

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS Z 2350 : 2002

(JSNDI/JSA)

Method for measurement of performance characteristics of ultrasonic probes

ICS 19.100

Reference number : JIS Z 2350 : 2002 (E)

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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 2350 : 1992** is replaced with this Standard.

This revision has been made based on **ISO 10375 : 1997** *Non-destructive testing—Ultrasonic inspection—Characterization of search unit and sound field* and **ISO 12715 : 1999** *Ultrasonic non-destructive testing—Reference blocks and test procedures for the characterization of contact search unit beam profiles* for the purposes of making easy to compare this Standard with International Standards; to prepare Japanese Industrial Standard conforming with International Standards; and to propose a draft of International Standard which is based on Japanese Industrial Standard.

Date of Establishment: 1992-03-01

Date of Revision: 2002-03-20

Date of Public Notice in Official Gazette: 2002-03-20

Investigated by: Japanese Industrial Standards Committee
Standards Board

Technical Committee on Iron and Steel

JIS Z 2350 : 2002, First English edition published in 2003-08

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

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

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Printed in Japan

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Method for measurement of performance characteristics of ultrasonic probes

Introduction This Japanese Industrial Standard has been prepared based on the first edition of **ISO 10375** *Non-destructive testing—Ultrasonic inspection—Characterization of search unit and sound field* published in 1997 and the first edition of **ISO 12715** *Ultrasonic non-destructive testing—Reference blocks and test procedures for the characterization of contact search unit beam profiles* published in 1999 with modifying some technical contents.

In addition, the portions with sidelines or dotted underlines in this Standard are the matters which are specified by altering the original International Standards. A list of modification with its explanation is shown in Annex 2.

1 Scope This Standard specifies the method for measurement of performance characteristics of ultrasonic probes with a nominal frequency 0.5 MHz or over to and including 15 MHz (hereafter referred to as “probes”).

Remarks : The International Standards corresponding to this Standard are as follows.

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

ISO 10375 : 1997 *Non-destructive testing—Ultrasonic inspection—Characterization of search unit and sound field* (MOD)

ISO 12715 : 1999 *Ultrasonic non-destructive testing—Reference blocks and test procedures for the characterization of contact search unit beam profiles* (MOD)

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) indicated below shall be applied.

JIS B 0601 *Geometrical Product Specification (GPS)—Surface texture : Profile method—Terms, definitions and surface texture parameters*

JIS G 0801 *Ultrasonic examination of steel plates for pressure vessels*

JIS G 0901 *Classification of structural rolled steel plate and wide flat for building by ultrasonic test*

JIS G 4103 *Nickel chromium molybdenum steels*

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

JIS Z 2345 *Standard test blocks for ultrasonic testing*

3 Definitions For the purposes of this Standard, the definitions shall be in accordance with **JIS Z 2300**, and the following definitions shall apply.

- a) **sine burst wave** A wave obtained by taking out the certain fixed cycle from continuous sine wave signals.
- b) **squint angle of beam center axis** The angle of squint between actual value and design value for the center axis of ultrasonic beam.
- c) **beam characteristics** The value showing beam profiles, such as focal length, depth of field and beam diameter.
- d) **non-focused probes** Probes other than focused probes and double transducer probes.
- e) **focal depth** The depth of focal length from a test surface.
- f) **convergence depth** The depth of convergence length from a test surface.

4 Symbols The symbols shall be as follows:

h	Echo height
B	Bandwidth (MHz)
B_W	Fractional bandwidth (%)
C_N	Number of cycles
d_{FA}	Beam diameter at the start point of depth of field
d_{FB}	Beam diameter at the end point of depth of field
d_{FL}	Beam diameter at focal length or convergence length
F_D	Depth of field or convergence range
F_L	Focal length or convergence length
f	Frequency
f_L	Lower frequency at the 6 dB drop amplitude from the maximum amplitude of frequency spectrum of a probe
f_U	Upper frequency at the 6 dB drop amplitude from the maximum amplitude of frequency spectrum of a probe
f_C	Center frequency of a probe
f_P	Peak frequency of a probe
P_N	Number of peaks
S_r	Relative sensitivity
T_K	Thickness of ultrasonic propagation medium
T_{PD}	Pulse duration time
V_{in}	Excitation voltage signal amplitude
V_{out}	Output voltage signal amplitude
X_0	Near field length
X	Lateral direction of a probe (a direction perpendicular to an ultrasonic beam on a test surface, and in the case of normal probe, it is specified separately.)

