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Methods for

Assessing the performance characteristics of ultrasonic flaw detection equipment —

Part 1: Overall performance: on-site methods

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Foreword

This British Standard, which is a revision of the 1968 edition of BS 4331-1, has been prepared under the direction of the Mechanical Engineering Standards Committee. Experience in the application of the previous edition has indicated that this Part of the standard should essentially be concerned with the routine practical checking of ultrasonic flaw detection equipment either on site or on the shop floor.

This revision accordingly describes the checks which are considered particularly suitable to be carried out by the operator of the equipment on site to ensure that it is functioning satisfactorily for the purpose of the tests to be conducted. No equipment other than standard steel calibration blocks in accordance with BS 2704 is required.

For detailed checking of the electrical performance of the equipment, reference should be made to Part 2 of this standard; guidance on the in-service monitoring of contact probes is provided in Part 3. It is emphasized that personnel responsible for assessing performance characteristics should be fully conversant with the equipment and with its application to meet the requirements of relevant testing standards.

The methods described in this standard would not normally be applicable to automated ultrasonic testing systems nor to equipment intended for medical or biological use, in both of which special considerations arise.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, 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 describes methods for checking the performance of ultrasonic flaw detection equipment (i.e. instrument and probes) by the use of appropriate standard calibration blocks selected from BS 2704, or of other suitable blocks based on the requirements of that standard. The methods described are suitable for the use of operators working under site or shop floor conditions.

1.2 The methods apply only to pulse-echo flaw detection equipment using A-scope presentation, with gain controls or attenuators calibrated in steps not greater than 2 dB, and used essentially in contact testing.

1.3 The methods described in this standard would not normally be applicable to automated ultrasonic testing systems in which special considerations apply.

2 References

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

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 3683-4 generally apply.

4 Range of checks

4.1 The checks covered in this standard are as follows.

	Clause no.
Linearity of the time base	**5**
Calibration of the time base	**6**
Linearity of equipment gain	**7**
Probe index (S)	**8**
Beam angle (S)	**9**
Sensitivity and signal-to-noise ratio	**10**
Beam alignment (squint) (S)	**11**
Beam width in vertical plane (S)	**12**
Pulse duration	**13**

NOTE (S) represents shear wave probes (angle probes) only. Special probes, e.g. angle compressional wave or surface wave probes, are not within the scope of the checks. In addition, some checks cannot be applied to probes with faces contoured for good contact on curved surfaces or to electro-dynamic probes.

4.2 The checks are listed in a logical order but can be carried out more rapidly if those which use the same reflector are done in sequence.

4.3 The checks carried out should be selected to reflect the requirements of the particular test for which the equipment is to be used. The frequency of checking should be in accordance with the requirements stated in clauses **5** to **13** and attention is drawn to the recommended tolerances on performance, where appropriate, contained therein.

5 Linearity of the time base

5.1 General. This check may be carried out using a standard calibration block e.g. A2 or A4, and a compressional wave probe. The linearity shall be checked over a range at least equal to that which is to be used in subsequent testing. Where appropriate, due allowance shall be made for the fact that a range of 91 mm for compressional waves in steel is equivalent to a range of only 50 mm for shear waves.

5.2 Method

5.2.1 Place the compressional wave probe on the calibration block in a position (side or face) where the range to the tenth backwall echo is equal to or exceeds the range (for compressional waves) over which the linearity has to be checked. Adjust the time base so that the first and last backwall echo indications coincide with particular scale marks.

5.2.2 Bring successive backwall echoes, in turn, to approximately the same height e.g. 80 % full screen. The leading edge of each should line up with the appropriate graticule line. Record any deviations, measured at approximately half full screen height, from the ideal positions.

5.2.3 Express the deviations from linearity as a percentage of the time base range between the first and last backwall echoes displayed.

5.3 Tolerance. Unless otherwise specified by the testing standard, deviations from linearity up to and including ± 2 % can be tolerated. Deviations in excess of ± 2 % shall be taken into account.

5.4 Frequency of checking. The check shall be carried out at least once per week.

6 Calibration of the time base

6.1 General

6.1.1 The preferred method is given for the calibration of the time base of an A-scope screen display such that echo positions can be read directly from the screen graticule in millimetres range from a zero which corresponds to the effective point of entry of the ultrasound pulses into the material to be examined for the particular probe being used. The calibration is achieved by positioning the probe on a standard calibration block in such a manner that a series of echo signals is obtained at well-defined, known ranges from the entry point.

6.1.2 The method described employs the standard steel A2 calibration block (see BS 2704, block A2, modification 1, Figure 2) and is directly applicable only to the testing of ferritic steels. The same principle may be employed using other standard calibration blocks, e.g. A4, or special test blocks (including blocks in other materials) manufactured for the purpose.

