ULTRASONIC INSPECTION OF WELD CONNECTIONS

MAY 1980
Classification Notes are publications which give practical information on classification of ships and other objects. Examples of design solutions, calculation methods, specifications of test procedures, quality assurance and quality control systems as well as acceptable repair methods for some components are given as interpretations of the more general rule requirements.

An updated list of Classification Notes available is given in the latest edition of the Introduction-booklet to the «Rules for Classification of Steel Ships». 
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1. INTRODUCTION

This Classification Note applies to procedures for ultrasonic testing of weld connections in steel with thicknesses in the range 5 mm - 250 mm. The requirements are in general to be adhered to, as far as applicable, when ultrasonic testing of weld connections are required by the Society. The use of other standards or manuals may, however, be granted if an equivalent ultrasonic inspection is ensured.
2. REQUIREMENTS TO ULTRASONIC EQUIPMENT

2.1 Ultrasonic apparatus

2.1.1 The ultrasonic apparatus is to cover a frequency range of at least 1.0 – 6.0 MHz.

2.1.2 The ultrasonic apparatus is to be fitted with a calibrated gain regulator with a maximum of 2 dB per step.

2.1.3 The ultrasonic apparatus is to be equipped with a flat screen extending to the front of the apparatus so that a reference curve can be drawn directly on the screen.

2.1.4 The ultrasonic apparatus must be able to work with both combined and separated transmitter and receiver probe.

2.2 Probes

2.2.1 Normal probes which are utilized, are to cover a frequency range of 1.0 – 6.0 MHz.
Typical values are 1.0 MHz, 2.0 MHz, 4.0 MHz and 6.0 MHz.

2.2.2 The angle probes which are used, are to cover a frequency range of 1.0 – 6.0 MHz.
Typical values are 1.0 MHz, 2.0 MHz, 4.0 MHz and 6.0 MHz.

2.2.3 Probes which are used, are not to cause more noise than that an echo with a height of 5 % of full screen height can easily be distinguished from the normal level of noise.

2.2.4 On surfaces with a small radius of curvature, such as pipes with a small diameter, it may be necessary to adjust the probe shoe to attain sufficient contact between the material and the probe.

2.3 Coupling medium

2.3.1 A satisfactory couplant, in either fluid or paste form, is to be used to transfer the ultrasound from the probe to the material. Oil, grease, glycerine or paste are well suited to this purpose. (A cellulose gum is particularly suitable as it can be removed with water after inspection is completed).
2.4 Calibration blocks for range and angle calibration

2.4.1 For the calibration of the ultrasound apparatus' range scale and the angular determination of angle probes, an IIW calibration block or a V2 calibration block is to be used (DIN 54122). These are shown on figure 1.

2.5 Other aids

2.5.1 "Ultrasound slide rules" or tables for determining the position of defects can be used. Similarly, a slide gauge for measuring the distance from the angle probe to the defect can be used as well as any other necessary measuring and marking equipment.

3 PREPARATION OF SURFACE

3.1 Contact surface

3.1.1 The contact surface is to be free of weld splatter and any other substance which may impede the free movement of the probe or hinder the transmission of ultrasound to the material. A light grinding of the surface may be necessary.

3.2 Weld reinforcement

3.2.1 Grinding of the weld can be necessary if its form is such that it masks reflections from defects near the weld or gives signals which makes inspection impossible.

4 CALIBRATION

4.1 Calibration of range scale

4.1.1 The calibration of the range scale with normal probe is to be carried out with an IIW calibration block, a V2 calibration block or on a defect free calibration block of the same material as that which is to be inspected, see figure 2. The range scale is to be selected such that there are always at least 2 backwall echoes (reflections) on the screen when one is calibrating. The first echo is put at 75 % of full screen height and with the test range selector and the zero point control of the ultrasonic apparatus one positions the echoes in such a way that the distance between them represents the thickness of the calibration block.

