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Methods for

Assessing the performance characteristics of ultrasonic flaw detection equipment —

**Part 3: Guidance on the in-service
monitoring of probes
(excluding immersion probes)**

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Foreword

This British Standard, which has been prepared under the authority of the Mechanical Engineering Industry Standards Committee, is intended to provide further guidance for assessing the performance characteristics of ultrasonic flaw detection equipment. Whereas Parts 1 and 2 of BS 4331 are concerned respectively with the overall and electrical performance of ultrasonic equipment, this Part essentially deals with the checking of probe characteristics. Experience gained from investigation of testing practice in industry, and also from training centres, has shown that there is a real need for the standardization of simple checking procedures and calibration blocks which will enable testers to establish initial probe characteristics and monitor variations of performance arising from such factors as age, wear and conditions of service.

The simpler and more directly informative the checks, the more likely is the tester to acquire the desirable habit of comparing probes with the above mentioned object in view. Hence, the chief aim has been to devise calibration blocks of limited size and weight and suitable for use on site. In certain cases, however, it has been found necessary to recommend blocks which can best be used only in a test room. Some recommendations cover only generic types of block, the choice of dimensions, test material and surface finish being left to contracting parties who will be guided by considerations of practical relevance such as test ranges and working sensitivity levels.

Guidance in the use of certain blocks is given in Appendix A, but it is anticipated that testers will occasionally need assistance from other personnel responsible for exercising technical control. For these in turn, this standard provides means of remote control as, for instance, in clauses 8, 9, 12, 14 and 15 which cover pulse length, dead zone, overall system gain and resolving power. Where probes or instructions on procedure are issued from a central source, it should be remembered that the characteristics of equipment on site may sometimes differ significantly from those of the master set. (See 3.2.)

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 34, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

1.1 This Part of this British Standard provides practical guidance for monitoring the parameters of ultrasonic probes which most strongly influence the integrity of flaw detection and assessment, in particular the nature of the sound field and the degree of signal resolution.

1.2 The standard applies to compressional wave and shear wave probes used in contact or gap scanning on surfaces which are essentially flat. It does not apply to probes used in immersion testing techniques for which more complex checks are required.

NOTE Although a fuller assessment of the sound field (or at least a more direct one) can be obtained by using laboratory equipment, e.g. a beam plotter or a simple optical (schlieren) visualizer, such techniques are regarded as beyond the scope of this standard.

2 References

The titles of the British Standards referred to in this standard are listed on the inside back cover.

3 Range and conditions of tests

3.1 Using the appropriate recommended types of test blocks, the design and manufacture of which are described in BS 2704, the range of tests covered in this standard is as follows:

probe index (shear wave probes)	clause 4
beam angle (shear wave probes)	clause 5
beam profile	clause 6
dominant frequency	clause 7
pulse length	clause 8
dead zone	clause 9
near field	clause 10
signal-to-noise ratio	clause 11
overall system gain	clause 12
beam alignment (squint)	clause 13
resolving power (depth)	clause 14
resolving power (angular)	clause 15

The order in which the tests are listed is not significant. The choice of checks and order of checking will vary with the nature of the work in hand. (For frequency of checking and actions to be taken, see clauses 16 and 17.)

3.2 Since the properties here referred to as probe characteristics (see also BS 3683-4) are in fact influenced by the acoustical and electronic characteristics of the test system as a whole (and including certain characteristics of the workpiece), it is essential that all checks are carried out with the tester's own flaw detector and under conditions which are as nearly as possible identical with those involved in the particular work in hand, e.g. type and length of probe leads, method of acoustical coupling, surface roughness.

3.3 In clauses 6, 8 and 9, the methodical choice of gain setting (i.e. working sensitivity) is important.

3.4 The tests in clauses 4, 5 and 6 are regarded as the foundation of good testing practice. Every care should be taken to ensure maximum accuracy and reproducibility of readings and, where beam profiles are involved, accuracy of plotting. (See also Appendix A.)

