SLOVENSKI STANDARD
SIST EN 12668-2:2002

01-junij-2002

Neporuġitveno preskuġanje - Ugotavljanje znaļ ilnosti in overjanje naprav za ultrazvoļ no preskuġanje - 2. del: Preskuġevalne glave

Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 2: Probes

Zerstörungsfreie Prüfung - Charakterisierung und Verifizierung der Ultraschall-Prüfausrüstung - Teil 2: Prüfköpfe

Essais non destructifs - Caractérisation et vérification de l'appareillage de contrôle par ultrasons - Partie 2: Traducteurs

Ta slovenski standard je istoveten z: **EN 12668-2:2001**

ICS:

19.100	Neporušitveno preskušanje	Non-destructive testing

SIST EN 12668-2:2002 **en**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 12668-2

May 2001

ICS 19.100

English version

Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 2: Probes

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This European Standard was approved by CEN on 16 April 2001.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 138, "Non-destructive testing", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2001, and conflicting national standards shall be withdrawn at the latest by November 2001.

This standard consists of the following parts :

— *EN 12668-1, Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 1: Instruments*

— *EN 12668-2, Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 2: Probes*

— *EN 12668-3, Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 3: Combined equipment*

Annex A is normative. Annex B is informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European standard covers probes used for ultrasonic non-destructive examination in the following categories with centre frequencies in the range 0,5 MHz to 15 MHz, focusing and without focusing means:

a) single or dual transducer contact probes generating compressional or shear waves ;

b) immersion probes.

Where material dependent ultrasonic values are specified in this standard they are based on steels having an ultrasonic sound velocity of (5 920 ± 50) m/s for longitudinal waves, and (3 255 ± 30) m/s for transverse waves.

Periodic tests for probes are not included in this standard. Routine tests for the verification of probes using on-site methods are given in EN 12668-3.

If parameters in addition to those specified in EN 12668-3 are to be verified during the probe's life time, as agreed upon by the contracting parties, the methods of verification for these additional parameters should be selected from those given in this standard.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1330-4, *Non destructive testing - Terminology - Part 4 : Terms used in ultrasonic testing.*

EN 12223, *Non-destructive testing - Ultrasonic examination - Specification for calibration block No. 1.*

EN 12668-1, *Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 1 : Instruments.*

EN 12668-3, *Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 3 : Combined equipment.*

EN 27963, *Welds in steel - Calibration block No. 2 for ultrasonic examination of welds (ISO 7963:1985).*

EN ISO 9001, *Quality systems - Model for quality assurance in design, development, production, installation and servicing (ISO 9001:1994).*

EN ISO 9002, *Quality systems - Model for quality assurance in production, installation and servicing (ISO 9002:1994).*

3 Terms, definitions, symbols and abbreviations

For the purposes of this European Standard the terms and definitions given in EN 1330-4 apply, together with the following terms and definitions.

3.1
dead zone
depth of the zone immediately beneath the coupling surface of the work piece, in which it is not possible to detect a given reflector

3.2
focal distance; (nearfield length)
point on the acoustical axis where the acoustic pressure is at its maximum

3.3
horizontal plane of a sound beam
with angle-beam probes the plane perpendicular to the vertical plane of sound beam including the acoustical axis in the material

3.4
operating frequency, f_o; (centre frequency)
in the frequency spectrum of an echo the upper and lower cut-off-frequencies are determined at -6 dB compared to the maximum amplitude. With these upper and lower frequencies f_u and f_l the centre frequency is calculated as :

$$f_o = \sqrt{f_u \cdot f_l}$$

3.5
peak-to-peak amplitude, *h*
maximum deviation between the largest positive and the largest negative cycles of the pulse (see Figure 1)

3.6
probe data sheet
sheet giving information on probe performance which accompanies each probe. The data sheet need not necessarily be a test certificate of individual probe performance

3.7
pulse duration
time interval over which the modulus of the unrectified pulse amplitude exceeds 10 % of its maximum amplitude, as shown in Figure 1

3.8
reference side
reference side is the right side of an angle beam probe looking in the direction of the beam, unless otherwise specified by the manufacturer

3.9
relative bandwidth, Δf_{rel}
ratio of the difference of the upper and lower cut-off frequencies f_u and f_l and the centre frequency f_o in percent

$$\Delta f_{rel} = [(f_u - f_l)/f_o] \times 100\ \%$$

3.10
squint angle for straight-beam probes, δ
deviation between the axis of the beam and a perpendicular to the coupling surface at the emission point (see Figure 2)

