement instrument

The thickness measurement instrument shall be as follows.

a) Ultrasonic thickness meter

- 1) **Ultrasonic thickness meter with digital display** A small ultrasonic thickness meter for general use, which is capable of measuring the thickness according to the technique specified in Table 1 and indicating the measured value on a digital display.
- 2) **Ultrasonic thickness meter with A-scan display** An ultrasonic thickness meter with digital display to which the A-scan display similar to that of an ultrasonic test instrument is added. In order to check the echo condition when the thickness of a corroded portion is measured and to select an appropriate echo

when the thickness through a composite material, coating, etc. is measured, an ultrasonic thickness meter with A-scan display should be used.

- b) **Ultrasonic test instrument** The apparatus to observe the response behaviour from the reflecting sources of the ultrasonic pulses emitted into the material, which can evaluate the flaws from the A-scan diagram.

5.1.2 Probe

The probes of the following types shall be used.

- a) Double crystal probe
- b) Single crystal probe

The probe cable specified by the manufacturer of the measurement apparatus shall be used.

See 6.3 for the selection of probes.

5.2 Couplant

Unless otherwise specified in other techniques than the immersion technique, the couplant shall be selected as shown in Table 2 depending on the roughness of the measuring surface. The surface roughness μmRz shall be in accordance with **JIS B 0601**.

Table 2 Selection of couplant

Roughness of measuring surface	
Under 25 μmRz	25 μmRz or more
Any but not having adverse effect on NDT personnel, test object and measurement apparatus.	Glycerol water solution of 75 % or more in concentration, glycerol paste or any other couplant whose acoustic coupling is confirmed to be equivalent thereto. Also, not having adverse effect on NDT personnel, test object and measurement apparatus.

5.3 Reference block

The measurement apparatus shall be set by a reference block having one or more thicknesses which represent the object to be measured. For the reference block, the sound velocity and the thickness should be almost equal to those of the test object, and the measuring surface and the reflecting surface parallel. The thickness or the steps of reference block should cover the range of thickness to be measured.

5.4 Test object

The test object shall be as follows.

- a) The test object shall allow for the ultrasonic-pulse propagation, and its surface shall also allow for an acoustic coupling with a probe.
- b) The measuring surface shall be free of all dirt, grease, lint, scale, welding flux and spatter, oil or other extraneous matter that could interfere with the ultrasonic-pulse propagation.

- c) If the measuring surface is coated, the coating shall have good adhesion to the material. Otherwise it shall be removed.

5.5 NDT personnel

The NDT personnel shall perform the measurement work by calibrating the measurement apparatus, and also have qualifications, experiences, knowledge and skills necessary for recording, classifying and reporting of measurement results.

The qualification and certification of NDT personnel or qualified personnel shall be as specified in **JIS G 0431** or **JIS Z 2305**.

6 Application of thickness measuring technique

6.1 Surface conditions and surface preparation

When there are obstacles to measurement on the measuring surface, pretreatment shall be performed. The pretreatment for the thickness measurement shall be performed by carefully removing the obstacles without damaging or waving the measuring surface as agreed between the purchaser and the manufacturer.

6.2 Thickness measurement

6.2.1 General

- a) **Selection of measuring point or measuring line** Unless otherwise specified, one of the following the measuring point or the measuring line shall be selected as agreed between the purchaser and the manufacturer, depending on the measuring purpose, test object, measuring range, usage situation, aging, corrosion state, etc.
 - 1) One typical point in each measuring range into which the test object is properly divided.
 - 2) Several points in each measuring range into which the shape changing part, etc. of the test object is properly divided.
 - 3) Intersecting points of grating lines provided at suitable interval in the measuring range.
 - 4) The necessary measuring points or lines selected according to the reduced thickness of the test object.
- b) **Selection of measuring technique** The measuring technique shall be selected as given in Table 1.
- c) **Selection of measuring method** The measuring method shall be selected as given in Table 3. The measuring methods are classified into the following five types according to the procedure for obtaining the measured results.

Table 3 Classification of measuring methods

	Measuring methods	Direction of acoustic barrier for double crystal probe
Measuring method by individual measuring points	One-time measuring method	Not specified.
	Two-time measuring method	Directions forming 90 degrees each other
Measuring method by movement on measuring line	Continuous measuring method	Acoustic barrier is perpendicular to measuring line.
Measuring method by increasing measuring points	Multiple points measuring method	Not specified.
	Precise measuring method	Not specified.

