IS 15452 (2004): Recommended Practice for Flaw Sizing by Ultrasonic DGS Method [MTD 21: Non-Destructive Testing]

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भारतीय मानक

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Indian Standard

RECOMMENDED PRACTICE FOR FLAW SIZING BY ULTRASONIC DGS METHOD

ICS 77.040.20

B U R E A U   O F   I N D I A N   S T A N D A R D S
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NEW DELHI 110002

September 2004

Price Group 5

Non-destructive Testing Sectional Committee, MTD 21

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Non-destructive Testing Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Ultrasonic non-destructive testing techniques are extensively employed for detection, location, sizing and characterization of defects in the material. If the size of the flaw is smaller than the ultrasonic beam diameter, the estimation of size becomes difficult. In such an eventually, only equivalent reflector size can be estimated which is related to the true size. This estimation of equivalent reflector size is done with the help of DGS diagram.

The DGS diagram differs from transducer to transducer but remains same for transducers having identical frequency and diameter. These diagram can be used without difficulty, when the test object is made of low sound attenuation material, has a simple geometry and an even surface quality. It is an obvious choice where sizes of the small defects are to be evaluated.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical value (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

RECOMMENDED PRACTICE FOR FLAW SIZING BY ULTRASONIC DGS METHOD

1 SCOPE

This standard deals with the procedure for establishing the flaw size by DGS method in 'A' scan presentation.

NOTE—The flaw size established is the equivalent flaw as given in **3.2**.

2 REFERENCE

The following standard contains provisions which through reference in this text, constitutes provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

IS No.	*Title*
12666 : 1988	Methods for performance assessment of ultrasonic flaw detection equipment

3 DEFINITIONS

3.1 DGS Diagram — The diagram is the basis of the DGS method (D = distance, G = gain, S = equivalent flaw size). It consists of a group of curves, each of different equivalent flaw size drawn for a given transducer in relation to the flaw distance and the gain required to make the flaw signal height equal to that from an infinite planar flaw at the same location.

3.2 Equivalent Flaw Size

3.2.1 Since it is not possible to describe the true size of the flaw in 'A' scan presentation, the equivalent flaw size method is used. Establishing the size of the flaw by DGS method is therefore the determination of the size of a circular reflector which would produce the same echo amplitude as the flaw at the same location. The diameter of the assumed flat circular reflector is specified as equivalent flaw size.

4 EQUIPMENT

4.1 The examination shall be carried-out using any pulse echo equipment having 'A' scan presentation.

4.2 The equipment shall satisfy the time base linearity, vertical scale linearity and amplitude control linearity and evaluated as per IS 12666.

5 NORMAL BEAM DGS DIAGRAM

5.1 General

5.1.1 The diagram is shown in Fig.1. In this figure the flaw distance is graduated in terms of near field length.

Flaw distance, $D = a/N$

where

D = reduced distance;

A = real distance of flaw in mm; and

N = near field length in mm.

Equivalent flaw size 'S' is given in terms of the effective diameter of the probe:

$$S = \frac{D}{D_{eff}}$$

where

S = reduced flaw size;

d = diameter of equivalent flaw size; and

D_{eff} = effective crystal diameter, in mm.

5.1.2 When the near field length 'N' is not known from the probe data sheet, it can be calculated from the formula

$$N = \frac{D_{eff}^2}{\text{Wave length}} = \frac{D_{eff}^2}{4 \times \text{Velocity of sound}} = \frac{D_{eff}^2 \times \text{Frequency}}{4 \times \text{Velocity of sound}}$$

6 SENSITIVITY SETTING

6.1 The recording limit of the smallest equivalent flaw size is pre-determined relevant to the intended application. The reference infinite reflector (back wall) is kept at 40 percent of vertical scale. The following plate testing example will illustrate the above method.

6.2 Example

Plate thickness	: 100 mm
Probe frequency	: 4 MHz
Probe diameter (eff)	: 25 mm
Near field length (N)	: 104 mm
Smallest flaw to be detected	: 5 mm diameter (S 0.2)
Flaw echo height	: 2 screen divisions (40 percent of full screen height)

6.2.1 The first back echo will be at a distance of approximately one near field. It can be seen from

Fig. 1 that closes to the surface of the test piece, a flaw of $S = 0.2$ will give an echo approximately 28 dB below the back echo. Near the back surface of the specimen such a flaw will only be 17 dB below, but at most unfavourable position ($D = 0.5$), it is 29 dB below.