- Y** Longitudinal direction of a probe (an ultrasonic beam direction on a test surface, and in the case of normal probe, it is specified separately.)
- Y_c, Y_1, Y_2** Distance on the test surface from the probe to the side-drilled hole, which indicates the probe location (Y_c) of the maximum echo height, two 6 dB drop probe locations (Y_1, Y_2) from the maximum echo height.
- Z** Distance from the test surface to the side-drilled hole center axis, and in the case of the immersion technique, water distance.
- Z_β** Longitudinal beam axis or path length of an angle probe
- Z_E** Electrical impedance
- θ** Refraction angle
- δ** Squint angle of beam axis, and in the case of an angle probe, it indicates squint angle of beam axis projected on the test surface.
- ϕ** Angle between X axis and beam axis projected on the test surface in the case of the normal beam technique

5 Marking of probe The marking symbol of probe shall be as shown in Table 1.

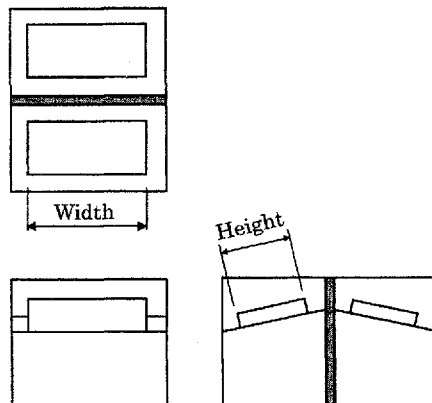
Table 1 Marking symbol of probe

Order of marking	Content	Class and symbol
1	Frequency bandwidth	Wide band: B , Narrow band: N ⁽¹⁾
2	Frequency	Nominal frequency expressed in MHz
3	Materials of transducer	Quartz: Q , Zircon lead titanate ceramics: Z , Piezoelectric-ceramics other than Z : C , Polymer system: P , Composite: K , Others: E , Materials not specified: M
4	Dimensions of transducer	Circular: diameter (unit: mm) For double transducer type, specify the dimensions of each transducer ⁽²⁾ . Square: height $\times$ width (unit: mm) ⁽³⁾
5	Mode of wave	Longitudinal wave: L ⁽⁴⁾ , Shear wave : S ⁽⁵⁾ , SH wave: H , Surface wave: R
6	Type	Normal beam: N , Angle beam: A , Variable angle: V , Immersion: I , Wheel: W , For double transducer type: add D
7	Refraction angle	To be expressed by nominal refraction angle into low-carbon steel. Unit: degrees. For other materials, add symbol, etc. indicating them.
8	Focal depth or convergence depth	For point focused type, add PF . For line focused type, add LF . For those having intersection point such as double transducer type, add F . Express the depth in mm.

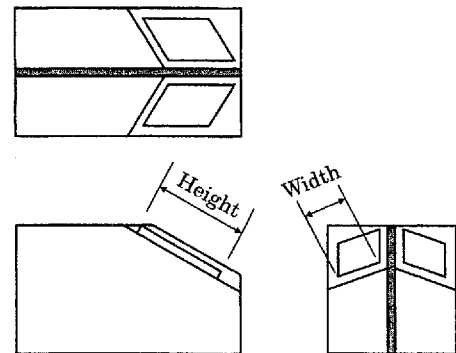
Notes ⁽¹⁾ It may be omitted.

⁽²⁾ Dimensions of transducer of double transducer probe.

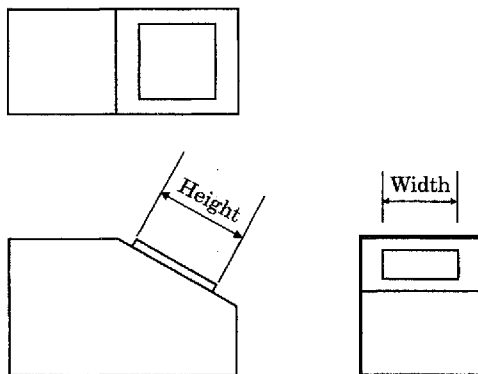
Normal probe



Angle probe



(3) Dimensions of transducer of single transducer probe.



(4) In the case of normal probe, it may be omitted.

(5) In the case of SV wave angle probe, it may be omitted.

Example 1 2Z20N: 2 MHz normal probe provided with zircon lead titanate ceramics transducer of $\phi 20$ mm.

Example 2 5Z10/2NDF10: 5 MHz double transducer normal probe of 10 mm in convergence depth provided with zircon lead titanate ceramics transducer divided into two semicircles of $\phi 10$ mm.

Example 3 2C20 $\times$ 14A45: 2 MHz angle probe of refraction angle of 45 degrees provided with piezoelectric-ceramics transducer other than zircon lead titanate ceramics system of 20 mm in height and 14 mm in width.

