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Method for ultrasonic examination
for welds of ferritic steel

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee, as the result of proposal for revision of Japanese Industrial Standard submitted by The Japanese Society for Non-Destructive Inspection (JSNDI)/the Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14. Consequently JIS Z 3060 : 1994 is replaced with this Standard.

This revision is made in consideration of the technological advancement and international technological trend with regard to ultrasonic examination.

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In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

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Method for ultrasonic examination for welds of ferritic steel

1 Scope This Japanese Industrial Standard specifies the method for detecting a discontinuity and for measuring its location and dimensions on full penetration welds of ferrite series steel with thickness of 6 mm or more, in the case of manual ultrasonic examination (hereafter referred to as "examination") using pulse echo technique by ultrasonic test instrument (hereafter referred to as "test instrument") with a scope display. However, this Standard is not applied to the examination of joint welds of steel pipes under production process.

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

JIS Z 2300 *Glossary of terms used in nondestructive testing*

JIS Z 2345 *Standard test blocks for ultrasonic testing*

JIS Z 2350 *Method for measurement of performance characteristics of ultrasonic probes*

JIS Z 2352 *Method for assessing the overall performance characteristics of ultrasonic pulse echo testing instrument*

3 Definitions For the purposes of this Standard, the definitions given in JIS Z 2300 and the following definitions shall apply.

- a) **paste** A pastelike couplant.
- b) **glycerol paste** The glycerol paste is a kind of couplant, which is made by adding a small amount of surfactant and thickener to glycerol.
- c) **probe-discontinuity distance** The distance for path length from probe index where the maximum echo height is obtained by using an angle probe to a discontinuity to be projected on the test surface.
- d) **L direction** L direction is the principal rolling direction of rolled steel materials.
- e) **C direction** C direction is the direction perpendicular to the principal rolling direction.
- f) **Q direction** Q direction is the direction at an angle of 45° from the principal rolling direction.
- g) **STB wave velocity ratio** A ratio (V/V_{STB}) of transverse wave velocities (V) measured so that the vibrating direction of transverse wave agrees with the scanning direction of test object to transverse wave velocities (V_{STB}) measured by using model A1 STB or one out of model A3 series STB.
- h) **STB difference of refraction angle by scanning direction** The difference between the refraction angle by test object and the STB refraction angle (θ_{STB}) measured by using model A1 STB or one out of model A3 series STB.

- i) **maximum transmission pulse** The transmission pulse of which amplitude is maximized when scanning a test object by the V path method.
- j) **ultrasonic discontinuity length** An apparent discontinuity length estimated by transference distance of the probe.

4 Examination personnel The personnel engaged in the examination of welds should possess not only the general knowledge of principle of ultrasonic examination and welds of ferritic steel, but also sufficient knowledge and experience of the examination of the specified test object.

5 Calibration blocks and reference blocks

5.1 Calibration blocks The calibration blocks (STB) to be used in this Standard shall be model A1 calibration blocks, model A2 and A3 series calibration blocks which are specified in JIS Z 2345.

5.2 Reference blocks The reference blocks (RB) shall be used for sensitivity adjustment.

- a) **RB-41**
 - 1) RB-41 shall be used for the examination of joint welds of flat plate and joint welds with the radius of curvature of 250 mm or over, and its form shall be as given in Fig. 1 and its size as given in Table 1.
 - 2) RB-41 shall meet one of the following requirements.
 - 2.1) Reference blocks with the test surface finished by using homogeneous low damping materials and without radius of curvature.
 - 2.2) Reference blocks of the same grade of steel as that of the test object used, which meet the following condition with respect to the state of test surface, and are without radius of curvature.

Condition : Thickness shall be within $\pm 10\%$ of the test object and wave velocity difference between the test object and reference block shall be within $\pm 2\%$.
- b) **RB-42** RB-42 shall have the curvature with the direction perpendicularly intersecting the scanning direction, and shall be used for the examination of circumferential joint welds with the radius of curvature of 50 mm or over, and its form shall be as given in Annex 3 Fig. 2 and its size as given in Table 1.
- c) **RB-43** RB-43 shall have the curvature with the direction parallel to the scanning direction, and shall be used for the examination of longitudinal joint welds with the radius of curvature of 50 mm or over, and its form shall be as given in Annex 4 Fig. 3 and its dimension as given in Table 1.
- d) **Other reference blocks** RB-A6 shall have the curvature with the direction perpendicularly intersecting the scanning direction, and shall be used for the examination of circumferential joint welds with the radius of curvature of 50 mm or over when the maximum path length to be used is 150 mm or under, and its form shall be as given in Annex 3 Fig. 3.

Table 1 Dimensions of RB-41, RB-42, RB-43

Unit : mm

Block number	Thickness of test object t	Thickness of reference T	Diameter of standard hole d
No. 1	20 or under	19 ⁽¹⁾ or $t^{(1)}$	3.0
No. 2	Over 20 up to and incl. 40	38 ⁽¹⁾ or $t^{(1)}$	3.0
No. 3	Over 40 up to and incl. 80	75 ⁽¹⁾ or $t^{(1)}$	3.0
No. 4	Over 80 up to and incl. 140	125 ⁽¹⁾ or $t^{(1)}$	6.0
No. 5	Over 140 up to and incl. 200	175 ⁽¹⁾ or $t^{(1)}$	6.0
No. 6	Over 200 up to and incl. 250	225 ⁽¹⁾ or $t^{(1)}$	6.0
No. 7	Over 250	$t^{(1)}$	6.0

Note (1) Blocks in 2) 2.1) of 5.2 a) and blocks in 2) 2.2) of 5.2 a)

6 Couplant Glycerol paste, glycerol water solution of 75 % or more, water, oil, or liquid of which acoustic impedance is known shall be used as a couplant. When the kind of couplant and delay materials of normal probe or wedge materials of angle probe are used in the following combination, it is not necessary to make corrections for the transfer loss in the case where the maximum surface roughness (R_y) of test surface is less than 100 μm .

a) **Kind of couplant** Glycerol paste or glycerol water solution of 75 % or more

b) **Delay materials and wedge materials** Polystyrene

7 Preparation of examination

7.1 Selection of examination method Unless specially specified, the examination of weld shall be performed by using single probe angle beam technique with ultrasonic beam perpendicular to the direction of the weld line, and by contact method. The method of parallel scanning by a slanted probe, the method of longitudinal scanning of weld surface, the method of straddle scanning or normal beam technique shall be applied to the place specially specified.

Tandem probe technique shall be applied to the place specially specified to detect the full penetration weld with groove face or root surface perpendicular to the test surface, and plate thickness of not less than 20 mm.

7.2 Selection of reference blocks or calibration blocks

7.2.1 Selection of blocks for angle beam technique For adjusting working sensitivity, any of RB-41, RB-42, RB-43, RB-A6 given in Annex 3 Fig. 3 or one out of model A2 series calibration blocks shall be previously designated. However, any of RB-41, RB-42, RB-43 shall be designated in the case where plate thickness of the test object of the part to which the probe is contacted is 75 mm or more, or in the case where refraction angle is selected in accordance with refraction angle by test object given in Table 4 from the measurement result of STB wave velocity ratio. Furthermore, in the case where the maximum path length to be used is not more than 150 mm, one out of model A2 series calibration blocks may be designated.

7.2.2 Selection of blocks for normal beam technique For adjusting working sensitivity, RB-41 shall be used. According to the maximum path length to be used, the location of standard hole from the test surface shall be designated.

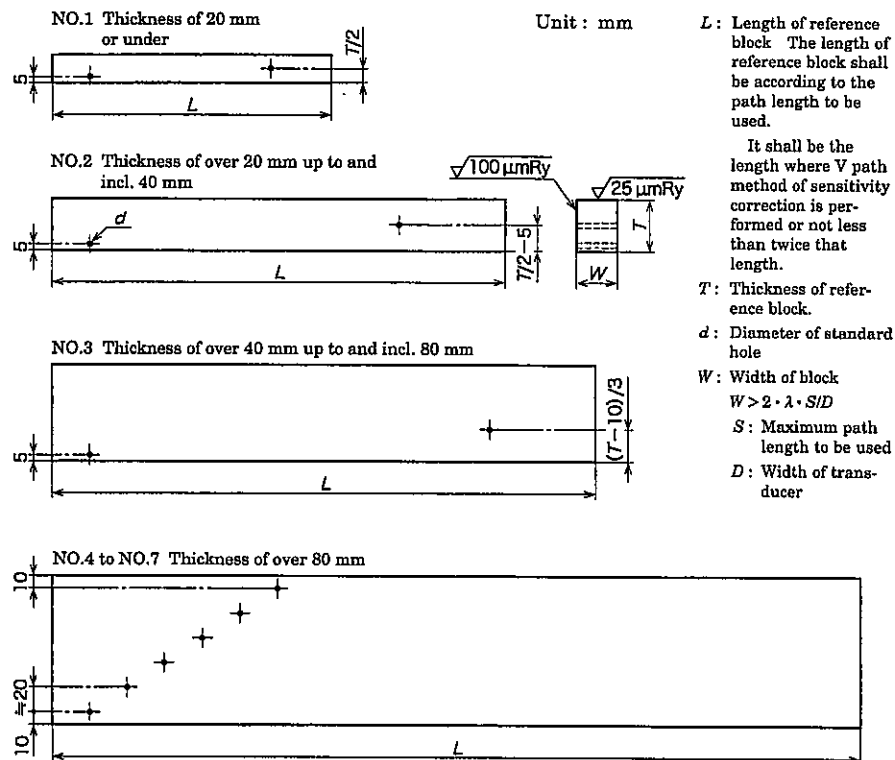


Fig. 1 RB-41

7.3 Selection of frequency The nominal frequency to be used shall be not less than 2 MHz but not more than 5 MHz. The frequency to be used as a standard shall be in accordance with Table 2 in the case of angle beam technique, and shall be in accordance with Table 3 in the case of normal beam technique.

In addition, the frequency lower than the value specified in Table 2 and Table 3 may be used for the examination of the test object with remarkable ultrasonic attenuation.

The test frequency shall be in the range of 90 % to 110 % of nominal frequency. For the probe with the wide-band frequency characteristics, the test frequency shall be measured in accordance with 5 of JIS Z 2350, and the number of peak shall be measured in accordance with 8 of JIS Z 2350.

Table 2 Nominal frequency used for angle beam technique

Max. path length to be used mm	Nominal frequency MHz
100 or under	5
Over 100 up to and incl. 150	2 or 5
Over 150	2

Table 3 Nominal frequency used for normal beam technique

Max. path length to be used mm	Nominal frequency MHz
40 or under	5
Over 40	2

7.4 Selection of disregard level According to purpose of the examination, the disregard level shall be either M disregard level for the object which exceeds M line created according to 8.1.4 or L disregard level for the object which exceeds L line.

7.5 Stage of examination The stage of the examination is the time when the final heat treatment is completed, in the case where heat treatment or the like after completion of weld is specified in the document.

7.6 Finishing of test surface When spatter and floating scales exist in the test surface, they shall be removed. When the transfer loss exceeds 12 dB due to the effects of roughness, rust and painting film of the test surface, it shall be finished in the range not exceeding 12 dB.

7.7 Examination of parent materials The parent materials of the part through which ultrasonic waves pass when angle beam examination is performed, are previously examined by normal beam technique as required. The probe nominal frequency and diameter to be used shall be 5 MHz and $\phi 20$ mm respectively in the case of plate thickness of 60 mm or under, and 2 MHz and $\phi 30$ mm respectively in the case of plate thickness of over 60 mm. The working sensitivity shall be adjusted to obtain 80 % fs height of the first back wall echo of the ultrasonically sound area. The range of a discontinuity shall exceed 20 % fs in echo height. When a discontinuity is detected, it shall be recorded. In the case where the range of a discontinuity is 100 mm² or over, it may obstruct the examination.

When a discontinuity which obstructs the examination was detected, in the case where it becomes a problem when the examination is performed, as required, the examination shall be performed either by changing the test surface or the refraction angle so that beam central axis passes through the whole of welds, or by changing to normal beam technique or other examination methods.

7.8 Measurement of wave velocity ratio to STB

7.8.1 Measuring conditions of STB wave velocity ratio Measuring conditions of STB wave velocity ratio shall be as follows:

- The site of measuring objects shall be the location of examination.
- The measurement shall be performed after welding, and under the same degree of state as that at the temperature when examining.
- Number of locations of examination shall be one, but it may be more according to the state of test object.

7.8.2 Measuring apparatus of wave velocity ratio to STB Measuring apparatus of wave velocity ratio to STB shall be as follows:

- For the measurement of STB wave velocity ratio (V/V_{STB}), the ultrasonic wave apparatus (the ultrasonic thickness meter or test instrument capable of using a transverse wave normal probe) which is capable of measuring thickness or path length with an accuracy which obtains to three significant digits or over and the transverse wave normal probe capable of propagating transverse wave vertically through the test object shall be used.
- For the measurement of thickness, the ultrasonic thickness meter or dimension measuring instrument which uses a longitudinal wave probe (a longitudinal wave normal probe or a double transducer longitudinal wave normal probe) capable of measuring with an accuracy which obtains to three significant digits or over shall be used.
- For the transverse wave normal probe, the vibrating direction shall be presented.
- For the measurement by transverse wave normal probe, the couplant for transverse wave shall be used.

7.8.3 Blocks or test objects to be used For the measurement of STB wave velocity ratio, the following shall be used.

- Any of model A1 calibration blocks, model A2 or A3 series calibration blocks shall be used.
- The test object shall be of the part to which the probe is contacted.

7.8.4 Confirmation of scanning direction of test object Before the measurement of STB wave velocity ratio, the relation between the scanning direction and L, C and Q direction shall be confirmed by the combination of the transverse wave normal probe and the ultrasonic thickness meter or test instrument. When the scanning direction is L or C direction, or when the difference between transverse wave velocities does not exist due to direction, it shall be confirmed in accordance with methods in 7.8.5, 7.9 and 7.10.1, but when the scanning direction is Q direction, in accordance with methods in 7.10.2.

7.8.5 Measuring method of STB wave velocity ratio The measuring method of STB wave velocity ratio shall be performed by either of the following.

- a) **Case by an ultrasonic thickness meter** The plate thickness of test object and STB measured by the ultrasonic thickness meter or dimension measuring instrument which uses the longitudinal wave probe shall be t_M (mm) and t_{SM} (mm), respectively. Furthermore, the plate thickness obtained so that the vibrating direction of transverse wave normal probe which is used for the ultrasonic thickness meter agrees with the scanning direction of the test object and the plate thickness obtained from STB shall be t_S (mm) and t_{STB} (mm), respectively.

These ratios shall be calculated down to the third decimal place according to the following formula, and it shall be taken as STB wave velocity ratio.

$$V/V_{STB} = (t_M \cdot t_{STB}) / (t_{SM} \cdot t_S)$$

- b) **Case by test instrument** The plate thickness of test object and STB measured by the ultrasonic thickness meter or dimension measuring instrument which uses the longitudinal wave probe shall be t_M (mm) and t_{SM} (mm), respectively. Furthermore, the path length of first back wall echo obtained so that the vibrating direction of transverse wave normal probe which is used for the test instrument agrees with the scanning direction of the test object and the path length of first back wall echo obtained from STB shall be W_S (mm) and W_{STB} (mm), respectively.

These ratios shall be calculated down to the third decimal place according to the following formula, and it shall be taken as STB wave velocity ratio.

$$V/V_{STB} = (t_M \cdot W_{STB}) / (t_{SM} \cdot W_S)$$

7.9 Selection of refraction angle according to wave velocity ratio The refraction angle to be used for examination from the results of measurements of wave velocity ratio to STB shall be selected according to Table 4. However, in the case of examining using a probe of 45° in nominal refraction angle, it shall be STB refraction angle of 43° or over up to and including 47° regardless of STB wave velocity ratio.

In addition, when the refraction angle of probe to be used for examination becomes STB refraction angle from the wave velocity ratio to STB, it may be replaced by the refraction angle by test object. Furthermore, when the plate thickness of test object exceeds 75 mm, in the case of $0.995 \leq V/V_{STB} \leq 1.005$, STB refraction angle of 69° to 71° may be used.

Table 4 Selection of refraction angle according to wave velocity ratio to STB

Plate thickness of test object mm	Wave velocity ratio to STB	Refraction angle to be used for examination
$6 \leq t \leq 25$	$0.990 \leq V/V_{STB} \leq 1.020$	STB refraction angle of 63° or over up to and incl. 72°
	$0.990 > V/V_{STB}$	Refraction angle by test object of 63° or over up to and incl. 72°
	$V/V_{STB} > 1.020$	Refraction angle by test object of 63° or over up to and incl. 72°
$25 < t \leq 75$	$0.995 \leq V/V_{STB} \leq 1.015$	STB refraction angle of 58° or over up to and incl. 72°
	$1.015 < V/V_{STB} \leq 1.025$	STB refraction angle of 58° or over up to and incl. 67°
	$0.995 > V/V_{STB}$	Refraction angle by test object of 58° or over up to and incl. 72°
	$V/V_{STB} > 1.025$	Refraction angle by test object of 58° or over up to and incl. 72°
$75 < t$	$0.995 \leq V/V_{STB} \leq 1.025$	STB refraction angle of 58° or over up to and incl. 67°
	$0.995 > V/V_{STB}$	Refraction angle by test object of 58° or over up to and incl. 67°
	$V/V_{STB} > 1.025$	Refraction angle by test object of 58° or over up to and incl. 67°

7.10 Calculation method of refraction angle by test object The calculation of refraction angle by test object shall be performed by either of the following.

7.10.1 Calculation by STB wave velocity ratio The refraction angle by test object, θ , shall be calculated from the STB refraction angle of a probe to be used and STB wave velocity ratio of V/V_{STB} by the following formula and shall be rounded to the necessary fineness of a 0.5° unit or under.

$$\theta = \sin^{-1} \left(\frac{V}{V_{STB}} \sin \theta_{STB} \right)$$

7.10.2 Calculation by V path method The location of probe shall be adjusted so that the maximum transmission pulse intensity is obtained on the test surface of test object in accordance with the arrangement of V path method given in Fig. 2 using the probe of the same type as that of angle probe to be used for examination. The refraction angle by test object, θ , shall be calculated from the distance between probe indices (Y) and the actually measured plate thickness (t) according to the following formula, and shall be rounded to the necessary fineness of a 0.5° unit or under.

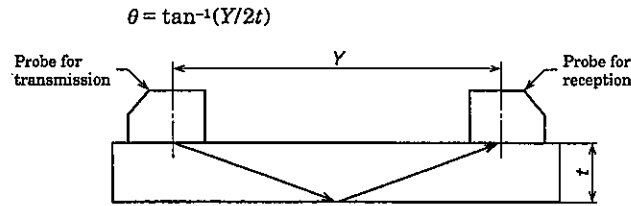


Fig. 2 Arrangement of V path method

8 Adjustment and check of ultrasonic test equipment

8.1 Angle beam examination

8.1.1 Measurement of probe index The probe index shall be measured by using model A1 calibration block or one out of model A3 series calibration blocks. The probe index shall be measured in units of 1 mm.

8.1.2 Adjustment of time base range The adjustment of time base range shall be performed by using model A1 calibration block or one out of model A3 series calibration blocks.

8.1.3 Measurement of STB refraction angle and refraction angle by test object

a) **Measurement of STB refraction angle** The measurement of STB refraction angle shall be performed by using model A1 calibration block or one out of model A3 series calibration blocks. The STB refraction angle shall be measured at the temperature of environment of examination work and read out to the necessary fineness of a 0.5° unit or under.

The STB refraction angle shall be used in the range of $\pm 2^\circ$ of nominal refraction angle.

b) **Measurement of refraction angle by test object** The measurement of refraction angle by test object shall be performed in accordance with the calculation method of refraction angle by test object in 7.10 by measuring STB wave velocity ratio and STB refraction angle. However, if the correction of refraction angle by test object is specified in Annex, the measurement shall be performed according to it.