6.2.2 The most unfavourable position $D = 0.5$ is considered for record level line and indicated by dotted lines in the DGS diagram. The scanning sensitivity is determined as +29 dB over the back wall echo kept at 40 percent of vertical scale. This calibration ensures that all flaws of $S = 0.2$ and above will produce indications not less than 40 percent of vertical scale.

6.2.3 *Material Attenuation*

6.2.3.1 Attenuation will be measured and a curve shall be drawn for the maximum test range as given in Annex A.

6.3 Flaw Size Estimation

6.3.1 Examination shall be carried out with the scanning sensitivity as detailed in **6.2.2**.

6.3.2 For any recordable flaw echo the gain difference between the scanning sensitivity and the gain noted for keeping the flaw echo at 40 percent of vertical scale, is determined. With that gain a correction shall be made for attenuation difference between record level line and attenuation curve at that flaw echo beam path. For the corrected gain, the flaw size shall be read above the record level in the DGS diagram (*see* Fig. 1).

6.3.3 *Example*

Back wall echo at 40 percent of vertical scale	: 17 dB
Scanning sensitivity	: 17 + 29 = 46dB
Flaw echo beam path	: 62 mm (0.6 N)
Gain difference between the scanning sensitivity and flaw echo at 40 percent of vertical scale	: 46 – 27 = 19 dB
Record level to attenuation curve at 0.6 N beam path	: 3 dB (Fig. 1)
Therefore final flaw position above record level	: 19 – 3 = 16 dB
Equivalent flaw size diameter	: $0.4 \times 25 = 10$ mm diameter

6.3.4 If it is not possible to obtain the back wall due to geometry, other reference block can be used. But the transfer loss has to be taken into consideration as done in normal beam examination (*see* Annex B).

6.3.5 Instead of general DGS normal beam diagram, specific diagram for the probe in use supplied by the probe manufacturer can be used.

6.4 Angle Beam DGS Diagram

6.4.1 *General*

6.4.1.1 DGS diagrams for the angle beam probes are shown in Fig. 2 and Fig. 3. In these diagrams the distance is indicated in beam path and projection distance from front edge of the probe. As the diagrams are for specific probe sizes the equivalent flaw size is directly given in millimetres. Similar diagrams for specific probes supplied by the probe manufacturer may be used.

6.4.2 *Scanning Sensitivity*

6.4.2.1 In angle beam examination there is no back wall echo for reference. So the reference echo is taken from the curved surface (100 mm radius) of V_1 block. When V_1 block is used corrections should be made for the different surface conditions (transfer loss) between the V_1 block and the test piece, and the difference in attenuation.

6.4.2.2 The following procedure shall be followed to arrive at the correct scanning sensitivity to ensure that the recordable flaw will give an echo equal and above 40 percent of vertical scale throughout the scanning distance:

a) Measure of material attenuation shall be done as per Annex C;

b) Measurement of transfer loss between reference block and the test piece shall be done as per Annex D;

c) The difference in decibels between back echo curve at 100 mm to minimum record level flaw at the maximum test range on DGS diagram of the particular probe shall be noted; and

d) Time base of the equipment shall be calibrated. The back wall echo from 100 mm radius of V_1 block shall be set at 40 percent of vertical scale. Difference in decibel as in (c) ; transfer loss in (b) and difference in attenuation between 100 mm beam path for V_1 block and maximum testing range of the test piece shall be added. This shall be the scanning sensitivity.

6.4.2.3 *Example*

1. Probe	: 4 MHz 8 × 9 mm crystal size
2. Record level	: 2 mm diameter equivalent flaw
3. Maximum test range	: 150 mm
4. Transfer loss	: 3 dB
5. Attenuation of V_1 block	: 40 dB/m of beam path
6. Attenuation of test plate	: 80 dB/m of beam path
7. Recording level height	: 40 percent of vertical scale