4.1.2 The calibration of the range scale with an angle probe is to be carried out with an IIW (I.S.O.) calibration block or a V2 calibration block, see figure 3.
The probe index on the probe is to be determined by placing the probe as shown in figure 3 a, and by maximizing the echo height against the cylinder surface with radius 100 mm (IIW) or 25 mm (V2), the echo height is adjusted to about 75 % of full screen height. The probe index can now be read off against the mark on the calibration block and is marked off on the probe or made a note of.

The range scale is calibrated by placing the probe as shown in figure 3 b (IIW) or 3 c (V2). In these positions one must always get at least 2 echoes. The echo heights are maximized, and the first echo is set at 75 % of full screen height. With the aid of the ultrasonic apparatus’ test range selector and zero point control the echoes are positioned so that they fall at 100 mm and 200 mm for the IIW block, see figure 3 b. The V2 block gives echoes at 25 mm and 100 mm or 50 mm and 125 mm, see figure 3 c.

4.2 Control of probe angle

4.2.1 The probe angle is to be checked on the IIW block using the probe index found under 4.1.2, the echo from the circular perspex reflector is maximized and put at 75 % of full screen height. The probe angle can now be read off on the calibration block against the engraved centre point, see figure 4.

4.3 Correction for deviation in sound velocity

Calibration as mentioned under 4.1 and 4.2 on IIW block or V2 block, is only valid for inspection of steel with approximately the same sound velocity as that of the calibration block (about 5900 m/s compressional wave velocity, 3200 m/s transverse wave velocity). If one is working with steel qualities which have other sound velocities, the probe angle is to be corrected in accordance with this, or one is to use a calibration block of the same material as that which is being investigated. Any deviation can be checked by calibrating the range scale on the IIW block with a normal probe and subsequently measuring a known material thickness with this calibration.

5 CALIBRATION OF AMPLIFICATION

Calibration of the gain control is carried out by utilizing drilled holes as reference reflectors. These are placed either in the production material or in reference blocks, and by means of varying the distance between reflector and probe, one can set up a reference curve on the screen of the ultrasonic apparatus.

5.1 Reference curve

In order to compensate for attenuation and sound beam spread with increasing sound path a reference curve is to be constructed, which is drawn on to the screen of the ultrasound apparatus, and which gives the echo height from the same reflector at varying distance between probe and reflector.
5.1.1 The reference curve is to be constructed by using a drill hole as reference reflector. This drill hole is to be placed either directly in the production material or in a reference block made from the production material, or possibly from material with the same acoustic properties and surface as that which is to be investigated.

5.1.2 The reference block is to have a thickness \( T \) in relation to the production material, as shown in figure 5. Where two or more thicknesses form part of the weld connection, \( T \) is to correspond to the thinnest of these. If the contact surface of the material to be checked has a radius of curvature \( < 250 \text{ mm} \), the reference blocks radius of curvature is to be within \( \pm 10\% \) of that of the material.

5.1.3 The drill hole as shown on figure 5, is used as a reference reflector and is to be drilled parallel to the contact surface in the reference block or the production material. The positioning and the diameter of the drill hole are given in figure 5.

5.1.4 When constructing a reference curve with angle probe, the first point on the reference curve is to be determined by placing the probe in position A as shown on figure 6 a for plate thicknesses \( < 10 \text{ mm} \), as shown on figure 6 b for plate thicknesses between 10 mm and 25 mm, and as shown on figure 6 c for plate thicknesses \( > 25 \text{ mm} \). The distance in sound path from point A to the reference reflector must not be less than 0.6 \( N \), where \( N \) is the near field length for the relevant probe.

The echo height from the drill hole is maximized and the gain control is regulated, so that the echo height is 75 % of full screen height. This gain setting is called the primary gain and is recorded. Without altering the primary gain the probe is positioned in half skip distances as shown on fig. 6 a, 6 b and 6 c, and the respective echo heights are marked on the screen. These points are connected by a smooth line with a length which covers the measuring area in question. This is the reference curve. When the reference curve has been set up, another curve, which is 20 % of the reference curve, is to be drawn in, see figures 6 a, 6 b and 6 c.