8.1.4 Making curves for dividing echo height

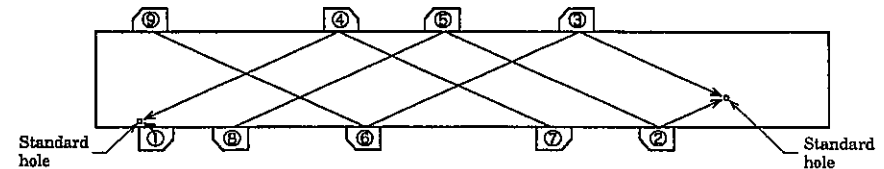
a) The curves for dividing echo height shall be made by using the test instrument and probe to be used.

In addition, if the difference between the echo height of plotted point in the range of path length to be used and curves dividing echo height made previously is within ± 2 dB, this may be used.

The curves for dividing echo height made shall be plotted on the scale plate or marked on the indicator.

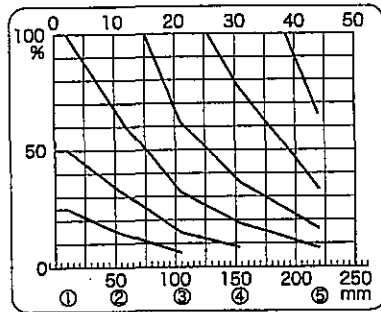
- b) When making curves for dividing echo height using RB-41, the standard hole of RB-41 shall be used. When making curves for dividing echo height using one out of model A2 series calibration blocks, the standard hole of $\phi 4 \text{ mm} \times 4 \text{ mm}$ shall be used.
- c) When making curves for dividing echo height, the probes shall be scanned at the location as shown in Fig. 3 and Fig. 4, and the each maximum echo height shall be plotted in the scale plate. Each of these points shall be connected by straight lines, and it shall be taken as the curve for dividing echo height.
- d) The curves for dividing echo height shall be made so as to include the range of 10 % to 100 % of the scale plate.
- e) The range up to the plotted point which has the shortest path length shall be the horizontal line.
- f) The number of curves for dividing echo heights shall be plural or one, and in the case of the plural curves, not less than three curves for dividing echo heights different each to each by 6 dB in height from this curve shall be drawn.

In the case of one curve for dividing pulse amplitude, it shall be drawn in the range of 20 % to 100 % of the scale plate. The example for drawing one curve shall be as shown in c) of Fig. 3.

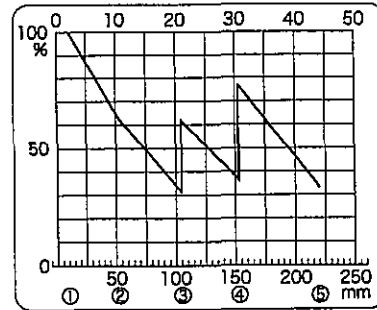


a) Location of scanning of probe When using RB-41 which is the same as the test object, for examination by single traverse technique, ① to ⑥ shall be used, and for examination by double traverse technique, ① to ⑦ shall be used.

Fig. 3 Making curves for dividing echo height by RB-41 No. 3



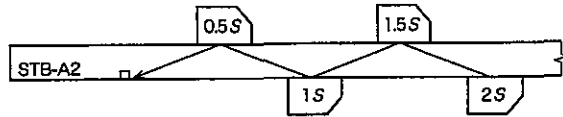
b) 2C20 × 20A65, time base range 250 mm, RB-41 No. 3



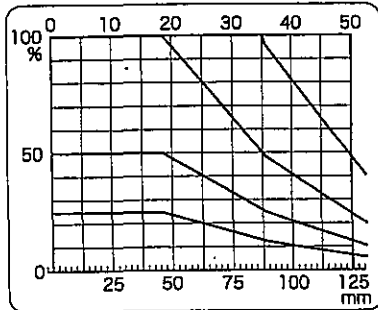
c) 2C20 × 20A65, time base range 250 mm, RB-41 No. 3

Example for drawing plotted points of ② and ④ by raising by 6 dB, and for drawing plotted points of ③ by raising by 12 dB in the case of one curve for dividing pulse amplitude.

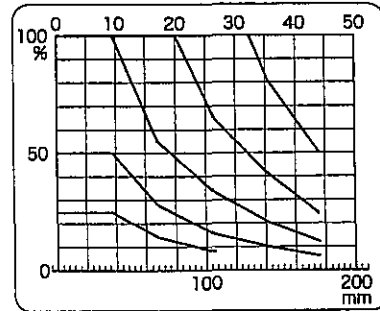
Fig. 3 (concluded)



a) Location of scanning of probe



b) 5C10 × 10A70, time base range 125 mm, STB-A2



c) 2C14 × 14A65, time base range 200 mm, STB-A2

Fig. 4 Making curves for dividing echo height by STB-A2

8.1.5 Determination of region for dividing echo height

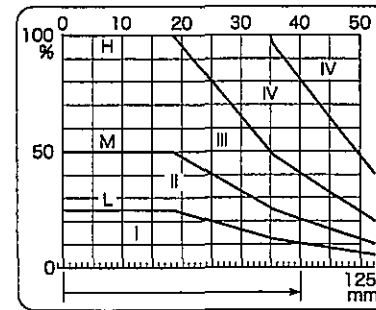
- a) **Determination of H line, M line and L line** Among the curves for dividing echo heights made in 8.1.4, a curve being at least the third or higher position from lowest curve shall be selected to be taken as H line. And it shall be taken as the reference line for adjusting working sensitivity.

The curve for dividing echo height lower than H line by 6 dB shall be taken as M line and the curve lower than H line by 12 dB shall be taken as L line.

The L line shall be taken as the line of which height becomes over 10 % in the range of path length to be used for evaluating the discontinuity echo (see Fig. 5).

When the number of curve for dividing echo height is one, H line, M line and L line one after another shall be changed to read by raising or lowering gain by the step of 6 dB.

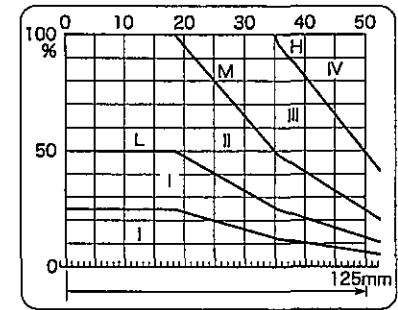
- b) The regions divided by H line, M line and L line for regional division of echo height shall be designated as given in Table 5.



- a) In the range of 0 mm to 100 mm, L line is over 10 %.

Probe to be used: 5Z10 × 10A70

When the time base range is 125 mm, and the first dividing line from the lowest is taken as L line, the range of path length of 0 mm to 100 mm may be used.



- b) In the range of 0 mm to 125 mm, L line is over 10 %.

Probe to be used: 5Z10 × 10A70

When the range of path length of 0 mm to 125 mm is used in a), the second dividing line from the lowest shall be taken as L line by raising gain by 6 dB.

Fig. 5 Examples of selection of H line and regional division

Table 5 Designation of regional division of echo heights

Range of echo height	Region of echo height
L line or under	I
Over L line up to and incl. M line	II
Over M line up to and incl. H line	III
Over H line	IV

8.1.6 Adjustment of working sensitivity The working sensitivity shall be adjusted either by using RB-41 or by using model A2 series calibration blocks.

- a) **Case of using RB-41** The gain of the instrument shall be adjusted so that the echo height of the standard hole agrees with H line. The quantity of sensitivity correction shall be added to it as required. The final adjustment condition shall be taken as working sensitivity.

The method for obtaining the quantity of sensitivity correction shall be in accordance with Annexes 2 to 6. When the sum of quantity of sensitivity correction is 2 dB or under, the sensitivity correction may not be performed.

- b) **Case of using model A2 series calibration blocks** In the case of using nominal refraction angle of 70°, the gain of the instrument shall be adjusted so that the echo height of the standard hole of $\phi 4 \times 4$ mm agrees with H line. The quantity of sensitivity correction shall be added to it as required. The final adjustment condition shall be taken as working sensitivity.

In the case of using nominal refraction angle of 65°, the gain of the instrument shall be adjusted so that the echo height of the standard hole of $\phi 4 \times 4$ mm agrees with M line. The quantity of sensitivity correction shall be added to it as required. The final adjustment condition shall be taken as working sensitivity.

In the case of using nominal refraction angle of 45°, after the gain of the instrument is adjusted so that the echo height of the standard hole of $\phi 4 \times 4$ mm agrees with H line, the gain shall be raised by 6 dB. The quantity of sensitivity correction shall be added to it as required. The final adjustment condition shall be taken as working sensitivity.

The method for obtaining the quantity of sensitivity correction shall be in accordance with Annexes 2 to 6.

- c) The working sensitivity of each method of parallel scanning of a probe slanted, longitudinal scanning of weld surface or straddle scanning shall be determined by the agreement between the manufacturer and the purchaser.

8.1.7 Period of measurement, adjustment and check of test equipment At the time for beginning the examination work, probe index, STB refraction angle, the time base range and working sensitivity shall be measured and adjusted. Furthermore, these items shall be checked at intervals not exceeding 4 h during working period to confirm that the conditions at that time are maintained. When the conditions are not maintained, measures in Table 6 and Table 7 shall be taken.

Table 6 Measures to be taken in the case where the sensitivity is not maintained

Range of change	Content of measures
± 4 dB or under	Readjust, and continue to carry out works.
Decrease of over 4 dB	Readjust, and repeat the test which was performed after the previous adjustment or check.
Increase of over 4 dB	Readjust, and re-test the indicated part of a discontinuity which was observed by the test performed after the previous adjustment or check.

Table 7 Measures to be taken in the case where the time base range is not maintained

Range of change	Content of measures
± 2 % or under	Readjust, and continue to carry out works.
Over 2 %	Readjust, and repeat the test which was performed after the previous adjustment or check.

8.2 Normal beam examination

8.2.1 Adjustment of time base range The adjustment of time base range shall be performed by using model A1 calibration block, etc.

8.2.2 Making curves for dividing echo heights

- a) The curves for dividing echo heights shall be made by the test instrument and the probe to be used.

In addition, if the difference between the echo height of plotted points in the range of path length to be used and the curve for dividing echo heights previously made is within ± 2 dB, this may be used.

The curves for dividing echo height made shall be plotted on the scale plate or marked on the indicator.

- b) In the case of making the curves for dividing echo heights, the probe shall be placed at the locations of ①, ②, ③, ④ as shown in Fig. 6, and each position of peak of the maximum echo height shall be plotted on the scale plate.

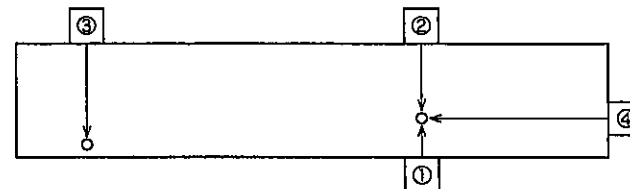
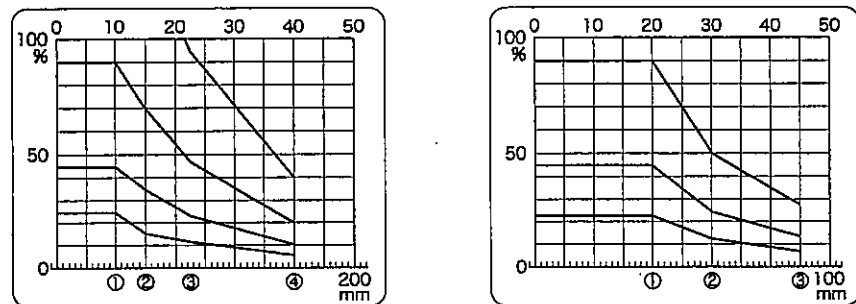


Fig. 6 Probe positions for drawing curves for dividing echo height

- c) Four points plotted on the scale plate with the respective fixed working sensitivities shall be connected with straight lines as shown in Figs. 7 a) and b), which shall be taken as a curve for dividing echo height.
- d) The number of curves for dividing echo heights shall be plural or one, and in the case of the plural curves, not less than three curves for dividing echo heights different each to each by 6 dB in height from this curve shall be drawn.

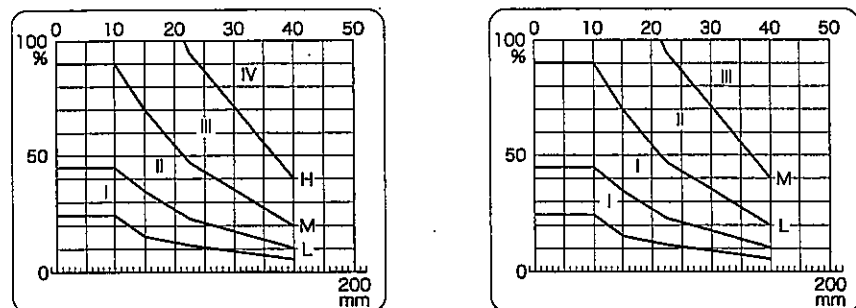


a) Case of time base range of 200 mm Probe to be used: 2C20N

b) Case of time base range of 100 mm Probe to be used: 5C10N

Fig. 7 Examples of drawing curves for dividing echo heights

8.2.3 Determination of regional division of echo height The regional division of echo height shall be determined in accordance with 8.1.5 as shown in Fig. 8.



a) An example in the case where main examination range is near the path length of 75 mm

b) An example in the case where the main examination range is near the path length of 150 mm

Fig. 8 Examples of regional division of echo heights

8.2.4 Adjustment of working sensitivity The gain of the instrument shall be adjusted so that the echo height of the standard hole of RB-41 agrees with H line. The quantity of sensitivity correction shall be added to it as required. The final adjustment condition shall be taken as working sensitivity.

8.2.5 Period of adjustment and check of test equipment At the time for beginning the examination work, the time base range and working sensitivity shall be adjusted. Furthermore, these items shall be checked at intervals not exceeding 4 h during working period to confirm that the conditions at that time are maintained. When the conditions are not maintained, measures in Table 6 and Table 7 shall be taken.

8.3 Tandem examination

8.3.1 Adjustment of time base range Using model A1 calibration blocks or model A3 series calibration blocks, the time base range shall be adjusted so as to agree with the path length equal to approximately 1 skip distance of the test object, by the single probe technique, and the angle probes shall be sequentially scanned on the test object by V path method to obtain the maximum transmission pulse. The path length where the maximum transmission pulse is obtained shall be marked on the scale plate by a marker and the like.

8.3.2 Nominal refraction angle and STB refraction angle The nominal refraction angle shall be 70° in the case of plate thickness of over 20 mm to and excluding 40 mm, and 45° in the case of plate thickness of 40 mm or over, and the difference between each STB refraction angle of the probe for transmission and reception shall be 2° or under.

8.3.3 Making lines for dividing echo heights The lines for dividing echo heights as shown in Fig. 9 shall be drawn on the scale plate of the instrument in advance. The line of 40 % of the scale plate shall be taken as M line. The line lower than M line by 6 dB shall be taken as L line and the line higher than M line by 6 dB shall be taken as H line.

8.3.4 Determination of regional division of echo height The regional divisions shall be determined in accordance with 8.1.5 as shown in Fig. 9.

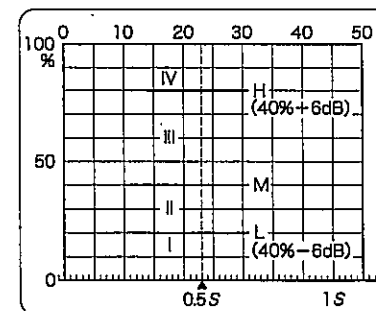


Fig. 9 An example of curves for dividing echo heights and regional division

8.3.5 Adjustment of working sensitivity For the adjustment of working sensitivity, the probe shall be scanned on the acoustical sound part of the test object by V path method, and after adjusting the gain of instrument so that the maximum

transmission pulse agrees with M line, the value of gain given in Table 8 shall be added according to plate thickness. The final adjustment condition shall be taken as the working sensitivity.

Table 8 Values of gain to be added

Plate thickness	Range of examination	Values of gain to be added
20 mm or over to and excl. 40 mm	Whole range of plate thickness	16 dB
40 mm or over to and excl. 75 mm	Whole range of plate thickness	10 dB
75 mm or over	From front face to $t/4$	10 dB
	Over $t/4$ to $t/2$ incl.	12 dB
	Over $t/2$ to reverse face	14 dB

8.3.6 Period of measurement, adjustment and check of test equipment At the time for beginning the examination work, probe index, STB refraction angle, the time base range and working sensitivity shall be measured and adjusted. Furthermore, these items shall be checked at intervals not exceeding 4 h during working period to confirm that the conditions at that time are maintained. When the conditions are not maintained, measures in Table 6 and Table 7 shall be taken.

9 Examination

9.1 Angle beam examination

a) **Method for scanning** The method for scanning by probe shall be such that a discontinuity is not overlooked. Furthermore, among the following methods of scanning, for detecting a discontinuity such as a transverse crack which is apt to be overlooked by the method of zig-zag scanning which is usually used, the method of straddle scanning, longitudinal scanning of weld surface, etc. shall be used in accordance with the agreement between the manufacturer and the purchaser.

- 1) **Swivel scanning** A method for scanning performed by rotating a probe centred on the probe index of probe in order to change the direction of ultrasonic wave beam to the weld line when performing the angle beam examination (see Fig. 10).
- 2) **Orbital scanning** A method for scanning performed by moving a probe to be toward the central point along the circumference centred on a discontinuity in order to change the direction of ultrasonic wave beam to a discontinuity when performing the angle beam examination (see Fig. 10).

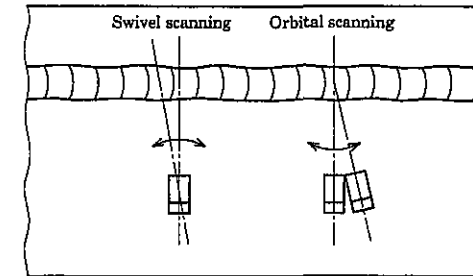


Fig. 10 Swivel scanning, orbital scanning

- 3) **Zig-zag scanning** A method for scanning performed by moving a probe in parallel to the weld line scanning back and forth mixing with a swivel scanning when performing the angle beam examination (see Fig. 11).

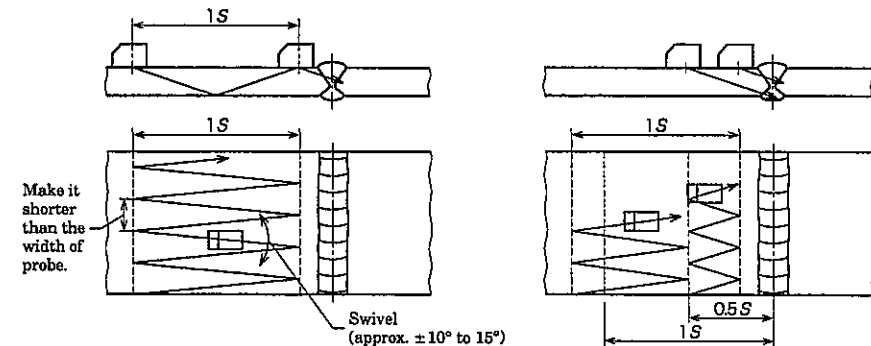


Fig. 11 Zig-zag scanning

- 4) **Lateral square scanning** A method for scanning performed by moving a probe in parallel to the weld line at regular intervals when performing the angle beam examination (see Fig. 12). In the case of tandem examination, it refers to lateral square tandem scanning.
- 5) **Square scanning** A method for scanning performed by moving a probe perpendicular to weld line at regular intervals when performing the angle beam examination (see Fig. 12). In the case of tandem examination, it refers to square tandem scanning.

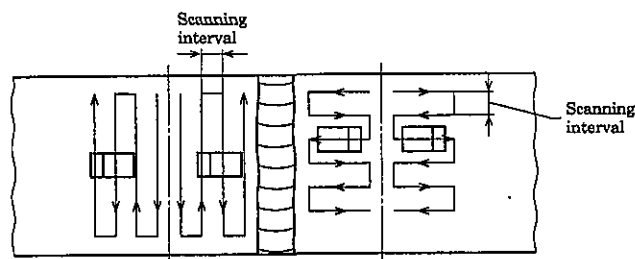


Fig. 12 Lateral square scanning, square scanning

- 6) **Parallel scanning of a probe slanted** A method for scanning performed by moving a probe, which is placed at an angle to the weld line by using only one probe as a simple method of straddle scanning, in parallel to the weld line when performing the angle beam examination (see Fig. 13).