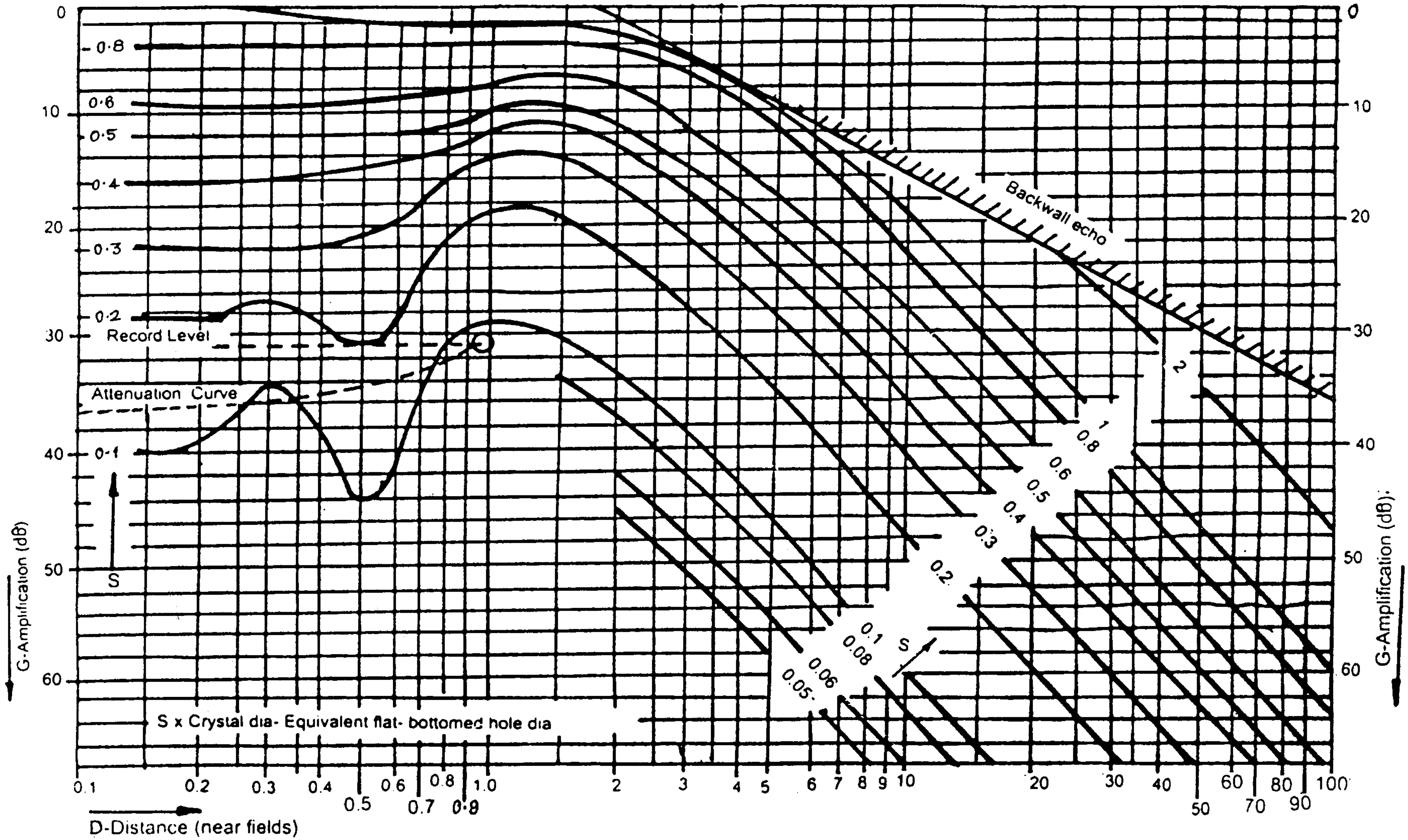

FIG. 1 TYPICAL DGS DIAGRAM FOR NORMAL PROBES FOR ANY PROBE AND ANY EQUIPMENT

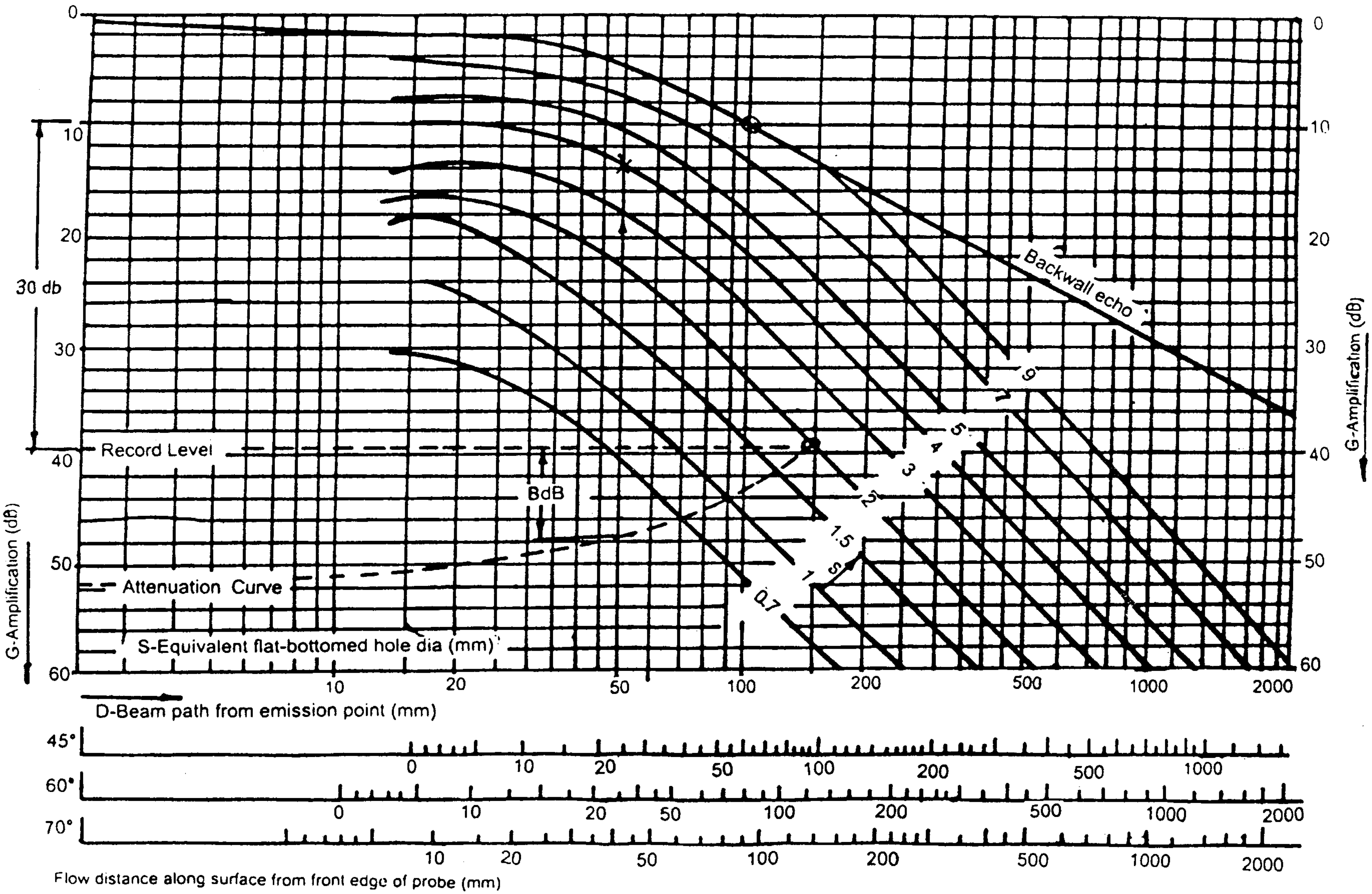

FIG. 2 TYPICAL DGS DIAGRAM FOR ANGLE PROBES OF 4 MHz 8 mm × 9 mm CRYSTAL SIZE FOR SPECIFIC PROBE AND ANY EQUIPMENT

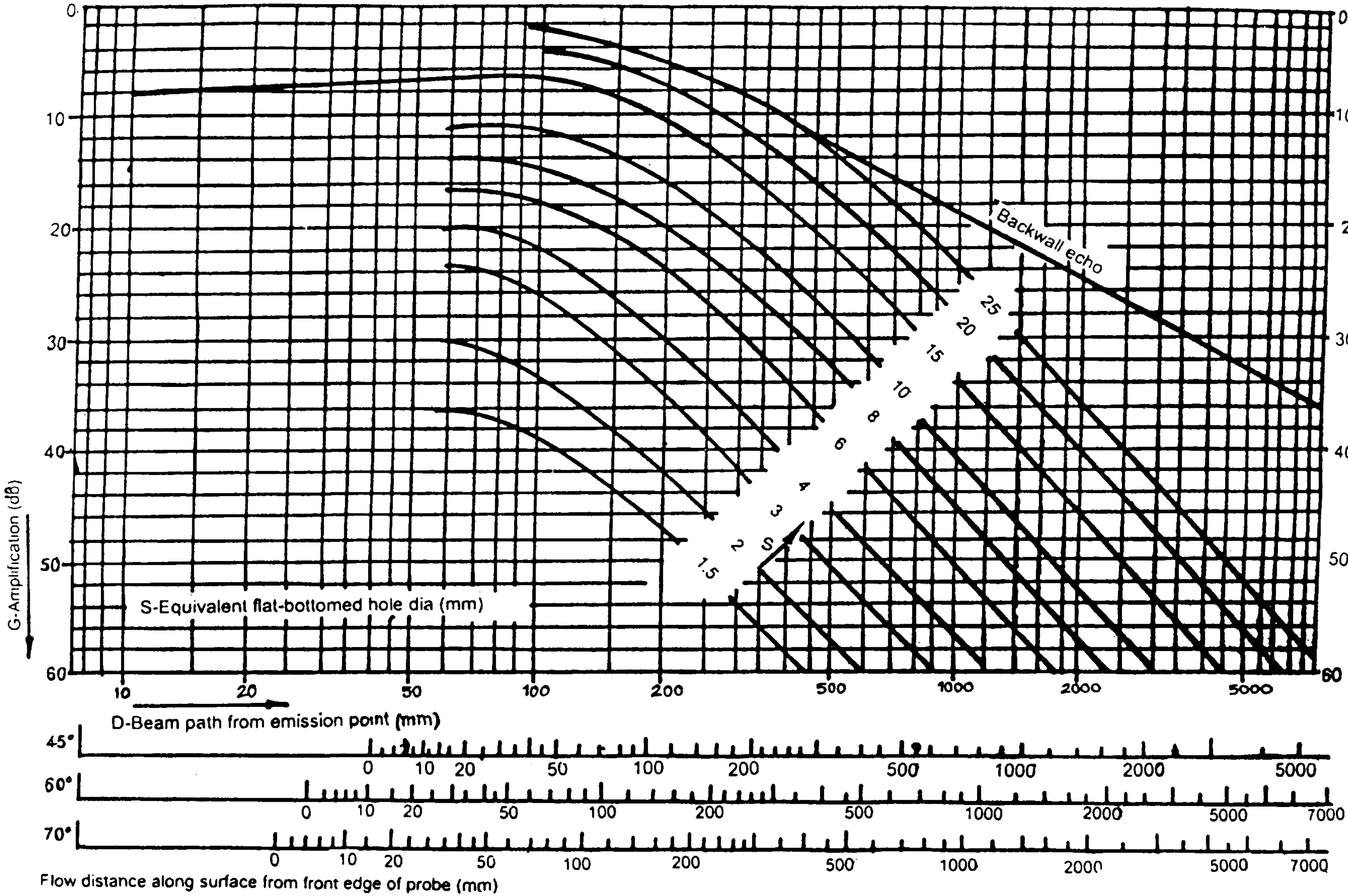

Fig. 3 Typical DGS Diagram for Angle Probes of 2 MHz of 20 mm × 22 mm Crystal Size

Scanning sensitivity for the above example:

Back wall echo of V_1 block at 40 percent of vertical scale : 25 dB

Difference in gain between back wall curve at 100 mm beam path and 2 mm curve (Record level) at 150 mm beam path (maximum test range). : 30 dB

Transfer loss : 3 dB