Example 4 2Z10 $\times$ 10HA45: 2 MHz SH wave angle probe of refraction angle of 45 degrees provided with zircon lead titanate ceramics transducer of 10 mm in height and 10 mm in width.

Example 5 B10K20I: 10 MHz wide band immersion probe provided with composite transducer of $\phi 20$ mm.

Example 6 3Z15IPF10: 3 MHz point focusing immersion probe of 10 mm in focal length provided with zircon lead titanate ceramics transducer of $\phi 15$ mm.

Example 7 5Z20 × 10AD45F30: 5 MHz double transducer angle probe of refraction angle of 45 degrees and 30 mm in convergence depth provided with zircon lead titanate ceramics transducer of 20 mm in height and 10 mm in width.

Example 8 10C5 × 5R: 10 MHz surface wave probe provided with piezoelectric-ceramics transducer other than zircon lead titanate ceramics system of 5 mm in height and 5 mm in width.

6 Items for measurement

6.1 Common items for measurement The common items for measurement shall be the items for measurement applied in common with all probes, and shall be as follows:

- a) Frequency response
- b) Time domain response
- c) Relative sensitivity
- d) Electrical impedance

6.2 Specific items for measurement The specific items for measurement shall be the items for performance measurement relevant to the ultrasonic beam profile of probe, and shall be classified into the following items from the difference in the shape of probe, and the measuring method shall be specified. **a) to d)** include items for measurement of contact probe, and **e)** includes those for measurement of immersion probe.

In addition, the shear wave normal probe and SH wave angle probe shall not apply.

- a) **Single transducer normal probe** The single transducer normal probe shall be as follows:
 - 1) Beam profile and distance amplitude characteristics
 - 2) Squint angle of beam center axis of non-focused probe
 - 3) Beam characteristics of focused probe
- b) **Double transducer normal probe** The double transducer normal probe shall be as follows:
 - 1) Beam profile and distance amplitude characteristics
 - 2) Beam characteristics
- c) **Single transducer angle probe** The single transducer angle probe shall be as follows:
 - 1) Longitudinal amplitude beam profile and distance amplitude characteristics
 - 2) Lateral amplitude beam profile and distance amplitude characteristics

- 3) Probe index and refraction angle of non-focused probe
 - 4) Squint angle of beam center axis of non-focused probe
 - 5) Longitudinal amplitude beam characteristics of focused probe
 - 6) Lateral amplitude beam characteristics of focused probe
 - 7) Dead zone
- d) **Double transducer angle probe** The double transducer angle probe shall be as follows:
- 1) Longitudinal amplitude beam profile and distance amplitude characteristics
 - 2) Lateral amplitude beam profile and distance amplitude characteristics
 - 3) Longitudinal amplitude beam characteristics
 - 4) Lateral amplitude beam characteristics
- e) **Single transducer immersion normal probe** The single transducer immersion normal probe shall be as follows:
- 1) Beam profile and distance amplitude characteristics
 - 2) Beam characteristics of focused probe

7 Measuring method of common items for measurement

7.1 Frequency response

7.1.1 Apparatus to be used and connection method The apparatus to be used for measurement of frequency response shall be the apparatus with the following specifications, and the connection method shall be as shown in Fig. 1.

- a) **Pulser and receiver**⁽⁶⁾ The pulser and receiver shall be the apparatus with spike pulse system which is capable of exciting the object probe in the appropriate frequency range.
- b) **Gate circuit**⁽⁷⁾ The gate circuit shall take only the target RF signal out, and the frequency band shall be 50 MHz or more.
- c) **Oscilloscope**⁽⁸⁾ The frequency band shall be 50 MHz or more.
- d) **Frequency analyzer**⁽⁹⁾ The frequency band shall be 50 MHz or more.
- e) **Coaxial cable** 50 Ω coaxial cable.

Notes ⁽⁶⁾, ⁽⁷⁾, ⁽⁸⁾, ⁽⁹⁾ The built-in function of ultrasonic test instrument may be used.

⁽⁷⁾, ⁽⁸⁾, ⁽⁹⁾ Fast Fourier transform (FFT) may be used with the AD converter and personal computer.