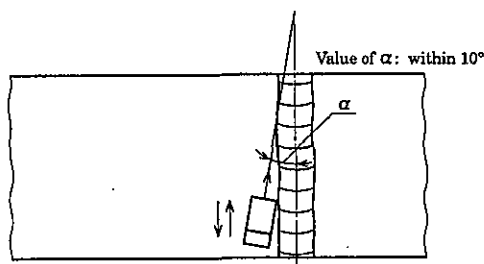


Fig. 13 Parallel scanning of a probe slanted

- 7) **Longitudinal scan of weld surface (parallel scanning)** A method for scanning performed by moving a probe, which is placed on the weld and heat-affected zone where weld reinforcement is deleted with the ultrasonic wave beam turned to the direction of weld line in order to detect a discontinuity such as a transverse crack, to the direction of weld line when performing the angle beam examination (see Fig. 14).

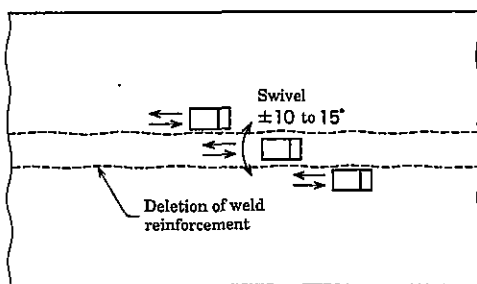
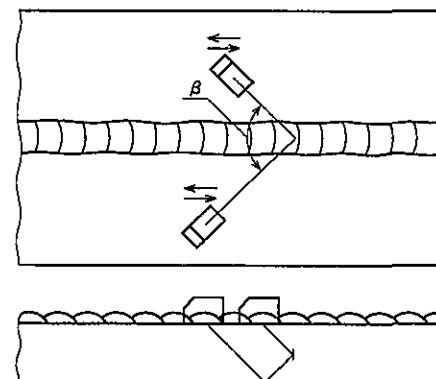


Fig. 14 Longitudinal scan of weld surface

- 8) **Straddle scanning** A method for scanning performed by moving two probes at the same time, which are placed one by one on the both sides of weld line in order to detect a discontinuity such as a transverse crack in the direction perpendicular to the weld line, when performing the angle beam examination (a type of double probe technique) (see Fig. 15).



Example of β

Nominal refraction angle	Angle of β
45°	110° to 130°
60°	110° to 130°
70°	80° to 120°

Fig. 15 Straddle scanning

- b) **Discontinuity regarded as object of evaluation** The discontinuity where the maximum echo exceeds M disregard level shall be regarded as the object of evaluation in the case of using M disregard level and the discontinuity where the maximum echo exceeds L disregard level shall be regarded as the object of evaluation in the case of using L disregard level, in the condition where the working sensitivity is adjusted to that specified in each Annex.

When the number of curve for dividing echo height is one, the gain of instrument shall be adjusted so that the curve for dividing echo height in the range of path length to be used becomes the disregard level.

- c) **Region of echo height** The probe is placed at the location where the maximum echo is indicated, and the region of echo height in which the peak of the maximum echo exists shall be taken.

In the case of detecting one discontinuity at the different refraction angle or on the different test surface, the region of echo height shall be taken as the highest region.

- d) **Ultrasonic discontinuity length** In the probe to weld distance indicating the maximum echo, the transference distance of the probe in the range where the echo height exceeds L line measured by lateral scanning method shall be taken as the ultrasonic discontinuity length (l). The measurement shall be performed in units of 1 mm. In this case, depth scanning method is used, but swivel scanning is not used. However, in the case of using the probe of nominal frequency of 2 MHz, the transference distance of the probe in the range where the echo height exceeds one half (-6 dB) of the height of the maximum echo shall be taken as the ultrasonic discontinuity length.

In the case of detecting one discontinuity at the different refraction angle or on the different test surface, each of the start and the end shall be obtained, and the largest length of their intervals shall be taken as the ultrasonic discontinuity length.

When the number of curve for dividing echo height is one, the gain of instrument shall be adjusted so that the curve for dividing echo height in the range of path length to be used becomes L line.

- e) **Presentation of location of discontinuity** As shown in Fig. 16, the location of a discontinuity in the transverse section shall be presented by depth (d) of a discontinuity obtained at the probe location (X_P) indicating the maximum echo and location (k) in the direction perpendicular to the weld line, and the location in the direction in parallel to the weld line shall be presented by the probe location (X_P) indicating the maximum echo, and the start (X_S) and the end (X_E) of ultrasonic discontinuity length (l).
- f) **Ultrasonic discontinuity height** The measurement of ultrasonic discontinuity height, if specially required, shall be performed in accordance with Annex 8.

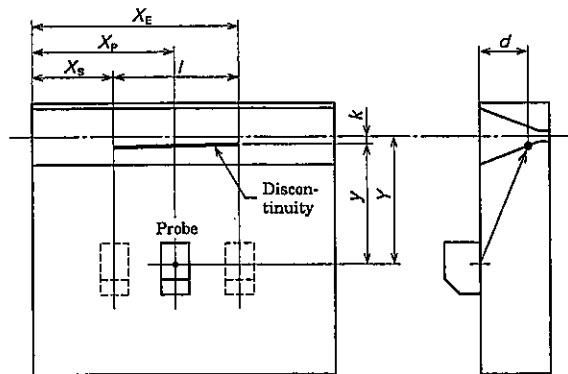


Fig. 16 Presentation of location of discontinuity for angle beam examination

9.2 Normal beam examination

- a) **Method for scanning** The method for scanning by probe shall be performed so that a discontinuity is not overlooked.
- b) **Discontinuity regarded as object of evaluation** The discontinuity where the maximum echo exceeds M disregard level shall be regarded as the object of evaluation in the case of using M disregard level and the discontinuity where the maximum echo exceeds L disregard level shall be regarded as the object of evaluation in the case of using L disregard level, in the condition where the working sensitivity is adjusted to that specified in 8.2.4.

- c) **Region of echo height** The probe shall be placed at the location where the maximum echo is indicated, and the region of echo height in which the peak of the maximum echo exists shall be taken.
- d) **Ultrasonic discontinuity length** The position indicating the maximum echo shall be taken as centre of scanning, and the transference distance of the probe (long diameter) in the range where the echo height exceeds L line measured by scanning its circumference shall be taken as the ultrasonic discontinuity length. However, in the case where the plate thickness of the part where the probe is contacted is not less than 75 mm, and the probe of nominal frequency of 2 MHz is used, the transference distance of the probe in the range where the echo height exceeds one half (-6 dB) of the height of the maximum echo shall be taken as the ultrasonic discontinuity length. The measurement shall be performed in units of 1 mm.
- e) **Presentation of location of discontinuity** As shown in Fig. 17, the location of a discontinuity in the transverse section shall be presented by depth (d) of a discontinuity obtained at the probe location (X_P) indicating the maximum echo, and the location in direction in parallel to the weld line shall be presented by the probe location (X_P) indicating the maximum echo and the start (X_S) and the end (X_E) of ultrasonic discontinuity length (l).

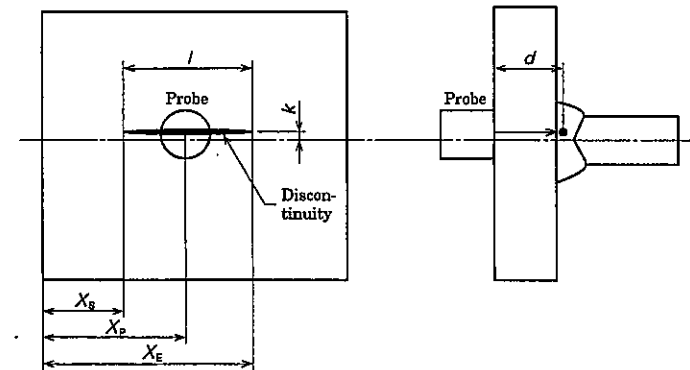


Fig. 17 Presentation of location of discontinuity for normal beam examination

9.3 Tandem examination

- a) **Examination method**
- Marking-off of tandem base line** On the weld line to be examined by tandem probe technique, the base line shall be marked at the definite distance (L') from the groove face prior to the welding.
 - Determination of tandem reference line** The distance from the test cross-section to tandem reference line ($L_{0.55}$) shall be obtained from the plate thickness (t) at the side which is used as the test surface of the test object

and STB refraction angles (θ_T and θ_R) of probes for transmission and reception according to the following formulae. The tandem reference line shall be determined at the location of the distance (L) away from the base line as shown in Fig. 18.

$$L_{0.5S} = t \times \tan \theta$$

$$\theta = \frac{\theta_T + \theta_R}{2}$$

$$L = L' - L_{0.5S}$$

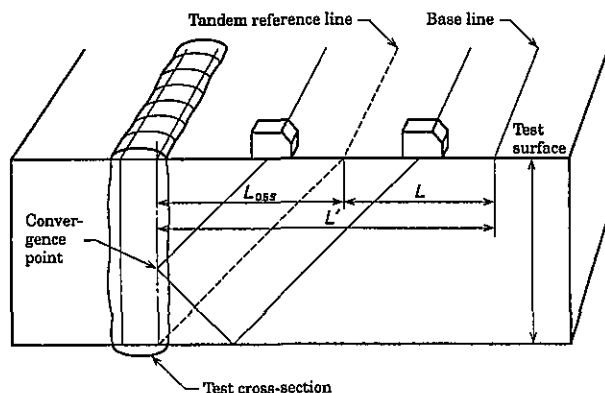


Fig. 18 Determination of tandem reference line

- 3) **Arrangement of probe** The probe index of probes for transmission and reception shall be arranged at the distance equal to the tandem reference line.
- 4) **Face and side to be examined** The face and side of the test object to be examined by tandem probe technique shall be single face and both sides of welds in the case of butt welds and shall be single face and single side of welds in the case of T shape and corner joints welds.
- 5) **Method for scanning** The method for scanning of probe shall be performed in accordance with the lateral square tandem scanning or square tandem scanning given in Fig. 12.
- b) **Discontinuity regarded as object of evaluation** The discontinuity where the maximum echo exceeds M disregard level shall be regarded as the object of evaluation in the case of using M disregard level and the discontinuity where the maximum echo exceeds L disregard level shall be regarded as the object of evaluation in the case of using L disregard level, in the condition where the working sensitivity is adjusted to that specified in 8.3.5.
- c) **Region of echo height** The probe shall be placed at the location where the maximum echo is indicated, and the region of echo height in which the peak of the maximum echo exists shall be taken.

- d) **Ultrasonic discontinuity length** The lateral scanning with depth scanning as the scanning centre indicating the maximum echo shall be used for this measurement. The transference distance of the probe in the range where the echo height exceeds M line shall be taken as the ultrasonic discontinuity length in the case of using M disregard level. And the transference distance of the probe in the range where the echo height exceeds L line shall be taken as the ultrasonic discontinuity length in the case of using L disregard level. The measurement shall be performed in units of 1 mm.
- e) **Presentation of location of discontinuity** As shown in Fig. 19, the location of a discontinuity in the transverse section shall be presented by depth (d) of a discontinuity obtained at the probe location (X_P) indicating the maximum echo and location (k) in the direction perpendicular to the weld line, and the location in the direction in parallel to the weld line shall be presented by the probe location (X_P) indicating the maximum echo and the start (X_S) and the end (X_E) of ultrasonic discontinuity length (l).

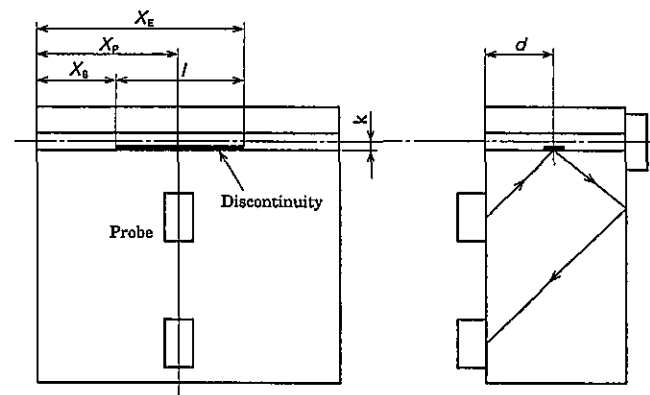


Fig. 19 Presentation of location of discontinuity for tandem examination

- 10 **Record** Necessary information shall be recorded from the following items after the examination:
 - a) Date of the examination
 - b) Name of the constructor or manufacturer of the test object
 - c) Name of work or products
 - d) Numbers or symbols of the examinations
 - e) Signature and qualification of the personnel engaged in the examination
 - f) Material and dimensions
 - g) Method of welding and form of groove

- h) Model of the test instrument used, its performance characteristics and date of check
- i) Model of the probe used, its performance characteristics and date of check
- j) Reference or calibration blocks used
- k) Thickness of reference block, curvature, condition of test surface and STB wave velocity ratio
- l) Condition of test surface of test object and method of finishing
- m) Range of the examination
- n) Kind of couplant
- o) Nominal frequency and test frequency
- p) Nominal refraction angle and STB refraction angle
- q) STB wave velocity ratio and its measurement method
- r) Refraction angle by test object and its method of calculation
- s) Time base range
- t) Curves for dividing echo height
- u) Working sensitivity
- v) Quantity of sensitivity correction
- w) Disregard level
- x) Location of probe measured along the direction of weld line indicating the maximum echo, probe to weld distance, path length, height of the maximum echo (region), ultrasonic discontinuity length, depth of discontinuity, location of direction perpendicular to weld line and the start and the end of ultrasonic discontinuity length
- y) Acceptance or rejection and criteria thereon
- z) The following items shall be recorded when DAC circuit is used.
 - 1) Model of the test instrument and performance characteristics in the case of using DAC
 - 2) Manufacturing number of the probe and performance characteristics in the case of using DAC
 - 3) Adjusted distance of DAC start point
 - 4) DAC inclination value
 - 5) Curves for dividing echo heights when using DAC
- aa) The following items shall be recorded in the case where tandem examination is applied.

- 1) Shadow zone
- 2) Specification of the jig for tandem examination
- 3) Position of tandem reference line
- 4) Location of discontinuity in the direction of plate thickness (depth)
- ab) Other items (designated items, subject of discussion, witnessing, sampling method, etc.)

Related standards:

- JIS B 0601 *Geometrical Product Specification (GPS)—Surface texture : Profile method—Terms, definitions and surface texture parameters*
- JIS Z 2344 *General rule of ultrasonic testing of metals by pulse echo technique*
- JIS Z 2351 *Method for assessing the electrical characteristics of ultrasonic testing instrument using pulse echo technique*

Annex 1 (normative)

Function and performance of ultrasonic test equipment

1 Scope This Annex specifies the function and performance of ultrasonic test equipment to be used in this Standard.

2 Test instrument

2.1 Function required for test instrument The function required for the test instrument shall be as follows:

- The test instrument shall be able to be used for either single probe technique or double probe technique.
- For the gain adjuster, the sum of adjusting quantity shall be not less than 70 dB with not more than 1 dB per step.
- For the auxiliary scale plate, curves for dividing echo height, etc. shall be able to be written, the attachment and detachment shall be easy to be carried out, and the measurement error by parallax shall be small.
- Among the continuously adjusting knobs, those which are related to time axis and have a possibility of working in use shall have a lock mechanism to be attached.
- The test instrument used in combination with the heavy damped short pulse probe shall be capable of displaying or outputting RF wave shape.

2.2 Performance required for test instrument The performance required for test instrument shall be as follows:

- The amplification linearity shall be measured in accordance with 4.1 of JIS Z 2352 and shall be within $\pm 3\%$.
- The time axis linearity shall be measured in accordance with 4.2 of JIS Z 2352 and shall be within $\pm 1\%$.
- The margin of sensitivity shall be measured in accordance with 4.3 of JIS Z 2352 and shall be not less than 40 dB.
- For the stability of power supply variation, the sensitivity variation in the range of rated voltage shall be within ± 1 dB, and the amount of transference of vertical axis, time axis, and starting point of DAC shall be within $\pm 2\%$ fs.

2.3 DAC function The test instrument to which DAC circuit is added may be used.

2.4 Inspection of performance of test instrument The test instrument shall be inspected at the time of purchase of instrument and at intervals not exceeding 12 months, and it shall be confirmed that the required performance is maintained with respect to a) to c) of 2.2 in accordance with 5 of JIS Z 2352.

3 Probe

3.1 Function required for probe The function required for probe shall be as follows:

- The probe shall be compatible with the test instrument to be used.
- In order to make the measurement of probe index easy, both sides of the angle probe shall be marked with a guide scale of the intervals of 1 mm.
- The nominal size of transducer of angle probe shall be 5 mm $\times$ 5 mm or over up to and including 20 mm $\times$ 20 mm. The nominal size to be used as a standard shall be in accordance with Annex 1 Table 1. However, the nominal size of transducer of probe to be used for tandem examination is not specially specified.
- The shape of transducer of normal probe shall be circular, and its nominal size shall be 10 mm or over up to and including 30 mm. The nominal diameter to be used as a standard shall be in accordance with Annex 1 Table 2.

Annex 1 Table 1 Nominal frequency of angle probe and nominal size of transducer to be used as a standard

Nominal frequency MHz	Nominal size of transducer mm
2	14 $\times$ 14, 20 $\times$ 20
5	5 $\times$ 5, 10 $\times$ 10

Annex 1 Table 2 Nominal frequency of normal probe and nominal diameter of transducer to be used as a standard

Nominal frequency MHz	Nominal diameter of transducer mm
2	20, 28
5	10

3.2 Performance required for angle probe The performance required for angle probe shall be as follows:

- The distance between probe index and front end of probe housing shall be within the values given in Annex 1 Table 3. However, the minimum distance between probe indices of probe to be used for tandem examination shall be 20 mm or under in the case of probe of 5 MHz in nominal frequency and 45° in nominal refraction angle, 27 mm or under in the case of probe of 70°, and 25 mm or under in the case of probe of 2 MHz, 45°.

Annex 1 Table 3 Distance between probe index and front end of probe housing

Nominal diameter of transducer mm	Distance between probe index and front end of probe housing mm
20 × 20	25
14 × 14	20
10 × 10	15
5 × 5	7

- b) The nominal refraction angle shall be 40°, 45°, 60°, 65° or 70°.
- c) SN ratio shall be not less than 22 dB in the range of path length to be used, measuring the noise level to H line in combination with the test instrument to be used.
- d) The far surface resolution shall be measured in accordance with 4.8 of JIS Z 2352 in combination with the test instrument to be used, and shall be within the values given in Annex 1 Table 4. However, it shall be 8 mm or under in the case of nominal frequency of other than 2 MHz and 5 MHz.

Annex 1 Table 4 Far surface resolution of angle probe

Nominal frequency MHz	Resolution mm
2	9 or under
5	5 or under

- e) The dead zone shall be measured in accordance with 13.4 of JIS Z 2350 when in combination with the test instrument to be used, and shall be within the values given in Annex 1 Table 5. However, it shall not be specified in the case of nominal frequency of other than 2 MHz and 5 MHz.

In the case of nominal dimension of transducer of 5 mm × 5 mm, it shall be measured with working sensitivity to be used.

The dead zone of probe to be used for tandem examination shall not be specified.

Annex 1 Table 5 Dead zone of angle probe

Nominal frequency MHz	Nominal size of transducer mm	Dead zone mm
2	14 × 14	25
	20 × 20	15
5	5 × 5	8
	10 × 10	15

- f) The deviation of the beam central axis shall be measured in accordance with the measuring method in 13.1 of JIS Z 2350 and this angle shall not exceed 2°.

3.3 Performance required for normal probe The performance required for normal probe shall be as follows:

- a) The echo height such as noise, in combination with the test instrument to be used, shall be 10 % or under of indicator scale in working sensitivity to be used.
- b) The far surface resolution shall be measured in accordance with 4.4 of JIS Z 2352 when in combination with the test instrument to be used, and shall be within the values given in Annex 1 Table 6. However, it shall be 8 mm or under in the case of nominal frequency of other than 2 MHz and 5 MHz.

Annex 1 Table 6 Far surface resolution of normal probe

Nominal frequency MHz	Resolution mm
2	9 or under
5	6 or under

- c) The dead zone shall be the length up to the point where the edge height becomes 20 % fs in the end from the rising point of transmitted pulse or surface echo with working sensitivity to be used, and shall be taken in distance in steel. The value of dead zone shall be 8 mm or under in the case of nominal frequency of 5 MHz, and 15 mm or under in the case of 2 MHz.

