SECTION 2. REQUIREMENTS FOR CALIBRATION BLOCK No 1 AND METHODS OF USE

2.1 DIMENSIONS. Calibration block No 1 shall conform to the dimensions shown in Fig. 2.1.

The sides of the block shall be engraved to permit beam angle measurement within the range of 35 degrees to 80 degrees inclusive at 5-degree intervals for angles up to 50 degrees, and at 2-degree intervals for angles greater than 50 degrees. The engraving shall be—

(a) relative to the 50 mm diameter hole for angles from 35 degrees to 75 degrees; and

(b) relative to the 1.5 mm diameter hole for angles from 75 degrees to 80 degrees.

2.2 METHODS OF USE—NORMAL PROBES.

2.2.1 Probe Positions. In the test methods which follow, reference is made to probe positions. These positions are identified as shown in Fig. 2.2.

2.2.2 Calibration of Test Range. The test range shall be calibrated by adjusting the time base and delay controls so that multiple back echoes from a section of known thickness are displayed at appropriate graticule markings. The probe shall be placed at the following positions:

(a) For ranges below 200 mm, at position 'H'.

(b) For ranges of 200 mm and above, at position 'F'.

2.2.3 Assessment of Horizontal Linearity (Method No 1).

2.2.3.1 *General*. Each course range setting used shall be assessed for horizontal linearity using probes of such frequency and pulse length as to enable the requisite number of multiple echoes to be clearly resolved.

2.2.3.2 *Procedure*. The procedure shall be as follows:

(a) *For ranges up to 100 mm.* Use calibration block No 1 or alternatively block No 5 (Fig.6.1). Place the probe on the block and adjust the time base (see step (c)) so as to produce several multiple echoes within the chosen range, the preferred number being 4 or 5 echoes.

(b) *For ranges 100 mm to 500 mm.* Use the procedure given in step (a) except that the cross-section of the test block used should be large enough to prevent the appearance of delayed side wall echoes.

(c) *Setting the time base.* Two of the repeat echo signals should be set to coincide with appropriate scale divisions, e.g. in a 5-echo display choose the 1st and the 4th echoes, and in a 4-echo display choose the 1st and 3rd echoes. The remaining echoes should then coincide with their assigned positions.

(d) *Setting the gain.* Successive echoes should be brought to the same amplitude, i.e. 80 percent of full screen height when measuring their position against the graticule.

(e) *Recording and plotting of results.* Record the actual echo position on the screen. Plot on a graph the actual echo position as a function of the theoretical echo position as shown in Fig. 2.3.

2.2.4 Assessment of Horizontal Linearity (Method No 2).

2.2.4.1 *Procedure for test ranges 250 mm to 500 mm.*

(a) Position the probe at 'H', or on any sample which complies with the requirements of Clause 2.2.4.2 below.

(b) Adjust the time base so that not less than 10 nor more than 20 multiple back echoes are displayed on the screen.

(c) Adjust the amplitude of the first back echo to a convenient height not less than half-screen height and position its leading edge to be coincident with the first screen vertical marker as shown in Fig. 2.4.

(d) Assess the positions of the leading edges of subsequent echoes at the baseline relative to the graticule with their amplitudes adjusted to that selected above. Record these positions to an accuracy of ±0.5 mm.

(e) Plot the distance between each echo and its successor ($d_{n+1}—d_n$) as a function of its distance along the time base as shown in Fig. 2.5.

(f) Draw a straight line ('ab', Fig. 2.5) parallel to the horizontal axis through the flat portion of the resultant curve.

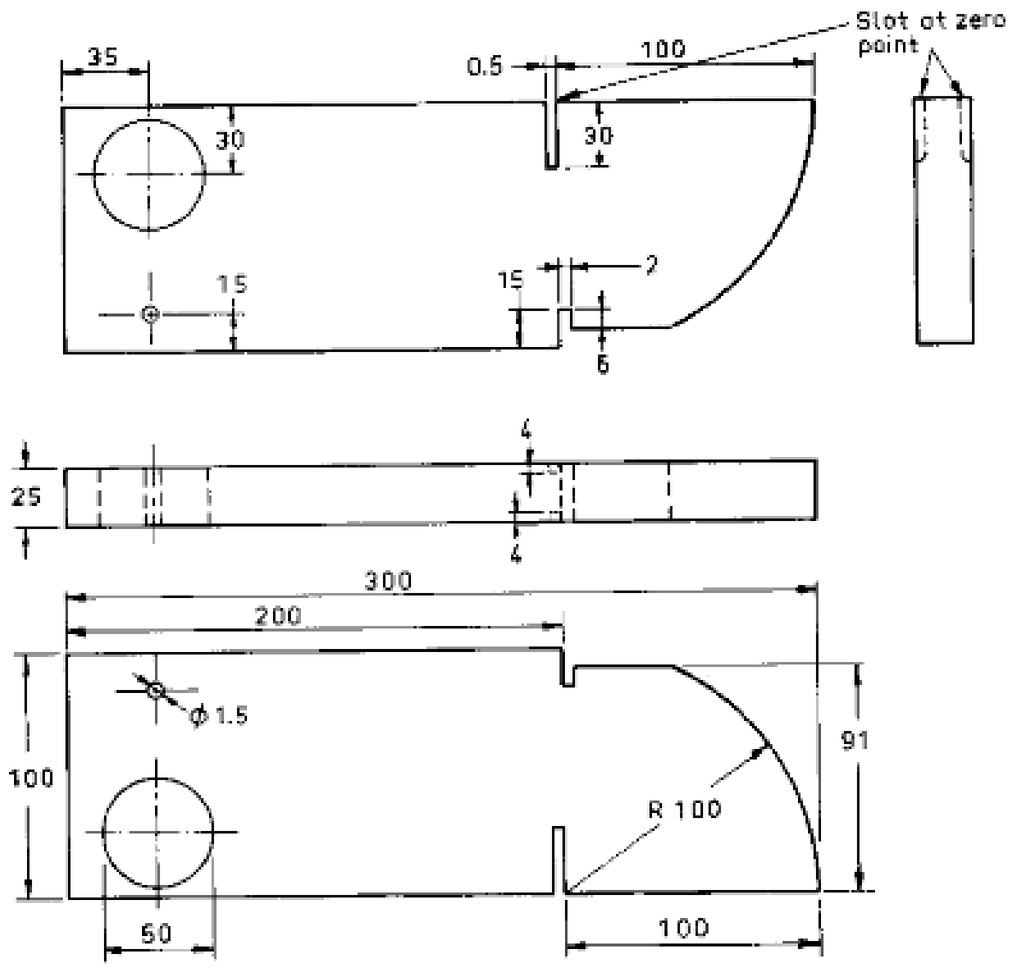
(g) On either side of 'ab' draw two further parallel lines at the distance corresponding to the required linearity limits. Thus, for the display represented in Fig. 2.5, which is of total graticule width 100 mm, 1 percent linearity requires that all plotted points lie within 1 mm of the mean and the additional lines are therefore drawn 1 mm either side of the 'ab'.