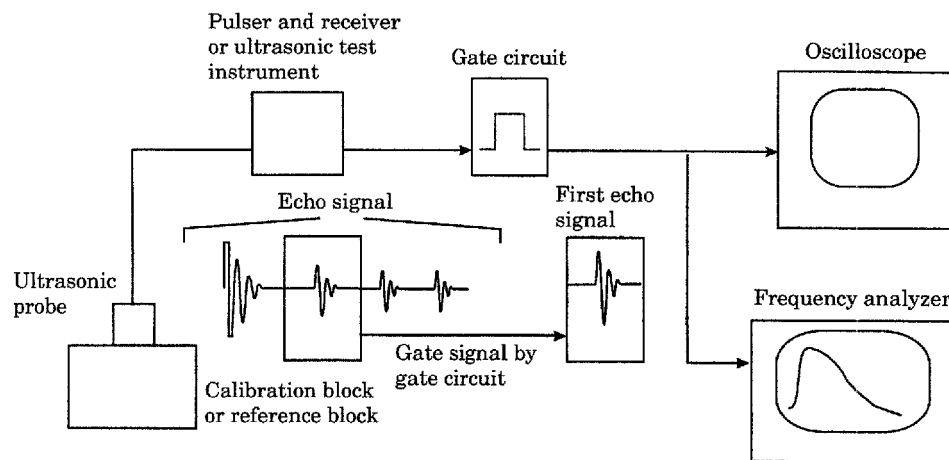


Fig. 1 Connection method for measurement of frequency response

7.1.2 Blocks The following blocks shall be properly used according to the kind of probe.

- In the case of normal probe** Plate reference block with the thickness needed for a test⁽¹⁰⁾ ⁽¹¹⁾. Or reference block RB-E (see Annex 1 of **JIS G 0801** or Annex 1 of **JIS G 0901**).
- In the case of angle probe** STB-A1 calibration block specified in Attached Fig. 3 of **JIS Z 2345**.
- In the case of immersion probe** Steel or glass plate blocks⁽¹²⁾.

Notes ⁽¹⁰⁾ The material shall be the ultrasonic characteristic material which is equivalent to STB-A1 or the test object material.

⁽¹¹⁾, ⁽¹²⁾ The processing accuracy shall be ± 0.1 mm, and the roughness of test surface and reflection surface shall be better than $25 \mu m R_a$ (see **JIS B 0601**).

7.1.3 Detection method of echo signal (see Fig. 2 and Fig. 3) The detection method of echo signal shall be as follows:

- In the case of normal probe**
 - Detect the bottom echo signal of a part having thickness of 0.75 times to 1.5 times the near field length X_0 or a part having thickness near focal length F_L using mineral oil or glycerin as the couplant⁽¹³⁾.
 - Then, add a moderate load and contact blocks with the probe uniformly.
 - For the transmission technique, detect the transmission pulse through the thickness of not less than the near field length X_0 .
- In the case of angle probe**
 - Detect the echo signal from the R100 surface of calibration block STB-A1 using mineral oil or glycerin as the couplant⁽¹⁴⁾.
 - Then, add a moderate load and make the probe contact blocks uniformly.

- For the transmission technique, detect the V transmission pulse using the flat side of calibration block STB-A1.

c) **In the case of immersion probe**

- Detect the surface echo signal of plate block which is located so that the water distance becomes the near field length X_0 or the focal length F_L .
- Then, adjust the direction of probe, and detect the echo signal when the amplitude is maximized.

Notes ⁽¹³⁾, ⁽¹⁴⁾ Use the couplant for shear wave in the case of shear wave normal probe or SH wave probe.

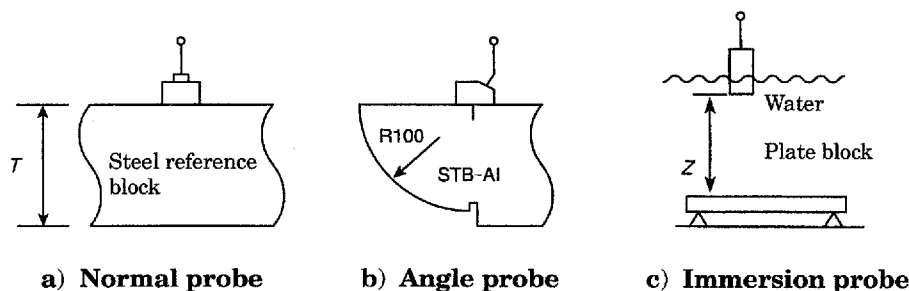


Fig. 2 Detection method of echo signal (single probe technique)