3.5 Attention is drawn to Appendix C concerning control of ambient temperature.

4 Probe index

4.1 General purposes

4.1.1 It is necessary to use block A2 (see Figure 1), which utilizes a representative cross section of the beam and provides a large target, in the manner described in BS 4331-1.

As a result, the influence of anomalous features such as non-uniform pressure distribution in the sound field, or irregular beam profile, may be masked by the integrating effect of reflection at a surface much larger than the beam cross section (see A.2).

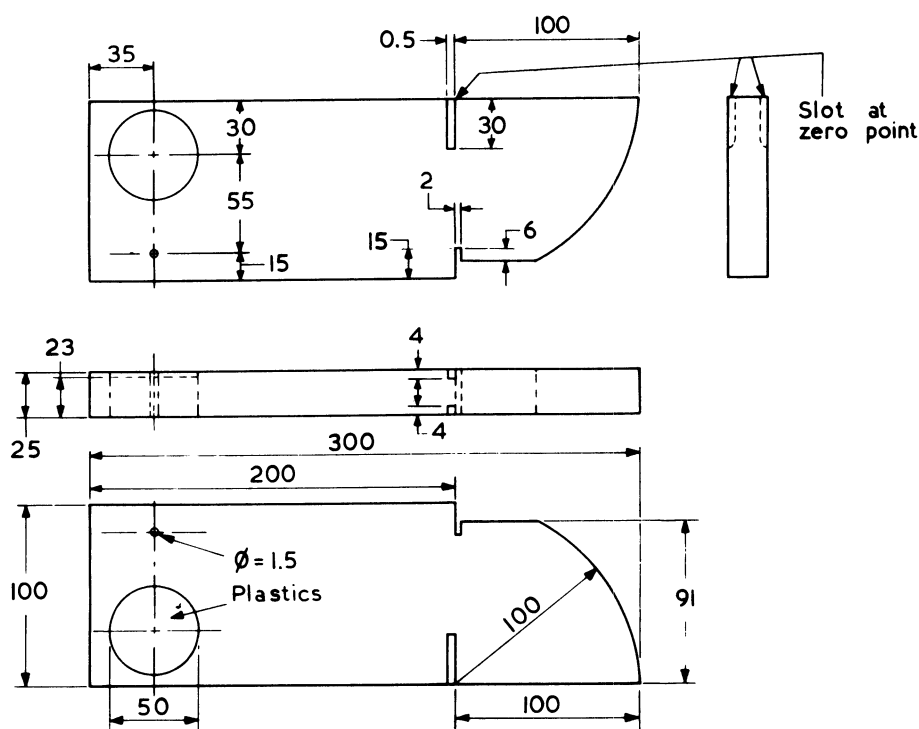
4.1.2 Block A2 provides one test range of 100 mm. It is advisable to position a guide strip on one side face in order to ensure that probe movement is always parallel to the side faces.

NOTE The block cannot be used to calibrate probes designed for use on non-ferrous metals, unless appropriately engraved.

4.1.3 If persistent sidewall echoes appear or the target echo is weaker when a guide strip is used, the probe should be checked for beam alignment (see clause 13).

4.1.4 The position of the probe index should be repeatable within ± 1 mm. It is the first, indispensable characteristic which should be determined before any comparisons of beam angle or beam profile are attempted. The index should be engraved on each side of the probe body.

NOTE The position of the maker's index mark on a shear wave probe is usually decided by the geometry of the probe shoe before assembly. It may be significantly inaccurate at high probe angles, e.g. 70° .



Unless otherwise indicated all dimensions correct to 0.1 mm.

Figure 1 — A2 calibration block

4.2 **Special requirements. Miniature blocks.** To meet cases where the specified procedure or the conditions of test call for continual checking on site, three virtually identical blocks are available, namely the A4 and those complying with the Netherlands standard NEN 2511¹⁾ and the German standard DIN 54-122²⁾ (March 1973 edition). With the exception of the A4 block which can be 12.5 or 20 mm thick, the miniature blocks are only 12.5 mm thick and are therefore prone to sidewall echoes if used with too large a probe. (Figure 2 illustrates the A4 block).