Attenuation difference between 100 mm beam path for V_1 block and 150 mm beam path for test plate : 8 dB

Hint

150 mm beam path for test plate = 150 × 0.08 = 12 dB

100 mm beam path for V_1 block = 100 × 0.04 = 4 dB

Attenuation difference = 12 – 4 = 8 dB

Therefore scanning sensitivity = 25 + 30 + 3 + 8 = 66 dB

6.4.3 *Flaw Size Estimation*

6.4.3.1 Record level line is marked on the DGS diagram taking the maximum of testing range.

6.4.3.2 Attenuation curve is drawn on the DGS diagram Fig. 2, as shown below:

Attenuation of V_1 Block = 40 dB/m of beam path

Attenuation of test plate = 80 dB/m of beam path

Beam Path	*V_1 Block Attenuation or 100 mm, B_1*	*Material Attenuation for Different Beam Path, B_2*	*Compensated Material Attenuation, B_3*	*Net Correction for Attenuation, $(B_1–B_2) + B_3$*
mm	dB	dB	dB	dB
(1)	(2)	(3)	(4)	(5)
10	4	0.8	8	11.2
25	4	2.0	8	10.0
50	4	4.0	8	8.0
80	4	6.4	8	5.6
100	4	8.0	8	4.0
150	4	12.0	8	0

6.4.3.3 Examination shall be carried out with scanning sensitivity at detailed in **6.4.2.3**.

6.4.3.4 For any recordable flaw echo the gain difference between the scanning sensitivity and the gain noted for keeping the flaw echo at 40 percent of vertical scale shall be noted. With that gain a correction shall be made for the attenuation difference between the record level and attenuation curve at that flaw beam path. For the corrected gain the flaw size shall be read above the record level line in the DGS diagram.