6.1.3 On equipment which is provided with pre-calibrated "material velocity", "range" or "delay" controls, the method described should also be used to check their calibration.

6.2 Method

6.2.1 Having first set the suppression to zero, position the probe on the A2 block (modification 1) to obtain the multiple echo pattern required. For example:

> **for compressional wave probes**, a face, side or end of the block may be used. The choice should be made so that the spacing between successive backwall echoes is not greater than the total range over which the screen display time base is to be calibrated;
>
> **for shear wave probes**, the probe should be placed so that the ultrasound pulses are directed into the cylindrical reflector (quadrant) of the block. Set up multiple echoes at 100 mm intervals by reflections between the quadrant and the notches on the faces of the block.

6.2.2 Carefully manipulate the probe to identify and maximize the chosen signals. Then adjust the time base controls (e.g. "delay" and "range multiplier") so that the first of the multiple echoes (*not* the transmission pulse) coincides with the zero graticule mark, and a subsequent echo coincides with an appropriate graticule mark at the right-hand end of the screen. For example, if the echoes are at 100 mm, 200 mm, 300 mm etc, the first echo would be set to the zero mark and the third to the "10" mark if calibration is required over a total range of 200 mm.

6.2.3 When the correct spacing of echoes has been established, adjust the "delay" only so that the first of the multiple echoes is placed at the graticule mark which is to correspond to its true range. The zero mark will then correspond to the effective point of entry of the ultrasound pulses into the material.

6.2.4 By the method given in **6.2**, the time base can be calibrated to an accuracy of ± 2 % or better of the total range represented on the screen. The accuracy of measurement of intermediate ranges will depend on the linearity of the time base. (See clause **5**.)

6.3 Tolerance. Accurate calibration of the time base to ± 2 % or better of the maximum range displayed is recommended for all types of A-scope flaw detector.

6.4 Frequency of checking. The check shall be carried out whenever the probe is changed, or daily, whichever is more frequent.

7 Linearity of equipment gain

7.1 General

7.1.1 This is a check on the combined result of two characteristics which affect linearity of equipment gain i.e. linearity of amplifier and the accuracy of the calibrated control. Any standard calibration block may be used, preferably in conjunction with a probe to be employed in subsequent testing.

7.1.2 The linearity shall be checked with the flaw detector controls (frequency, range, pulse energy, etc.) switched to positions to be employed in subsequent testing. Variable suppression and swept gain controls shall be switched to "off".

7.2 Method

7.2.1 Position the probe on a calibration block to obtain a reflected signal from a small reflector e.g. the 1.5 mm hole in the A2 block or the 1.5 mm or 5 mm hole in the A4 block.

7.2.2 Adjust the gain to set this signal to 80 % of full screen height and note the value of the calibrated control (dB). Adjust the calibrated control to increase the gain by 2 dB. The signal should increase to full screen height (100 %). Restore the gain to its original value and then reduce it by a further 6 dB. The signal should fall to 40 % of full screen height. Reduce the gain by a further 12 dB. The signal should fall to 10 % of full screen height. Reduce the gain by a further 6 dB. The signal should fall to 5 % of full screen height.

7.3 Tolerance. Deviations outside the limits given in the following table should be taken into account in subsequent testing.

Gain (dB)	Expected screen height (%)	Limits
+ 2	100	Not less than 90 %
0	80	—
– 6	40	35 % to 45 %
– 18	10	8 % to 12 %
– 24	5	Must be visible above base line

NOTE 1 For logarithmic amplifiers, the amplifier should give equally spaced dB steps throughout the graticule height.

NOTE 2 Attention is drawn to BS 4331-2 for the detailed checking of amplifiers.

7.4 Frequency of checking. The check shall be carried out at least once per week.

8 Probe index

8.1 General

8.1.1 This check applies only to shear wave probes. The probe index may be checked on the standard A2 or A4 calibration block each of which has a cylindrical reflector (quadrant).

8.1.2 It may be found that manufacturers' marks are not of sufficient accuracy for the purpose envisaged and the probe index is the first probe characteristic which should be checked prior to checking the beam angle or profile.

8.2 Method

8.2.1 Position the probe on the appropriate side of the block to obtain a reflection from the quadrant. Move the probe backwards and forwards to maximize the amplitude of the reflected signal, taking care to move the probe parallel to the block sides.

8.2.2 When the signal is at maximum, the probe index will correspond to the engraved line on the block which marks the geometrical centre of the quadrant.

NOTE If the maximum signal is not obtained with the edge of the probe parallel to the edge of the block, this may be indicative of significant beam squint. (See clause **11**.)

8.2.3 The probe index measurement should be repeatable to within ± 1 mm. If the measured position differs from the existing mark by more than 1 mm the new position should be marked on the probe sides, or recorded, and should be used in subsequent probe checks and defect plotting.