For angle-beam probes
angle between the sides of the probe housing and the measured beam axis, projected onto the plane of the probe face (see Figure 3)

3.11
transducer
element in the probe which transforms electrical oscillations to mechanical oscillations and vice versa, in most cases piezoelectric elements

3.12
vertical plane of a sound beam
with angle-beam probes the plane in which the sound beam axis in the probe wedge and the sound beam axis in the inspected component both lie

4 General requirements for compliance

A probe complies with this standard if it satisfies the following conditions:

a) the probe shall meet the technical requirements of this standard ;

b) the probe carries a unique serial number, showing operating frequency, transducer size, angle, and wave mode, or a permanent reference number from which this information can be traced ;

c) a data sheet is available for the appropriate type and series of probes which gives the performance in accordance with clause 5 of this standard.

The quality of probes will be assured in one of the following ways :

a) where a large number of identical probes are manufactured under a quality management system, e.g. EN ISO 9001 and EN ISO 9002, measurements are made on a statistically selected number of probes. The manufacturer supplies a data sheet which includes the values of the specified parameters with tolerances ;

b) by issuing a declaration of conformity quoting the results of measurements made on an individual probe. This is suitable where only a small number of probes of each type is manufactured or where probes are required for special applications.

5 Manufacturer's technical specification for probes

Table 1 gives the list of information to be reported by a manufacturer in a data sheet for all probes within the scope of this standard (I = Information, M = Measurement, C = Calculation). The data sheet shall also contain information concerning the instrument used for the test, its settings and coupling conditions etc.

The manufacturer shall also state the operating temperature range of the probe, and any special conditions for storage or protection during transport.

The supplier and the customer can agree where necessary to preclude some of the information and/or include some other details not included in Table 1.

For probes intended for use at elevated temperatures the manufacturer shall provide information on the maximum operating temperature in relation to the time of use, and the effect of temperature on the sensitivity and on the beam angle.

Table 1 — List of information to be given in a data sheet

Information to be given	Category of probe															
	Contact														Immersion	
	Straight beam					Angle beam									Straight	
	Compressional				Shear	Compressional				Shear					Compressional	
	Single		Double		Single	Single		Double		Single		Double			Single	
	non-f.	focus.	non-f.	focus.	non-f.	non-f.	focus.	non-f.	focus.	non-f.	focus.	non-f.	focus.		non-f.	focus.
Manufacturer's name	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I
Type of probe	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I
Weight & size of probe	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I
Type of connectors	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I
TR connect. interchangeable			I	I				I	I			I	I			
Material of transducers	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I
Shape & size of transducers	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I
Material of wedge, delay	I	I	I	I		I	I	I	I	I	I	I	I			
Material of wear plate	I															
Wear allowance	I	I	I	I		I	I	I	I	I	I	I	I			

I = Information ;

M = Measurement ;

C = Calculation

continued

Table 1 *(continued)*

Parameters to be measured or calculated	Category of probe														
	Contact													Immersion	
	Straight beam					Angle beam								Straight	
	Compressional				Shear	Compressional				Shear				Compressional	
	Single		Double		Single	Single		Double		Single		Double		Single	
	non-f.	focus.	non-f.	focus.	non-f.	non-f.	focus.	non-f.	focus.	non-f.	focus.	non-f.	focus.	non-f.	focus.
Cross talk damping			M	M				M	M			M	M		
Pulse shape (time & frequency)	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Centre frequency, band width	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Pulse-echo sensitivity	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Distance-amplitude curve	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C
Impedance, static capacitance	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M

I = Information ;
M = Measurement ;
C = Calculation ;
M,C = Measurement or calculation

continued

Table 1 *(concluded)*

Parameters to be measured or calculated	Category of probe														
	Contact													Immersion	
	Straight beam					Angle beam								Straight	
	Compressional				Shear	Compressional				Shear				Compressional	
	Single		Double		Single	Single		Double		Single		Double		Single	
	non-f.	focus.	non-f.	focus.	non-f.	non-f.	focus.	non-f.	focus.	non-f.	focus.	non-f.	focus.	non-f.	focus.
Probe index						M	M	M	M	M	M	M	M		
Beam angle						M	M	M	M	M	M	M	M		
Angles of divergence	M				M	M				M				M	
Beam axis offset	M	M	M	M	M	M	M	M	M	M	M	M	M		
Squint angle	M	M	M	M	M	M	M	M	M	M	M	M	M		
Focal distance, nearfield	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C	M,C
Focal width	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Focal length	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Physical aspects	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M

