
**Steel castings — Ultrasonic
examination —**

Part 2:
**Steel castings for highly stressed
components**

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4992-2 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 11, *Steel castings*.

ISO 4992 consists of the following parts, under the general title *Steel castings* — *Ultrasonic examination*:

- *Part 1: Steel castings for general purposes*
- *Part 2: Steel castings for highly stressed components*

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Steel castings — Ultrasonic examination —

Part 2: Steel castings for highly stressed components

1 Scope

This part of ISO 4992 specifies the requirements for the ultrasonic examination of steel castings (with ferritic structure) for highly stressed components, and the methods for determining internal discontinuities by the pulse echo technique.

This part of ISO 4992 applies to the ultrasonic examination of steel castings which have usually received a grain-refining heat treatment and which have wall thicknesses up to and including 600 mm. For greater wall thicknesses, special agreements apply with respect to the test procedure and recording levels.

This part of ISO 4992 does not apply to austenitic steels and joint welds.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5577, *Non-destructive testing — Ultrasonic inspection — Vocabulary*

ISO 7963, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 2*

EN 583-1, *Non-destructive testing — Ultrasonic examination — Part 1: General principles*

EN 583-2, *Non-destructive testing — Ultrasonic examination — Part 2: Sensitivity and range setting*

EN 583-5,2005, *Non-destructive testing — Ultrasonic examination — Part 5: Characterization and sizing of discontinuities*

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 12668-2, *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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, EN 583-1, EN 583-2, EN 583-5 and EN 1330-4, and the following, apply.

3.1 reference discontinuity echo size
smallest indication to be recorded during the assessment phase of an ultrasonic examination, usually expressed as an equivalent flat-bottomed hole diameter

3.2 point discontinuity
discontinuity, the dimensions of which are smaller than or equal to the sound-beam diameter

NOTE Dimensions in this part of ISO 4992 relate to length, width and/or dimension in the through-wall direction.

3.3 complex discontinuity
discontinuity, the dimensions of which are larger than the sound-beam diameter

NOTE Dimensions in this part of ISO 4992 relate to length, width and/or dimension in the through-wall direction.

3.4 planar discontinuity
discontinuity having two measurable dimensions

3.5 volumetric discontinuity
discontinuity having three measurable dimensions

3.6 special rim zone
outer rim-zone part with special requirements

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NOTE Examples of special requirements are machined surfaces, higher stresses and sealing surfaces.

3.7 production welding
any welding carried out during manufacturing before final delivery to the purchaser

3.7.1 joint welding
production welding used to assemble components together to obtain an integral unit

3.7.2 finishing welding
production welding carried out in order to ensure the agreed quality of the casting

4 Requirements

4.1 Order information

The following information shall be available at the time of enquiry and order (see also EN 583-1):

- the areas of the casting and the number or percentage of castings to which the ultrasonic examination requirements apply;
- the severity level to be applied to the various zones or areas of the casting;

- requirements for a written examination procedure;
- whether there are any additional requirements for the examination procedure, see also 5.5.1.

4.2 Extent of examination

The casting shall be examined so that the agreed areas are totally covered (insofar as this is possible from the shape of the casting) by the use of the best applicable examination technique.

For wall thicknesses greater than 600 mm, agreement shall be made between the parties concerned on the test procedure and also on the recording and acceptance levels.

4.3 Maximum permissible size of discontinuities

4.3.1 General

The purchaser shall specify the acceptance level according to the required severity level for planar and volumetric discontinuities within each zone and in each specified area of the casting.

The wall section shall be divided into zones as shown in Figure 1. These sections relate to the sizes of castings ready for assembly (finish machined).

4.3.2 Indications without measurable dimensions

In special rim zones and at weld preparation ends, indications without measurable dimensions are limited to a maximum number of indications.

These indications shall not exceed the limits given in Table 1.

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4.3.3 Indications with measurable dimensions

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4.3.3.1 Planar discontinuities

Planar discontinuities shall not exceed the limits given in Figure 2.

The area of indication with measurable length, but with a non-measurable dimension in the through-wall direction, shall be calculated in accordance with the formula given in Figure 2.