If the reference curve by excessive sound paths falls to below 25 % of full screen height the gain in this area is to be increased in the following way.

The probe is placed in position B (alt. C) as shown on figure 7 and the echo height is maximized and put at 75 % of full screen height. The new primary gain is noted. Without altering this, the probe is moved to position C (alt. D) and a new reference curve is set up on the screen of the ultrasonic apparatus and its 20 % curve is drawn in. The primary gain will now be greater than for the original reference curve and applies only for inspection in this area.

5.1.5 For checking weld connections with a normal probe, for plate thicknesses less than 50 mm one is to construct a reference curve as follows:

On the production material or reference block with reference reflector as under 5.1.2 and 5.1.3, the probe is placed in position A, figure 8 a, the echo height is maximized and put at 50 % of full screen height. The primary gain is noted. The reference curve is drawn as a horizontal line on the screen.
For checking of weld connections with a normal probe for thicknesses greater than 50 mm, one is to construct a reference curve as follows:

On the production material or the reference block with reference reflector as under 5.1.2 and 5.1.3, the probe is placed over the drill hole in position A, see figure 8 b, the echo height is maximized and with the aid of the gain control is set at 50% of full screen height. This gain setting is the primary gain and is noted. Without altering this, the probe is moved to position B, the echo height is maximized and the appurtenant echo height is marked on the screen. The two points are connected with a straight line, which is extended in such a way that it covers the measurement area in question. This is the reference curve.

5.1.6 As shown on figures 6 a, 6 b and 6 c, the area of the reference curve between scale zero and the first point on the reference curve (A) is not defined for defect evaluation. The reason for this is that one enters here the probe near field and on account of the interference phenomena in the near field it is very difficult to assess the size of a defect. There is, however, nothing to prevent one looking for defects in this area. One is often forced to do this, for example when checking incomplete penetration in the root area of butt welds in thin plates with a face and root reinforcement which often conceal defects if one does not come close into the weld. If the reinforcement(s) can be ground down, there will be no problems, but this is often impossible when one is checking, for example, pipelines. When one finds defects by utilizing the near field area, the defect evaluation must take place in the area within the reference curve, i.e. the sound path to the defect is increased so that the echo from the defect remains within the reference curve area.

5.1.7 If the ultrasonic apparatus is fitted with electronic distance/amplitude correction, this can be used for angle probes and normal probes. The echo height from the drill hole in the production material or reference block is then to be adjusted to 75% of full screen height over the whole of the range in question. The reference curve will thus be a horizontal line. The gain setting is noted and comprises the primary gain.

5.1.8 Any possible differences in attenuation and surface character between the reference block and the production material when inspecting with angle probes, are to be checked in the following way:

One is to use two angle probes of the same type as those to be utilized during the inspection. The probes are placed on the production material as shown on figure 9. One of the probes works as transmitter probe, whilst the other acts as receiver probe. The first echo is maximized and with the aid of the gain control is put at a certain height on the screen, for example 4/5ths of the screen height. The gain setting is noted. Without altering this gain setting the probes are moved to the reference block, the echo height is noted and any difference in echo height between the two materials can be determined with the aid of the gain control. If any correction is found necessary, it is to be carried out as follows:

When the echo height from the production material is less than the echo height from the reference block, the difference, in dB, is to be added to the primary gain.

When the echo height from the production material is greater than that from the reference block, the difference, in dB, is to be subtracted from the primary gain.

This is the corrected primary gain, which is to be used when inspecting weld connections.
6. PERIODIC INSPECTION OF ULTRASONIC APPARATUS AND PROBES

In order to ensure at any time that the ultrasonic equipment is in order, the operator is to check the equipment during use.

6.1 Ultrasonic apparatus

At approximately two-hourly intervals the following checks are to be made:

6.1.1 Check the range scale with the aid of the IIW block or the V2 block as under 4.

6.1.2 Check the corrected primary gain as under 5.1.8.

6.2 Probes

The probes are to be checked frequently and always before and after a specific ultrasonic inspection. Angle probes used on rough surfaces are to be checked at two-hourly intervals.