- 1) **One-time measuring method** Measuring method in which the specified measuring points are measured only once. In this method, the direction of acoustic barrier is not specified.
- 2) **Two-time measuring method** Measuring method in which measurement is carried out in two directions at right angles to each other by the double crystal probe. The measurement is carried out twice at the same measuring point, changing the direction of the acoustic barrier by 90°, and the smaller display value obtained is taken as the measured value.
- 3) **Continuous measuring method** One-time measurement carried out by moving the probe along the measuring line, either at specified intervals in contact scanning of double crystal probe or continuously in other scanning method. The thickness change along the measuring line can be shown by a cross-sectional presentation.

When the pitch is not designated, it shall be not more than 5 mm, and simultaneously the direction of acoustic barrier shall be maintained at right angles with the measuring line when the measurement is carried out by using the double crystal probe.

- 4) **Multiple points measuring method** Measuring method in which the measuring range is expanded centering on one measuring point. The measurements are performed at many points in this range, and the minimum display value is taken as the measured value. The expansion of the measuring range is normally determined according to the condition of corrosion or reduced thickness, and selected as agreed between the purchaser and the manufacturer. Unless otherwise designated, multiple points may be measured in a circle of 30 mm diameter. In this measuring method, the direction of acoustic barrier of the double crystal probe is not specified.
- 5) **Precise measuring method** Measuring method in which the thickness change in the designated range is precisely estimated by increasing the measuring points in that range. The measurement results may be displayed in plane by contour lines or the like. When the measuring range is not designated, the probe to be applied and the measuring pitch shall be adequately selected as agreed between the purchaser and the manufacturer.

6.2.2 Thickness measurement in product inspection

The measurement apparatus shall be selected from 5.1. For the selection of probes, in consideration of the thickness, shape, required precision, etc. of test object, the probe type (double transducer or single transducer), frequency, dimension of transducer, dimension of contact surface, necessity of delay path, etc. shall be determined. Figure A.1 and Figure A.2 are shown as reference for selection.

When the double crystal probe is used, the convergence range and the convergence distance that are appropriate for the thickness to be measured shall be selected. When the focused probe is used, the probe of appropriate focal zone shall be also selected.

If the material is highly attenuative and no echo technique can be used, the transmission technique (technique 4) is applicable. In most cases, the frequency should be 1 MHz or lower.

6.2.3 Residual thickness measurement in in-service inspection

6.2.3.1 General

The measurement apparatus shall be selected from 5.1.

For the selection of probes, in consideration of the estimated thickness, shape, etc. of test object, the probe type (double transducer or single transducer), frequency, dimension of transducer, dimension of contact surface, necessity of material of delay path, etc. shall be determined. Figure A.3 and Figure A.4 are shown as a reference for selection.

When the double crystal probe is used, the convergence range and the convergence distance that are appropriate for the thickness to be measured shall be selected. When the focussed probe is used, the probe of appropriate focal zone shall be selected in the same way.

When using the double crystal probe in the contact scanning, in the two-time measuring method, continuous measuring method or the like, the probe shall be separated from the measuring surface whenever its direction or position is changed.

6.2.3.2 General measuring method of thickness of plane object

- a) Thickness is measured by using the ultrasonic thickness meter with digital display. In the case where there is no abnormality, the display value shall be taken as the measured value.

The abnormality means the following cases.

- 1) The display value is about twice the estimated thickness.
 - 2) The display value is about half of the estimated thickness.
 - 3) The display value fluctuates (the deviation of display values exceeds the tolerance determined between the purchaser and the manufacturer or the display values are not stable).
 - 4) The display value cannot be obtained.
- b) In the case where abnormalities exist, the views on the causes and the display values should be recorded.

- 1) The measurement is carried out by the continuous measuring method or the precise measuring method in addition to the multiple points measuring method, and the abnormalities are judged from the general state neighbouring the measuring point.
- 2) The thickness is obtained from the sound path length with observations of existence of an echo signal from discontinuity and appearance of back wall echo signal through the A-scan diagram using the ultrasonic thickness meter with A-scan display or the ultrasonic thickness meter.

6.2.3.3 Notes on measuring method of thickness of corroded portion

The corrosion in containers, piping, etc. can occur due to various mechanisms. The causes and mechanisms of various corrosions are given in Annex B as a reference.

When corrosion is expected on the measuring surface or the back wall of the test object, the following points shall be noted.