(h) Express horizontal linearity in terms of the percentage length of the used horizontal base line representing the relevant percentage linearity. For example, the display represented in Fig. 2.5 exhibits 1 percent linearity over full graticule width and 0.5 percent linearity over 92 percent of graticule width.

2.2.4.2 *Procedure for other test ranges.* Other test ranges shall be assessed by applying the probe to a parallel-sided sample of material the nature and thickness of which is such as to permit the display of the number of multiple back echoes required by Clause 2.2.4.1, at the test range to be assessed. The dimensions of the sample shall be such that, with the probe used, no echoes which result from sidewall reflections are displayed.

When assessing the linearity of relatively long test ranges, it may be found that, at the high gain setting required to display the required number of back echoes, the presence of 'grass' interferes with the assessment of echo position. In such cases, suppression may be used to clarify the display provided that all echoes are assessed with the same degree of suppression introduced.

When assessing test ranges of 25 mm or less, it may be found that it is not possible to resolve the required



DIMENSIONS ARE IN MILLIMETRES

Fig. 2.1 DIMENSIONS OF CALIBRATION BLOCK NO 1

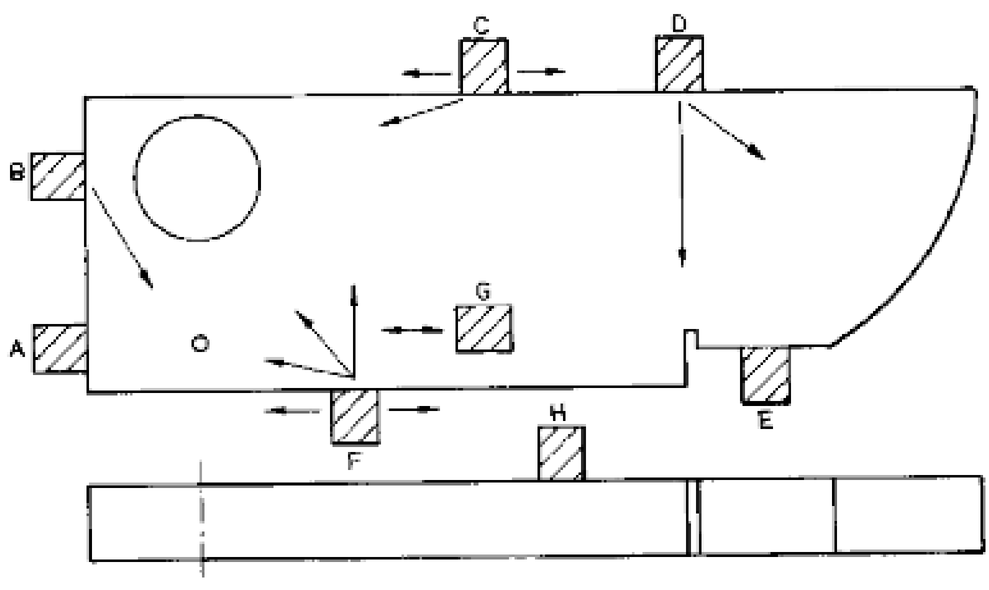


Fig. 2.2. PROBE POSITIONS FOR BLOCK NO 1

number of back echoes at the base line. If higher frequency and/or shorter pulse length probes are not available, an assessment of linearity may be made by measuring the positions of the echo peaks. Such a procedure is at best approximate and is not recommended.

2.2.5 Assessment of Vertical Linearity.

2.2.5.1 *General.* Each frequency range used shall be assessed for vertical linearity using any compression wave probe compatible with the test frequency range.

2.2.5.2 *Procedure.*

(a) Turn all accessible suppression and/or swept gain controls to the 'off' position.

(b) Select a test range of approximately 250 mm and place the probe at position 'H'.

(c) Select a back echo (the *n*th echo) which is adjacent to the centre of the screen and adjust the gain so that its height (h_n) is 5 mm, or 10 percent of graticule height.

(d) Measure and record the height of the next succeeding back echo ($h_{(n+1)}$). Repeat this procedure, adjusting the gain so that h_n is increased by increments of 5 mm or 10 percent of graticule height.

(e) Present the information graphically by plotting values of height (h_n) in either distance units (mm) or as a percentage on the vertical axis against values of height-ratio ($h_n/h_{(n+1)}$) on the horizontal axis as shown in Fig. 2.6. Draw a line 'ab' which is parallel to the vertical axis and passes through the intersection of the curve and the graticule height line.