6.2.1 Inspect the angle probe shoe for possible wear. If wear has caused an angle deviation $\geq 2^\circ$ from the nominal value, the probe is to be changed. When changing a probe, the whole of the gain calibration is to be repeated, see 5.1.4.

6.2.2 Normal probes are to be checked by placing them on the production material or reference block, and at least three bottom echoes must be able to be produced when the first bottom echo is put at 100 % of full screen height.

The protective cover is to be inspected. If it is deficient, it must be changed, and the whole of the gain calibration is to be repeated, see 5.1.5.

7. INSPECTION PROCEDURE

This procedure covers control of the parent metal with a normal probe and control of the weld connection with an angle probe and a normal probe.

7.1 Preceding information

Before investigation commences, the operator is to be informed of the following factors:
7.2 Inspection of parent metal

Inspection of the parent metal with a normal probe on both sides of the weld comprises a necessary part of ultrasonic inspection of the weld connection. It is meant to reveal possible laminations, large variations in attenuation and thickness variations in the plate material.

7.2.1 Inspection of the parent metal is to be carried out with a normal probe with a frequency between 2 and 6 MHz. The highest frequency which ensures good sound penetration, is selected, see 6.2.2. After range calibration 4.1.1 and gain calibration 5.1.5, the whole of the area on both sides of the weld connection which will transfer ultrasound on inspection with an angle probe, is to be checked. Defects in the parent metal are to be assessed in order, if necessary, to correct the test method to ensure a control of the weld connection without the influence of these defects. The extent of the defects is measured with the aid of the half-value method see, 7.3.5.

7.3 Inspection of weld connections

Inspection of weld connections is to be undertaken for the purpose of revealing possible:

- defects in the parent metal
- defects in the weld metal and heat-affected zone
- lack-of-fusion in transition between weld and parent metal.

Choice of probe is dependent upon the type of defect being sought.

7.3.1 A favourable probe angle in relation to the plate thickness for internal weld defects is given in table I and table II for weld connections with and without grinding.

<table>
<thead>
<tr>
<th>Plate thickness, mm</th>
<th>Favourable probe angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 15</td>
<td>70°</td>
</tr>
<tr>
<td>15 - 30</td>
<td>45°, 60°, 70°</td>
</tr>
<tr>
<td>30 - 60</td>
<td>45°, 60° (70°)</td>
</tr>
<tr>
<td>over 60</td>
<td>45°, 60°</td>
</tr>
</tbody>
</table>
Table II  Weld not ground

<table>
<thead>
<tr>
<th>Plate thickness, mm</th>
<th>Favourable probe angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 20</td>
<td>70°</td>
</tr>
<tr>
<td>20 - 40</td>
<td>45°, 60°, 70°</td>
</tr>
<tr>
<td>over 40</td>
<td>45°, 60° (70°)</td>
</tr>
</tbody>
</table>

7.3.2 A favourable probe angle when the weld connection is being inspected for lack of fusion in the transition between weld and parent metal, is the angle which gives incident sound normal to lack-of-fusion defects, see fig. 10. The optimum angle for a V-grove is given by the groove geometry and can be calculated as in figure 10. If the calculated angle does not agree with any standard probe angle, the nearest larger probe angle is to be selected.

7.3.3 The frequency is to be within the range of 1-6 MHz, and is to be chosen as high as possible and also give a satisfactory sound transmission.

7.3.4 The gain which is to be used in the defect evaluation, is the corrected primary gain. When seeking defects, the gain is to be further increased by 6 dB in order to increase the sensitivity to defects with a difficult orientation. (The gain must then be reduced by 6 dB when one carries out a defect evaluation).

7.3.5 The extent of defects in the longitudinal direction is to be determined by the half-value method. This method can be employed for both normal and angle probes, see figure 11. The extent of the defect is to be determined by maximizing the echo height in the middle of the defect, the echo height on the screen is noted and 6 dB gain is added to this. Subsequently, the probe is traversed towards the edge of the defect until the echo height has dropped to the original level. The centre of the probe is then marked off as the edge of the defect. This method is suited to defects with an area equal to or greater than the cross section of the ultrasonic beam, i.e. relatively large defects.