5 Beam angle

5.1 General purposes

5.1.1 It is necessary to use block A2 (see Figure 1) in the manner described in BS 4331-1 and the recommendations given in 4.1 apply.

5.1.2 Additional recommendations are made in respect of the index positions engraved on the side faces of block A2. These index positions should be clearly visible when covered by the pouplant, but should have a depth not greater than 0.1 mm. Beam angle values stamped at index marks should be not less than 3 mm high.

¹⁾ NEN 2511 "Reference block 2 for the ultrasonic examination of materials".

²⁾ Din 54-122 "Non-destructive testing; reference block 2 and its use for the adjustment and control of ultrasonic echo equipment".

5.2 Special requirements

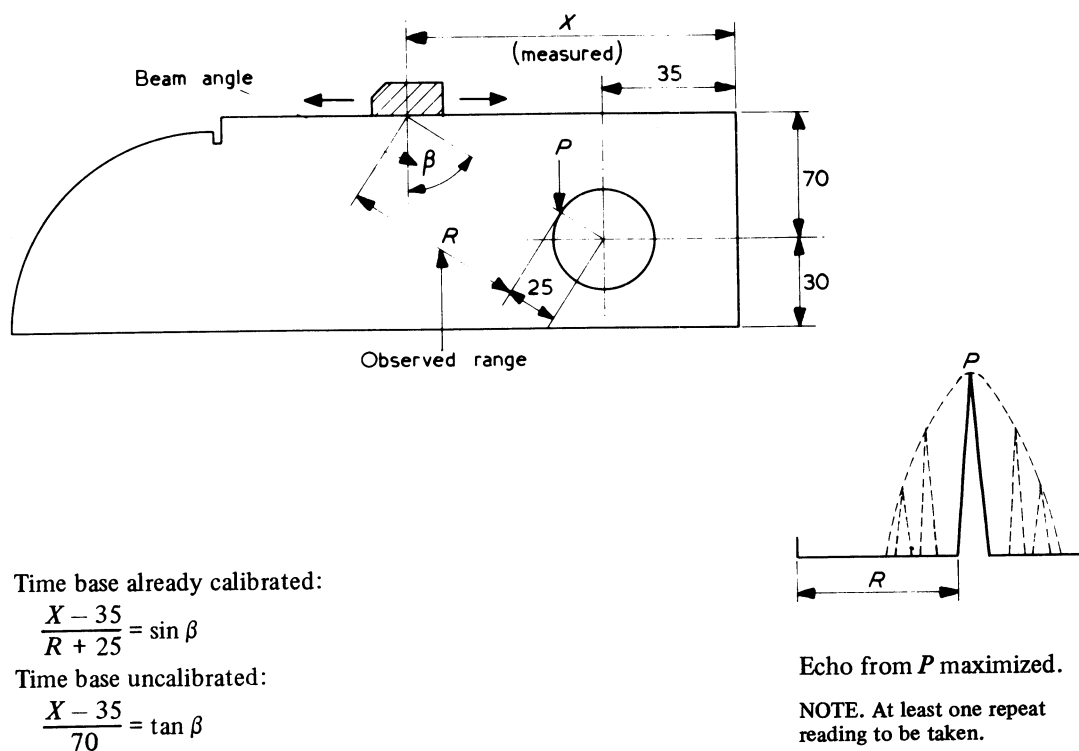
5.2.1 Miniature blocks. The recommendations given in 4.2 apply for checking beam angle, but since the interpolation of readings between the engraved markings cannot readily be checked by calculation or protractor, miniature blocks are not recommended for the accurate determination of beam angle. They are, however, quite suitable for the detection of drift in the value of an angle previously determined as in 5.1, provided that the original reading is referred to the miniature block and recorded before testing is commenced.

NOTE These miniature blocks are graduated for beam angles in steel only.