The sizing of small planar discontinuities, as given in Figure 2, becomes more difficult with increasing beam-path length and sound-beam diameter. As a guide, these sizings are normally applied to a rim zone of 30 mm. This makes the use of probes with focussed beams, such as twin-crystal probes, necessary.

4.3.3.2 Volumetric discontinuities

Volumetric discontinuities shall not exceed the sizes given in Figure 3 for the rim zone and Figure 4 for the core zone. Indications with measurable dimensions are not permissible in severity level 1. The area of an indication with measurable length but non-measurable width shall be calculated in accordance with the formula given in Figures 3 and 4.

4.4 Personnel qualification

It is assumed that ultrasonic examination is performed by qualified and capable personnel. In order to prove this qualification, it is recommended to certify personnel according to ISO 9712 or EN 473.

4.5 Wall-section zones

The wall section shall be divided into zones as shown in Figure 1. These sections relate to the dimensions of the casting ready for assembly (finish machined).

4.6 Severity levels

If the purchaser specifies different severity levels in different areas of the same casting, all of these areas shall be clearly identified on the purchaser's drawing and shall include:

- all necessary dimensions for accurate location of zones;
- the full extent of all weld preparations and the thickness of any special rim zone.

Severity level 1 is only applied to weld preparations and special rim zones.

Unless other requirements have been agreed by the time of acceptance of the order, for finishing welds, the requirements for the parent metal shall apply.

5 Examination

5.1 Principles

The principles of ultrasonic examination given in EN 583-1, EN 583-2 and EN 583-5 shall apply.

5.2 Material

The suitability of material for ultrasonic examination is assessed by comparison with the echo height of a reference reflector (usually the first backwall echo) and the noise signal. This assessment shall be carried out on selected casting areas which are representative of the surface finish and of the total thickness range. The assessment areas shall have parallel surfaces.

The reference echo height according to Table 2 shall be at least 6 dB above the noise signal.

If the echo height of this smallest detectable flat-bottomed or equivalent side-drilled hole diameter at the end of the test range to be assessed is less than 6 dB above the grass level, then the ultrasonic testability is reduced. In this case, the flat-bottomed or side-drilled hole diameter which can be detected with a signal-noise ratio of at least 6 dB shall be noted in the test report and the additional procedure shall be agreed between the manufacturer and the purchaser.

NOTE For the definition of an adequate flat-bottomed hole size, the distance gain size system (DGS) or a test block of identical material, heat treatment condition and section thickness containing flat-bottomed holes with a diameter according to Table 2 or equivalent side-drilled holes, can be used. The following formula is used for converting the flat-bottomed hole diameter into the side-drilled hole diameter:

$$D_Q = \frac{4,935 \times D_{FBH}^4}{\lambda^2 \times s} \quad (1)$$

where

- D_Q is the side-drilled hole diameter, in millimetres;
- D_{FBH} is the flat-bottomed hole diameter, in millimetres;
- λ is the wave length, in millimetres;
- s is the path length, in millimetres.

The formula is applicable for $D_Q \geq 2\lambda$ and $s \geq 5 \times$ near-field length and is only defined for single element probes.

5.3 Equipment, coupling medium, sensitivity and resolution of detection

5.3.1 Ultrasonic instrument

The ultrasonic instrument shall meet the requirements given in EN 12668-1 and shall have the following characteristics:

- range setting, from at least 10 mm to 2 m continuously selectable, for longitudinal and transverse waves transmitted in steel;
- gain, adjustable in 2 dB maximum steps over a range of at least 80 dB with a measuring accuracy of 1 dB;
- time-base and vertical linearities less than 5 % of the adjustment range of the screen;
- suitability, at least for nominal frequencies from 1 MHz up to and including 6 MHz, in the pulse-echo technique with single-crystal and twin-crystal probes.

5.3.2 Probes and transducer frequencies

The probes and transducer frequencies shall be as given in EN 12668-2 and EN 12668-3 with the following exceptions:

- nominal frequencies shall be in the range 1 MHz to 6 MHz;
- for oblique incidence, angle probes with angles between 35° and 70° shall be used.

