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Non-destructive testing of welds — Ultrasonic testing — Characterization of indications in welds

Contrôle non destructif des assemblages soudés — Contrôle par ultrasons — Caractérisation des indications dans les assemblages soudés

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Foreword

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ISO 23279 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*.

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Introduction

Classification of indications as planar or non-planar is based on several parameters:

— welding techniques;

— geometrical position of the indication;

— maximum echo height;

— directional reflectivity;

— echostatic pattern (i.e. A-scan);

— echodynamic pattern.

The classification process involves comparing each parameter to all the others in order to arrive at an accurate conclusion.

The flowchart in Annex A gives the classification of internal weld indications suitable for general applications.

Non-destructive testing of welds — Ultrasonic testing — Characterization of indications in welds

1 Scope

This International Standard defines a procedure for classifying internal indications as planar or non-planar.

This procedure is only suitable for indications located at least 5 mm below the unground surface of the joint.

Annex A defines the procedure in the form of a flowchart. Figure 1 illustrates the location of indications.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1712, *Non-destructive examination of welds — Ultrasonic examination of welded joints — Acceptance levels*

3 Criteria

3.1 General

The classification is carried out by the successive application of several discriminatory criteria, i.e.

— echo amplitude;

— directional reflectivity;

— echostatic pattern (A-scan);

— echodynamic pattern.

The classification is carried out in accordance with EN 1712.

The flowchart procedure is stopped as soon as one of the above criteria is fulfilled.

The probes used for the classification are, as a general rule, the same as those specified for the detection.

The flowchart procedure standardizes a quality control system of classification. Several levels are defined in decibels (dB) by a comparison with the distance amplitude curve (DAC) or by a comparison between the maximum echo heights from the discontinuity when tested at different angles of incidence.

Proposed dB levels for the different stages in the flowchart procedure are given in Table 1.

Table 1 — Proposed dB levels for the different stages in the flowchart procedure

Reflectivity level	S1	S2	S3	S4
Decibel	DAC – 10 dB	DAC + 6 dB	DAC – 6 dB	9 dB [a]/15 dB [b]

[a] Shear waves.

[b] Between reflections obtained with a shear and a longitudinal wave.

The flowchart procedure calls for five stages, each having a precise aim:

— Stage 1: to avoid the classification of indications with very low echo amplitudes;

— Stage 2: to classify all indications with high echo amplitude as planar;

— Stage 3: primarily to classify lack of fusion;

— Stage 4: primarily to classify inclusions;

— Stage 5: primarily to classify cracks.

NOTE The "hybrid" indications resulting from the association of an inclusion and a lack of fusion are classified as planar by the flowchart procedure. An example of this type of flaw is given in Figure A.3.

3.2 Conventions used

The reference echoes shall be obtained on 3 mm side drilled holes.

By convention,

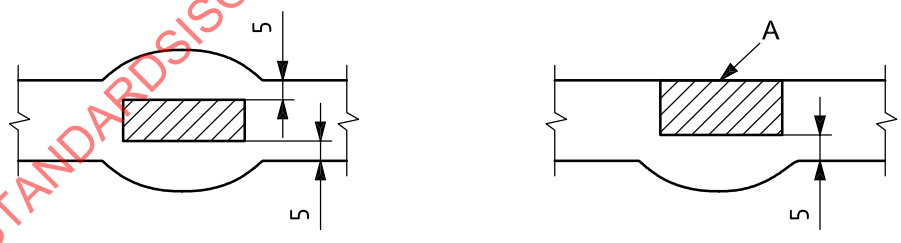
— a negative level value means that the indication has a lower echo amplitude than the reference;

— a positive level value means that the indication has a higher echo amplitude than the reference.

3.3 Location of indications

Figure 1 illustrates the location of indications.

Dimensions in millimetres



Key

A ground weld

Figure 1 — Location of indications

3.4 Echo height criteria (Stages 1 and 2)

3.4.1 Low amplitudes (Stage 1)

It is accepted that an indication with a lower echo amplitude than level S1 (DAC – 10 dB) is not significant.

For special applications, this S1 value should be lowered if agreed between the contracting parties.

3.4.2 High amplitudes (Stage 2)

It is assumed that an echo height that is at least equal to the level S2 (DAC + 6 dB) comes from a planar indication.

3.5 Directional reflectivity criteria (Stage 3)

This stage of the flowchart procedure shall be applicable either to all indications or, if agreed between the contracting parties, only to those indications exceeding a specified length. For the range of thicknesses 8 mm $\leqslant t \leqslant$ 15 mm, this length is t, and for thicknesses over 15 mm, this length is $t/2$ or 20 mm, whichever is the larger. For indications not exceeding the specified length, proceed to Stage 4.

For the criteria below, the angle of incidence of examination which gives the highest echo amplitude relative to a DAC curve, H_{dmax}, is taken as reference. The minimum echo amplitude relative to a DAC curve, H_{dmin}, obtained from the other angles of incidence, is compared with H_{dmax}.