5.2.2 Different test ranges

5.2.2.1 There are circumstances, for example the precise location of small flaws at critical positions, in which it is necessary to supplement a standard block with a block designed to detect the variations of effective beam angle which arise from the fact that a probe is likely to give different responses when used on targets lying at different ranges. Other possible sources of significant variation are an unusually rough surface (see note), undulating surface profile or variable velocity of ultrasound, i.e. in excess of the not uncommon variation (in one and the same workpiece) of $\pm 0.5\%$.

NOTE The term "rough" in this context refers only to unevenness resulting from the manufacturing process or from heat treatment, or from pitting due to pickling (steel) or to atmospheric corrosion. A surface roughened by deep machine marks, regularly spaced, is basically unsuitable for ultrasonic flaw detection and should never be accepted.



All dimensions in millimetres.

Figure 3 — Calculation of beam angle (alternative to visual estimation)

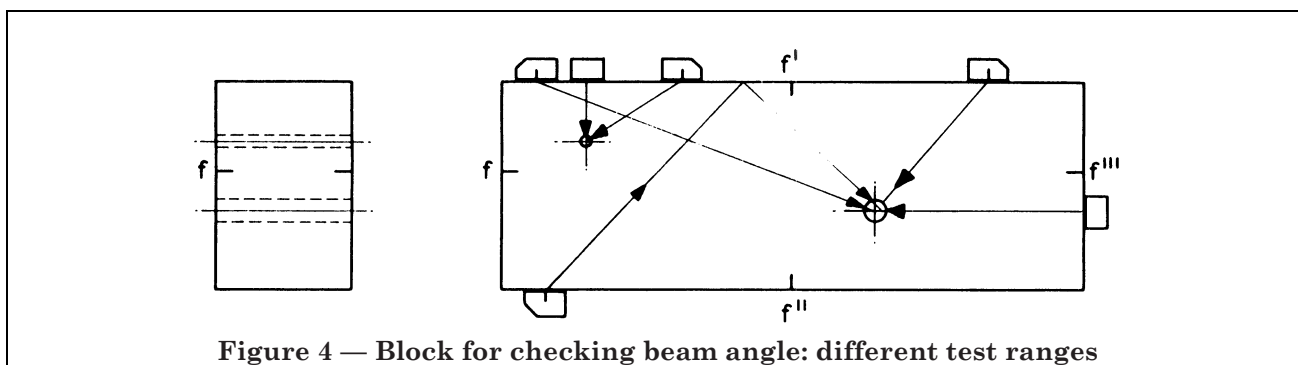


Figure 4 — Block for checking beam angle: different test ranges

5.2.2.2 A block of the type shown in Figure 4 is recommended, the target size and coverage of test ranges being chosen to suit the work in hand. For the reasons given in 5.2.2.1 it may be preferable to prepare the block from an off-cut of the material under test. Otherwise, it should be made from a material specified in BS 2704.

5.2.2.3 The side and end faces of the block should be provided with permanent reference marks as at f , f' , f'' , f''' for recording the probe positions required for the subsequent protractor reading or calculation of beam angle (see A.1 on preferred system for taking readings). One or more alternative sizes of target may be incorporated at appropriate ranges in order to simulate conditions in the workpiece, but the recommended maximum hole diameter is 5 mm.

5.2.2.4 The targets may be produced by spark erosion where this is economically justifiable, but most technical requirements can be met by a small diameter side-drilled hole, the primary object being to ensure that any anomaly in the geometry or acoustics of the ultrasonic beam, e.g. eccentric beam axis, non-uniform sound field, will be made apparent before the probe under test is released for use.