- a) **When measuring surface is corroded** When the measuring surface has unevenness due to corrosion, since the transmission of ultrasonic pulse is reduced, the value sometimes cannot be displayed or the wrong value is sometimes displayed due to the layer of couplant.
- b) **When back wall is corroded** When the slope of corroded portion is comparatively gentle, the comparatively stable display values are obtained. In the case of needle-like pitting, however, the echo cannot be easily obtained from the tip of the pitting, which could result in the limited indication of thickness around the corrosion or the indication failure.
- c) **Method of action** When the display values are not stable due to corrosion or pitting or when the display values cannot be obtained, the echo shall be observed from an A-scan diagram using an ultrasonic thickness meter with A-scan display or an ultrasonic test instrument. The condition and degree of corrosion, and the residual thickness shall be measured. The echo from the corroded portion may often become multimodal as shown in Figure 2. When the residual thickness is read, the start-up of the echo signals in stead of the peak position shall be used.

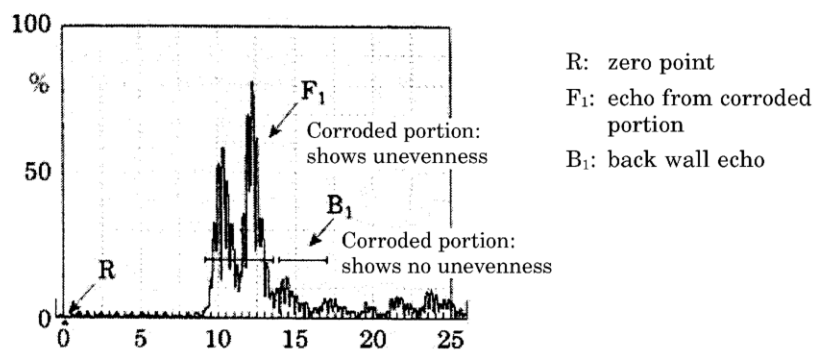


Figure 2 Example of echo from corroded portion ^[1]

6.2.3.4 Measuring method of wall thickness of tubular object

The notes on the measuring method of wall thickness of tubular object is given in Annex JA as a reference.

6.3 Selection of probe

The selection of probe shall be as follows.

- a) A suitable measurement procedure shall be chosen according to **6.2** and the probe type (double transducer or single transducer) shall be determined. There are other parameters that need to be considered when matching the probe to the measuring conditions.
- b) Broadband probes offer a shorter pulse than narrow band probes, giving a better resolution when measuring thin sheets or coating layers.
- c) Probes of low-frequency or broadband probes shall be used to obtain a stable echo even when test objects made of attenuating materials have to be measured.
- d) Probe size and frequency shall be chosen to cover the measurement range by a narrow sound beam to get an echo from a well-defined area.
- e) When measuring the test object having extremely small thickness, delay path probe should be used. The measuring technique shall be technique 2 or technique 3 as shown in Table 1. The material of delay path shall be chosen to generate a suitable interface echo. Using the same material as the test object will not generate an interface echo. When the material of delay path has a lower acoustic impedance than the material to be tested, e.g. plastics delay on metals, there will be a phase shift of the interface echo. This requires correction to get accurate results. Some ultrasonic thickness meters do this correction automatically.
- f) When measuring the surface at elevated temperatures, the probe with the material of delay path shall be used by referring to data sheets of the probe manufacturers showing the range of temperatures a probe is suitable for and the time it can be used at those temperatures. In this case, the influence of the temperature on the acoustical properties of the delay path shall be known (drift of sound attenuation and velocity).

6.4 Selection of thickness measurement instrument

The thickness measurement instrument shall be selected from 5.1.1.

6.5 Materials different from reference block

See Annex C. Only if the display value of sound velocity is corrected, other test pieces may be used.

6.6 Special measuring conditions

6.6.1 General

General matters under the special measuring conditions shall be as follows.

- a) There shall be strict observation of all legislative procedures governing the safe use of chemicals and electrical equipment on the thickness measurement environment or the test objects.
- b) Where there is a requirement for high-accuracy measurements, the test piece for calibration or the reference block to be used shall be at the same temperature as the test object.

6.6.2 Thickness measurement at low temperatures

The measurements at temperatures below 0 °C shall be as follows.

- a) The couplant chosen shall retain its acoustic characteristics and have a freezing point below the temperature of the measuring surface.
- b) Most probes are rated for use between 0 °C and 50 °C. At temperatures below 0 °C, specially designed probes may be required.
- c) The contact time should be limited as recommended by the manufacturer.

6.6.3 Thickness measurement at elevated temperatures

The measurements at temperatures above 50 °C shall be as follows.