6.4.3.5 *Example* (see *Fig.* 2)

Flaw echo beam path : 50 mm

Scanning sensitivity : 66 dB

Flaw echo at 40 percent of vertical scale : 32 dB

Gain difference between the scanning sensitivity and the flaw echo at 40 percent of vertical scale : 66 – 32 = 34 dB

Record level to attenuation curve at 50 mm beam path : 8 dB

Therefore final flaw position above record level : 34 – 8 = 26 dB

Equivalent flaw size : 4 mm diameter

6.4.4 *Correction for Quadrant*

6.4.4.1 For the back wall echo obtained from 100 mm quadrant a correction shall be applied as recommended by the probe manufacturer. Some typical values are given below:

Frequency MHz	*Crystal Size*	*Angle*	dB *Correction*
2	20 mm × 22 mm	45°	+1
		60°	+2
		70°	+4
2	8 mm × 9 mm	45°	+10
		60°	+10
		70°	+10
4	8 mm × 9 mm	45°	+5
		60°	+6
		70°	+9

ANNEX A

(*Clause* 6.2.4.1)

MEASUREMENT OF ATTENUATION FOR NORMAL BEAM

A-1 The following procedure shall be adopted.

A-1.1 Probe of same frequency and size as used for the test shall be used.

A-1.2 First and second wall echoes will be obtained from the test piece.

A-1.3 Second back echo will be kept at 40 percent of vertical scale.

A-1.4 Gain required to bring the first back echo to 40 percent of vertical scale will be noted.

A-1.5 From this value, the difference in dB of first and second back wall echo beam paths with respect to back wall curve as noted from DGS diagram will be subtracted. That will give the attenuation for the wall thickness of the specimen.

Example

Probe	:	4 MHz, 25 mm diameter crystal size
Test plate thickness	:	100 mm
Gain required to keep 2nd back echo at 40 percent of the vertical scale	:	48 dB
Gain required to bring 1st back echo to 40 percent of vertical scale	:	40 dB
Difference according to DGS diagram	:	1.5

$$\text{Therefore attenuation, } \frac{8-1.5}{100} = \frac{6.5}{100}$$

= 0.065 dB/mm of beam path

A-1.6 From the point of inter section of record level line and back wall echo distance the attenuation curve will be drawn in Fig. 1 as shown below:

Beam Path (1)	*Material Attenuation for Back Wall* (0.06 dB/mm *for* 100 mm) (2)	*Calculated Attenuation for Different Beam Path* (3)	*Correction Gain for Attenuation* (4)
100	6	6	0
80	6	4.8	1.2
60	6	3.6	2.4
40	6	2.4	3.6
20	6	1.2	4.8

ANNEX B

(*Clause* 6.3.4)

TRANSFER LOSS WITH NORMAL BEAM

B-1 When cylindrical specimen are examined [*see* Fig. 4(a)] with normal beam the back wall echo can be considered for reference only if the diameter of the specimen is larger than three near field length of the probe being used. If, however, the internal boring on hollow specimen is to serve as the reference reflector [Fig. 4(b) and Fig. 4(c)] the echo from the boring cannot be used as a normal equivalent back wall echo. The gain values set using the boring are too high. In this case the dB value set with boring is to be reduced by the amount read from the monograph (*see* Fig. 5). This correction supplies approximate values which give good results at test frequencies 2 to 4 MHz.