(f) Draw an additional line parallel to 'ab' at a position representing the limits at which the accuracy is to be assessed determined by multiplying the value of the height-ratio represented by 'ab' by the appropriate factor given below.

Accuracy of assessment	*Factor*
± 0.5 dB	1.12
± 1 dB	1.26
± 2 dB	1.58

(g) Express vertical linearity in terms of the graticule height range over which the plotted points lie between the last drawn lines. For example, the display represented in Fig. 2.6 exhibits ±0.5 dB linearity from 32 percent to 100 percent of graticule height and ±2 dB linearity from 12 percent to 100 percent.

2.2.6 Measurement of Dominant Frequency.

(a) Position the probe at 'D' and use the echoes from the slot and bottom face to calibrate accurately the portion of the display in which they occur (see Note 1).

(b) Using an unrectified display, bring any back echo into the calibrated section of the display so that its leading edge coincides with an appropriate graticule division.

(c) Estimate the dominant frequency for the particular instrument/probe combination by counting the number of cycles occurring in 1 µs (see Note 2).

NOTES:

1. The distance travelled by compression waves in steel in 1 µs is 5.9 mm. By convention, the time base is calibrated for range so that 6 mm represents 12 mm total path length and a travel time of 2 µs.
2. Figs 2.7(a) and 2.7(b) are reproductions of typical unrectified displays for a 2.5 MHz and 4 MHz probe respectively.

2.2.7 Assessment of Resolution—Normal Probes.

2.2.7.1 *Procedure.* Assess the resolution of the equipment/probe combination as follows:

(a) Calibrate the range to 100 mm in accordance with Clause 2.2.2 and then position the probe at 'D' (see Fig. 2.2).

(b) With the suppression control in the 'off' position, adjust the probe position to bring the echoes from the 91 mm and 100 mm beam path surfaces both to 80 percent graticule height.

(c) Assess the resolution in accordance with the procedures specified in (i) or (ii) below:

(i) Assess the resolution by comparing the echoes displayed from the 85 mm and 91 mm beam path presentations by use of one of the following formulas:

A. Resolution = $(91 - 85)\dfrac{a}{a-b} = 6\dfrac{a}{a-b}$ mm

B. Resolution = $(91 - 85)\dfrac{d}{c} = 6\dfrac{d}{c}$ mm

The higher the numerical value obtained the poorer is the resolution. Typical forms of traces used in the assessment of resolution are given in Fig. 2.8(A).

NOTE: The preferred method for the assessment of resolution is given in Section 7.

(ii) Use the difference in display height (h) between the 91 mm and 100 mm echoes and the separating trough.

Note the calibrated gain setting (see Clause 2.2.7.1(b)). Adjust the calibrated gain to bring the trough to 80 percent graticule height and note the new setting. The difference (h) between the two gain settings, expressed in decibels, gives an assessment of the resolution of the equipment/probe combination (see Fig. 2.8(B)).

2.2.8 Assessment of Resolution by Measurement of Pulse Length. Assess the resolution as follows:

Position the probe at 'D' (see Fig. 2.2) and calibrate the test range using the 6 mm step (equivalent to a 1 µs transit time in steel) to a short time range.

(a) *Rectified display.* Place the probe on a suitable surface of the block to produce a back-echo and adjust the delay and amplification to display the back-echo at an amplitude within the vertical linearity.

Estimate the pulse length as the distance between the points on the rising and falling flanks of the displayed pulse which are at 10 percent of the peak amplitude (see Fig. 2.12(A)). The pulse length can be expressed in millimetres of material, or, from a knowledge of velocity of propagation, as a time interval.

(b) *Unrectified display.* The pulse length may be determined during the assessment of probe performance from an unrectified display, and should be expressed as the number of cycles in the pulse to the nearest positive half-cycle of greater than 10 percent of peak amplitude (see Fig. 2.12(B)).