3.4 Inspection of performance of angle probe The angle probe shall be inspected with respect to items given in 3.2 at the period specified in Annex 1 Table 7, and it shall be confirmed that the required performance is maintained.

Annex 1 Table 7 Inspection period of performance of angle probe

Inspection items	Inspection period
Deviation of beam central axis SN ratio Distance between probe index and front end of probe housing Far surface resolution Dead zone	At the time of purchase and just after repairing
Test frequency	At the time of purchase

3.5 Inspection of performance of normal probe The normal probe shall be inspected with respect to items given in 3.3 at the time of purchase and at least once every month, and it shall be confirmed that the required performance is maintained.

4 Jig for tandem examination The jigs for tandem examination shall be capable of arranging two probes for transmission and reception, and performing lateral square tandem scanning or square tandem scanning.

Annex 2 (normative)
Examination method for joint welds of flat plate

1 Scope This Annex specifies the ultrasonic examination method for butt joint weld of flat plate, T form joint weld, corner joint weld, circumferential joint weld with not less than 1 000 mm in curvature radius of a test surface and longitudinal joint weld with not less than 1 500 mm in curvature radius of a test surface.

2 Reference and calibration blocks to be used The reference and calibration blocks to be used shall be RB-41 or STB described in 5 of the body. However, RB-41 shall be used for adjustment of working sensitivity in the case where the test object having the transverse wave velocity different from STB wave velocity (the test object in the range of STB wave velocity ratio which uses an angle of refraction by test object in Table 4 of the body) is examined.

3 Probe to be used The probe to be used is selected in accordance with Table 4 of the body and 3 of Annex 1.

In addition, when the plate thickness of test object exceeds 75 mm, the nominal refraction angle of 45° in addition to the angle of refraction selected in Table 4 of the body shall be used.

4 Adjustment of test equipment

4.1 Adjustment of time base range The time base range shall be adjusted in accordance with 8.1.2, 8.2.1 or 8.3.1 of the body.

4.2 Measurement of probe index, STB refraction angle and refraction angle by test object The probe index shall be measured in accordance with 8.1.1 of the body. STB refraction angle and the refraction angle by the test object shall be measured in accordance with 8.1.3 of the body.

4.3 Making curves for dividing echo height The curves for dividing echo height shall be made in accordance with 8.1.4, 8.2.2 or 8.3.3 of the body.

4.4 Method for obtaining quantity of sensitivity correction The quantity of sensitivity correction in the angle examination shall be obtained by the following methods.

- a) After adjusted to the time base range to be used, the probe to be used for examination and the probe of the same model as that shall be used by double probe technique.
- b) The probes are arranged at the positions on the practical test object as shown in Annex 2 Fig. 1 a), the distance between both probes shall be adjusted so that the maximum transmission pulse is obtained. The height of maximum transmission pulse shall be adjusted to 50 % fs and the indication of gain controls is read out and the value shall be taken as V (dB).

- c) The probes are arranged at the positions on reference block or one out of model A2 series calibration blocks as shown in Annex 2 Fig. 1 b), and by the same procedure as b) above, the height of maximum transmission pulse shall be adjusted to 50 % fs, and the indication of gain controls is read out and the values shall be taken as V_1 (dB) and V_2 (dB).
- d) In the case where the path lengths of both cases are not correspondent, as shown in c) of Annex 2 Fig. 1, the value of V' on two path lengths which are longer and shorter than the path length in the test object shall be read out.
- e) $|V' - V|$ shall be taken as the quantity of sensitivity correction.

4.5 Adjustment of working sensitivity The working sensitivity shall be adjusted in accordance with 8.1.6, 8.2.4 or 8.3.5 of the body.

5 Examination method

5.1 Test surface The test surface shall be in accordance with Annex 2 Table 1. In the case of T form joint and corner joint, the test surface when applying single probe angle beam examination technique shall be the face on the side where groove is taken. The faces and sides shall be as shown in Annex 2 Fig. 2.

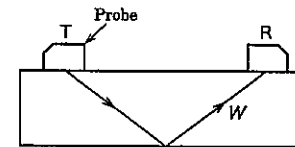
5.2 Scanning direction The scanning direction shall be the direction with not less than two directions of ultrasonic beams in order to prevent overlooking a discontinuity due to its inclination as shown in Annex 2 Figs. 3 to 5.

5.3 Scanning method The scanning method of probe shall be performed so that a discontinuity is not overlooked by using zig-zag scanning in 3) among other scanning methods in 9.1 a) of the body.

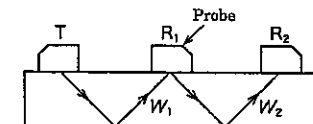
6 Estimation method of discontinuity location In the case where a discontinuity is detected, its location shall be estimated from the probe-to-welds distance, path length, and refraction angle selected according to the wave velocity ratio to STB in 7.9 of the body.

Annex 2 Table 1 Test surface

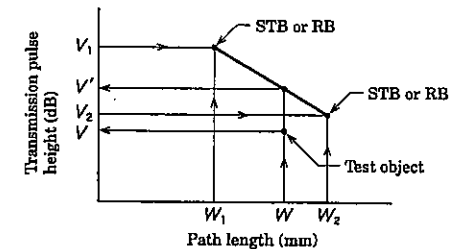
Specification of joint	Maximum path length to be used mm	Frequency	Test surface	Examination method
Butt joint	150 mm or under	2 MHz or 5 MHz	Single face/ both sides	Single and double traverse
	Over 150 mm up to and incl. 250 mm	2 MHz	Single face/ both sides	Single and double traverse
	Over 250 mm	2 MHz	Both faces/ both sides	Single traverse
T form joint	150 mm or under	2 MHz or 5 MHz	Single face/ single side	Single and double traverse
	Over 150 mm up to and incl. 250 mm	2 MHz	Single face/ single side	Single and double traverse
	Over 250 mm	2 MHz	Both faces/ single side	Single traverse
Corner joint (case of closed section)	150 mm or under	2 MHz or 5 MHz	Single face/ single side	Single and double traverse
	Over 150 mm up to and incl. 250 mm	2 MHz	Single face/ single side	Single and double traverse
	Over 250 mm	2 MHz	Single face/ single side	Single and double traverse



a) Test object

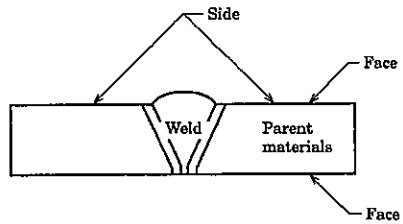


b) STB or RB

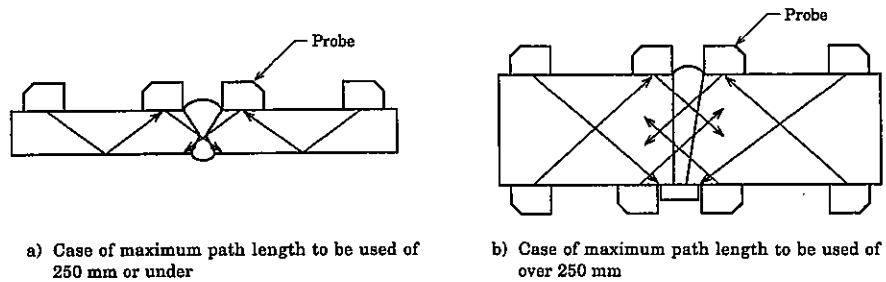


c) Quantity of sensitivity correction ($V' - V$)

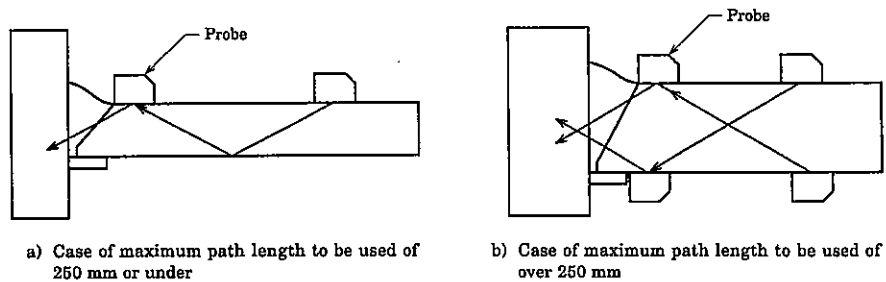
Annex 2 Fig. 1 Method for obtaining quantity of sensitivity correction



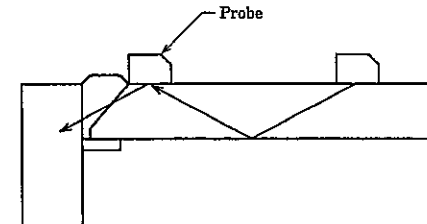
Annex 2 Fig. 2 Faces and sides of weld



Annex 2 Fig. 3 Examination method for butt joint weld



Annex 2 Fig. 4 Examination method for T form joint weld



Annex 2 Fig. 5 Examination method for corner joint weld of closed section

Annex 3 (normative)

Method for the examination of circumferential joint welds

1 Scope This Annex specifies the method for the ultrasonic examination of circumferential joint welds with which the curvature radius of test surface is 50 mm or more to and excluding 1 000 mm.

2 Reference and calibration blocks to be used

2.1 Scope of reference and calibration blocks The reference block and calibration block shall be used in accordance with Annex 3 Fig. 1 in consideration of the adjustment items of the instrument and curvature radius of the test object.

In addition, RB-A6 may be used in place of RB-41 of Table 1 of the body and Fig. 1 of the body.

Curvature radius	50 mm	250 mm	1 000 mm
Measurement of probe index	STB-A1 or model A3 series calibration block		
Adjustment of time base range			
Adjustment of refraction angle			
Dividing echo height	RB-42 or RB-A6		
Making curves			
Adjustment of working sensitivity			
		RB-41	

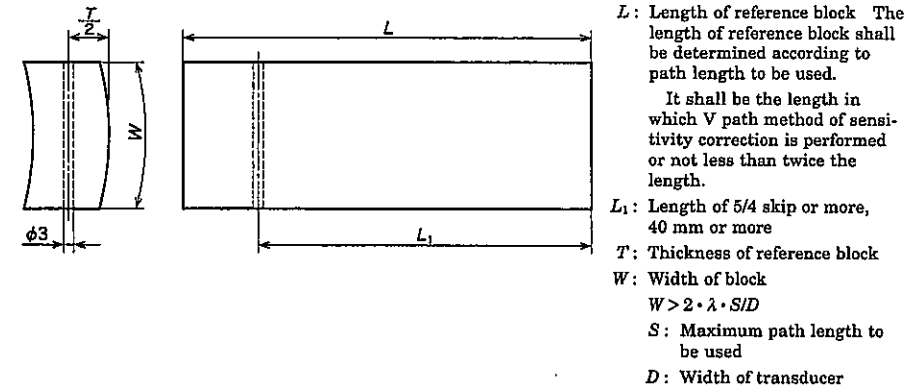
Annex 3 Fig. 1 Scope of reference and calibration blocks

2.2 Reference block of RB-42 The form and dimensions of reference block of RB-42 shall be as shown in Annex 3 Fig. 2.

In addition, RB-42 shall be any of the following:

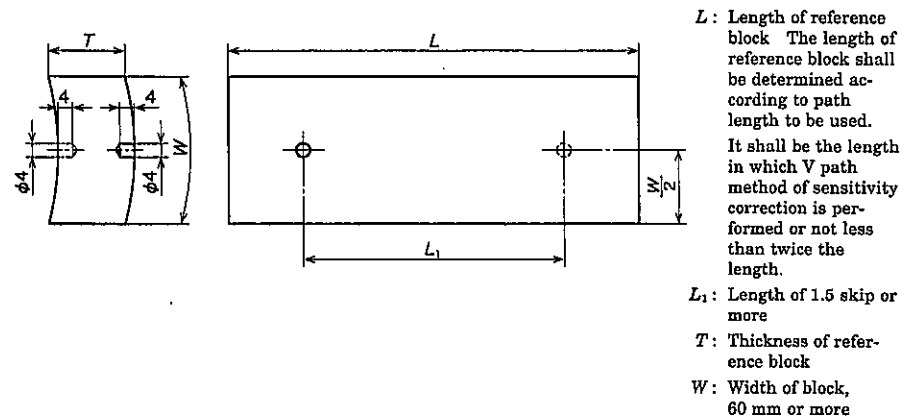
- Having the curvature to the direction perpendicular to the scanning direction with the test surface finished with homogeneous low damping materials.
- Having the curvature meeting the following conditions in the state of the same grade of steel, test surface as those of the test object.

Conditions : The thickness and curvature shall be within $\pm 10\%$ of those of test object, and the wave velocity difference between RB-42 and test object shall be within $\pm 2\%$.



Annex 3 Fig. 2 Example of RB-42

2.3 Reference block RB-A6 The form and dimensions of reference block RB-A6 shall be as shown in Annex 3 Fig. 3. The perpendicularity of hole of RB-A6 shall be 0.5° or less, top angle of hole shall be 118° , and the corner of hole shall not be chamfered. Furthermore, the thickness and curvature of RB-A6 shall be within $\pm 10\%$ of those of test object, and the wave velocity difference between RB-A6 and test object shall be within $\pm 2\%$.



Annex 3 Fig. 3 RB-A6

3 Probe to be used

3.1 Contact face of probe The process for making the contact face of probe curved surface shall not be carried out. In the case of curvature radius of 250 mm or less, jigs for stabilizing contact of probe may be used.

3.2 Nominal refraction angle of probe The nominal refraction angle of probe to be used shall be as shown in Table 4 of the body.

In addition, when the thickness of test object is over 75 mm, the nominal refraction angle of 45° in addition to the angle of refraction selected in Table 4 of the body shall be used.

4 Adjustment of test equipment

4.1 Adjustment of time base range The adjustment of time base range shall be performed in accordance with 8.1.2 of the body by using model A1 calibration blocks or model A3 series calibration blocks.

4.2 Measurement of probe index and refraction angle by test object The probe index and refraction angle by test object shall be measured in accordance with 8.1.1 of the body and 8.1.3 of the body.

4.3 Making curves for dividing echo height

4.3.1 Case of using RB-41, RB-42 The curves for dividing echo height in the case of using RB-41, RB-42 shall be made in accordance with 8.1.4 of the body.

4.3.2 Case of using RB-A6 The curves for dividing echo height shall be made according to the following procedure in accordance with 8.1.4 of the body by using the probe to be used. However, the curves for dividing echo height in the case of examining the test object having the transverse wave velocity different from STB wave velocity shall be made by using RB-41.

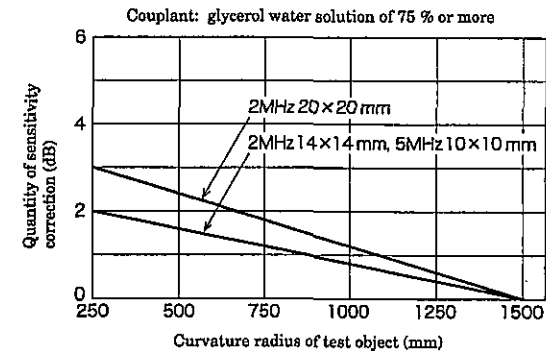
- The positions of peaks of the maximum echoes at 0.5 skip and 1.0 skip, or 1.0 skip and 1.5 skip shall be plotted on the scale plate, and these two points shall be connected with straight line.
- The horizontal line shall be drawn in the range of left side from 0.5 skip.

4.4 Method for obtaining quantity of sensitivity correction

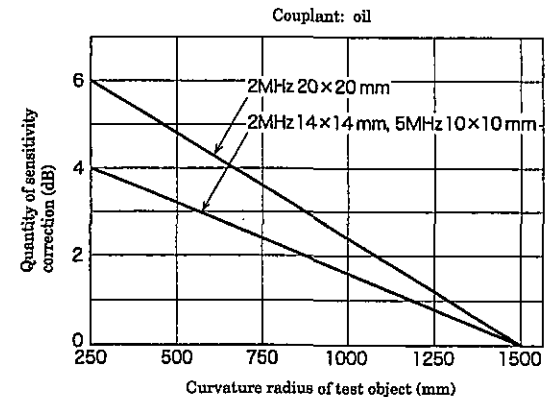
4.4.1 Case of using RB-42 and RB-A6 The sensitivity shall not be corrected in the case of using RB-42 and RB-A6.

4.4.2 Case of using RB-41

- Case of examining test object from outer side** In the case where the curvature radius of the test object is 250 mm or more and the examination is performed from the outside of the test object, the quantity of the sensitivity correction shall be obtained from Annex 3 Fig. 4 and Annex 3 Fig. 5 by the nominal frequency, nominal transducer size of the probe to be used and couplant, in units of 1 dB.



Annex 3 Fig. 4 Quantity of sensitivity correction due to curvature of circumferential joint



Annex 3 Fig. 5 Quantity of sensitivity correction due to curvature of circumferential joint

b) Case of examining test object from inner surface (concave surface)

- Both the angle probe to be used and the angle probes having the same model shall be opposite to each other as shown in Annex 3 Fig. 6 b) and the distance between the probes shall be adjusted to obtain the maximum transmission pulse with V path method (arrangement of T-R₁) and V path method of triple bounce (arrangement of T-R₂). Two peaks of the transmission pulses obtained shall be plotted and connected by a straight line [see Annex 3 Fig. 6 c)].
- At the same sensitivity as 1), both angle probes are opposite to each scanning direction as shown in Annex 3 Fig. 6 a) and the distance between the probes shall be adjusted to obtain the maximum transmission pulse with

V path method. The difference in height of the transmission pulses in that path length shall be read out in units of 1 dB (round off), and it shall be taken as the quantity of sensitivity correction.

4.5 Adjustment of working sensitivity

4.5.1 Case of using RB-A6 Gain of the instrument shall be adjusted so that the echo height of calibration hole of RB-A6 agrees with H line. The condition shall be taken as the working sensitivity. However, the adjustment of sensitivity in the case of examining the test object having the transverse wave velocity different from STB wave velocity shall be performed by RB-41, RB-42.

4.5.2 Case of using RB-41, RB-42 Adjustment of the working sensitivity in the case of using RB-41, RB-42 shall be performed in accordance with 8.2.4 of the body.

5 Examination method

5.1 Test surface The test surface shall be in accordance with Annex 3 Table 1.

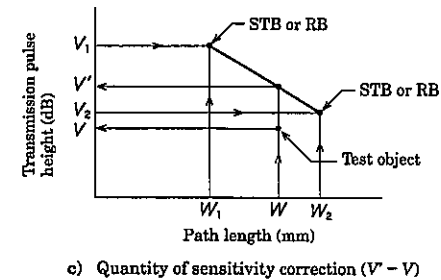
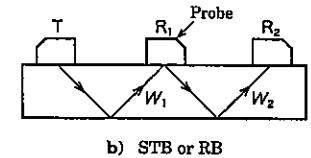
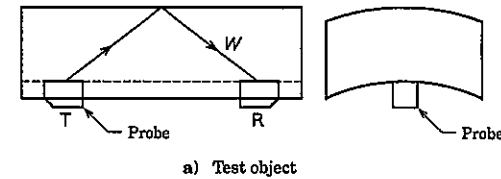
5.2 Scanning direction The scanning direction shall be the direction with not less than two directions of ultrasonic beams in order to prevent overlooking a discontinuity due to its inclination.

5.3 Scanning method The scanning method of probe using zig-zag scanning in 3) among other scanning methods in 9.1 a) of the body shall be performed so that a discontinuity is not overlooked.

6 Estimation method of discontinuity location In the case where a discontinuity is detected, its location shall be estimated from the probe to welds distance, path length, and refraction angle selected by the wave velocity ratio to STB in 7.9 of the body.