7.3.6 "The 20 dB drop" method can be used for both normal probes and angle probes when sizing small defects. The method is based on the delimitation of defects with the aid of the edge of the beam where the intensity is 20 dB lower than in the central axis of the beam, see figure 12.

The 20 dB level in the beam must therefore be plotted out in all the material distances in question, and a special calibration block intended for this purpose has been developed, see figure 13. This block consists of a number of 1.5 mm diameter drilled holes, which are 22 mm deep, positioned in such a way that one can determine the 20 dB points at different sound paths in both the horizontal and vertical plane. When one must find the profile of the 20 dB level in the vertical plane for a probe, one is to proceed in the following way:

The probe is first placed in position 1, as shown on figure 14a, and as near as possible to the reflector, but not closer than the near field length for the relevant probe. The echo height is maximized and the probe index is marked off. The probe is then traversed straight forward until the echo height has dropped 20 dB (or echo height is reduced to 1/10 of the original
height) and marks the probe index. Afterwards one draws the probe backwards through maximum and until the echo height has again dropped 20 dB, and the probe index is marked off, see figure 14 a. This procedure is followed for differing material distances, and finally, one can draw a profile of the sound beam in the vertical plane, where the outer limits mark a reduction in the acoustic pressure from the central axis of 20 dB, see figure 14 b. The drawing should be made in full scale. The 20 dB level has been chosen because the edge here is relatively sharp and easy to identify.

When one is determining the size of a defect in, for example a weld, one makes use of the profile of the sound beam in the following way, see figure 15

The echo height is maximized, and the probe is traversed towards the weld until the echo height has fallen to 20 dB. In this point the lower part of the sound beam will come into contact with the upper edge of the defect. The distances probe/weld and sound path read off on the screen are noted, \((d_1, a_1)\). The probe is now drawn away from the weld until the echo height has dropped 20 dB. The upper edge of the sound beam will now touch the lower edge of the defect. The distance probe/weld and sound path read off on the screen are noted \((d_2, a_2)\). These data are transferred to an "ultrasonic slide rule", which consists of the constructed profile of the sound beam in correct size and a cursor which illustrates the movement of the probe. By transferring \(d_1, d_2\) and the sound path readings \(a_1\) and \(a_2\), the size of the defect is drawn on to the slide in correct size, see figure 16.

This method is relatively time consuming and is only used in critical assessment of defect sizes.

8 INSPECTION OF BUTT WELDS, WITH DOUBLE V-GROOVE AND V-GROOVE

8.1 Use of angle probe for detection of longitudinal defects

Where possible the butt weld is to be checked from one side of the plate and from both sides of the weld connection. The angle probe is placed on the parent metal in such a way that the sound beam is normal to the weld. The probe is to be moved forwards and backwards in the area between and somewhat beyond the distance for half and full skip distances and is gradually shifted laterally, so that the whole weld connection is covered at the inspection, see figure 17. During this movement the probe is to be continuously turned 5–10° in the horizontal plane, as intimated on figure 17. Where there is only access to one side and one surface, the weld connection is also to be inspected between the distance for full skip distance and 1 1/2 skip distance. For plate thicknesses greater than 150 mm it may be necessary to inspect from both sides and from both surfaces.

The double probe technique can be used for the detection of defects with the reflection surface normal to the surface, see figure 18. Two separate angle probes are used, and the most favourable sound beam angle, which covers the measurement area in question, is selected. For this type of inspection one can make a holder for the probes, so that the distance \(A\) between the probes is kept constant. The probe combination is moved along the weld connection at the distance \(B\) from the centerline.

8.2 Use of angle probe for detection of transverse defects

Transverse cracks can be detected by placing the probe alongside the weld connection, so
that the beam forms a small angle with the centre line of the weld connection, see figure 19 a. Inspection is to be carried out on both sides of the weld.