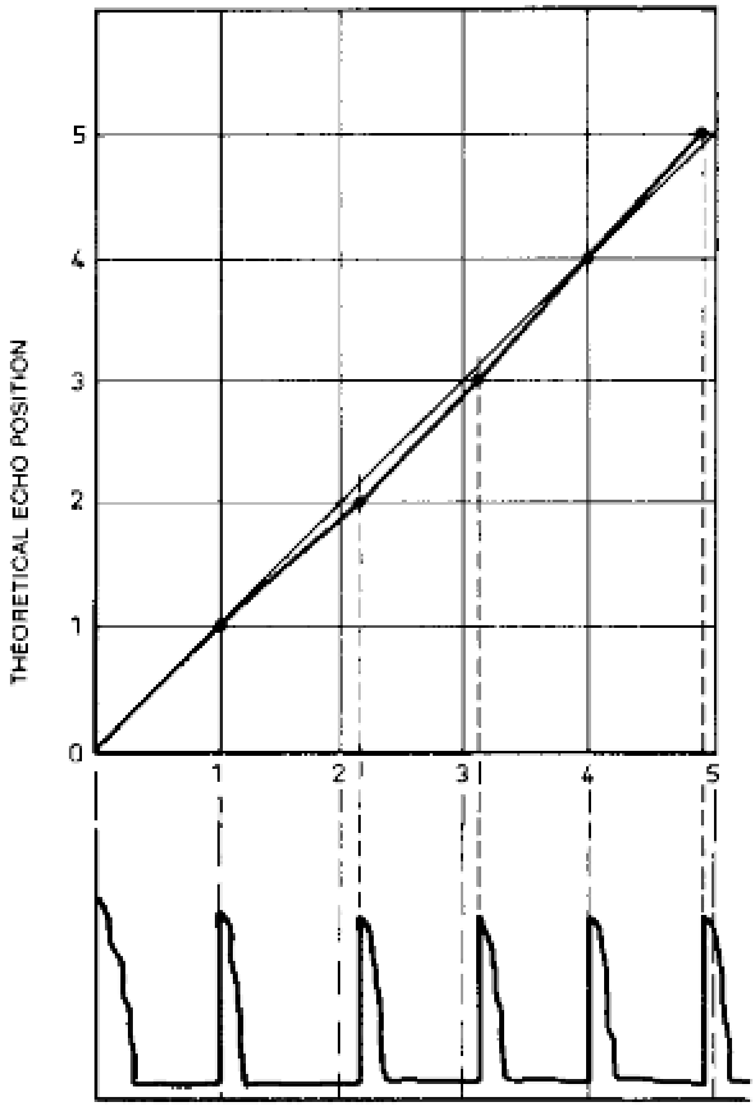


Fig. 2.3. GRAPH OF NON-LINEAR TIME BASE

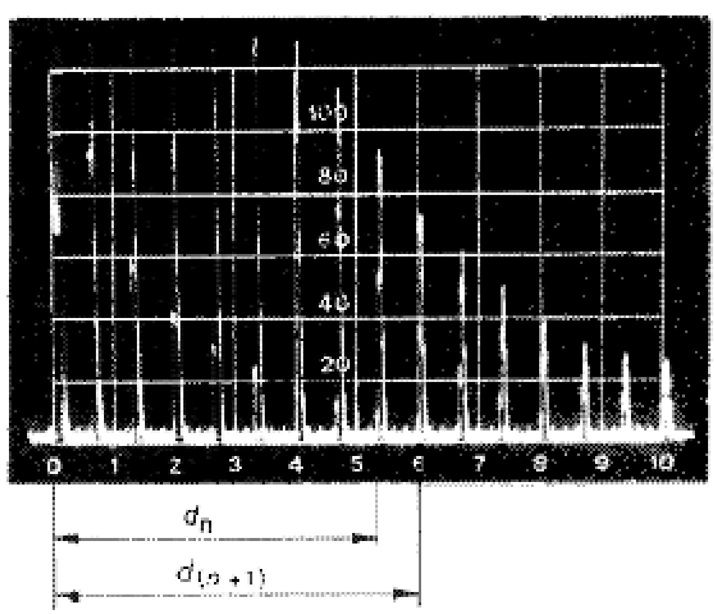


Fig. 2.4. TYPICAL SCREEN DISPLAY USED IN THE ASSESSMENT OF HORIZONTAL LINEARITY

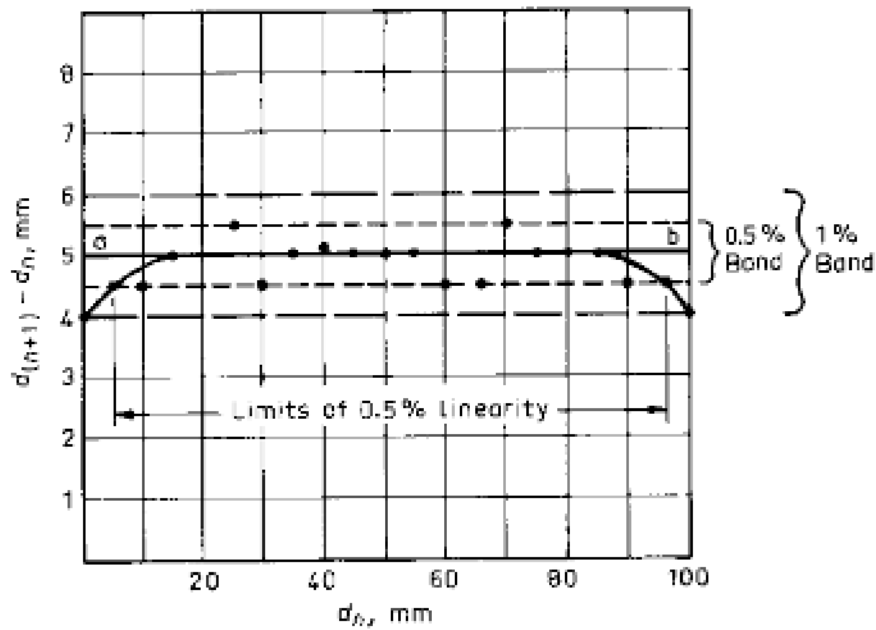


Fig. 2.5. TYPICAL PLOT USED FOR THE ASSESSMENT OF HORIZONTAL LINEARITY

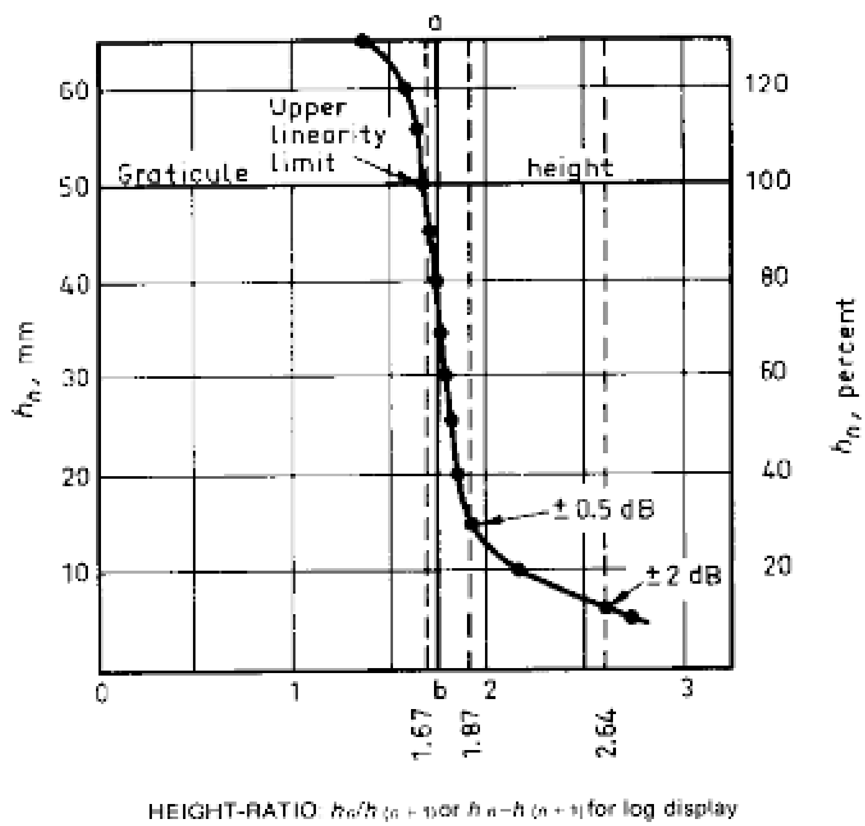


Fig. 2.6 TYPICAL PLOT USED FOR THE ASSESSMENT OF VERTICAL LINEARITY

2.2.9 Assessment of Overall System Gain.

(a) Position the probe at 'A' (see Fig. 2.2).

(b) Optimize the echo from the 1.5 mm diameter hole with any uncalibrated gain controls set at maximum. Adjust the calibrated attenuator to give an echo amplitude of full graticule height.

(c) Remove the probe and clean it to remove any couplant.

(d) Adjust the calibrated attenuator until the amplitude of any noise equals the amplitude of the echo from the 1.5 mm diameter hole selected previously or the limit of adjustment is reached.

(e) Record the difference in decibels between this reading and the previous setting as the overall system gain.

NOTE: The suitability of a test system for a particular application can be assessed similarly by determining the usable amplification in hand, referred to a back echo or any other appropriate reflector at a defined path length.

2.3 METHODS OF USE—ANGLE PROBES.

2.3.1 Calibration of Test Range. The test range shall be calibrated in a similar manner to that described in Clause 2.2.2 for normal probes by using either of the following procedures:

(a) *Procedure for ranges 200 mm and above.* Position a probe at 'D' (see Fig. 2.9) and beam towards the 100 mm radius face. Successive echoes occur at 100 mm intervals.

NOTE: As an alternative to procedure (a), refer to Clause 6 when calibrating equipment for test ranges less than 200 mm.

(b) *Procedure for shear wave probes only.* Position a normal wave probe at 'E' at which the distance of 91 mm corresponds to 50 mm for shear waves (see Fig. 2.9). Position a shear wave probe at 'D' and adjust the transmission point so that the echo from the 100 mm radius face coincides with the position of the 100 mm reflection previously obtained with the compression wave probe, thereby correcting for the delay which occurs in the probe shoe.