8.3 Tolerance. Tolerance will depend on application but for plotting of defects it is recommended that a probe index accurate to within ± 1 mm be employed.

8.4 Frequency of checking. This will depend on the rate of probe wear due to usage and to the roughness of the testing surface. When a probe is in continuous use, it is recommended that the check be carried out at least every few hours; otherwise, a daily check is recommended.

9 Beam angle

9.1 General

9.1.1 Beam angle can be checked on several standard calibration blocks. The A5 block is particularly useful for this purpose as it permits accurate measurements of beam angle at a series of ranges by sighting the probe on a series of small diameter transverse holes. Careful measurement and plotting (or calculation) is, however, necessary to obtain beam angle because the block does not have calibrated graduations or reference marks.

9.1.2 Some of the standard blocks have reference markings in degrees which refer to a particular reflector in the block i.e. the large 50 mm diameter hole in the A2 block and the 1.5 mm or 5 mm diameter hole in the A4 block. These reference marks provide a means for a rapid check on beam angle. Interpolation between markings may be used to measure beam angle but the accuracy may not be sufficient. If high accuracy is needed, the angle should be determined by measurement (see BS 4331-3).

9.1.3 The beam angle check shall preferably be made on a probe in conjunction with the flaw detector to be used in subsequent testing.

9.2 Method

9.2.1 Place the probe in such a position as to receive a reflected signal from the selected transverse hole in the calibration block. Move the probe backwards and forwards to maximize the signal from the hole. When the signal is maximized, the beam angle can be measured using the probe index position determined as described in **8.1**. If the maximum signal is not obtained with the edge of the probe parallel to the edge of the block, this may be indicative of significant beam squint (see clause **11**).

9.2.2 If only a rapid check (accurate to say ± 3°) is required, this can be made by visual interpolation between the reference markings on the block.

9.2.3 For an accurate measurement, the probe index position should be measured with respect to the edge of one end of the block. Knowing the position of the drilled hole, the angle can then be calculated.

9.3 Tolerance. By the method given in **9.2**, it should be possible to measure the beam angle to an accuracy of ± 1.5°. Nominally marked angles may not be so accurate, especially on 70° or higher angle probes or on worn probes. It is recommended that the measured angle be recorded or marked on the probe and used in subsequent probe checks and defect plotting.

9.4 Frequency of checking. Frequency of checking will depend on the rate of probe wear due to usage and to the roughness of the testing surface. When a probe is in continuous use, it is recommended that the check be carried out at least every few hours; otherwise, a daily check is recommended.

10 Sensitivity and signal-to-noise ratio

10.1 General

10.1.1 The main objective of this check is to provide the operator with a simple method which will allow a deterioration in sensitivity of the probe and the flaw detector in combination to be identified. A simple method for checking sensitivity is given but it is not intended as a method of defining working sensitivity which should be set according to the requirements of the job and the testing standard being applied.

10.1.2 The standard A2 calibration block, using the 1.5 mm diameter hole, or the A4 block, using the 1.5 mm or 5 mm diameter hole, are suitable. The method can also be adapted for more extensive checks, e.g. (a) as a function of range by using the A5 block and (b) to assess sensitivity to near-surface defects by using the A6 block.

10.1.3 The sensitivity shall be checked with the relevant flaw detector controls, e.g. frequency, pulse, energy, suppression/reject, pulse repetition frequency range setting, set to the positions to be used in subsequent testing. Uncalibrated gain controls shall be set at maximum or a previously determined position. Cables, connectors and matching transformers (if used) shall be those which will be employed in subsequent testing.

10.2 Method

10.2.1 Place the probe on the chosen calibration block and adjust its position to maximize the signal from the transverse hole to be used as a sensitivity check. Adjust the calibrated control (dB) to set this signal to a low but clearly readable screen height, e.g. 20 %, and note the setting. Using the calibrated control, increase the gain until the overall system noise (electronic noise or grain structure grass) at the same range as the target hole reaches the same chosen height, and note the new setting.

10.2.2 The first gain measurement noted provides a check on the sensitivity of the probe and flaw detector, and the difference between the first and second measurements (dB) gives the signal-to-noise ratio. In each case, check these parameters at the particular range selected.

10.3 Tolerance. Tolerance will depend on application.

NOTE 1 A demonstration of the sensitivity of probe and flaw detector on a calibration block does not guarantee that the same size of reflector could be detected in the workpiece. This will depend on the surface condition, coupling and the grain structure of the workpiece.

NOTE 2 A demonstration of the sensitivity of the probe and flaw detector at one range does not guarantee the sensitivity of the equipment at other ranges, shorter or longer. If it is desired to check the sensitivity as a function of range, the use of the standard A5 block is recommended for longer ranges. If it is necessary to demonstrate the sensitivity of the equipment to near surface defects, the use of the standard A6 block is recommended. This block provides for the measurement of dead zone and the assessment of sensitivity to near surface flaws in the range 0 mm to 15 mm. It should be used for both single crystal and twin crystal probes.