Another method using two separate probes is also shown in fig. 19 a. The probes are placed on each side of the weld connection and form an angle of 45° or less, with the centre line of the weld connection. For this type of inspection one may make a holder for the probes so that the angle is kept constant. If the structure is such that inspection with an angle probe along the centre line of the weld is judged to be the only method of reliable inspection, the weld reinforcement is to be ground flush with the parent metal, see figure 19 b. The probe is moved along the centre line, so that the entire depth and breadth of the weld connection is covered.

8.3 Use of normal probe for detection of weld defects

If the weld has been ground flush with the parent metal; weld defects with a reflection surface parallel to the contact surface can be detected with a normal probe. This is placed on the weld and moved along and across the weld connection so that the whole joint is inspected.

8.4 Use of angle probe for detection of defects in root area on butt welds with V-groove

Weld connections effected from one side, with a large root reinforcement or backing strip can be difficult to inspect in the stipulated way in the root area. This results from the fact that spurious echoes can arise from the root reinforcement or the edge of the backing strip, and these will often mask echoes from defects in the root area. One may, therefore, make special reference blocks for this inspection.

The reference block is to be welded in the same way as the weld connection to be inspected, and one inserts artificial defects in the form of drilled holes or machined cracks in the root area, see figure 20. These reference reflectors will help to distinguish defects from spurious echoes.

9 INSPECTION OF T-OR CORNER JOINTS WITH SINGLE BEVEL OR DOUBLE BEVEL GROOVE

9.1 Use of angle probe for detection of longitudinal defects.

The inspection is carried out as described in 8.1. The scanning area for the probe is shown on figure 21.

9.2 Use of normal probe for detection of longitudinal defects with reflection surface parallel to the contact surface and incomplete penetration in zone A – A

The inspection of above mentioned defects is to be effected with a normal probe, as shown on figure 21.
10 INSPECTION OF OTHER WELD CONNECTIONS AND GROOVE TYPES

Weld connections and groove types deviating considerably from those mentioned above, can be met with, but the majority of them can be inspected ultrasonically using the same guidance lines as those given in these requirements. In doubtful cases one should contact Det norske Veritas' Division for Materials Engineering and Inspection, Department for Classification.

11 DEFECT EVALUATION

11.1 Defect evaluation by inspection of parent metal

11.1.1 All defects which give an echo above the reference curve, are to be reported. The extent of the defect is to be determined by means of the half value method.

11.2 Defect evaluation by inspection of weld connections

11.2.1 All indications of defects giving echos, which exceed the 20 per cent curve when examining with the 6 dB increased gain, are to be investigated, and the echo height maximized by using probe angles, 45°, 60° and 70° and by turning the probe.

11.2.2 All defects giving an echo over 20% of the reference curve with corrected primary gain, are to be inspected by means of checking from one plate side and from both sides of the weld connection and subsequently reported.

12 ACCEPTANCE CRITERIA

This inspection procedure does not contain acceptance criteria, but indicates methods for measuring defect size. As regards acceptance criteria for welds on structures or components which are subject to classification in DnV, we refer to the inspection programmes and special requirements applicable to the relevant structure or component.

13 REPORTS

All ultrasonic inspection of weld connections is to be followed by a report. This report should cover:
13.1 Material, weld

- Material employed in structure
- Heat treatment
- Surface character
- Weld surface

13.2 Ultrasonic equipment

- Ultrasonic apparatus, used type
- Probes, used size, angle, frequency
- Value for corrected primary gain

13.3 Method

- Examination method used in inspection

13.4 Sketches

- Dimensioned sketches of weld connection

All defects are to be entered on the sketch with details of position, depth below surface for maximum echo in mm, length extent in mm and maximum echo height in relation to reference curve, see figure 22. Positive indication states how many dB above the reference curve the echo height is, negative sign indicates how many dB below the reference curve the echo height lies. Indications of defect type are to be given with the following abbreviations:

<table>
<thead>
<tr>
<th>Pores</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slag inclusion</td>
<td>B</td>
</tr>
<tr>
<td>Lack of fusion</td>
<td>C</td>
</tr>
<tr>
<td>Root defect</td>
<td>D</td>
</tr>
<tr>
<td>Crack</td>
<td>E</td>
</tr>
</tbody>
</table>

On figure 22 is shown an example of lack-of-fusion, depth below surface 20 mm, length extent 200 mm, and the echo height is 10 dB above the reference curve.
FIG. 1.
CALIBRATION BLOCKS
FIG. 2.