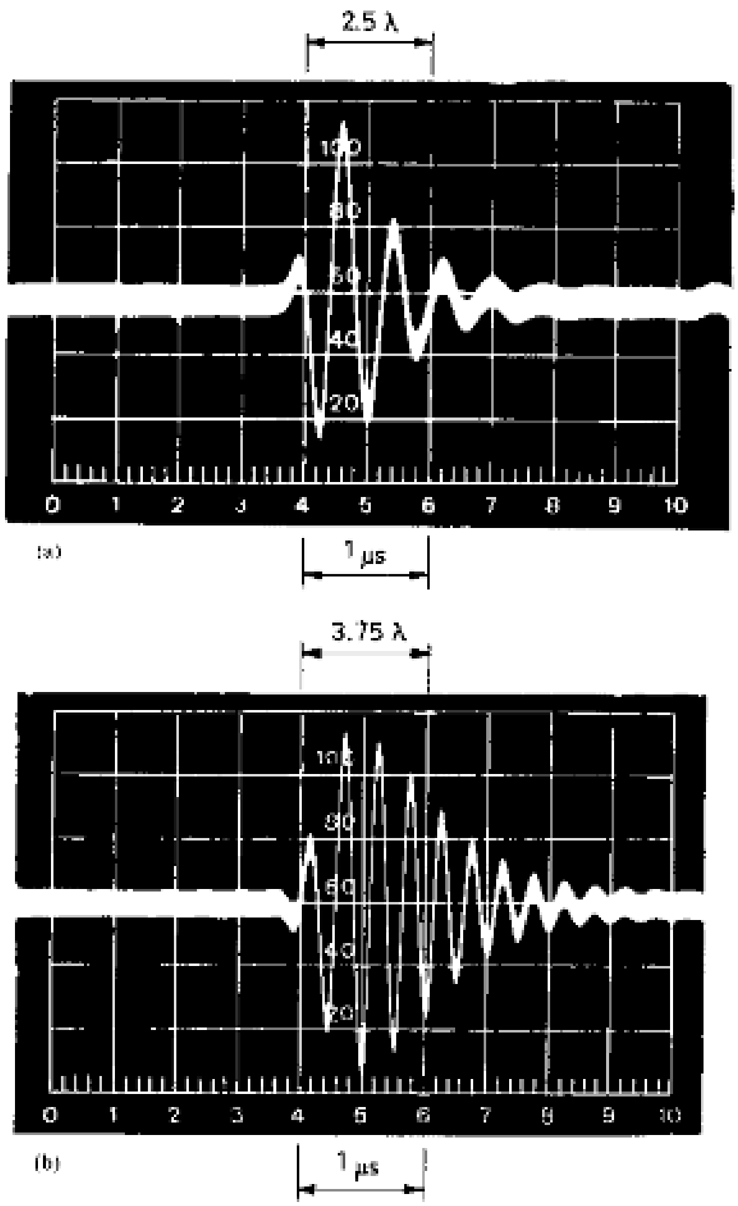


Fig. 2.7. TYPICAL UNRECTIFIED DISPLAYS

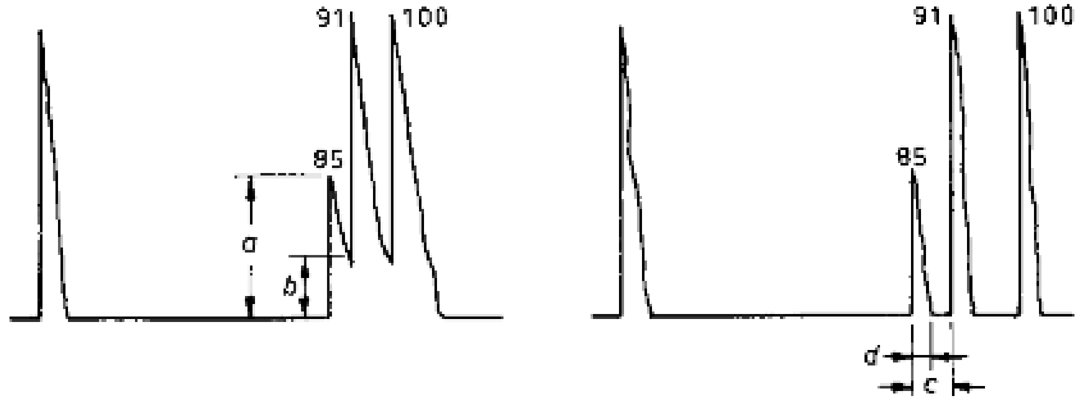


Fig. 2.8(A). TYPICAL DISPLAYS FOR THE ASSESSMENT OF RESOLUTION—PROCEDURE(i)
(See Clause 2.2.7.1(c)(i))

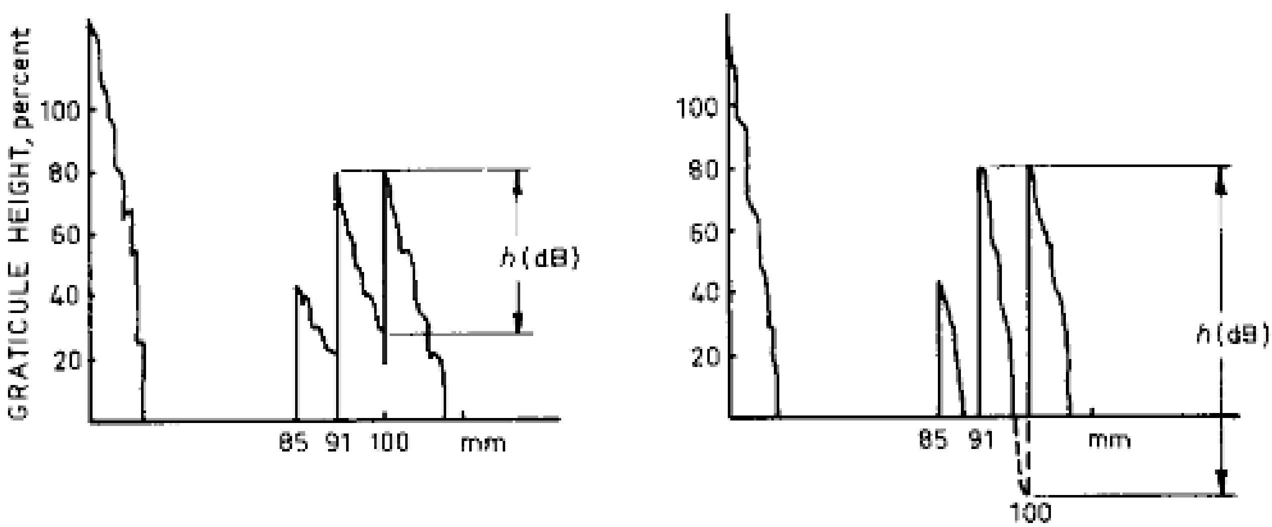


Fig. 2.8(B). TYPICAL DISPLAYS FOR THE ASSESSMENT OF RESOLUTION—PROCEDURE(ii)
(See Clause 2.2.7.1(c)(ii))

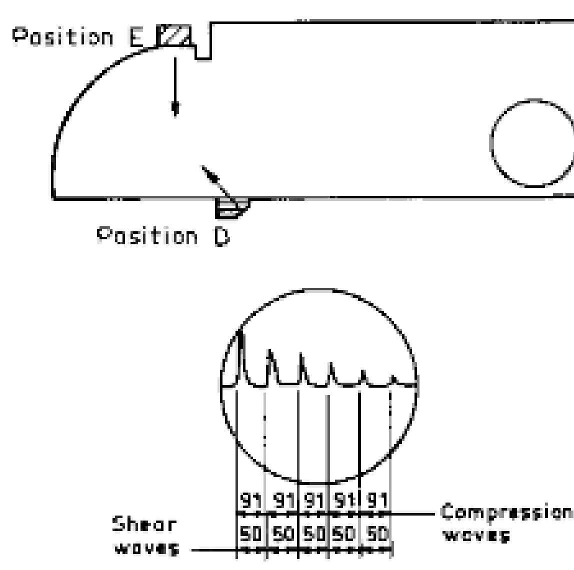


Fig. 2.9. CALIBRATION OF TEST RANGE USING CALIBRATION BLOCK NO 1

2.3.2 Determination of Probe Index. Position the probe at 'D' (see Fig. 2.9) and maximize the signal amplitude from the 100 mm radius surface. When this maximum is reached, the probe index corresponds to the 0.5 mm slot in the block. The position of the probe index should be noted or marked on the probe.

NOTE: To ensure that probe movement is always parallel to the side faces, it is advisable to position a guide strip on one of the side faces. 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 2.3.5).