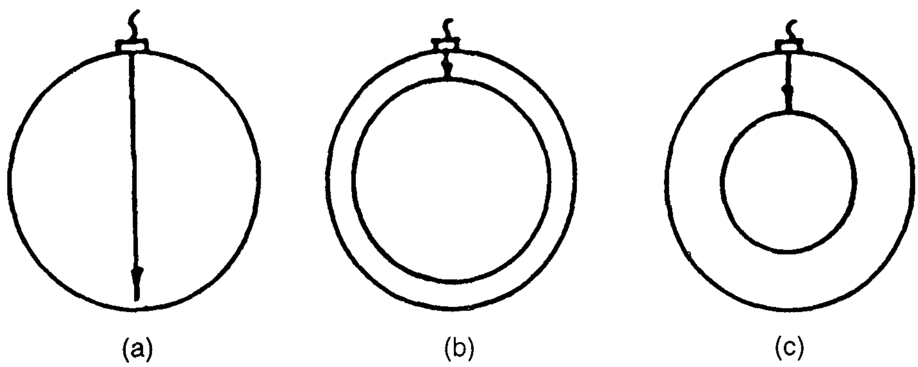

FIG. 4 CYLINDRICAL SPECIMEN

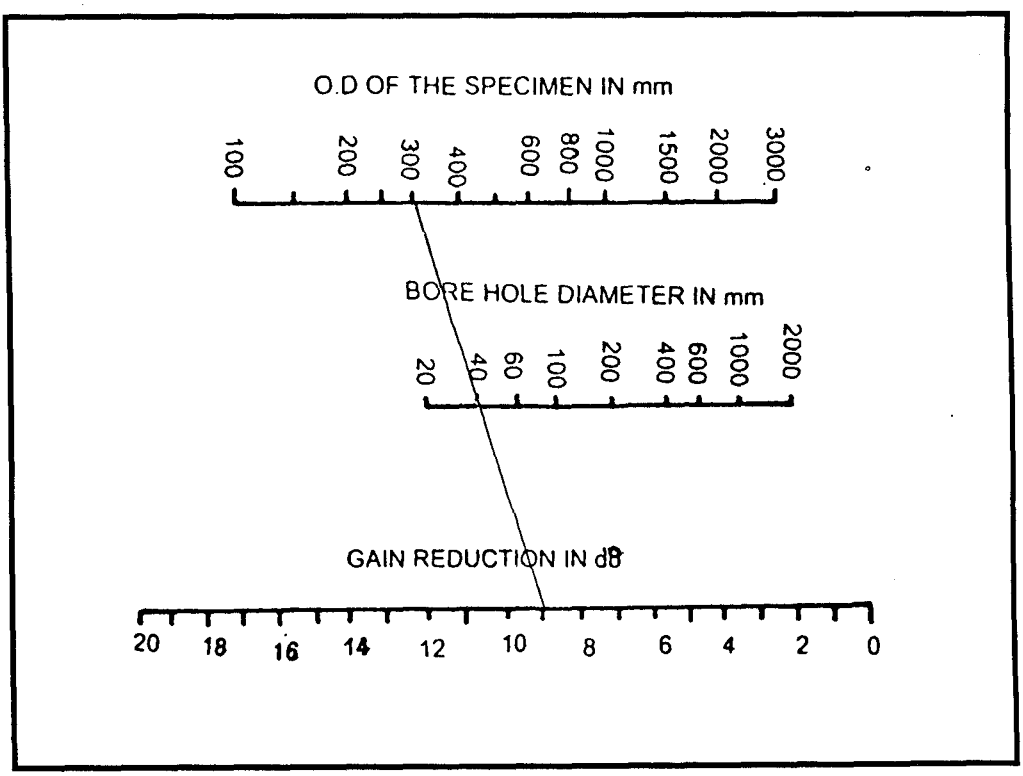

FIG. 5 MONOGRAPH

ANNEX C

(*Clause* 6.3.2.2)

MEASUREMENT OF SHEAR WAVE ATTENUATION

C-1 The following procedure shall be adopted.

C-1.1 Probe of the same angle and frequency as used for the test will be used and the time base shall be calibrated in beam path.

C-1.2 Two separate probes from transmitter and other to the receiver will be arranged as shown in Fig. 6, so that signal for configuration AB_1 appears at 50 mm and signal for AB_2 at 100 mm on the screen.

C-1.3 The gain difference in decibels between the signal heights AB_1 and AB_2 will be noted.

C-1.4 The difference in decibels for these beam paths with back wall curve as indicated on the DGS diagram will be subtracted. The remainder will be the attenuation for half skip distance.

Example

Probe	:	4 MHz, 8×9 mm crystal size
Difference in beam path between AB_1 and AB_2, that is 1/2 skip distance	:	50 mm
Echo height corresponding for configuration AB_1	:	44 dB
Echo height corresponding for configuration AB_2	:	53 dB
		9 dB

Difference according to DGS diagram = 5dB

Therefore, attenuation $= \dfrac{9\text{ dB} - 5\text{ dB}}{50} = 0.08$ dB/mm of beam path.

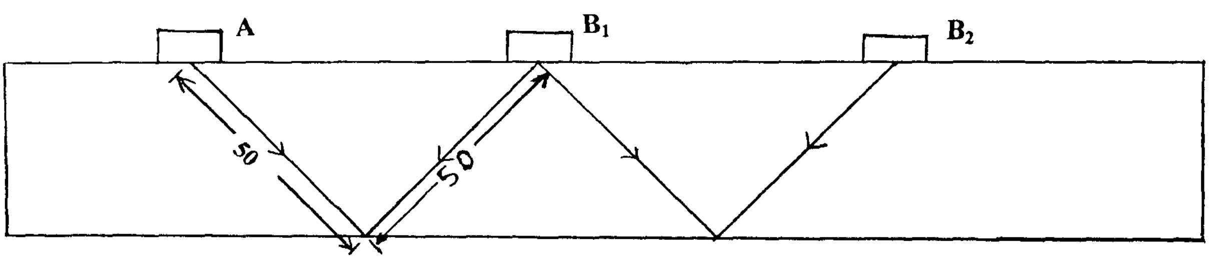

FIG. 6 PROBE ARRANGEMENT

ANNEX D

(*Clause* 6.3.2.2)

MEASUREMENT OF TRANSFER LOSS

D-1 The following procedure shall be adopted.