CALIBRATION OF RANGE WITH NORMAL PROBE
CALIBRATION OF RANGE WITH ANGLE PROBE
FIG. 4.
CHECKING THE PROBE ANGLE.
L = length of reference block given by probe angle and material range to be covered.

T = thickness of reference block.

B = width of reference block, minimum 40 mm.

<table>
<thead>
<tr>
<th>Plate thickness (t) mm</th>
<th>Thickness (T) of reference block mm</th>
<th>Position of drilled hole (see fig. 5)</th>
<th>Diameter D of drilled hole mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 25</td>
<td>20 or t</td>
<td>T/2</td>
<td>2.4</td>
</tr>
<tr>
<td>above 25</td>
<td>50</td>
<td>20 or t</td>
<td>T/4</td>
</tr>
<tr>
<td>above 50</td>
<td>100</td>
<td>75 or t</td>
<td>T/4</td>
</tr>
<tr>
<td>above 100</td>
<td>150</td>
<td>125 or t</td>
<td>T/4</td>
</tr>
<tr>
<td>above 150</td>
<td>200</td>
<td>175 or t</td>
<td>T/4</td>
</tr>
<tr>
<td>above 200</td>
<td>250</td>
<td>225 or t</td>
<td>T/4</td>
</tr>
<tr>
<td>above 250</td>
<td>t</td>
<td>T/4</td>
<td></td>
</tr>
</tbody>
</table>

* For each increase in plate thickness of 50 mm, the diameter is to be increased by 1.6 mm.

FIG. 5.

REFERENCE BLOCK FOR CONSTRUCTION OF REFERENCE CURVE.
FIG. 6.

CONSTRUCTION OF REFERENCE CURVES. THE NUMBERS IN BRACKETS GIVE NUMBERS OF EIGHTS OF A FULL SKIP DISTANCE.
FIG. 7.

INCREASE OF GAIN AT EXCESSIVE SOUND PATH.
FIG. 8.
CALIBRATION OF GAIN WITH NORMAL PROBES.
ATTENUATION AND SURFACE CORRECTION
\[ \alpha = \beta \] FOR NORMAL INCIDENCE ON TRANSITION ZONE

FIG. 10.

DETECTION OF LACK-OF-FUSION.
FIG. 11.
HALF VALUE METHOD
The intensity in Point A is 20 dB greater than in Point B.

**FIG. 12**

Conventional beam spread diagram showing the 20 dB levels of a probe.

**FIG. 13**

Low-calibration block for drawing of sound beam profile.
FIG. 14.
PROFILE DRAWING OF SOUND BEAM AT THE 20 dB LEVEL.
FIG. 15.
ESTIMATION OF DEFECT SIZE.

FIG. 16.
TRANSFER OF MEASURED VALUES TO "THE ULTRASONIC SLIDE RULE" FOR DETERMINING THE DEFECT SIZE.
FIG. 17.

PROBE MOVEMENT FOR TESTING BUTT WELDS WITH X-GROOVE AND V-GROOVE.
Fig. 18.

DOUBLE-PROBE TECHNIQUE.

Fig. 19.

DETECTION OF TRANSVERSE CRACKS.
SPURIOS ECHOS
WILL ARISE HERE

DRILL HOLE

MACHINED CRACK

FIG. 20.
REFERENCE BLOCKS WITH ARTIFICIAL
DEFECTS IN THE ROOT AREA.
FIG. 21.
INSPECTION OF T-OR CORNER JOINTS (SINGLE-BEVEL OR DOUBLE-BEVEL GROOVE WELDS.)
EXAMPLE OF REPORT SHEET WITH DEFECT NOTES.