2.3.3 Determination of Beam Angle. Position the probe at 'C' or 'F' (see Fig. 2.10) and maximize the signal from the 50 mm or 1.5 mm diameter hole, as applicable. The beam angle can be estimated from the engravings on the block. Alternatively, the angle can be calculated by use of the following formulas:

(a) *For position 'F'.*

Time base calibrated: $\sin \alpha = \dfrac{x - 35}{R + 25}$

Time base uncalibrated: $\tan \alpha = \dfrac{x - 35}{70}$

where x and R are determined from Fig. 2.10 and are in millimetres.

(b) *For position 'C'.*

Time base calibrated: $\sin \beta = \dfrac{x - 35}{R_1 + 25}$

Time base uncalibrated: $\tan \beta = \dfrac{x - 35}{30}$

where x and R_1 are determined from Fig. 2.10 and are in millimetres.

The determination of beam angles of 70 degrees and greater is made more accurately by using the 1.5 mm diameter hole. Calibration block No 2 also provides a means for the more accurate determination of beam angle (see Section 3).

Since the velocity of ultrasonic waves is temperature dependent, beam angle determinations should be made at a temperature similar to that which pertains to the working environment.

NOTE: For a probe with a Perspex shoe transferred from a surface cool to the touch (e.g. 10°C) to one warm to the touch (e.g. 40°C), there would be a reduction in velocity of the order of 3.5 percent which in turn would result in an increase of beam angle of the order of 2 degrees for a 45-degree probe and 6 degrees for a 70-degree probe.

2.3.4 Setting of Reference Sensitivity. The reference sensitivity may be set by either of the following procedures:

(a) *Using the 100 mm radius.* Position a probe at 'D' (see Fig. 2.2) and maximize the echo from the 100 mm radius surface. Adjust the attenuator to provide a reference echo of chosen amplitude. The resulting attenuator reading can be used as a reference sensitivity with which a working sensitivity can be correlated.

(b) *Using the 1.5 mm diameter hole.* By reference to Fig. 2.2, position the probe at 'B' for probes of beam angles less than 63 degrees, and at 'F' for probes of beam angles 70 degrees or greater to provide a reference echo from the 1.5 mm diameter hole and proceed as in (a) above.

2.3.5 Assessment of Beam Alignment. Maximize the echo from a corner reflector by swivelling the probe in the position illustrated in Fig. 2.11. Lay a straight-edge against the probe shoe and mark its position. The angle between the line so drawn and a line at right angles to the edge of the block is the angular deviation from optimum beam alignment and may be measured with a protractor as shown. The angle and the direction of deviation, i.e. left or right, shall be noted.

NOTES:

1. A magnetized straightedge is preferable.
2. In order to obtain sufficient accuracy, the protractor should be at least 150 mm diameter.

2.3.6 Measurement of Dominant Frequency. Measure the dominant frequency of the testing system by calibrating the time base using a compression wave probe as described in Clause 2.3.1(a) and proceeding as described in Clause 2.2.6(a) and (b).

2.3.7 Assessment of Resolution by Measurement of Pulse Length. Position the probe at 'D' (see Fig. 2.2) and obtain a back echo from the 100 mm radius. Assess the resolution by measuring the pulse length by using either of the following procedures:

(a) *Rectified display.*

(i) Using a rectified display, no suppression and that degree of filtration appropriate to the test conditions, calibrate the time base to a short range (10 mm to 25 mm full screen) to expand the envelope of the pulse.

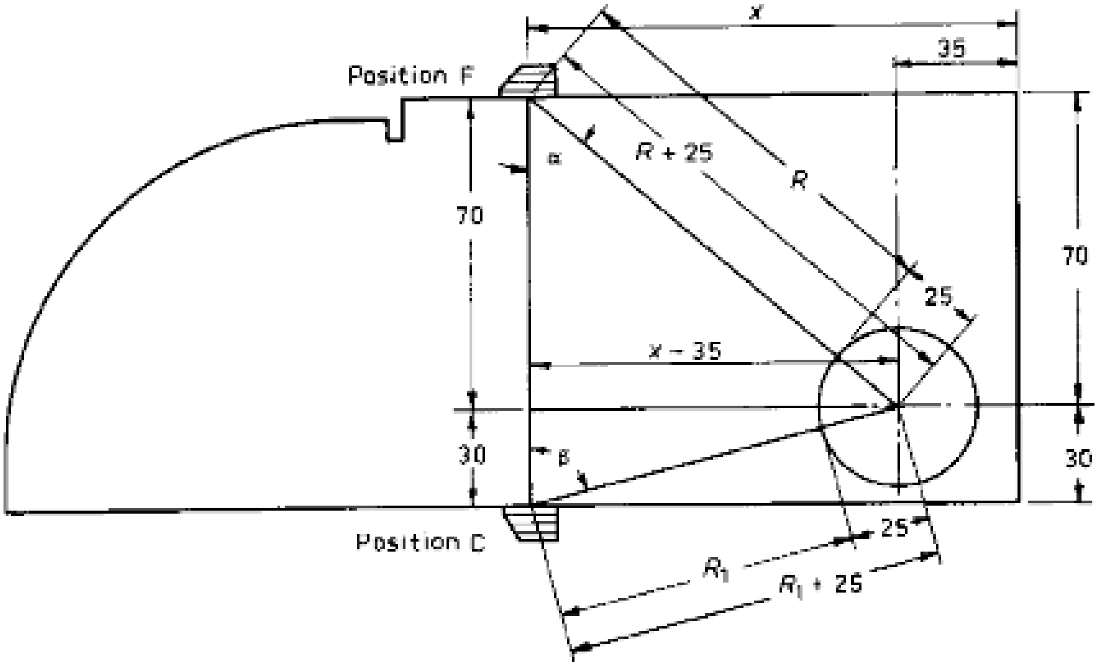
(ii) Place the probe on a suitable surface of the block to produce a back echo and adjust the delay and amplification to display the back echo at an amplitude within the vertical linearity.