Annex 3 Table 1 Test surface

Examination from inner and outer sides	Maximum path length to be used mm	Frequency	Test surface	Examination method
Case where examination from only outer side is possible	150 mm or under	2 MHz or 5 MHz	Outer face (convex surface) both sides	Single and double traverse techniques
	Over 150 mm up to and incl. 250 mm	2 MHz	Outer face (convex surface) both sides	Single and double traverse techniques
	Over 250 mm	2 MHz	Outer face (convex surface) both sides	Single and double traverse techniques
Case where examination from both inner and outer sides are possible	150 mm or under	2 MHz or 5 MHz	Outer face (convex surface) both sides	Single and double traverse techniques
	Over 150 mm up to and incl. 250 mm	2 MHz	Outer face (convex surface) both sides	Single and double traverse techniques
	Over 250 mm	2 MHz	Inner and outer faces (concave and convex surface) both sides	Single traverse technique



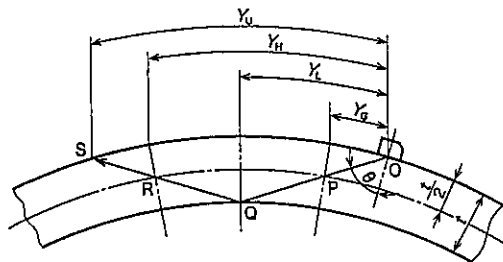
Annex 3 Fig. 6 Quantity of sensitivity correction for examination from inner surface (concave surface)

Annex 4 (normative) Examination method for longitudinal joint welds

1 Scope This Annex specifies the ultrasonic examination method for longitudinal joint welds having a test surface whose curvature radius is 50 mm or more to and excluding 1 500 mm and having a wall thickness to outer diameter ratio of not more than 16 %.

2 Definitions For the purposes of this Annex, the definitions given in the body and JIS Z 2300, and the following definitions shall apply.

- wall thickness centre-path length** In the angle beam examination of the test object having curvature, the wall thickness centre-path length shall be the distance between the probe index of probe, O and the centre of wall thickness, P (W_G in Annex 4 Fig. 1). This path length in the angle beam examination of longitudinal joint welds shall not be half of 0.5 skip path length (W_L in Annex 4 Fig. 1) to wall thickness.
- wall thickness centre-probe distance** In the angle beam examination of the test object having curvature, the wall thickness centre-probe distance shall be the distance for wall thickness centre-path length W_G to be projected on the outer surface of test object (Y_G in Annex 4 Fig. 1). This distance in the angle beam examination of longitudinal joint welds shall not be half of 0.5 skip probe distance (Y_L in Annex 4 Fig. 1) to wall thickness.
- $\frac{t}{D}$ The ratio of wall thickness (t) to outer diameter (D).



$$\begin{aligned} W_G &= \overline{OP} & W_R &= \overline{OQ} + \overline{QR} \\ W_L &= \overline{OQ} & W_U &= \overline{OQ} + \overline{QR} \end{aligned}$$

Annex 4 Fig. 1 Symbols in angle beam examination of test object with curvature

3 Calibration and reference blocks to be used

3.1 Scope of blocks The calibration and reference blocks to be used shall be specified in Annex 4 Fig. 2 according to curvature radius of the test object.

In the case where curvature radius of the test object is under 250 mm, the reference block of RB-43 shall be used.

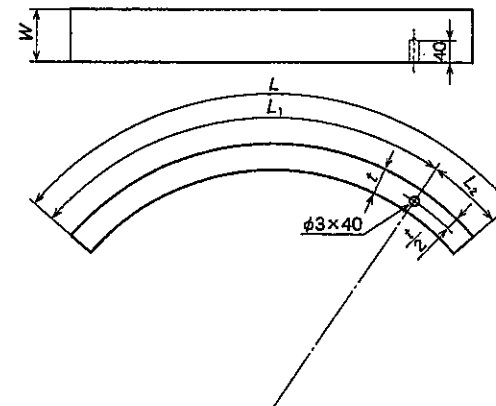
In the case where curvature radius of the test object is 250 mm or more, the reference block of RB-41 of 5.2 of the body shall be used.

Curvature radius	50 mm	250 mm	1 000 mm
Measurement of probe index			
Adjustment of time base range	STB-A1 or model A3 series calibration block		
Adjustment of refraction angle			
	RB-43	STB-A1 or model A3 series calibration block, or test object	
Making curves for dividing echo height			
Adjustment of working sensitivity	RB-43	RB-41	

Annex 4 Fig. 2 Scope of blocks

3.2 Reference block RB-43 The reference block RB-43 shall be as follows:

- The form and dimensions of RB-43 shall be given in Annex 4 Fig. 3 and it shall be made from a part of the test object or steel materials having the ultrasonic characteristics equal to that of the test object.
- In the case of examining the test object having the transverse wave velocity different from STB wave velocity, the reference block shall be made from the steel of the same materials as the test object.
- The condition of the test surface of RB-43 shall be equal to that of the test surface of the test object.



where,
 L : length of reference block
 L_1 : length of 2 skip or more
 L_2 : length of 1 skip or more
 t : thickness of reference block
 W : width of reference block, 60 mm or more

Annex 4 Fig. 3 Example of reference block RB-43

4 Probe to be used

4.1 Contact face of probe The process for making the contact face of probe curved surface shall not be carried out. In the case of the curvature radius of 250 mm or under, jigs for stabilizing contact of probe shall be used.

4.2 Nominal refraction angle of probe The refraction angle of the probe to be used shall be selected according to Annex 4 Table 1. In the case of selecting the nominal refraction angle of 40° or 45°, 65° or 70° shall be used together.

Annex 4 Table 1 Nominal refraction angle of probe usable for examining longitudinal joint welds

$\frac{t}{D}$ (%)	Usable nominal refraction angle (degree)
2.3 or under	70, 65, 60, 45, 40
Over 2.3 up to and incl. 5.8	60, 45, 40
Over 5.8 up to and incl. 11.1	45, 40
Over 11.1 up to and incl. 16.0	40

5 Adjustment of test equipment

5.1 Adjustment of time base range The adjustment of time base range shall be performed in accordance with 8.1.2 of the body.

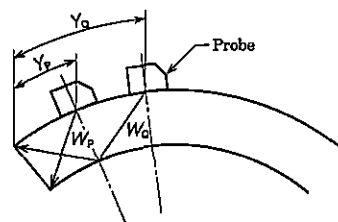
5.2 Measurement of refraction angle by test object

5.2.1 Case of using RB-43

- a) The path length of 0.5 skip W_L shall be calculated according to the following formula by using W_P and W_Q in Annex 4 Fig. 4.

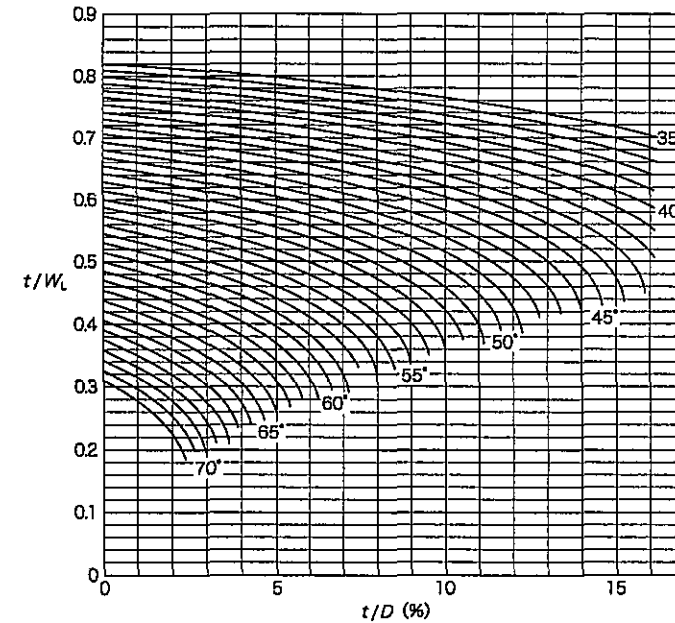
$$W_L = W_Q - W_P$$

Next, $\frac{t}{W_L}$ shall be calculated.



Annex 4 Fig. 4 Explanatory drawing of W_L

- b) The refraction angle by the test object shall be obtained from the intersection point of the value $\frac{t}{W_L}$ taken on vertical axis and the value $\frac{t}{D}$ on horizontal axis of Annex 4 Fig. 5.



Annex 4 Fig. 5 Calculation chart of refraction angle by test object

5.2.2 Refraction angle by test object having the transverse wave velocity different from STB wave velocity

- a) The refraction angle by test object in the case of examining the test object having the transverse wave velocity different from STB wave velocity shall be obtained by using the value Y_L of 0.5 skip calculated by the following formula from Y_P and Y_Q obtained from Annex 4 Fig. 4.

$$Y_L = Y_Q - Y_P$$

Next, $\frac{t}{Y_L}$ shall be calculated.

- b) The refraction angle by the test object shall be obtained from the intersection point of the value of $\frac{t}{Y_L}$ taken on vertical axis and the value of $\frac{t}{D}$ on horizontal axis of Annex 4 Fig. 6.

5.2.3 Case of using RB-41 In accordance with 8.1.3 of the body.

5.3 Indication of specific point on time base axis The positions on the time base axis corresponding to the positions of outer and inner surfaces and centre of wall thickness shall be indicated as follows:

- a) **Indication of positions of inner and outer surfaces** The path lengths corresponding to the positions of outer and inner surfaces shall be indicated on the scale plate from W_P and W_Q measured in 5.2.1 a).

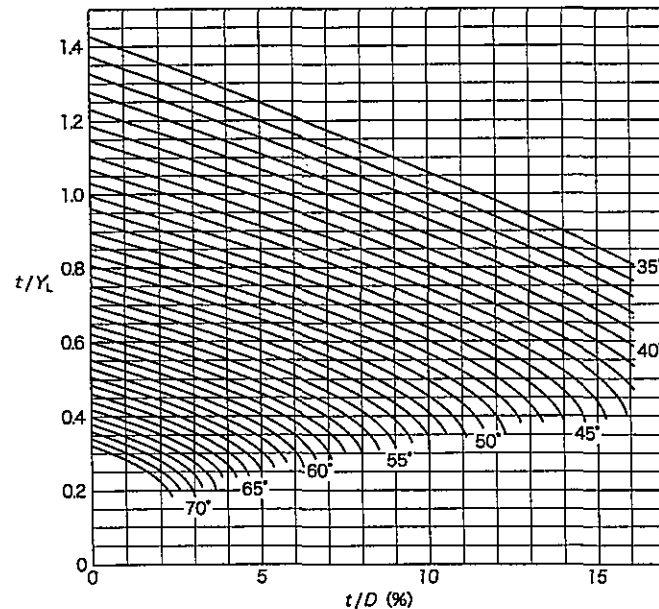
$$\text{Inner surface } W_L = W_Q - W_P$$

$$\text{Outer surface } W_U = W_L \times 2$$

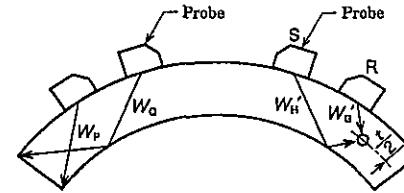
- b) **Position on time axis corresponding to centre of wall thickness** As shown in Annex 4 Fig. 7, the calibration hole of RB-43 shall be aimed from the positions of R and S, sequentially, and each rising position of echo where the maximum echo is obtained shall be indicated on the scale plate. Those present path lengths (W_G') and (W_H') by single and double traverse techniques, respectively (see Annex 4 Fig. 8).

5.4 Making curves for dividing echo height The curves for dividing echo height shall be made in accordance with 8.1.4 of the body.

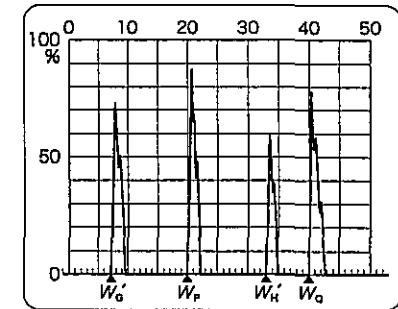
5.5 Method for obtaining quantity of sensitivity correction by curvature The sensitivity correction by curvature in the case of using RB-41 shall be performed as follows:



Annex 4 Fig. 6 Calculation chart of refraction angle by test object in the case of examining the test object having the transverse wave velocity different from STB wave velocity

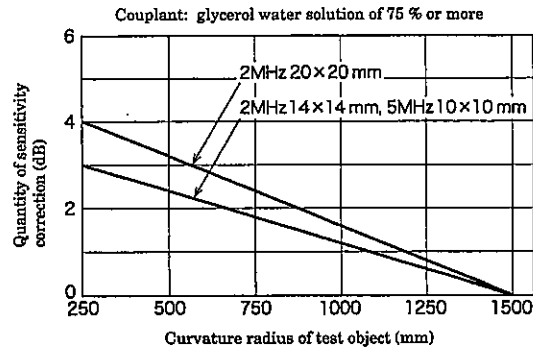


Annex 4 Fig. 7 Path of probe location and path length of upper end and lower end of standard hole and end face

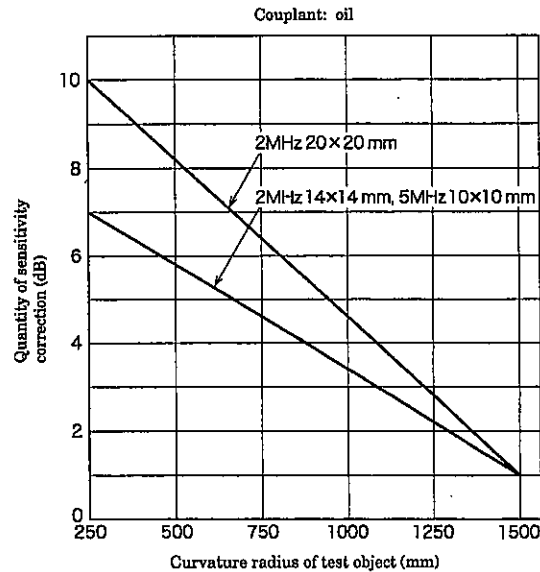


Annex 4 Fig. 8 An example of indicating specific points on time base axis

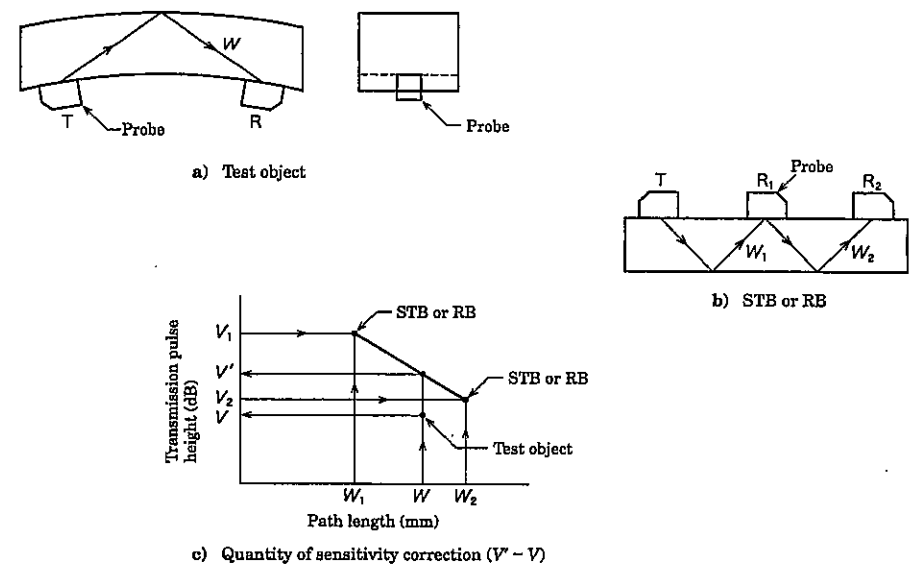
- a) **Case of examining test object from outer surface** In the case where the curvature radius is 250 mm or more and the test object is examined from the outer surface, the quantity of sensitivity correction shall be obtained from Annex 4 Figs. 9 and 10 in units of 1 dB (round off) according to nominal frequency of the angle probe to be used, nominal size of transducer and couplant.
- b) **Case of examining test object from inner surface (concave surface)**
- 1) Both the angle probes to be used and the angle probe having the same model shall be opposite to each other as shown in Annex 4 Fig. 11 b) and the distance between the probes shall be adjusted to obtain the maximum transmission pulse with V path method (arrangement of T-R₁) and V path method of triple bounce (arrangement of T-R₂). Two peaks of the transmission pulses obtained shall be plotted and connected by a straight line [see Annex 4 Fig. 11 c)].
 - 2) At the same sensitivity as 1), both angle probes are opposite to each scanning direction as shown in Annex 4 Fig. 11 a) and the distance between the probes shall be adjusted to obtain the maximum transmission pulse with V path method. The difference in height of the transmission pulses from STB, RB-41 or RB-43 in that path length shall be read out in units of 1 dB (round off), and it shall be taken as the quantity of sensitivity correction.



Annex 4 Fig. 9 Quantity of sensitivity correction due to curvature of longitudinal joint



Annex 4 Fig. 10 Quantity of sensitivity correction due to curvature of longitudinal joint



Annex 4 Fig. 11 Quantity of sensitivity correction for examination from inner surface (concave surface)

5.6 Adjustment of working sensitivity The adjustment of working sensitivity shall be performed in accordance with 8.1.6 of the body.

6 Examination method

6.1 Test surface The test surface shall be in accordance with Annex 4 Table 2.

6.2 Scanning direction The scanning direction shall be the direction with not less than two directions of ultrasonic beams in order to prevent overlooking a discontinuity due to its inclination.

6.3 Scanning method The scanning method of probe using zig-zag scanning in 3) among other scanning methods in 9.1 a) of the body shall be performed so that a discontinuity is not overlooked.

Annex 4 Table 2 Test surface

Examination from inner and outer sides	Maximum path length to be used mm	Frequency	Test surface	Examination method
Case where examination from only outer side is possible	150 mm or under	2 MHz or 5 MHz	Outer face (convex surface) both sides	Single and double traverse
	Over 150 mm up to and incl. 250 mm	2 MHz	Outer face (convex surface) both sides	Single and double traverse
	Over 250 mm	2 MHz	Outer face (convex surface) both sides	Single and double traverse
Case where examination from both inner and outer sides are possible	150 mm or under	2 MHz or 5 MHz	Outer face (convex surface) both sides	Single and double traverse
	Over 150 mm up to and incl. 250 mm	2 MHz	Outer face (convex surface) both sides	Single and double traverse
	Over 250 mm	2 MHz	Inner and outer faces (concave and convex surfaces) both sides	Single traverse

7 Estimation of location of discontinuity After path length and probe distance have been corrected by 7.1 and 7.2, the position of a discontinuity in the transverse cross-section of longitudinal joint shall be estimated by 7.3 (see Annex 4 Fig. 12 and Annex 4 Fig. 1). However, in the case of examining the test object having the transverse wave velocity different from STB wave velocity the refraction angle by the test object obtained from the direction in which a discontinuity has been detected shall be used.

7.1 Method for correction of path length

- a) **Path length corresponding to positions of outer and inner surfaces** The correction factor (α) of the path length shall be read out from the scale of the vertical axis corresponding to the intersection point of the refraction angle by the test object of the probe to be used, θ and scale of the horizontal axis of $\frac{t}{D}$ of the test object in Annex 4 Fig. 13.

The path length W_L and W_U corresponding to the positions of outer and inner surfaces shall be calculated by the following formulae, respectively.

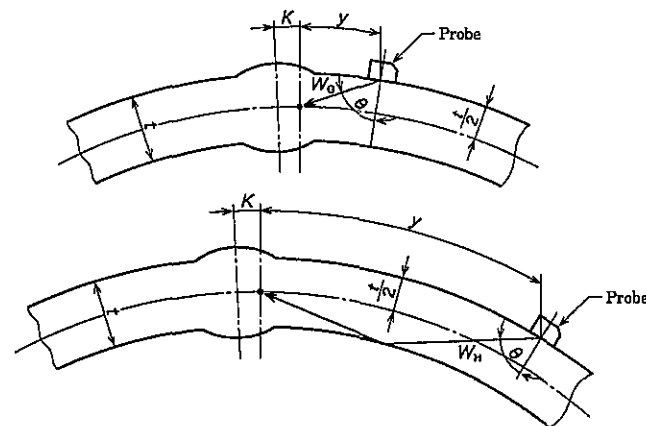
$$W_L = \frac{t}{\cos \theta} \times \alpha$$

$$W_U = W_L \times 2$$

- b) **Wall thickness centre-path length** The correction factor (α_H) of the path length shall be taken by the same procedure as a), taking half of $\frac{t}{D}$ of the test object on the horizontal axis in Annex 4 Fig. 13. The wall thickness centre-path length by single traverse technique W_G and wall thickness centre-path length by double traverse technique W_H shall be calculated according to the following formulae, respectively.

$$\text{Path length by single traverse technique } W_G = \frac{t}{2\cos \theta} \times \alpha_H$$

$$\text{Path length by double traverse technique } W_H = W_U - W_F$$



Annex 4 Fig. 12 Transverse cross-section of position of discontinuity

7.2 Method for correction of probe distance

- a) **Probe distances of positions of inner and outer surfaces** The correction factor of the probe distance shall be taken from the scale of the vertical axis corresponding to the intersection point of the refraction angle by the test object of the probe to be used (θ) and scale of the horizontal axis of $\frac{t}{D}$ of the test object in Annex 4 Fig. 14. It shall be taken as b .