5.2.2.5 The beam angle should be determined at the same gain setting as that used when examining the workpiece.

6 Beam profile

6.1 Compressional wave probes

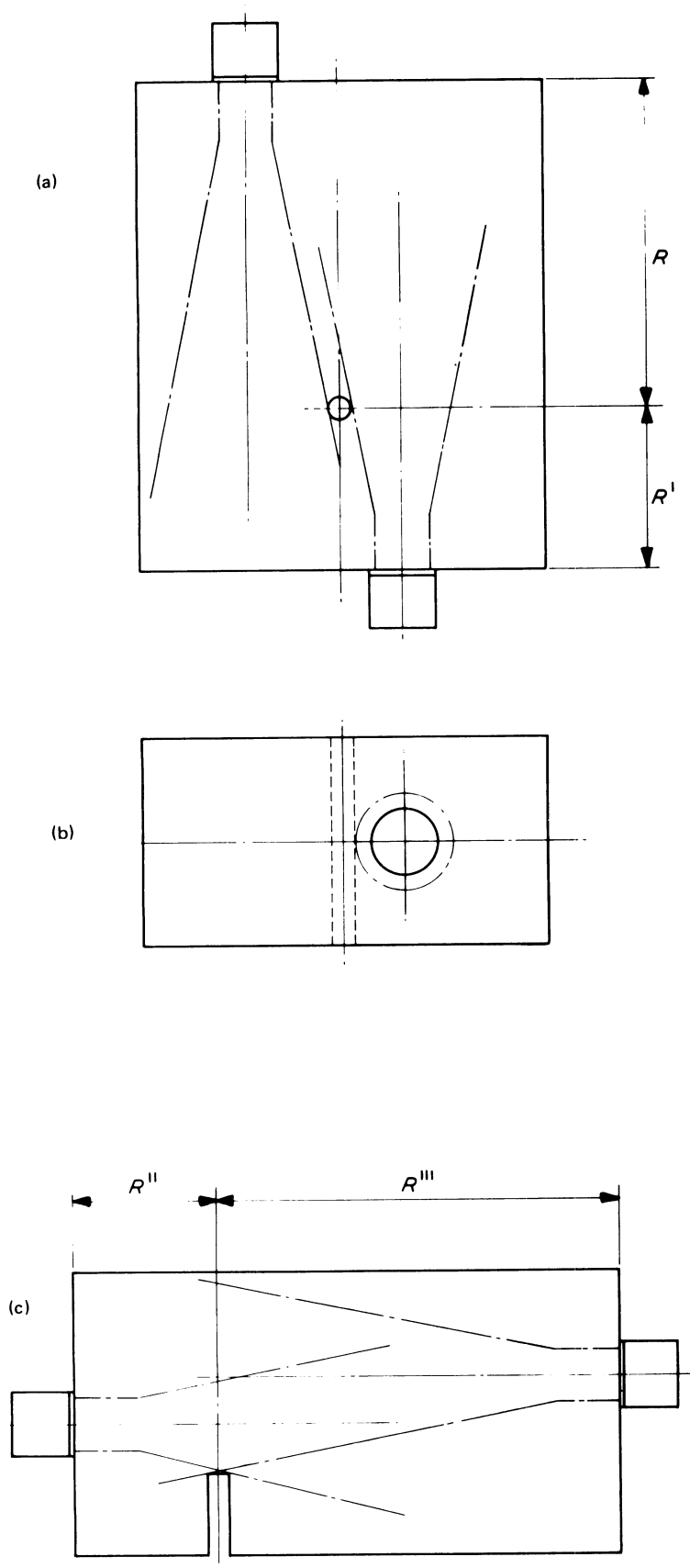
6.1.1 This is an important check, particularly for probes with square or rectangular crystals, e.g. twin-crystal probes.

6.1.2 Special purpose blocks are recommended. Recommendations concerning special purpose blocks are given in Appendix A of BS 2704:1978.

6.1.3 The target may be a cylindrical hole or a planar surface as shown in Figure 5(a), Figure 5(b) and Figure 5(c), the choice being based on the purpose for which the profile is to be plotted. A planar reflector such as the slot seen in Figure 5 should be used if, for example, the probe is to be used for assessing internal lamination in thick steel plate.