I = Information ;
M = Measurement ;
C = Calculation ;
M,C = Measurement or calculation
Non-f. = non-focusing

6 Test equipment

6.1 Electronic equipment

The ultrasonic instrument (or laboratory pulser/receiver) used for the tests specified in clause 7 shall be of the type designated on the probe data sheet, and shall comply with EN 12268-1 as applicable. Where more than one type of ultrasonic instrument is designated the tests shall be repeated with each of the additional designated types.

Testing shall be carried out with the probe cables and electrical matching devices, specified on the probe data sheet for use with the particular type of ultrasonic instrument.

NOTE Probe leads more than about 2 m long could have significant effect on probe performance.

In addition to the ultrasonic instrument or laboratory pulser/receiver the items of equipment essential to assess probes in accordance with this standard are as follows :

a) an oscilloscope with a minimum bandwith of 100 MHz ;

b) a frequency spectrum analyzer with a minimum bandwith of 100 MHz, or an oscilloscope/digitizer capable of performing Discrete Fourier Transforms (DFT) ;

c) an impedance analyzer.

The following additional equipment is optional :

For contact probes only :

d) an electromagnetic-acoustic probe (EMA) and receiver ;

e) a plotter to plot directivity diagrams.

For immersion probes only :

f) hydrophone receiver with an active diameter less than two times the central ultrasonic wavelength of the probe under test but not less than 0,5 mm. The bandwidth of the amplifier should be higher than the bandwidth of the probe under test.

6.2 Test blocks and other equipment

The following test blocks shall be used to carry out the specified range of tests, for contact probes only :

a) semi-cylinders with different radii (R) in the range from 12 mm to 200 mm steps of $R\sqrt{2}$ are recommended. Steel quality is as defined in EN 27963. The thickness of each block shall be equal to or larger than it's radius, up to a maximum thickness of 100 mm ;

b) steel blocks with parallel faces and side-drilled holes of 3 mm diameter as shown in Figure 4 a). The dimensions of the blocks shall meet the following requirements :

— length, l, height, h, and width, w, shall be such that the sides of the blocks shall not interfere with the ultrasonic beam ;

— depths of the holes, d_1, d_2, ... shall be such that at least 3 holes shall fall outside the near field ;

— the distance between the holes, s, shall be such that the amplitude profile across the holes shows an amplitude drop of at least 26 dB between two adjacent holes ;

— steel quality is as defined in EN 27963.

c) steel blocks with inclined faces with a notch as shown in Figure 4 b), and steel blocks with hemispherical holes as in Figures 4 c) and 4 d). Steel quality is as defined in EN 27963. These blocks are used to measure the beam divergence in the vertical and horizontal plane respectively ;

d) an alternative steel block to measure index point, beam angle and beam divergence for angle beam probes is given in annex A ;

e) ruler ;

f) feeler gauges starting at 0,05 mm.

NOTE Not all blocks are required if only special kinds of probes are to be checked, e.g. blocks to measure the index point and beam angle are not necessary if only straight-beam probes have to be measured.

For testing immersion probes the following reflectors and additional equipment shall be used :

g) a steel ball or semi-spherical ended rod with smooth reflective surface. For each frequency range the diameter of ball or rod to be used is given in Table 2.

Table 2 — Steel ball (rod) diameters for different frequencies

Probe centre frequency (MHz)	**Diameter *d* of ball or rod** (mm)
$3 < f \leq 15$	$d \leq 3$
$0{,}5 \leq f \leq 3$	$3 < d \leq 5$

h) a large plane and flat reflector target. The target's lateral size shall be at least ten times wider than the diameter of the beam of the probe under test at the end of focal zone, as defined in 7.7.2.2.