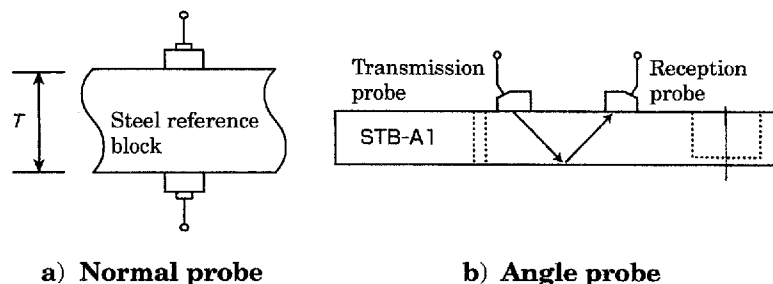


Fig. 3 Detection method of echo signal (transmission technique)

7.1.4 Measurement (see Fig. 4) The whole first echo waveform shall be taken out by the gate circuit, input into the frequency analyzer, and frequency spectrum shall be obtained. The peak frequency, lower frequency, upper frequency, center frequency, bandwidth and fractional bandwidth shall be determined from the frequency spectrum according to the following.

- Peak frequency (MHz) f_P : a frequency at the maximum amplitude point of frequency spectrum
- Lower frequency (MHz) f_L : a lower frequency at the 6 dB drop amplitude points from the maximum amplitude
- Upper frequency (MHz) f_U : a upper frequency at the 6 dB drop amplitude points from the maximum amplitude point
- Center frequency (MHz) f_C : $f_C = (f_L + f_U)/2$
- Bandwidth (MHz) B : $B = f_U - f_L$
- Fractional bandwidth (%) B_W : $B_W = [(f_U - f_L)/f_C] \times 100$

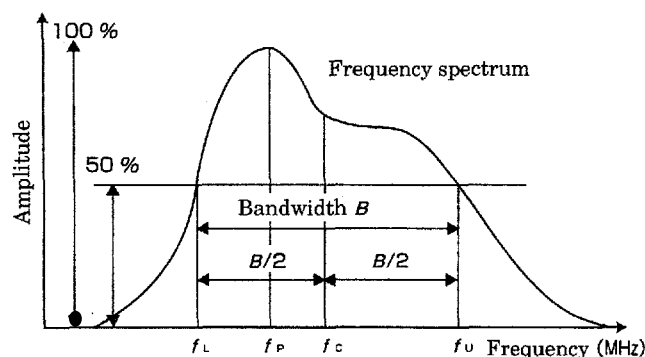


Fig. 4 Example of frequency spectrum

7.2 Time domain response

7.2.1 Apparatus to be used and connection method For the measurement of time domain response, the apparatus connected as shown in Fig. 5 shall be used. The performance of apparatus shall be the same as that in the case (7.1.1) of measurement of frequency response.

7.2.2 Blocks The same blocks (7.1.2) as those for measurement of frequency response shall be used.

7.2.3 Detection method of echo signal Detect the first echo signal by the same method (7.1.3) as that for measurement of frequency response.

7.2.4 Measurement The magnitude of the peak which is the maximum in absolute value in the observed echo wave form shall be h_{MAX} , and the number of peaks P_N , number of cycles C_N , pulse duration time T_{PD} shown below shall be determined (see Fig. 6).

- | | |
|---------------------------------------|---|
| Number of peaks P_N : | Number of peaks exceeding $\pm 20\%$ of h_{MAX} |
| Number of cycles C_N : | Half of number of peaks ($= P_N/2$) |
| Pulse duration time T_{PD} : | Time from the leading edge zero cross point of the first peak exceeding $\pm 20\%$ of h_{MAX} to the trailing edge zero cross point of the last peak exceeding $\pm 20\%$ of h_{MAX} (μsec). |

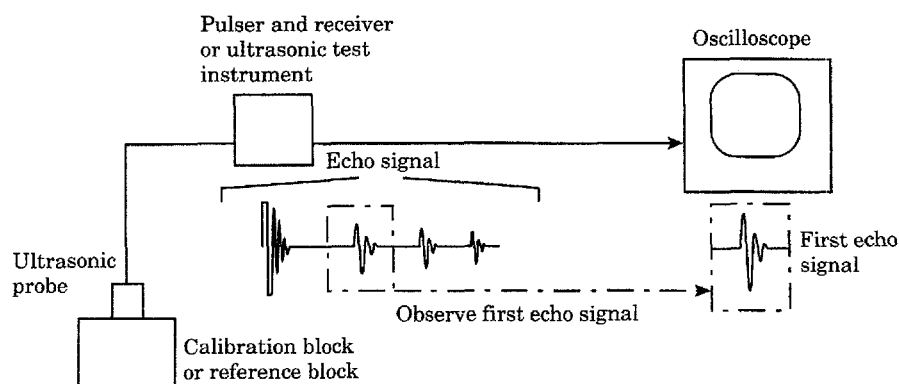


Fig. 5 Connection method for measurement of time domain response