The probe distances Y_L and Y_U of inner and outer surfaces shall be calculated by the following formulae, respectively.

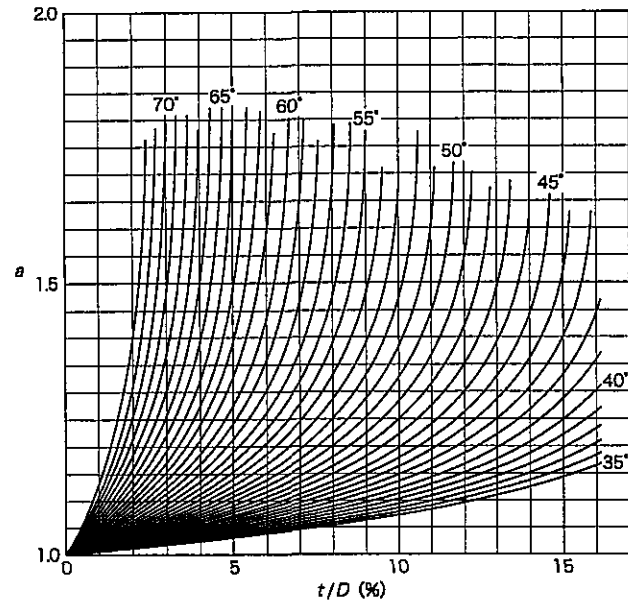
$$Y_L = (t \cdot \tan \theta) \times b$$

$$Y_U = Y_L \times 2$$

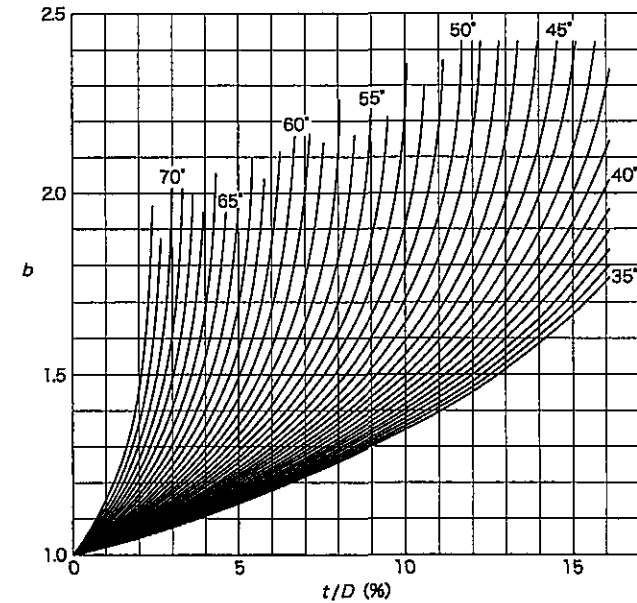
- b) **Wall thickness centre-probe distance** The correction factor (b_H) of the probe distance shall be taken by the same procedure as a), taking half of $\frac{t}{D}$ of the test object on the horizontal axis in Annex 4 Fig. 14. The wall thickness centre-probe distance by single traverse technique Y_G and wall thickness centre-probe distance by double traverse technique Y_H shall be calculated according to the following formulae, respectively.

$$\text{Wall thickness centre-probe distance by single traverse technique } Y_G = \left(\frac{t}{2} \times \tan \theta \right) \times b_H$$

$$\text{Wall thickness centre-probe distance by double traverse technique } Y_H = Y_U - Y_G$$



Annex 4 Fig. 13 Correction factor of probe distance according to $\frac{t}{D}$ a)



Annex 4 Fig. 14 Correction factor of probe distance according to $\frac{t}{D}$ b)

7.3 Method for estimation of location of discontinuity

7.3.1 Case of examining from outer surface The probe distance Y and the depth of a discontinuity d shall be calculated by the proportional distribution from the path length W and wall thickness centre-probe distance W_G or W_H which have been taken.

a) Case where path length W is W_G or less

$$y = Y_0 \times \frac{W}{W_G}$$

$$d = \frac{1}{2} \times \frac{W}{W_G}$$

b) Case where path length W is over W_G to W_L or less

$$y = Y_0 + (Y_L - Y_0) \times \frac{W - W_G}{W_L - W_G}$$

$$d = \frac{1}{2} \left(1 + \frac{W - W_G}{W_L - W_G} \right)$$

c) Case where path length W is over W_L to W_H or less

$$y = Y_L + (Y_H - Y_L) \times \frac{W - W_L}{W_H - W_L}$$

$$d = t \left\{ 1 - \frac{1}{2} \left(\frac{W - W_L}{W_R - W_L} \right) \right\}$$

d) Case where path length W is over W_H to W_U or less

$$y = Y_H + (Y_U - Y_H) \times \frac{W - W_H}{W_U - W_H}$$

$$d = \frac{1}{2} \left(1 - \frac{W - W_H}{W_L - W_H} \right)$$

7.3.2 Case of examining from inner surface The probe distance Y and the depth of a discontinuity d in the case of examining from inner surface shall be calculated as follows by using W_M and W_N (see Annex 4 Fig. 15).

$$W_M = W_L - W_G \qquad W_N = W_U - W_M$$

$$Y_M = Y_L - Y_G \qquad Y_N = Y_U - Y_M$$

When taking $c = 1 - \frac{2t}{D}$ as the correction factor of the length of circular arc of the outer surface and the inner surface, d and y shall be given by the following formulae in each case.

a) **Case where the path length W is W_M or less**

$$y = c \left(Y_M \times \frac{W}{W_M} \right)$$

$$d = \frac{1}{2} \times \frac{W}{W_M}$$

b) Case where the path length W is over W_M to W_L or less

$$y = c \left(Y_M + Y_H \times \frac{W - W_M}{W_G} \right)$$

$$d = \frac{1}{2} \left(1 + \frac{W - W_M}{W_G} \right)$$

c) **Case where the path length W is over W_L to W_N or less**

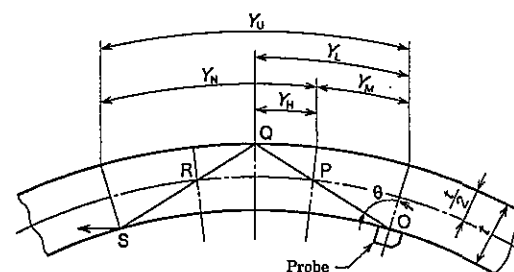
$$y = c \left\{ Y_L + (Y_N - Y_L) \times \frac{W - W_L}{W_N - W_L} \right\}$$

$$d = t \left(1 - \frac{1}{2} \times \frac{W - W_L}{W_N - W_L} \right)$$

d) Case where the path length W is over W_N to W_U or less

$$y = c \left(Y_N + Y_M \times \frac{W - W_N}{W_M} \right)$$

$$d = \frac{1}{2} \left(1 + \frac{W - W_N}{W_M} \right)$$



$$\begin{array}{ll} W_M = \overline{OP} & W_H = \overline{OQ} + \overline{QR} \\ W_L = \overline{OQ} & W_U = \overline{OQ} + \overline{QS} \end{array}$$

Annex 4 Fig. 15 Symbols in examination from inner side of test object with curvature

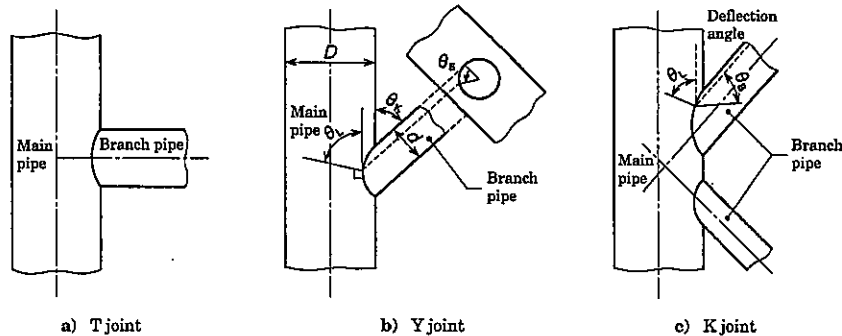
Annex 5 (normative)

Examination method for steel pipe branch joint weld

1 Scope This Annex specifies the method for ultrasonic examination of the steel pipe branch joint welds of which the curvature radius of test surface is 150 mm or more to and excluding 1 500 mm and ratio of wall thickness to outer diameter is 16 % or less.

2 Definitions For the purposes of this Annex, the following definitions shall apply (see Annex 5 Fig. 1).

- a) **T joint** The steel branch joint of which a main pipe and a branch pipe join at 90° to each other.
- b) **Y joint** The steel branch joint of which a main pipe and a branch pipe join at an angle other than 90°.
- c) **K joint** The steel branch joint of which a main pipe and two branch pipes join at an angle other than 90°.
- d) **crossing angle θ_K** Angle at which a main pipe joins with a branch pipe.
- e) **mutual penetration angle θ_S** Angle in the circumferential direction of the branch pipe from the intersecting line of a surface which has been made by the axis of main pipe and the axis of branch pipe, and the surface of that branch pipe.
- f) **deflection angle θ_L, θ_B** Angle included by the axial directions of main pipe and branch pipe, and the normal line of the groove line of the main pipe or branch pipe on the surface of the main pipe or branch pipe.



Annex 5 Fig. 1 T, Y and K joint weld

3 Calibration block and reference block to be used The calibration block and the reference block to be used shall be model A1 calibration block or A3 series calibration block and RB-41 specified in 5 of the body.

4 Probe to be used

4.1 Contact surface of probe The contact surface of the probe shall be flat.

4.2 Nominal refraction angle of probe The nominal refraction angle of the probe shall be selected from 45°, 60° and 70°, by drawing the stereoscopic figure (including also the form of groove) of each examining location, and by taking into consideration $\frac{t}{D}$ of branch pipe, ratio of outer diameter of the branch pipe to that of the main pipe, crossing angle and mutual penetration angle so that the main beam of ultrasonic wave can be incident to the groove face at a suitable angle. However, the nominal refraction angle of the probe shall be selected from 45°, 60° and 65° in the case of the test object having the transverse wave velocity different from STB wave velocity.

4.3 Measurement of refraction angle by test object in case of test object having the transverse wave velocity different from STB wave velocity

4.3.1 Case of examining from branch pipe of T joint After an angle θ_T between the direction of pipe axis and rolling direction (L direction) is obtained, the refraction angle by the test object in L direction, Q direction, or C direction shall be measured by the method specified in 8.1.3 of the body, in accordance with the value of θ_T .

- a) In the case where θ_T is under 22.5°, the refraction angle by the test object of L direction is measured.
- b) In the case where θ_T is 22.5° or more to and excluding 67.5°, the refraction angle by the test object of Q direction is measured.
- c) In the case where θ_T is 67.5° or over up to and including 90°, the refraction angle by the test object of C direction is measured.

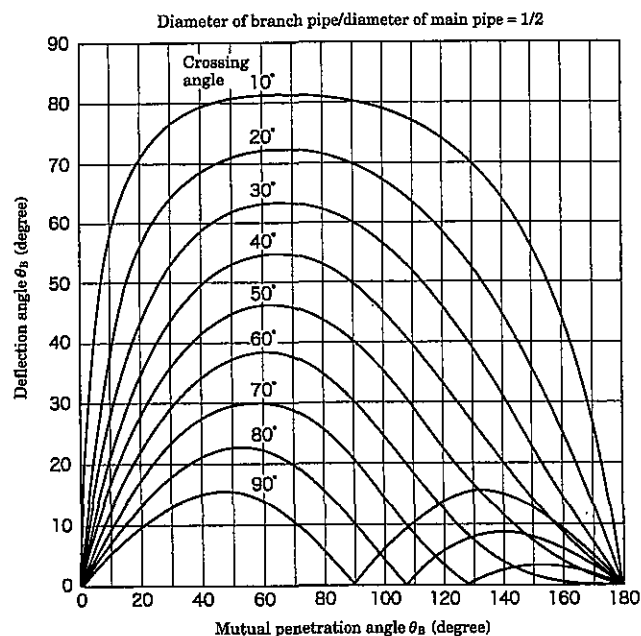
4.3.2 Case of examining from branch pipes of Y and K joints The deflection angle θ_B shall be obtained by the actual measurement or according to the following formula based on the values of ratio of outer diameter of the main pipe to that of the branch pipe, crossing angle θ_K , mutual penetration angle θ_S at the location of examination. An example of calculation shall be as shown in Annex 5 Fig. 2.

$$\theta_B = \left| \tan^{-1} \left\{ \sin \theta_S \left(\cot \theta_K + \frac{d \cos \theta_S}{\sin \theta_K \sqrt{D^2 - d^2 \sin^2 \theta_S}} \right) \right\} \right|$$

On the other hand, the angle θ_T between the direction of pipe axis and rolling direction shall be obtained. The refraction angle by the test object in L direction, Q direction, or C direction shall be measured according to the value of $|\theta_B - \theta_T|$ in accordance with 8.1.3 of the body.

- a) In the case where $|\theta_B - \theta_T|$ is 0° or over to and excluding 22.5°, the refraction angle by the test object of L direction shall be measured.
- b) In the case where $|\theta_B - \theta_T|$ is 22.5° or over to and excluding 67.5°, the refraction angle by the test object of Q direction shall be measured.

- c) In the case where $|\theta_B - \theta_T|$ is 67.5° or over up to and including 90° , the refraction angle by the test object of C direction shall be measured.



Annex 5 Fig. 2 An example of chart for obtaining θ_B from crossing angle of mutual penetration angle

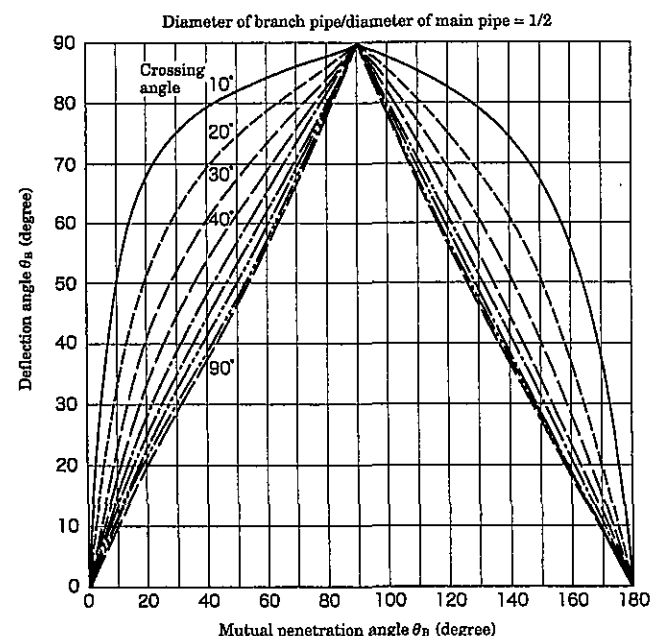
4.3.3 Case of examining from main pipe The deflection angle θ_L shall be obtained by the actual measurement or according to the following formula based on the values of ratio of outer diameter of the main pipe to that of the branch pipe, crossing angle θ_K , mutual penetration angle θ_S at the examination location. An example of calculation shall be as shown in Annex 5 Fig. 3.

$$\theta_L = \left| \tan^{-1} \left(\frac{d \cot \theta_K \times \sin \theta_S}{2D} + \frac{\operatorname{cosec} \theta_K \times \sin \theta_S \sqrt{D^2 - d^2 \sin^2 \theta_S}}{D \cos \theta_S} \right) \right|$$

On the other hand, the angle θ_T between the direction of pipe axis and rolling direction shall be obtained. The refraction angle by the test object in L direction, Q direction, or C direction shall be measured according to the value of $|\theta_L - \theta_T|$ in accordance with 8.1.3 of the body.

- a) In the case where $|\theta_L - \theta_T|$ is 0° or over to and excluding 22.5° , the refraction angle by the test object of L direction shall be measured.
- b) In the case where $|\theta_L - \theta_T|$ is 22.5° or over to and excluding 67.5° , the refraction angle by the test object of Q direction shall be measured.

- c) In the case where $|\theta_L - \theta_T|$ is 67.5° or over up to and including 90° , the refraction angle by the test object of C direction shall be measured.



Annex 5 Fig. 3 An example of chart for obtaining θ_L from crossing angle of mutual penetration angle

5 Adjustment of test equipment

5.1 Adjustment of time base range The time base range shall be adjusted in accordance with 8.1.2 of the body.

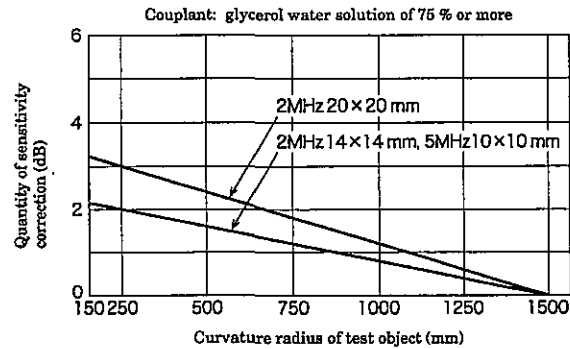
5.2 Making curves for dividing echo height The curves for dividing echo heights by RB-41 shall be made in accordance with 8.1.4 of the body.

5.3 Method for obtaining quantity of sensitivity correction

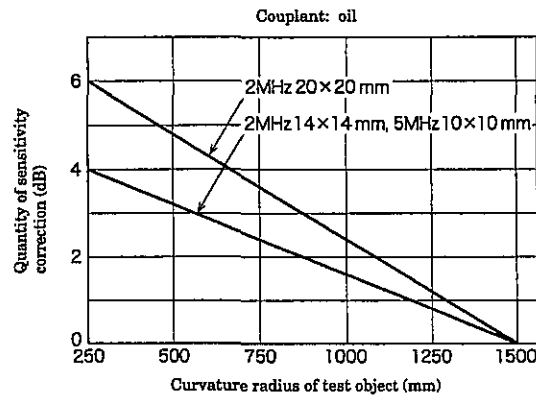
5.3.1 Case of examining from outer surface (convex surface) The quantity of sensitivity correction shall be obtained in accordance with nominal frequency and transducer size of the angle probe to be used, couplant and outer diameter from Annex 5 Fig. 4 or Annex 5 Fig. 5 in units of 1 dB (round off) in the case of examining from the branch pipe of T joint; and from Annex 5 Fig. 6 or Annex 5 Fig. 7 in units of 1 dB (round off) in other cases.

5.3.2 Case of examining from inner surface (concave surface) The sensitivity shall be corrected in accordance with 4.4.2 b) of Annex 3.

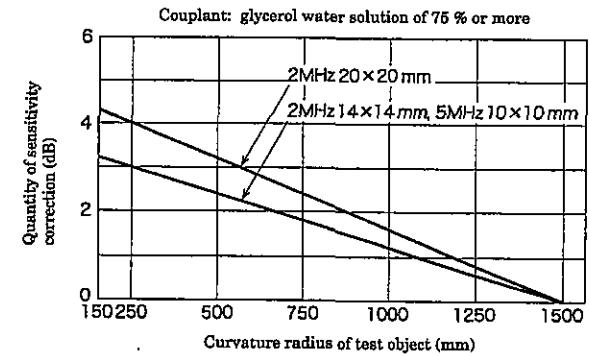
5.4 Adjustment of working sensitivity The working sensitivity shall be adjusted in accordance with 8.1.6 of the body.