(iii) Estimate the pulse length as the distance between the points on the rising and falling flanks of the displayed pulse which are at 10 percent of the peak amplitude (see Fig. 2.12(A)). The pulse length can be expressed in millimetres of material, or, from a knowledge of velocity of propagation, as a time interval.

(b) *Unrectifed display.* The pulse length may be determined during the assessment of probe performance from an unrectified display, and should be expressed as the number of cycles in the pulse, to the nearest positive half-cycle of greater than 10 percent of peak amplitude (see Fig. 2.12(B)).

NOTE: The shorter the pulse length the higher the resolution. Increased accuracy of resolution can be achieved by the use of calibration block No 6 (see Section 7).

2.3.8 Assessment of Overall System Gain. Position the probe at 'F' (see Fig. 2.2) and assess the overall system gain in a similar manner to that described in Clause 2.2.9.



DIMENSIONS ARE IN MILLIMETRES

Fig. 2.10. GEOMETRIC DETERMINATION OF BEAM ANGLE USING CALIBRATION BLOCK NO 1

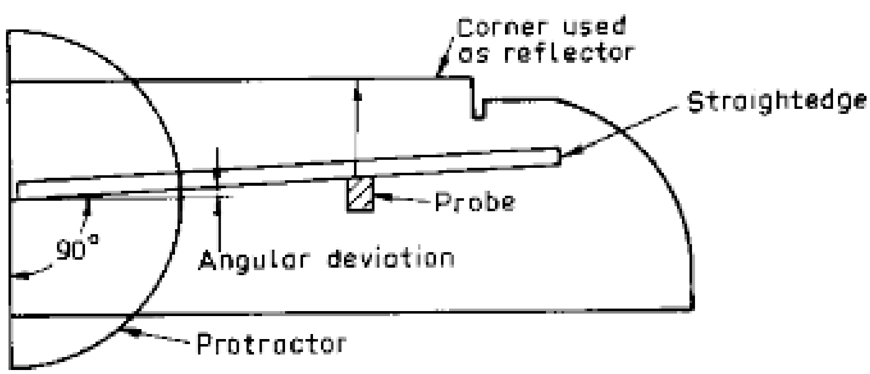


Fig. 2.11. MEASUREMENT OF ANGULAR DEVIATION USING CALIBRATION BLOCK NO 1

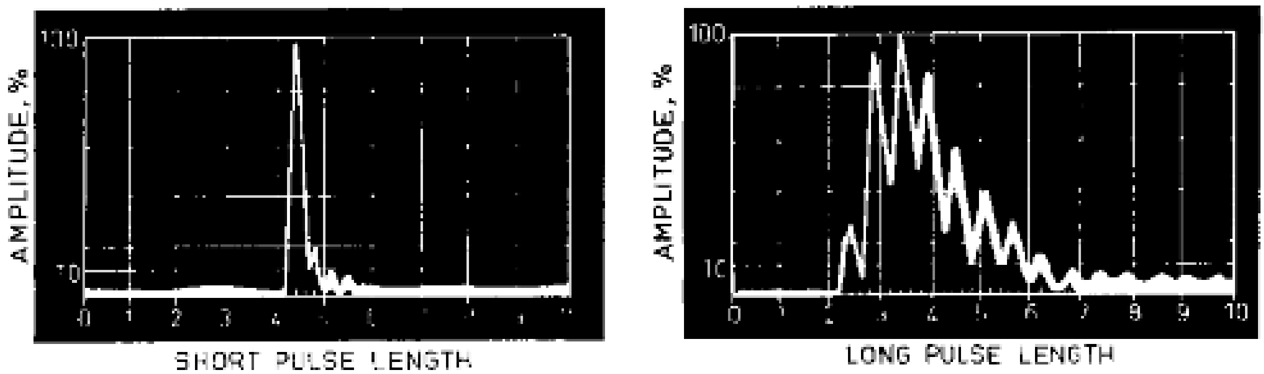


Fig. 2.12(A). TYPICAL RECTIFIED DISPLAY

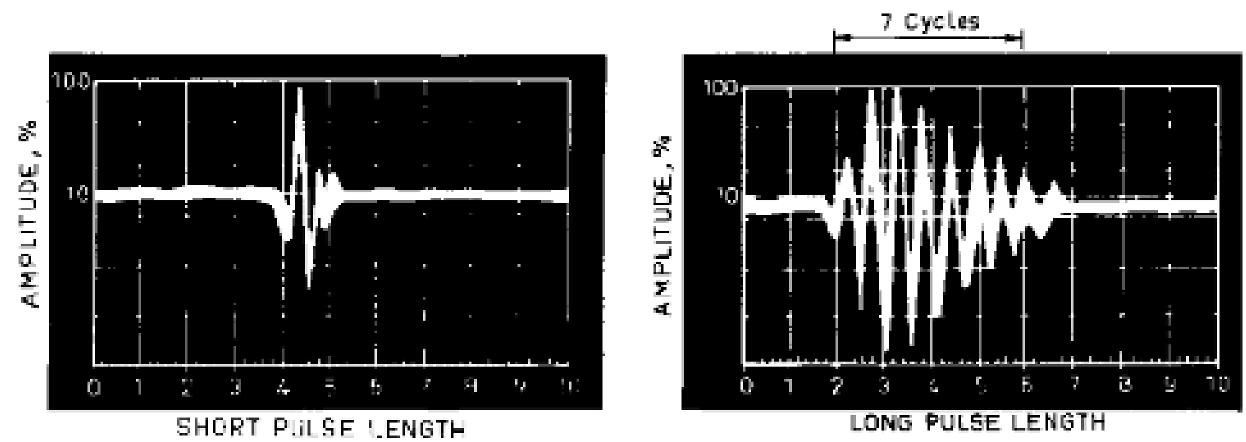


Fig. 2.12(B). TYPICAL UNRECTIFIED DISPLAY