Thickness is at least five times the wave length of the probe under test, calculated using the velocity of ultrasound in the material of the target.

i) immersion tank equipped with a manual or automatic scanning bridge with five free axes :

— three linear axes X, Y, Z ;

— two angular axes Θ and Ψ.

j) Automatic recording means: If the amplitudes of ultrasonic signals are recorded automatically, then it is the responsibility of the manufacturer to ensure that the system has sufficient accuracy. In particular consideration shall be given to the effects of the system bandwidth, spatial resolution, data processing and data storage on the accuracy of the results.

Throughout this standard the coordinate system shown in Figures 12 and 13 is used.

The scanning mechanism used with the immersion tank should be able to maintain alignment between the target and the probe in the X and Y directions, i.e. within ± 0,1 mm for 100 mm distance in the Z direction.

The temperature of the water in the immersion tank shall be maintained at (20 ± 2) °C during the beam characterization of immersion transducers described in 7.7.

Care shall be taken about the influence of sound attenuation in water, which, at high frequencies, causes a downshift of the echo frequency when using broadband probes.

Table 3 shows the relation between frequency downshift and water path.

Table 3 — Frequency downshift in percent of centre frequency *f*o depending on total water path length, for relative bandwidths (b.w.) 50 % and 100 %

f_o	b.w.	Total water path in mm															
MHz	%	10	20	30	40	50	60	70	80	90	100	150	200	250	300	350	400
5	50	0	0	0	0	0	0	1	1	1	1	1	2	2	2	3	3
	100	0	1	1	1	2	2	2	3	3	3	5	6	7	9	10	11
10	50	0	1	1	1	2	2	2	3	3	3	5	6	7	9	10	11
	100	1	3	4	5	6	7	8	9	10	11	16	21	24	28	31	34
15	50	1	1	2	3	4	4	5	6	6	7	10	13	15	18	20	23
	100	3	6	8	10	13	15	17	19	21	23	30	37	42	47	50	54
20	50	1	3	4	5	6	7	8	9	10	11	16	21	24	28	31	34
	100	5	10	13	17	21	24	27	29	32	34	44	51	56	61	64	67
25	50	2	4	6	7	9	11	12	14	15	17	23	29	34	38	41	45
	100	7	14	20	24	29	33	36	39	42	45	55	62	67	70	74	76
30	50	3	6	8	10	13	15	17	19	21	23	30	37	42	47	50	54
	100	10	19	26	32	37	41	45	48	51	54	64	70	74	78	80	82

7 Performance requirements for probes

7.1 Physical aspects

7.1.1 Method

Visually inspect the outside of the probe for correct identification and assembly and for physical damage which can influence its' current or future reliability. In particular for contact probes measure the flatness of the contact surface of the probe using a ruler and feeler gauges.

7.1.2 Acceptance criterion

For flat faced probes, over the whole probe face the gap shall not be larger than 0,05 mm.

7.2 Radio frequency pulse shape

7.2.1 Method

The amplitude and pulse duration of the echo is determined with a measurement setup as in Figure 5 (contact probe) or Figure 13 (immersion) :

a) for contact probes with a single transducer the echo out of a semi-cylinder is used whose radius is larger than 1,5 of the nearfield length of the probe or within the focal range of focused probes ;

b) for dual-transducer probes a semi-cylinder is used whose radius is nearest to the focal point of the probe ;

c) for immersion probes a large flat reflector is used at the focal distance for focused probes or at more than 1 of the nearfield length for flat transducers.

The pulser setting shall be recorded, and the peak-to-peak amplitude of the transmitter pulse shall be measured. It is recommended to plot the transmitter pulse shape and it is preferable that the plot of the transmitter pulse be included in the results of this test.

7.2.2 Acceptance criterion

The pulse duration shall not deviate by more than ± 10 % from the manufacturer's specification.

7.3 Pulse spectrum and bandwidth

7.3.1 Method

Use the same blocks and the same setup is used as in 7.2. Gate the reflector echo and determine the frequency spectrum using a spectrum analyzer or a Discrete Fourier Transform.

Spurious echoes from the probe's wedge, housing, damping block, etc. are not to be analyzed together with the echo from the reference block. The gate has to be twice the pulse duration as a minimum and centered on the maximum of the pulse.

The lower and upper frequencies for a - 6 dB drop of echo amplitude have to be measured. For immersion technique the values shall be corrected according to Table 3.

From these upper and lower frequencies f_u and f_l the centre frequency f_o is calculated :

$$f_o = \sqrt{f_u \times f_l} \qquad (1)$$