D-1.1 Probe of the same angle and frequency as used for the test will be used and the time base will be calibrated in beam path.

D-1.2 Two probes of separate transmitter and receiver will be used as shown in Fig. 7.

D-1.3 The dB difference between signal heights of V_1 block and test plate is noted.

D-1.4 The difference in decibels for these beam paths as noted from the DGS diagram and attenuation difference of reference block at 50 mm and plate at 80 mm, will be subtracted. The remainder will be the transfer loss.

Example

Probe	:	4MHz – 8×9 mm crystal size
Through transmission signal of reference block	:	56 dB
Through transmission signal of test plate	:	66 dB
		10 dB
Attenuation of V_1 block for 50 mm beam path	:	50 × 0.04 = 2 dB
Attenuation of test plate for 80 mm beam path	:	80 × 0.08 = 6.4 dB
Difference in attenuation between V_1 block	:	6.4 – 2 = 4.4 dB
Difference according to DGS diagram 50 mm to 80 mm	:	3 dB
Therefore, transfer loss = 10 – (4.4+3)	:	3 dB (approximately)

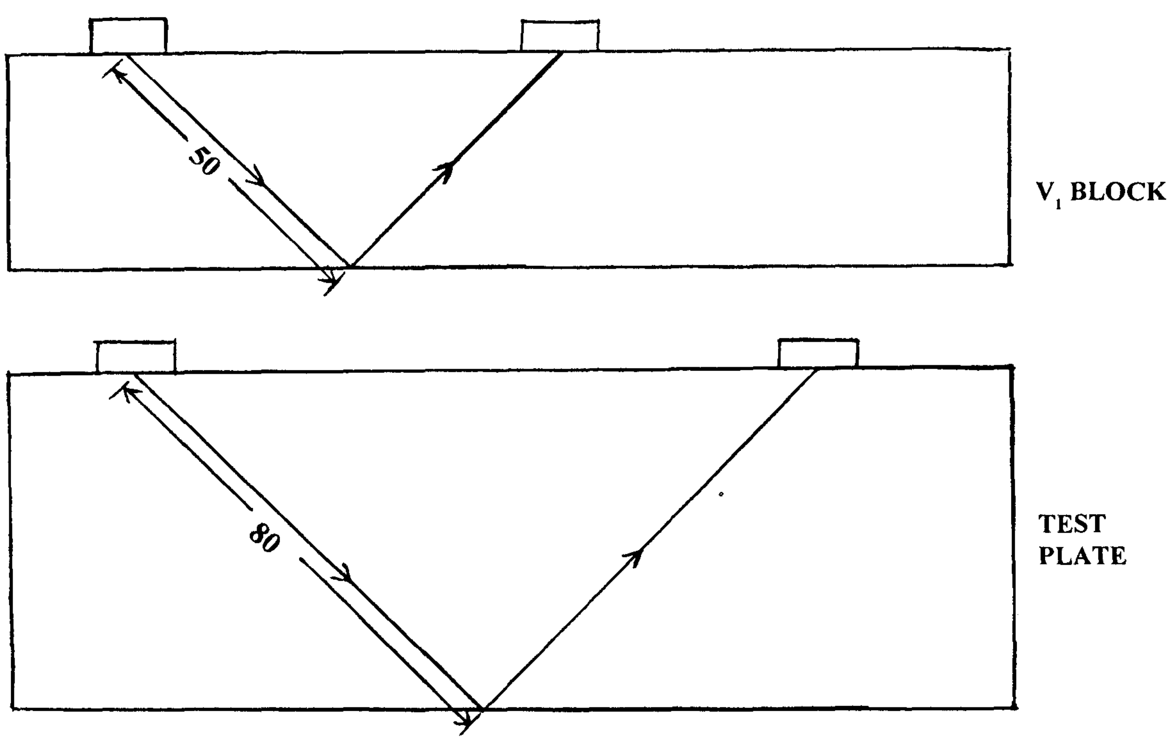

FIG. 7 PROBE ARRANGEMENT

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Amendments Issued Since Publication

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