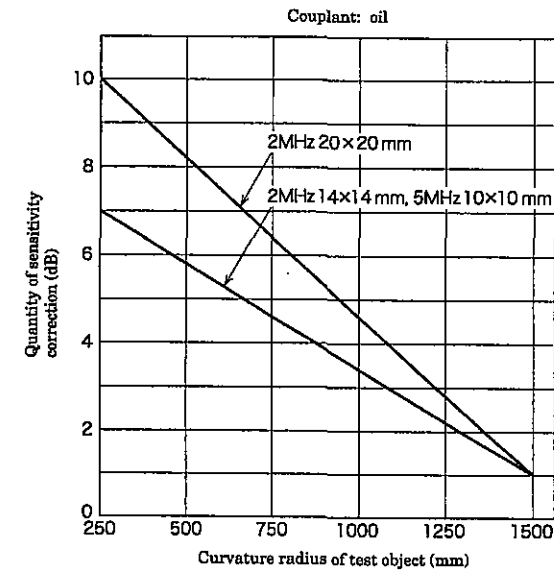
Annex 5 Fig. 4 Quantity of sensitivity correction due to curvature of circumferential joint



Annex 5 Fig. 5 Quantity of sensitivity correction due to curvature of circumferential joint



Annex 5 Fig. 6 Quantity of sensitivity correction due to curvature of longitudinal joint



Annex 5 Fig. 7 Quantity of sensitivity correction due to curvature of longitudinal joint

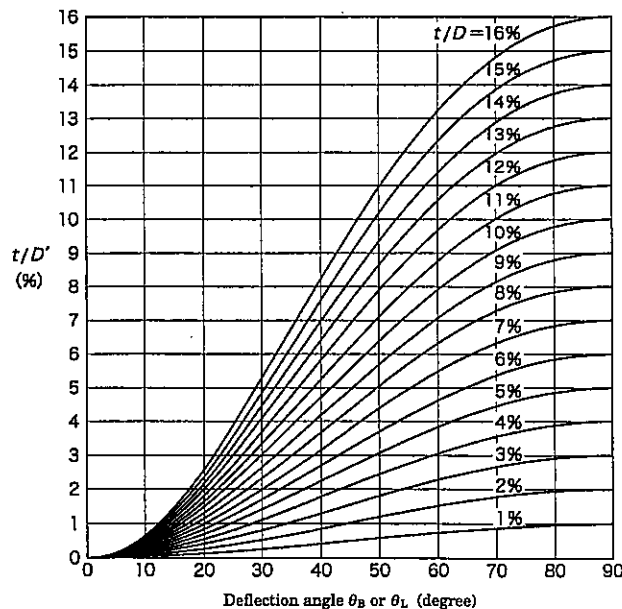
6 Examination method

6.1 Preparation of examination

6.1.1 Wall thickness measurement The thicknesses of four points of main pipe and branch pipe shall be measured by the ultrasonic thickness meter and the points measured shall be marked on the member and it shall be collated with the value given in the drawings, at the same time.

6.1.2 Method for obtaining probe to weld distance and path length

- a) **Case of examining from branch pipes of K and Y joints** The deflection angle θ_B between the direction of pipe axis and scanning direction shall be obtained by actual measurement or by Annex 5 Fig. 2 from ratio of outer diameters of main pipe to that of the branch pipe, crossing angle and mutual penetration angle, and the value of apparent $\frac{t}{D'}$ shall be obtained by using Annex 5 Fig. 8 from the value of $\frac{t}{D}$ obtained from the nominal values or actual values.
- b) **Case of examining from main pipe** The deflection angle θ_B between the direction of pipe axis and scanning direction shall be obtained by actual measurement or by Annex 5 Fig. 2 from ratio of outer diameters of main pipe to that of the branch pipe, crossing angle and mutual penetration angle, and the value of apparent $\frac{t}{D'}$ shall be obtained by using Annex 5 Fig. 8 from the value of $\frac{t}{D}$ obtained from the nominal values or actual values.



Annex 5 Fig. 8 Chart for obtaining $\frac{t}{D'}$ from deflection angle θ_B or θ_L and $\frac{t}{D}$

- a) **Probe to weld distance and path length** The value of $\frac{t}{D'}$ obtained by the procedures of a) and b) shall be taken as $\frac{t}{D}$ in Annex 4 Fig. 12 and Annex 4 Fig. 13, the correction factors a and b shall be obtained, and the path length and probe weld distance at the points of 0.5 skip and 1.0 skip shall be calculated from the following formulae.

$$W_{0.5} = \frac{t}{\cos \theta} \times a \quad W_{1.0} = 2 \times W_{0.5}$$

$$Y_{0.5} = t \times \tan \theta \times b \quad Y_{1.0} = 2 \times Y_{0.5}$$

However, the value of θ is taken as the refraction angle by the test object in the case of the test object having the wave velocity different from STB wave velocity.

6.1.3 Marking-off of base line The base line shall be marked at the definite distance from groove face prior to the welding.

6.2 Test surface The test surface shall be selected as required so that the main beam of ultrasonic wave can be incident to the groove face at a suitable angle.

6.3 Scanning direction The scanning direction shall be perpendicular to the weld line, and whenever possible, the direction with not less than two directions of ultrasonic beams in order to prevent overlooking a discontinuity due to its inclination.

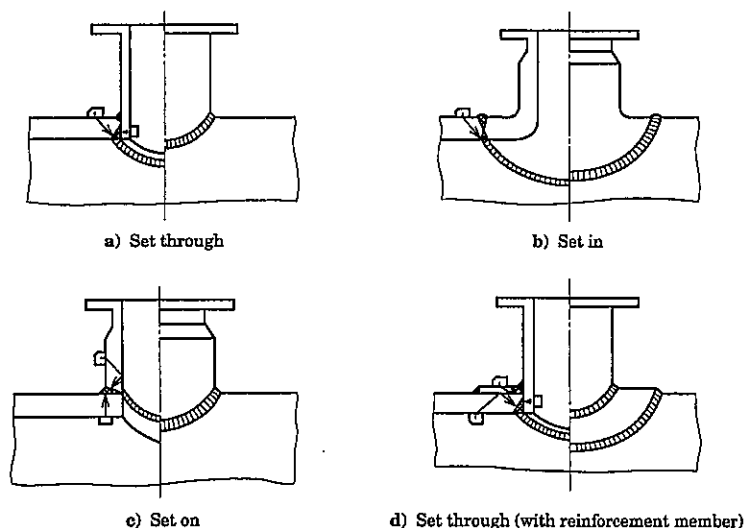
6.4 Scanning method The scanning method of probe using zig-zag scanning in 3) among other scanning methods in 9.1 a) of the body shall be performed so that a discontinuity is not overlooked.

7 Method for estimating location of discontinuity

- a) The probe to weld distance and path length in which the maximum echo is obtained shall be recorded.
- b) The form of the weld section in the direction of ultrasonic beam shall be made up by the shaping gauge or clay and shall be made into drawings.
- c) The location of a discontinuity shall be estimated from the drawings in which probe to weld distance, path length and STB refraction angle are written in the drawings of weld section in the direction of ultrasonic beam or shall be estimated by the calculation with the same procedure as 7 of Annex 4. However, the refraction angle by the test object obtained in the direction in which a discontinuity has been detected shall be used for this estimation in the case of the test object having the wave velocity different from STB wave velocity.

Annex 6 (normative)
Examination method for nozzle joint weld

1 Scope This Annex specifies the method for ultrasonic examination of the nozzle joint welds of which the curvature radius of test surface is 250 mm or more to and excluding 1 500 mm and ratio of wall thickness to outer diameter is not more than 16 %.



Annex 6 Fig. 1 Examples of nozzle joint weld

2 Calibration block and reference block to be used The calibration block and the reference block to be used shall be model A1 calibration block or model A3 series calibration block specified in 5.1 of the body and RB-41 specified in 5.2 of the body.

3 Probe to be used

3.1 Contact surface of probe The contact surface of the probe to be used shall be flat.

3.2 Nominal refraction angle of probe The nominal refraction angle of the probe shall be selected so that the main beam of ultrasonic wave can be incident to the groove face at a suitable angle by drawing the stereoscopic figure (including also the form of groove) of each examining location. However, the nominal refraction angle of not more than 65° shall be selected in the case of the test object having the wave velocity different from STB wave velocity.

4 Adjustment of test equipment

4.1 Adjustment of time base range The time base range shall be adjusted in accordance with 8.1.2 of the body.

4.2 Measurement of probe index, STB refraction angle and refraction angle by test object The probe index and STB refraction angle shall be measured in accordance with 8.1.1 and 8.1.3 of the body.

The refraction angle by the test object shall be measured by using RB-41 or the test object in each direction in the case of the test object having the wave velocity different from STB wave velocity.

4.3 Making curves for dividing echo height The curves for dividing echo heights shall be made in accordance with 8.1.4 of the body.

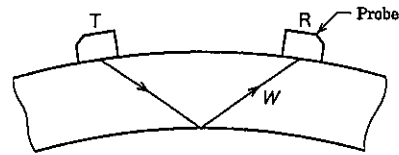
4.4 Method for obtaining quantity of sensitivity correction

4.4.1 Case of nozzle joint weld attached to cylindrical body

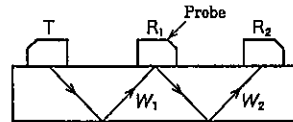
- a) **Case of examining from outer surface (convex surface)** The quantity of sensitivity correction shall be obtained from Annex 4 Fig. 9 or Annex 4 Fig. 10 in accordance with the nominal frequency, transducer size of the probe to be used, couplant and outer diameter of the cylindrical body in units of 1 dB (round off).
- b) **Case of examining from inner surface (concave surface)** The quantity of sensitivity correction shall be obtained in accordance with 4.4.2 b) of Annex 3.

4.4.2 Case of nozzle joint weld attached to end plate

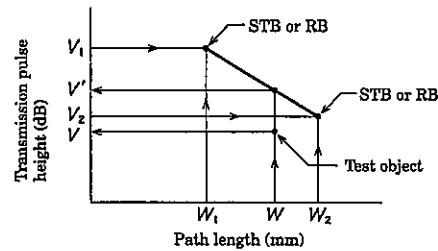
- a) **Case of examining from outer surface (convex surface)** The case of examining from outer surface (convex surface) shall be as follows:
 - 1) The angle probe to be used and an angle probe which has the same form as that of the probe to be used shall be arranged so that they face each other like T-R₁ and T-R₂ as shown in Annex 6 Fig. 2 b), the distances between two different probes shall be adjusted so that the maximum transmission pulses are obtained in each case and these two peaks of the maximum echoes are plotted and connected with a straight line [see Annex 6 Fig. 2 c)].
 - 2) In the same sensitivity as 1), the distance between two probes shall be adjusted by V path method in the same direction as the scanning direction so that the maximum transmission pulse is obtained. Next, the difference between the heights of these transmission pulses in the path lengths and the heights of the transmission pulses in the same path length on the straight line as the mentioned above shall be taken in units of 1 dB (round off) and it shall be taken as the quantity of sensitivity correction.



a) Test object



b) STB or RB



c) Quantity of sensitivity correction ($V' - V$)

Annex 6 Fig. 2 Method of sensitivity correction for examination from outer surface

b) **Case of examining from inner surface (concave surface)** The sensitivity correction shall be performed in accordance with of 4.4.2 b) of Annex 3.

4.4.3 Case of examining from outer surface of nozzle The quantity of sensitivity correction shall be obtained from Annex 3 Fig. 6 or Annex 3 Fig. 7 in accordance with nominal frequency and transducer size of the angle probe to be used, couplant and outer diameter of the nozzle in units of 1 dB (round off).

4.5 Adjustment of working sensitivity The working sensitivity shall be adjusted in accordance with 8.1.6 of the body.

5 Method for examination

5.1 Confirmation of probe to weld distance and path length

5.1.1 Case of nozzle joint weld attached to cylindrical body The axial direction of the cylindrical body shall be taken as 0° as shown in Annex 6 Fig. 3, and the probe to weld distance of 0.5 skip and 1.0 skip in each deflection angle of 0° , 30° , 45° , 60° and 90° , and their path lengths shall be obtained by either of the following two items.

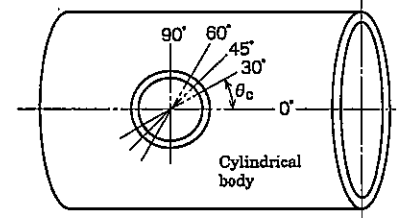
- The stereoscopic figure (including form of groove) of each examining location shall be made up by the shaping gauge as shown in Annex 6 Fig. 4 and the probe to weld distance and path length shall be obtained from the stereoscopic figure. The mark lines shall be drawn at the positions of the probe to weld distances Y_L and Y_U , on the test surface.
- The value of $\frac{t}{D'}$ shall be obtained by using Annex 6 Fig. 5 from the value of $\frac{t}{D}$ of the nominal value or of the actual value and the deflection angle θ_c between the probe direction and the axial direction of cylindrical body.

Furthermore, the value of $\frac{t}{D'}$ shall be taken as $\frac{t}{D}$ in Annex 4 Fig. 12 and Annex 4 Fig. 13, the correction factors a and b shall be obtained, and the probe to weld distance and path length shall be calculated from the following formulae.

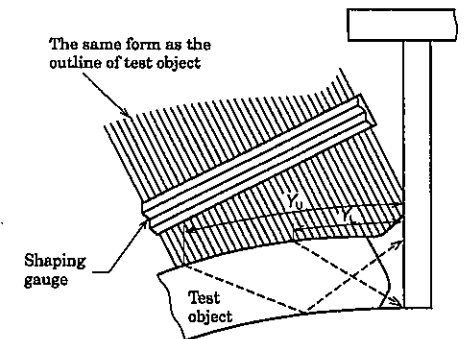
$$Y_L = (t \cdot \tan \theta) \times b, \quad Y_U = 2 \times Y_L$$

$$W_L = (t / \cos \theta) \times a, \quad W_U = 2 \times W_L$$

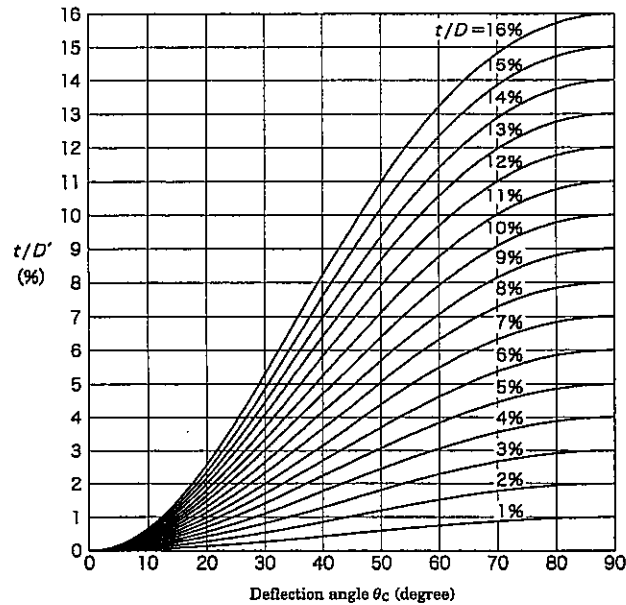
The mark lines shall be drawn at the positions of the probe to weld distances Y_L and Y_U on the test surface.



Annex 6 Fig. 3 Relationship among deflection angle θ_c , direction of probe and axial direction of cylindrical body



Annex 6 Fig. 4 An example of use of shaping gauge



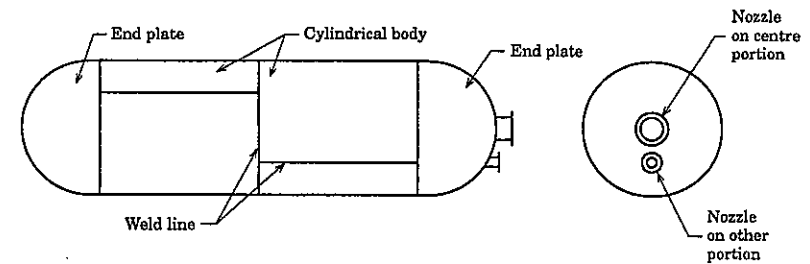
Annex 6 Fig. 5 Chart for obtaining $\frac{t}{D'}$ from deflection angle θ_c and $\frac{t}{D}$

5.1.2 Case of nozzle joint weld attached to end plate

- a) In the case where the nozzle joint weld is attached to the central portion of the whole hemispherical and dish form end plate (see Annex 6 Fig. 6) The probe to weld distance and path length shall be obtained in accordance with 7.1 and 7.2 of Annex 4. The mark lines shall be drawn at the positions of Y_L and Y_U in the obtained probe to weld distances on the test surface.

For ellipsoidal end plates, the probe to weld distance and path length shall be obtained in accordance with 5.1.1, and the mark lines shall be drawn at the positions of Y_L and Y_U in the obtained probe to weld distances on the test surface.

- b) In the case where the nozzle joint weld is attached to portions other than the central portion of the end plate (see Annex 6 Fig. 6) The stereoscopic figure (including also the form of groove) of each examining location in accordance with the method described in 5.1.1 a), and the probe to weld distance and path length shall be obtained. The mark lines shall be drawn at the positions of Y_L and Y_U in that probe to weld distances on the test surface.



Annex 6 Fig. 6 Attaching portions of nozzles

5.2 Combined use of types of examination In order to help the detection of a discontinuity in the angle beam examination, the normal examination shall be used whenever possible.

5.3 Test surface The test surface shall be selected as required so that the main beam of ultrasonic wave can be incident to the groove face at a suitable angle as follows.

- a) The angle beam examination shall be performed from cylindrical body, end plate or either outer face (convex face) of the nozzle or inner face (concave face) of the nozzle or both faces.

The normal examination shall be performed from inner face (concave face) of the nozzle or inner face (concave face) of the body, as far as possible.

- b) In the case of the nozzle joint weld of set on type as shown in Annex 6 Fig. 1 c), the angle beam examination shall be performed from outer face of nozzle neck and the normal examination shall be performed from inner face of the body or the end plate, as far as possible.
- c) In the case of examining the nozzle joint weld having reinforcement member, the examination shall be performed from inner face of reinforcement member and cylindrical body or end plate.

5.4 Scanning direction The scanning direction shall be perpendicular to the weld line, and whenever possible, the direction with not less than two directions of ultrasonic beams in order to prevent overlooking a discontinuity due to its inclination.

5.5 Scanning method The scanning method of angle probe using zig-zag scanning in 3) among other scanning methods in 9.1 a) of the body shall be performed so that a discontinuity is not overlooked.

6 Method for estimating location of discontinuity The location of a discontinuity shall be estimated by the method shown in 7.3 of Annex 4 or the drawing method in accordance with 5.1. However, the refraction angle by the test object obtained in the direction in which the discontinuity is detected shall be used in the case of the test object having the wave velocity different from STB wave velocity.

Annex 7 (normative)
Method for classifying examination results

1 Scope This Annex applies to the case where the classification of the results of the angle beam examination and normal examination is performed.

2 Classification of examination results The examination results shall be classified in accordance with Annex 7 Table 1 corresponding to the region of echo height and ultrasonic discontinuity length.

Annex 7 Table 1 Classification of discontinuity in accordance with region of echo heights and ultrasonic discontinuity length

Unit : mm

Region Plate thickness mm Grade	Case using M-disregard level: III Case using L-disregard level: II and III			IV		
	18 or less	Over 18 up to and incl. 60	Over 60	18 or less	Over 18 up to and incl. 60	Over 60
Grade 1	6 max.	$\frac{t}{3}$ max.	20 max.	4 max.	$\frac{t}{4}$ max.	15 max.
Grade 2	9 max.	$\frac{t}{2}$ max.	30 max.	6 max.	$\frac{t}{3}$ max.	20 max.
Grade 3	18 max.	t max.	60 max.	9 max.	$\frac{t}{2}$ max.	30 max.
Grade 4	Discontinuity exceeding Grade 3					

Remarks : The symbol t is plate thickness (mm) of the parent materials of the groove side. However, in the case of butt joint weld with different plate thickness of the parent materials, the thinner plate thickness is adopted.

In applying Annex 7 Table 1, in the case where the distance between discontinuities is smaller or equal to the length of the discontinuity with longer ultrasonic discontinuity length at the depth considered to be the same and at the location of the direction perpendicular to the weld line, these discontinuities shall be regarded as the same discontinuity group and treated as a continuous discontinuity including such distance.