6.1.4 In any case, it is to be expected that variations due either to the differing wave frequencies to which the targets are sensitive, or to differing designs of probe, may appear in profiles plotted from different targets and at different gain settings. When flaw detectors are fitted with separate attenuator and amplification controls, it is recommended that beam profiles be plotted at two appropriate levels of working sensitivity.

6.1.5 It is recommended that the targets be so placed that they can be scanned from two ranges representing the minimum and maximum testing distances in the workpiece (R , R' etc., see Figure 5). Permanent reference marks should be provided to facilitate the recording of successive probe positions. (See also Appendix A.)



NOTE For detailed sketch and plotting procedure see Figure 26 and A.2.1.

Figure 5 — Principle for plotting beam profile (compressional waves)

6.2 Shear wave probes

6.2.1 Vertical plane

6.2.1.1 Calibration block A5 (see Figure 6) introduced by the Welding Institute in 1965, is recommended for checking shear wave probes. Its dimensions of 50 mm × 75 mm × 305 mm are suitable for most probes, though for some probes the 50 mm dimension may be too narrow. The procedure is described in Appendix A.

6.2.1.2 The location and spacing of the 1.5 mm diameter drilled target holes has to be adhered to in order to obtain the maximum number of approaches to them by direct and indirect scanning, i.e. one “bounce”.

6.2.1.3 The recommendations given in 6.1 apply regarding the need to plot beam profiles for more than one gain setting.

6.2.2 Horizontal plane

6.2.2.1 The horizontal profile is plotted in the same way as the vertical, but using the 50 mm × 305 mm face shown in Figure 6(b). This procedure involves maximizing the echoes from the tips of the target holes and traversing the probe laterally to find the 10/1 signal-drop position.

6.2.2.2 Since some uncertainty attaches to results obtained by working off the tip of a hole it is recommended that, if knowledge of the full horizontal profile is indispensable, a thick plate be used having one hole passing through its thickness. Two such plates are described in this standard, block A2 shown in Figure 1(a) (1.5 mm hole) and the one shown in Figure 25 for plotting resolving power (angular).

7 Dominant frequency

7.1 General

7.1.1 The test block recommended for checking dominant frequency is a plain bar of dimensions approximately 50 mm × 25 mm × 150 mm, machined on the 25 mm × 150 mm faces and having a rectangular slot in one of them, cut to a depth equivalent to the distance travelled by ultrasonic waves in 1 μs (5.9 mm in steel for compressional waves). The slot can, if desired, be incorporated in a multi-purpose block which will cover the checks described in clauses 7, 8, 9 and 14.

7.1.2 The echoes from the slot and the bottom face respectively (see Figure 7) are used to calibrate a sufficient length of time base with sufficient accuracy for evaluation of a probe under service conditions. (There is also a 6 mm slot in block A2.)

NOTE Wave frequency and pulse length (see clause 8) are both checked in the same operation. The combination of these two characteristics determines the result of the check for depth resolution (see clause 14).

7.2 Procedures

7.2.1 Rectified display. There is some uncertainty attached to the assessment of rectified signals and therefore no recommendations can be made.

7.2.2 Unrectified display (compressional wave probes). The trace of a pulse reflected from a small target as at R [see Figure 7(a)] is brought into the calibrated section of the time base so that the leading edge coincides with an appropriate graticule division [see Figure 7(b)]. The wave frequency is then estimated by counting the number of cycles occurring in a given time interval. Figure 8(a) and (b) are examples of cathode ray tube traces for nominal 2.5 MHz and 4 MHz probes respectively.

NOTE When counting cycles, the parts of the trace which lie outside the lines y and y^1 are to be ignored (see also Figure 10).

7.2.3 Unrectified display (shear wave probes). Using a compressional wave probe on the slot described in 7.1.2, the time base is calibrated so that the graticule represents a known time interval. Without adjusting the time base control, a shear wave probe is then connected to the flaw detector and aimed at a small target as at R in Figure 9. Using only the delay control to bring the signal from R on to the graticule, the number of cycles occurring in a given time is noted in the same way as described in 7.2.2.