- a) The high temperature probe shall be used.
- b) The couplant designed for use at the temperature of measuring surface shall be used.
- c) It is recommended that the ultrasonic test instrument equipped with the waveform recordable function be used.
- d) The probe contact time shall be limited to the minimum time necessary to achieve measurement as recommended by the manufacturer.

Notes on the thickness measurement of test object at elevated temperatures are given in Annex JB as a reference.

6.6.4 Hazardous atmospheres

In the thickness measurement in hazardous atmospheres, the following shall be satisfied.

- a) There shall be strict compliance with prevailing safety regulations and standards on the thickness measurement environment and the test objects.
- b) In explosive atmospheres, the combination of probe, cable and thickness measurement instrument shall be classified as intrinsically safe, and relevant safety certification or documentation shall be checked and completed prior to use.
- c) In corrosive atmospheres, the couplant shall not react adversely with the environment and shall retain its acoustic properties.

6.6.5 Thickness measurement through coating

For the thickness measurement through coating, the B₁-B₂ (B_m-B_n) technique shall be applied.

When the interface between a coating layer and a test object is identifiable, the S-B₁ technique (also called I-B₁ technique) in which an interface echo is regarded as a surface echo may be applied.

The notes on the thickness measurement through coating are given in Annex JC as a reference.

7 Setting of thickness measurement instrument

7.1 General

The setting of thickness measurement instrument shall be carried out with the same apparatus as that to be used for the thickness measurements. It shall be carried out in accordance with the manufacturer's instruction, procedure manual or **9.15 of JIS Z 2355-2**.

7.2 Method

7.2.1 General

The setting of thickness measurement instrument shall suit the measuring technique and the measurement apparatus in use. The setting shall be carried out under comparable environmental conditions as those of the thickness measurement of the test object.

The guidance for the selection of setting method of thickness measurement instrument is given in Annex C.

7.2.2 Ultrasonic thickness meter

The setting of ultrasonic thickness meter shall be as follows.

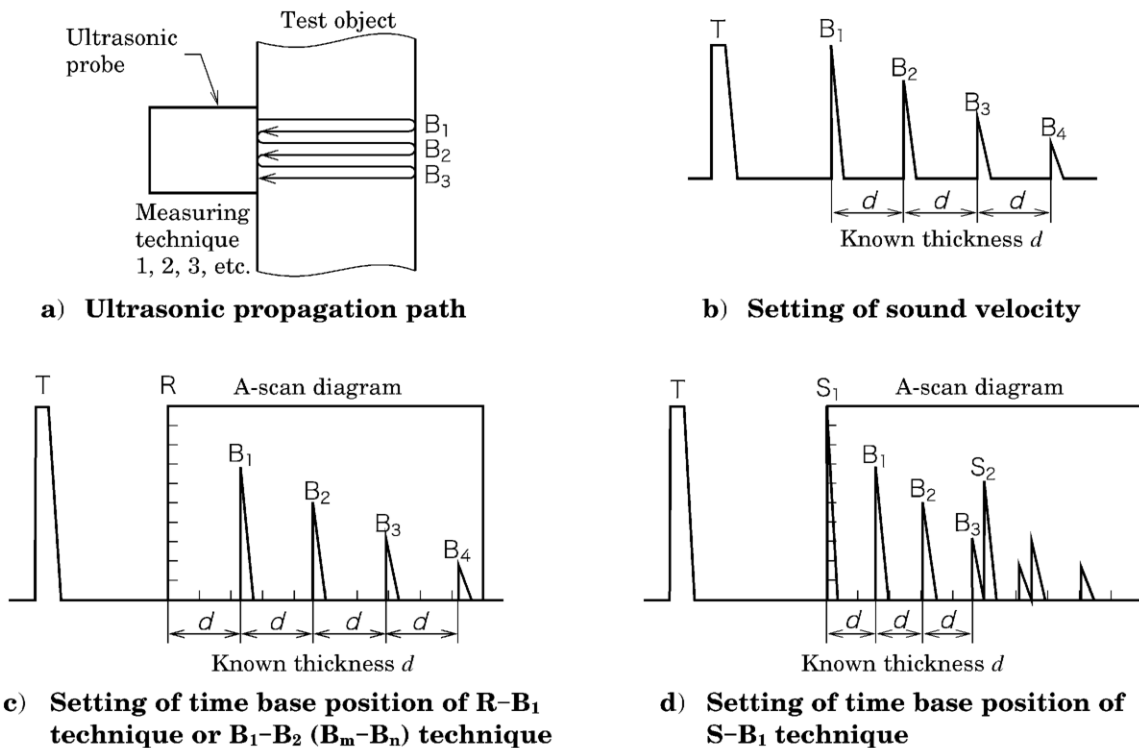
- a) When the R-B₁ technique is used, the zero point shall be set, and the sound velocity shall be set so that the display value indicates the thickness by using the test piece for calibration (setting may be made so that the sound velocity of an ultrasonic thickness meter is the same as the sound velocity of a test object).
- b) When the B₁-B₂ (B_m-B_n) technique or the S-B₁ technique is used, the sound velocity shall be set so that the display value indicates the thickness by using the test piece for calibration (setting may be made so that the sound velocity of an ultrasonic thickness meter is the same as the sound velocity of a test object).