NOTE Normal or angle probes can be used for the examination of steel castings for highly stressed components. The type of probe used depends on the geometry of the casting and the type of discontinuity to be detected.

For examining zones close to the surface, twin-crystal probes (normal or angle) should be preferred.

5.3.3 Checking the ultrasonic examination equipment

The ultrasonic examination equipment shall be checked regularly by the operator in accordance with EN 12668-3.

5.3.4 Coupling medium

A coupling medium in accordance with EN 583-1 shall be used. The coupling medium shall wet the examination area to ensure satisfactory sound transmission. The same coupling medium shall be used for calibration and all subsequent examination operations.

NOTE The sound transmission can be checked by ensuring one or more stable backwall echoes in areas with parallel surfaces.

5.3.5 Sensitivity and resolution of detection

The detection sensitivity of the instrument shall allow at least the setting of the sensitivity in accordance with the requirements of 5.5.2.

The resolution of detection of the instrument/probe combination shall meet the requirements of Annex A.

5.4 Preparation of casting surfaces for testing

For the preparation of casting surfaces for examination, see EN 583-1.

The casting surfaces to be examined shall be such that satisfactory coupling with the probe can be achieved.

In the case of single-crystal probes, satisfactory coupling can be achieved if the condition of the surfaces to be examined corresponds at least to the limit comparator 4 S1 or 4 S2 according to EN 1370.

The roughness of any machined surface to be examined shall be $R_a \leq 12,5 \mu\text{m}$.

For special techniques, higher surface qualities such as 2 S1, 2 S2 (see EN 1370) and $R_a \leq 6,3 \mu\text{m}$ can be necessary.

5.5 Examination procedure

5.5.1 General

Because the choice of both the direction of incidence and suitable probes largely depends on the shape of the casting, or on the possible casting discontinuities or on the possible discontinuities from finishing welding, the applicable examination procedure shall be specified by the manufacturer of the casting. In special cases, specific agreements can be made.

If possible, the areas to be tested shall be examined from both sides. When testing from one side only, short-range resolving probes shall be used additionally for the detection of discontinuities close to the surface. Testing with twin-crystal probes is only adequate for wall thicknesses up to 50 mm.

Additionally, when not otherwise agreed between the purchaser and the manufacturer, for all castings, twin-crystal normal and/or angle probes shall be used to examine the following areas up to a depth of 50 mm:

- critical areas, e.g. fillets, changes in cross-section, areas with external chills;
- finishing welds;
- weld preparation areas, as specified in the order;
- special rim zones, as specified in the order, critical for the performance of the casting.

Finishing welds which are deeper than 50 mm shall be subject to supplementary examination with other suitable angle probes.

For angle probes with angles over 60° , the sound beam path shall not exceed 150 mm.

Complete coverage of all areas specified for examination shall be conducted by carrying out systematically overlapping scans.

The scanning rate shall not exceed 150 mm/s.

5.5.2 Range setting

Range setting shall be carried out in accordance with EN 583-2 on the screen of the test instrument, using normal or angle probes in accordance with one of the three options given below:

- with the calibration block No. 1 in accordance with EN 12223, or No. 2 in accordance with ISO 7963;
- with an alternative calibration block made in a material exhibiting similar acoustic properties to those of the material to be examined;
- on the casting itself when using normal probes. In this case, the casting to be tested shall have parallel surfaces, the distance between which shall be measured.

5.5.3 Sensitivity setting

5.5.3.1 General

Sensitivity setting shall be carried out after range setting (see 5.5.2) in accordance with EN 583-2. One of the following two techniques shall be used:

- Distance-amplitude correction curve technique (DAC)

The distance-amplitude correction curve technique makes use of the echo-heights of a series of identical reflectors (flat-bottomed holes FBH or side-drilled holes SDH), each reflector having a different sound-beam path.

NOTE A frequency of 2 MHz and a diameter of 6 mm for the flat-bottomed holes are most commonly used.

- Distance gain size technique (DGS)

The distance gain size technique makes use of a series of theoretically derived curves which link the sound-beam path, the apparatus gain and the diameter of a disc-shaped reflector which is perpendicular to the beam axis.