10.4 Frequency of checking. Unless otherwise agreed, the check shall be carried out once per probe per day.

11 Beam alignment (squint)

11.1 General. Detailed methods of measuring beam squint are given in BS 4331-3. The method given in **11.2** provides a simple means by which equipment operators can check that squint of shear wave probes is within broad tolerances.

11.2 Method

11.2.1 Squint may be checked in the course of carrying out the checks on probe index or beam angle (see clauses **8** and **9**). If the probe beam is correctly aligned, the maximum reflected signal from the quadrant of the A2 or A4 blocks will be obtained with the edge of the probe parallel to the edge of the block. If this is not the case, the beam alignment (squint) angle can be estimated by measuring the angle between the two edges.

11.2.2 For shear wave probes, the method described in **11.2.1** will detect a squint angle of about 5°.

11.3 Tolerance. Tolerance will depend on the accuracy of defect plotting that is required in subsequent testing. It should be noted that, for a squint of 5°, the error in plotting will be 8.7 mm at a working range of 100 mm.

11.4 Frequency of checking. Unless otherwise agreed, the check shall be carried out once per week and when probe wear/damage is suspected.

12 Beam width in vertical plane

12.1 General

12.1.1 The following method provides a check on the beam width of shear wave probes at just one range. The check can be carried out using the standard A2, A4 (with 1.5 mm diameter hole) or A5 calibration block, each of which incorporates a small transverse hole at a convenient range.

12.1.2 A complete plot of beam profile at a series of ranges may be measured, as described in BS 4331-3, using, for example, the standard A5 calibration block. It is recommended that a plot of full beam profile is drawn up for a probe when new, and then at intervals, whenever a significant change of index, beam angle, squint or width indicates it may be required, and whenever a particularly critical testing situation demands it.

12.2 Method

12.2.1 Measure the distance between the positions (forward and backward for shear wave probes) at which the signal falls to one tenth (i.e. by 20 dB) of its maximum. Note any subsidiary peaks in the signal if these exceed one tenth of the maximum.

12.2.2 The measurement gives the 20 dB beam width in the vertical plane at the depth of the reflector hole selected. If subsidiary peaks are noted, these will be an indication of the presence of sidelobes on the beam or unwanted modes.

12.3 Tolerance. Tolerance will depend on the requirements of the test. However, a change of ± 2 mm in the beam width for a reflector hole at a depth of less than 40 mm, or the presence of sidelobes/unwanted modes, should be taken as an indication that the complete beam profile needs to be rechecked if accurate defect plotting is required.

12.4 Frequency of check. This will depend on the rate of probe wear due to usage and to the roughness of the testing surface. When a probe is in continuous use, it is recommended that the check be carried out at least every few hours; otherwise, a daily check is recommended.

13 Pulse duration

13.1 General

13.1.1 This check on the probe and flaw detector in combination, which is similar to that described in BS 4331-3, measures the effect on the displayed signal of probe damping, matching, amplifier bandwidth, built-in suppression and smoothing circuits.

13.1.2 The pulse duration check requires only the display on the calibrated time base of the reflected signal from a transverse hole in a standard A2 or A4 calibration block for shear wave probes, or a backwall echo for compressional wave probes.

13.1.3 The check should be made with the relevant flaw detector controls e.g. frequency, pulse energy, suppression/reject level, set to the positions to be used in subsequent testing and the probe should be connected in the same manner (cables, connectors, matching coils, etc.) as will subsequently be used.

13.2 Method

13.2.1 Having calibrated the time base in millimetres, display the required signal and set its peak to 100 % screen height. Measure the width of the signal in millimetres at the 10 % screen height position.

13.2.2 If desired, the measurement in millimetres can be converted to microseconds, but this is not necessary for present purposes.

13.3 Tolerance. Tolerance will depend on application. A long pulse duration will limit range resolution and indicate the need for a resolution check employing a technique described in. BS 4331-3 using the standard A7 calibration block. A short pulse duration may indicate that the flaw detector has built-in suppression that could prevent the observation of small signals.

13.4 Frequency of checking. Unless otherwise agreed, the check should be carried out daily and, for shear wave probes, in conjunction with the check on probe index (see clause **8**).

Standards publications referred to

BS 2704, *Calibration blocks for use in ultrasonic flaw detection.*
BS 3683, *Glossary of terms used in non-destructive testing.*
BS 3683-4, *Ultrasonic flaw detection.*
BS 4331, *Methods for assessing the performance characteristics of ultrasonic flaw detection equipment.*
BS 4331-2, *Electrical performance.*
BS 4331-3, *Guidance on the in-service monitoring of probes (excluding immersion probes).*

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