7.2.3 Ultrasonic test instrument

The setting of time base when the thickness is read from an A-scan display using an ultrasonic test instrument shall be as follows.

- a) **Setting of sound velocity** The time base shall be set so that the sound path length of the intervals among multiple echoes which have travelled in a reference block corresponds to the thickness of the reference block [Figure 3 a) and Figure 3 b)].
- b) **Setting of time base position** In the case of the R-B₁ technique or the S-B₁ technique, the transmission pulse shall not be displayed and the interface echo shall be made to agree with almost zero of the scale. Next, the first back wall echo shall be made to agree with the scale position of the sound path length corresponding to the known thickness of a reference block [Figure 3 c)].

In the case of the B_m-B_n technique, the first back wall echo shall be made to agree with the position of the sound path length corresponding to the known thickness of a reference block, then the n th back wall echo shall be made to agree with the position of the sound path length corresponding to n times the known thickness of the reference block [Figure 3 d)].



T: transmission pulse

R: zero point

S₁, S₂: surface echo

B₁ to B_n: back wall echo

Figure 3 Setting of time base of A-scan display

7.3 Check of settings

Unless otherwise specified, the setting values shall be checked at the measurement start, measurement end, and, if necessary, arbitrarily during measurement. In the case where the calibration value exceeds the specified allowable value, compared with the previous calibration value which is determined between the purchaser and the manufacturer, the measurement shall be carried out again after checking the previous setting value. Also, setting shall be carried out in the following cases.

- If it is suspected that there are abnormalities like operation failure of measurement apparatus rather than the problem of the ultrasonic pulse.
- If whole or some parts of measurement apparatus have been replaced.
- If measurement has been taken over by a new NDT personnel.
- If power has been turned on again.
- If material of test object differs.

- f) If temperature of test object or measurement apparatus has been changed significantly.

7.4 Maintenance and check of measurement apparatus

7.4.1 General

The maintenance of measurement apparatus shall be as follows.

- a) If there are flaws, unevenness, unsymmetrical wear, etc. on the contact surface of probe, they may cause the lowering of echo height and the variation of measured values. After smoothing the contact surface, the performance of the probe shall be measured. When the performance to be required (convergence distance and convergence range) is not satisfied, the probe shall be replaced.
- b) When the couplant has been adhered for a long time, it may cause the damage in instruments due to its penetration. The couplant adhered to the probe, the junction of probe cable or the body of an ultrasonic thickness meter shall be thoroughly wiped off after measurement. Also, the couplant on the contact surface of probe shall be thoroughly wiped off after the measurement end (and also when the automatic cut-off function operates).

7.4.2 Daily check

As specified in clause **11** of **JIS Z 2355-2**.

An example of a daily check record table is given in Annex JD.

7.4.3 Periodical check

The periodical check shall be carried out according to clause **10** of **JIS Z 2355-2** once a year, and the results shall be recorded.

7.4.4 Special check

When a measurement apparatus falls, when an impact is given during conveyance, or when environmental conditions such as temperature exceeds the specification range of the supplier, the same check as the periodical check shall be carried out.

8 Influence on measurement accuracy

8.1 Operational conditions

Pay attention to the condition of test object that may affect the measured values as shown below.

8.1.1 Condition of measuring surface

- a) **Cleanliness** The cleanliness of measuring surface may affect its measured values. Inadequate surface precleaning may lead to inconsistent results. Adhering dirt and scale shall be removed by brushing, etc. before measurement.
- b) **Surface roughness** Surface roughness interferes with the estimate of thickness, and modifies the coefficients of reflection and transmission at the interface. In circumstances where there is significant roughness, the sound path length is increased and the wrong value may be displayed.