5.5.3.2 Transfer correction

Transfer correction shall be determined in accordance with EN 583-2.

When calibration blocks are used, transfer correction can be necessary. When determining the transfer correction, consideration shall be given not only to the quality of the coupling surface but also to that of the opposite surface, because the opposite surface also influences the height of the backwall echo (used for calibration). If the opposite surface is machined or complies at least to the limit comparator 4 S1 or 4 S2 according to EN 1370, this surface has a quality which is sufficient for transfer correction measurements.

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5.5.3.3 Detection of discontinuities

For discontinuity detection, the gain shall be increased until the noise level becomes visible on the screen (search sensitivity).

The echo heights of the flat-bottomed holes given in Table 2, or of the equivalent side-drilled holes, shall be at least 40 % of the screen height at the end of the thickness range to be tested.

If, during testing, suspicion arises that the reduction of backwall-echo indication exceeds the recordable value (see Table 3), testing shall be repeated using locally reduced test sensitivity and the reduction of backwall-echo indication shall be determined quantitatively in decibels.

The sensitivity setting of angle-beam probes shall be such that the typical dynamic echo pattern of these reflectors (see Figure 3) is clearly visible on the screen.

It is recommended that the sensitivity setting of angle-beam probes is verified on real (not artificial) planar discontinuities (cracks with dimensions in the through-wall direction) or on walls perpendicular to the surface and infinite to the sound beam. In these circumstances, the probe shoe should be contoured to fit the casting shape (see EN 583-2).

5.5.4 Consideration of various types of indications

The following types of indications can occur separately or jointly during the examination of castings and shall be observed and evaluated:

- reductions of backwall echo which are not due to the casting shape or the coupling;
- echo indications of discontinuities.

The reduction of backwall echo is expressed in decibels as the drop of the backwall-echo height. The height of the echo indication is given as the flat-bottomed or side-drilled hole diameter.

5.5.5 Recording and recording limits

5.5.5.1 Reduction of backwall echo

All backwall-echo reductions in excess of 12 dB (for a nominal test frequency of 2 MHz) shall be recorded. The backwall-echo reductions to be recorded shall be marked and measured as indication areas.

5.5.5.2 Echo indications from discontinuities

The recording limit of an echo indication is defined by its signal amplitude according to a reference discontinuity echo size.

All echo indications from discontinuities with measurable dimensions shall be recorded, when the signal amplitude exceeds both the levels given in Table 3 and the criteria given in Figures 3 and 4.

Distinction shall be made between the different types of indications given in Table 4.

To identify the type of indication, the test sensitivity can be changed according to the distance from the test surface, the geometrical shape and the surface finish of the test surface.

When using transverse wave probes, irrespective of amplitude, all indications which display travelling characteristics or have an apparent dimension in the through-wall direction shall be recorded for subsequent assessment in accordance with 5.5.7.3.

Each location, where indications to be recorded have been found, shall be marked and indicated in the test report. The location of reflection points shall be documented, e.g. by a sketch or photograph.

5.5.6 Investigation of indications to be recorded

The locations where indications to be recorded have been found (see 5.5.5) shall be investigated more closely with respect to their type, shape, size and position. This investigation can be achieved by altering the ultrasonic test technique (e.g. changing the angle of incidence) or by additionally carrying out radiographic examination.

5.5.7 Characterization and sizing of discontinuities

5.5.7.1 General

For characterization and sizing of discontinuities, see EN 583-5.

The ultrasonic determination of the dimensions of a discontinuity with an accuracy sufficient for engineering applications is only possible under certain preconditions (e.g. knowledge of the type of discontinuity, simple geometry of the discontinuity and optimum impact of the sound beam on the discontinuity).

The characterization of the type of discontinuities can be improved by using additional sound directions and angles of incidence. For a simplification of the procedure, the following categorizations of discontinuities are made:

- discontinuities without measurable dimensions (point discontinuities);
- discontinuities with measurable dimensions (complex discontinuities).

NOTE 1 Annex B gives information on sound-beam diameters in order to distinguish between discontinuities with or without measurable dimensions.