In the case where the distance between discontinuities is longer than the larger one of the two ultrasonic discontinuity lengths, these discontinuities shall be regarded as independent from each other.

In addition, the examination results of straddle scanning, parallel scanning by slanted probe and longitudinal scanning on the weld line shall be classified in accordance with the agreement between the parties concerned.

Annex 8 (informative)
Method for measurement of ultrasonic discontinuity height

1 Scope This Annex specifies the method for measurement of ultrasonic discontinuity height with respect to a plane discontinuity (hereafter referred to as "discontinuity") in the direction of thickness of joint welds of flat plate by using the single probe angle beam end echo technique of ultrasonic examination.

In addition, when other methods are judged to be suitable from the standpoints such as form and dimension of the test object and test surface, and location, dimension, shape, inclination of a discontinuity, other confirmed methods are applicable.

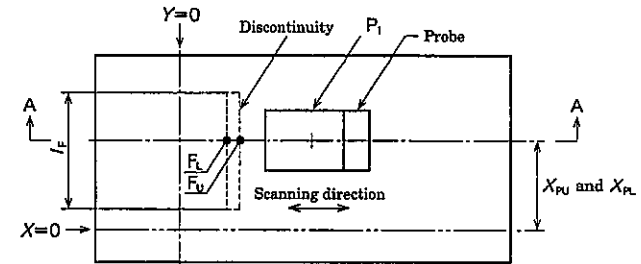
2 Definitions For the purposes of this Annex, the definitions given in the body and JIS Z 2300 and the following definitions shall apply.

- a) **ultrasonic discontinuity height** An apparent height of a discontinuity measured in accordance with this Annex.
- b) **single probe angle beam end echo technique** A method to obtain ultrasonic discontinuity height geometrically from the path length of end echo obtained from the upper end of a discontinuity and the lower end of a discontinuity, STB refraction angle of single transducer angle probe and refraction angle by test object of single transducer focused angle probe and double transducer angle probe.

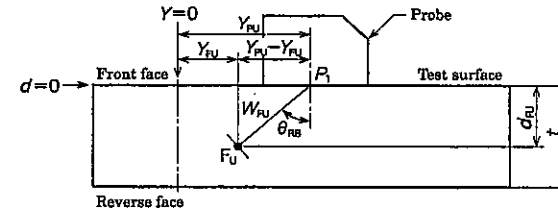
3 Symbols The symbols used in this Annex shall be in accordance with the body and the following, and shall be as shown in Annex 8 Fig. 1.

- a) F_U The upper end of a discontinuity or echo of the upper end of a discontinuity.
- b) F_L The lower end of a discontinuity or echo of the lower end of a discontinuity.
- c) P_1 (mm) Probe index.
- d) θ_{RB} (degree) Refraction angle by test object.
- e) θ_{STB} (degree) STB refraction angle.
- f) X_{PU} (mm) The distance on test surface between $X=0$ of test reference line and the centre in width direction of angle probe at the location of probe in X direction when detecting the maximum echo of the upper end of a discontinuity.
- g) X_{PL} (mm) The distance on test surface between $X=0$ of test reference line and the centre in width direction of angle probe at the location of probe in X direction when detecting the maximum echo of the lower end of a discontinuity.
- h) Y_{PU} (mm) The distance on test surface between $Y=0$ of test reference line and the probe index of angle probe P_1 at the location of probe in Y direction when detecting the maximum echo of the upper end of a discontinuity.
- i) Y_{PL} (mm) The distance on test surface between $Y=0$ of test reference line and the probe index of angle probe P_1 at the location of probe in Y direction when detecting the maximum echo of the lower end of a discontinuity.

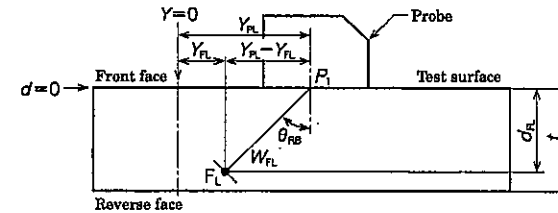
- j) W_{FU} (mm) Path length of the upper end of a discontinuity.
- k) W_{FL} (mm) Path length of the lower end of a discontinuity.
- l) Y_{FU} (mm) The distance on test surface between $Y = 0$ of test reference line and the upper end of a discontinuity at the location of probe in X direction when detecting the maximum echo of the upper end of a discontinuity.
- m) Y_{FL} (mm) The distance on test surface between $Y = 0$ of test reference line and the lower end of a discontinuity at the location of probe in X direction when detecting the maximum echo of the lower end of a discontinuity.
- n) $Y_{PU} - Y_{FU}$ (mm) The distance on test surface between the probe index of probe P_1 and the upper end of a discontinuity at the location of probe in Y direction when detecting the maximum echo of the upper end of a discontinuity ($= W_{FU} \times \sin \theta_{RB}$).
- o) $Y_{PL} - Y_{FL}$ (mm) The distance on test surface between the probe index of probe P_1 and the lower end of a discontinuity at the location of probe in Y direction when detecting the maximum echo of the lower end of a discontinuity ($= W_{FL} \times \sin \theta_{RB}$).
- p) d_{FU} (mm) The distance in thickness direction between the test surface and the upper end of a discontinuity ($= W_{FU} \times \cos \theta_{RB}$).
- q) d_{FL} (mm) The distance in thickness direction between the test surface and the lower end of a discontinuity ($= W_{FL} \times \cos \theta_{RB}$).
- r) $Y_{FU} - Y_{FL}$ (mm) The deviance of location on test surface in Y direction of the upper end of a discontinuity and the lower end of a discontinuity.
- s) l_F (mm) Ultrasonic discontinuity length
- t) t_{NF} (mm) Ultrasonic discontinuity height
- u) ϕ_F (degree) Ultrasonic discontinuity inclination



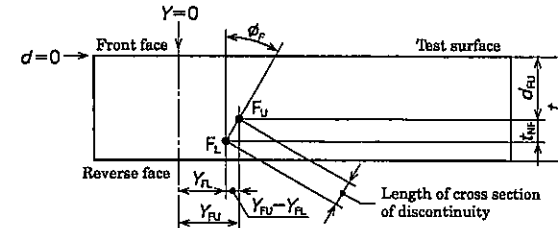
a) Location where maximum echo is detected (X_{FU} and X_{FL})



b) Location of upper end of discontinuity (A-A cross section)



c) Location of lower end of discontinuity (A-A cross section)



d) Ultrasonic discontinuity height (locations of upper end of discontinuity and lower end of discontinuity are composed.)

Annex 8 Fig. 1 Symbols

4 Calibration block and reference block

4.1 Calibration block The calibration block used in this Annex shall be model A1 calibration block or model A3 series calibration block specified in 5 of the body.

4.2 Reference block The reference block used in this Annex shall be RB-41 specified in 5 of the body and horizontal hole reference block RB-SDH specified in 3 of Annex of JIS Z 2350 (reference block for measuring the performance of single transducer focused normal probe, single transducer focused angle probe and double transducer angle probe).

5 Probe The probe shall be any of single transducer angle probe, single transducer focused angle probe and double transducer angle probe.

6 Preparation of measurement

6.1 Selection of frequency The selection of frequency shall be in accordance with 7.3 of the body.

6.2 Nominal dimension of transducer of probe For the nominal dimension of transducer of probe, the dimension confirmed to be valid in addition to those specified in Annex 1 Table 1 may be used.

6.3 Selection of refraction angle The refraction angle shall use STB refraction angle of $45^\circ \pm 2^\circ$ as a standard. As required, the refraction angle by test object of 58° to 72° may be used.

6.4 Selection of disregard level of echo of upper end of a discontinuity F_U and echo of lower end of a discontinuity F_L The disregard level of echo of upper end of a discontinuity F_U and echo of lower end of a discontinuity F_L shall be the level which makes echo of upper end of a discontinuity F_U distinguishable from echo of lower end of a discontinuity F_L when increasing the sensitivity of test instrument until the noise echo height becomes 20 % fs on the indicator.

7 Adjustment of test equipment

7.1 Adjustment of test equipment when using single transducer angle probe

7.1.1 Measurement of probe index The measurement of probe index shall be performed in accordance with 8.1.1 of the body.

7.1.2 Adjustment of time base range The adjustment of time base range shall be performed in accordance with 8.1.2 of the body.

7.1.3 Measurement of STB refraction angle and refraction angle by test object The measurement of STB refraction angle and refraction angle by test object shall be performed in accordance with 8.1.3 of the body.

7.1.4 Adjustment of working sensitivity For the adjustment of working sensitivity, gain of the instrument shall be increased until the noise echo becomes 20 % fs on the indicator with respect to the test object, and this condition shall be taken as working sensitivity.

7.2 Single transducer focused angle probe and double transducer angle probe

7.2.1 Measurement of probe index, measurement of refraction angle by test object, and selection and adjustment of time base range The measurement of probe index P_1 , measurement of refraction angle by test object θ_{RB} , and selection and adjustment of time base range shall be performed by making use of two horizontal holes of $\phi 3$ mm including the location of upper end of a discontinuity F_U and lower end of a discontinuity F_L of the object using horizontal hole reference block RB-SDH.

a) **Preparatory adjustment of time axis** For the time base range, firstly, the preparatory adjustment of time axis shall be performed so that the time axis becomes that of traverse wave of 25 mm or integral multiple of 25 mm by using 45.5 mm of height of calibration block STB-A3 and single transducer normal probe, and next, the probe shall be replaced with single transducer focused angle probe or double transducer angle probe to be used.

b) **Measurement of probe index P_1 and measurement of refraction angle by test object θ_{RB}**

1) **Measurement of location of probe, Y_1 and Y_2** The location of probe, Y_1 and Y_2 , shall be measured in units of 0.1 mm by examining two horizontal holes, 01 and 02 of $\phi 3$ mm as shown in Annex 8 Fig. 2 and by fixing the probe when echo of horizontal holes of $\phi 3$ mm becomes maximized. Y_1 and Y_2 are the dimension of one end side ($Y = 0$) of horizontal hole reference block RB-SDH to the tip of probe.

2) **Measurement of probe index P_1** The measurement of probe index P_1 shall be performed according to formula (1) by using the locations of centre of respective two horizontal holes of $\phi 3$ mm, d_{01} and d_{02} , and the locations of probes A and B as shown in Annex 8 Fig. 2. The probe index, P_1 , shall be calculated in units of 0.1 mm.

$$P_1 = [d_{01}(Y_2 - Y_{02}) - d_{02}(Y_1 - Y_{01})] / (d_{02} - d_{01}) \text{ (mm)} \dots\dots\dots (1)$$

3) **Measurement of refraction angle by test object θ_{RB}** For the measurement of refraction angle by test object θ_{RB} , the refraction angles, θ_{01} and θ_{02} , at the locations of probes A and B given in Annex 8 Fig. 2, respectively, shall be obtained according to formula (2) and formula (3), and the mean of these values shall be obtained according to formula (4), and this shall be taken as the refraction angle by test object θ_{RB} . The refraction angles by test object, θ_{01} , θ_{02} and θ_{RB} shall be calculated in units of 0.1° .

$$\theta_{01} = \tan^{-1}[(Y_1 + P_1) - Y_{01}] / d_{01} \text{ (degree)} \dots\dots\dots (2)$$

$$\theta_{02} = \tan^{-1}[(Y_2 + P_1) - Y_{02}] / d_{02} \text{ (degree)} \dots\dots\dots (3)$$

$$\theta_{RB} = (\theta_{01} + \theta_{02}) / 2 \text{ (degree)} \dots\dots\dots (4)$$

- c) **Calculation of path lengths, W_{01} and W_{02}** The path lengths, W_{01} and W_{02} , of the probe index P_1 to the horizontal hole 01 of $\phi 3$ mm and the horizontal hole 02 of $\phi 3$ mm, respectively, shall be obtained according to formula (5) and formula (6) by using the refraction angle by test object θ_{RB} obtained in formula (4). The path lengths, W_{01} and W_{02} , shall be calculated in units of 0.1 mm.

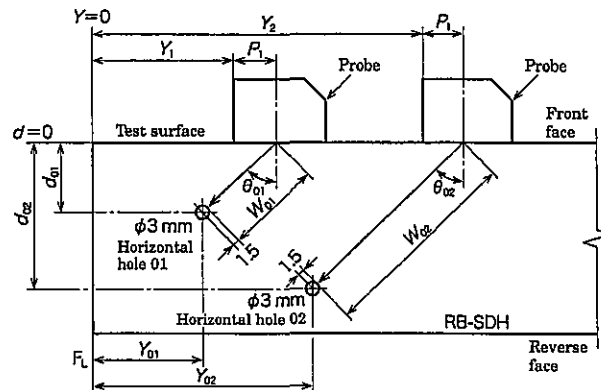
$$W_{01} = (d_{01}/\cos\theta_{RB}) - 1.5 \text{ (mm)} \dots\dots\dots (5)$$

$$W_{02} = (d_{02}/\cos\theta_{RB}) - 1.5 \text{ (mm)} \dots\dots\dots (6)$$

- d) **Adjustment of time base range** The adjustment of time base range shall be performed as follows:

- 1) When the echo height from the horizontal hole 01 of $\phi 3$ mm with the probe placed at the location A in Annex 8 Fig. 2 becomes maximized, the probe shall be fixed, and the zero-point adjustment shall be performed so that the rising location of the echo agrees with the path length W_{01} calculated from formula (5).
- 2) Next, the measured value of path length W_{02} at the location B of the probe shall be taken as W_{02U} , and the difference ΔW_{02} between W_{02U} and W_{02} obtained from formula (6) shall be obtained according to formula (7), and if the value is within 0.5 mm, it shall be taken that the time base range is adjusted correctly, and if it is over 0.5 mm, the adjustment of equipment shall be performed again.

$$\Delta W_{02} = W_{02U} - W_{02} \text{ (mm)} \dots\dots\dots (7)$$



Annex 8 Fig. 2 Measurement of probe index P_1 , measurement of refraction angle by test object θ_{RB} , and adjustment of time base range

7.2.2 Adjustment of working sensitivity The adjustment of working sensitivity shall be performed in accordance with 7.1.4.

8 Measurement

8.1 Incident direction of test surface and ultrasonic wave For the incident direction of test surface and ultrasonic wave, the measurement shall be performed by making the ultrasonic wave incident from two or more incidence directions or from the test surfaces (single face both sides, both faces single side, both faces both sides) whenever possible.

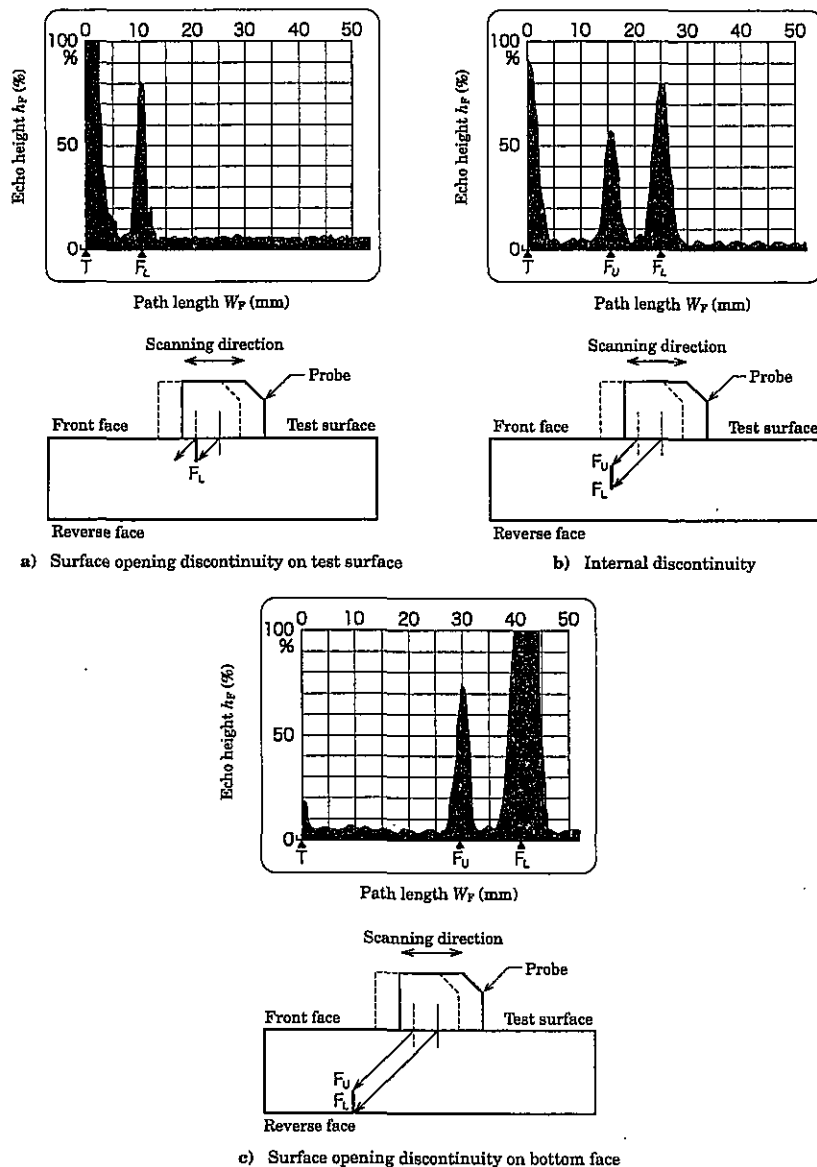
8.2 Scanning direction of probe For the scanning of probe when measuring, the depth scanning shall be performed in the direction perpendicular to the long direction of a plane discontinuity. When performing the depth scanning, some swivel scanning may be performed so that the echo of upper end of a discontinuity F_U and echo of lower end of a discontinuity F_L can be detected obviously.

8.3 Method for detecting echo of upper end of a discontinuity F_U and echo of lower end of a discontinuity F_L

8.3.1 Case of surface opening discontinuity on test surface The peak echo of echo of lower end of a discontinuity F_L shall be detected by performing the depth scanning of probe as shown in a) of Annex 8 Fig. 3.

8.3.2 Case of internal discontinuity The peak echoes of echo of upper end of a discontinuity F_U and echo of lower end of a discontinuity F_L shall be detected by performing the depth scanning of probe as shown in b) of Annex 8 Fig. 3.

8.3.3 Case of surface opening discontinuity on bottom face The peak echo of echo of upper end of a discontinuity F_U shall be detected by performing the depth scanning of probe as shown in c) of Annex 8 Fig. 3.



Annex 8 Fig. 3 An example of method for detecting echo of upper end of a discontinuity F_U and echo of lower end of a discontinuity F_L

8.4 Readout of path lengths W_{FU} and W_{FL} of echo of upper end of a discontinuity F_U and echo of lower end of a discontinuity F_L . The readout of path lengths W_{FU} and W_{FL} of echo of upper end of a discontinuity F_U and echo of lower end of a discontinuity F_L shall be performed by reading the rising location of echo when making the echo heights h_{FU} and h_{FL} of upper end of a discontinuity F_U and lower end of a discontinuity F_L be in agreement with H line. The readout at this time shall be performed in units of 0.1 mm or in units of 1/10 scale.

8.5 Measurement of ultrasonic discontinuity height

8.5.1 Case of a surface opening discontinuity on test surface The ultrasonic discontinuity height t_{NF} shall be calculated according to formula (8).

$$t_{NF} = W_{FL} \times \cos \theta_{RB} \text{ (mm)} \dots\dots\dots (8)$$

8.5.2 Case of an internal discontinuity The ultrasonic discontinuity height t_{NF} shall be calculated according to formula (9).

$$t_{NF} = (W_{FL} - W_{FU}) \cos \theta_{RB} \text{ (mm)} \dots\dots\dots (9)$$

8.5.3 Case of a surface opening discontinuity on bottom face The ultrasonic discontinuity height t_{NF} shall be calculated according to formula (10) or formula (11).

$$t_{NF} = (W_{FL} - W_{FU}) \cos \theta_{RB} \text{ (mm)} \dots\dots\dots (10)$$

$$t_{NF} = t - (W_{FU} \times \cos \theta_{RB}) \text{ (mm)} \dots\dots\dots (11)$$

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