To satisfy the directional reflectivity, the two conditions below shall be fulfilled simultaneously.

a) The reflectivity of the indication, for at least one of the angles of incidence, is higher than or equal to S3 (DAC – 6 dB).

b) There is a high directional reflectivity, i.e.

   1) an imbalance of, at least, 9 dB between two angles of incidence of examination, if the examination is carried out with shear waves:

      $|H_{\text{dmax}} - H_{\text{dmin}}| \geqslant 9$ dB, or

   2) an imbalance of, at least, 15 dB between two angles of incidence of examination, where one of them is carried out with shear waves, the other with longitudinal waves:

      $|H_{\text{dmax}} - H_{\text{dmin}}| \geqslant 15$ dB.

The incidence of examination results from the association of a refraction angle and examination conditions (half skip, full skip). Some examples are given in Annex B.

An example of the application of these criteria is given in Figure A.2.

The attenuation of the weld could be taken into account.

The following conditions apply.

— Normally, the wave length of the different angles of incidence of examination shall be almost the same (e.g. 4 MHz for longitudinal waves and 2 MHz for shear waves).

— In all cases, the differences between the compared angles of incidence are equal to or greater than 10° (the nominal refraction angles are taken into account).

— The comparison of reflectivities shall be made at the position on the indication which exhibits the highest reflectivity.

— Such comparisons make sense only if it is certain that the compared echoes come from the same reflectors.

— It shall be certain before the application of these criteria that:

  — there is no segregation in the base metal;

— there is no corrosion and the two sides are parallel if full skip is used;

— the materials are isotropic.

3.6 Echostatic pattern criteria (Stage 4)

At this stage, the echostatic pattern (i.e. A-scan) is considered.

With the echo height requirements met (neither very high, nor very low) and a low directional reflectivity, if the echostatic pattern is single and smooth, the indication is classified as non-planar.

If the echostatic pattern is not single and smooth, the next stage of the procedure is followed.

The shape of the echostatic pattern depends on the transducer and equipment used. It is therefore imperative to compare the pattern of the indication with that obtained from the reference reflector (3 mm diameter side drilled hole).

3.7 Echodynamic pattern criteria (Stage 5)

If the static echo is not single and smooth, it shall be classified as single and jagged, or multiple. This point is made use of at Stage 5 of the flowchart procedure.

The transverse echodynamic pattern of a reflector is the envelope of the resulting echoes when the ultrasonic beam passes it transversely. The analysis takes into account not only the envelope of the curve, but also the behaviour of the echoes inside it.

The pattern can be classified into four types, as given in Annex C.

If the transverse echodynamic exhibits Pattern 3 (varial class) for at least two angles of incidence, the indication is classified as planar.

Normally, the two angles of incidence chosen are those that give the highest reflectivities.

If only one angle of incidence of examination gives echodynamic Pattern 3, it is possible to use a third angle of incidence, or to call for some complementary examination (see 3.8).

The other types of echodynamic pattern lead to non-planar indications:

— Pattern 1: single non-planar;

— Pattern 4: cluster of non-planar.

At this stage of the flowchart procedure, a Pattern 2 cannot be obtained, since such indications would have been classified as planar from the earlier stages (high reflectivity).

3.8 Complementary examination

In case of any doubt, the following examinations should be carried out:

— analysis of echodynamic pattern in the lateral movement;

— use of additional transducers;

— results from other non-destructive testing (i.e. radiography).

The above list is not restrictive.

Annex A
(normative)

Classification of internal indications in welds — Flowchart procedure

The flowchart procedure is defined in Figure A.1. The flowchart should be applied in conjunction with the two first parameters listed in the Introduction, and not taken in isolation.

Key

H_d indication echo amplitude

H_{dmax} maximum echo amplitude relative to DAC curve

H_{dmin} minimum echo amplitude relative to DAC curve

L length of indication

NOTE 1 The decibel levels S1 to S5 are defined in Table 1.

NOTE 2 The echo patterns are those defined in Annex C.

NOTE 3 The reference echoes are obtained on 3 mm side drilled holes.

[a] No indications below level S1 are classified.

[b] An indication being at least twice as reflective as the reference is classified as planar.

[c] If the indication echo amplitude is at least half of the reference and if the imbalance reflectivity is greater or equal to S4, the indication is classified as planar:

— with S4 = 9 dB for shear waves;

— with S4 = 15 dB between reflections obtained with a shear and a longitudinal wave.

The angles at which the ultrasonic beam is incident upon the indication shall have a difference of at least 10°. The comparison shall be made upon the same area of the indication.

[d] These criteria shall be fulfilled for at least two angles of examination.

[e] If the echodynamic does not exhibit Pattern 3, the indication is classified as non-planar.

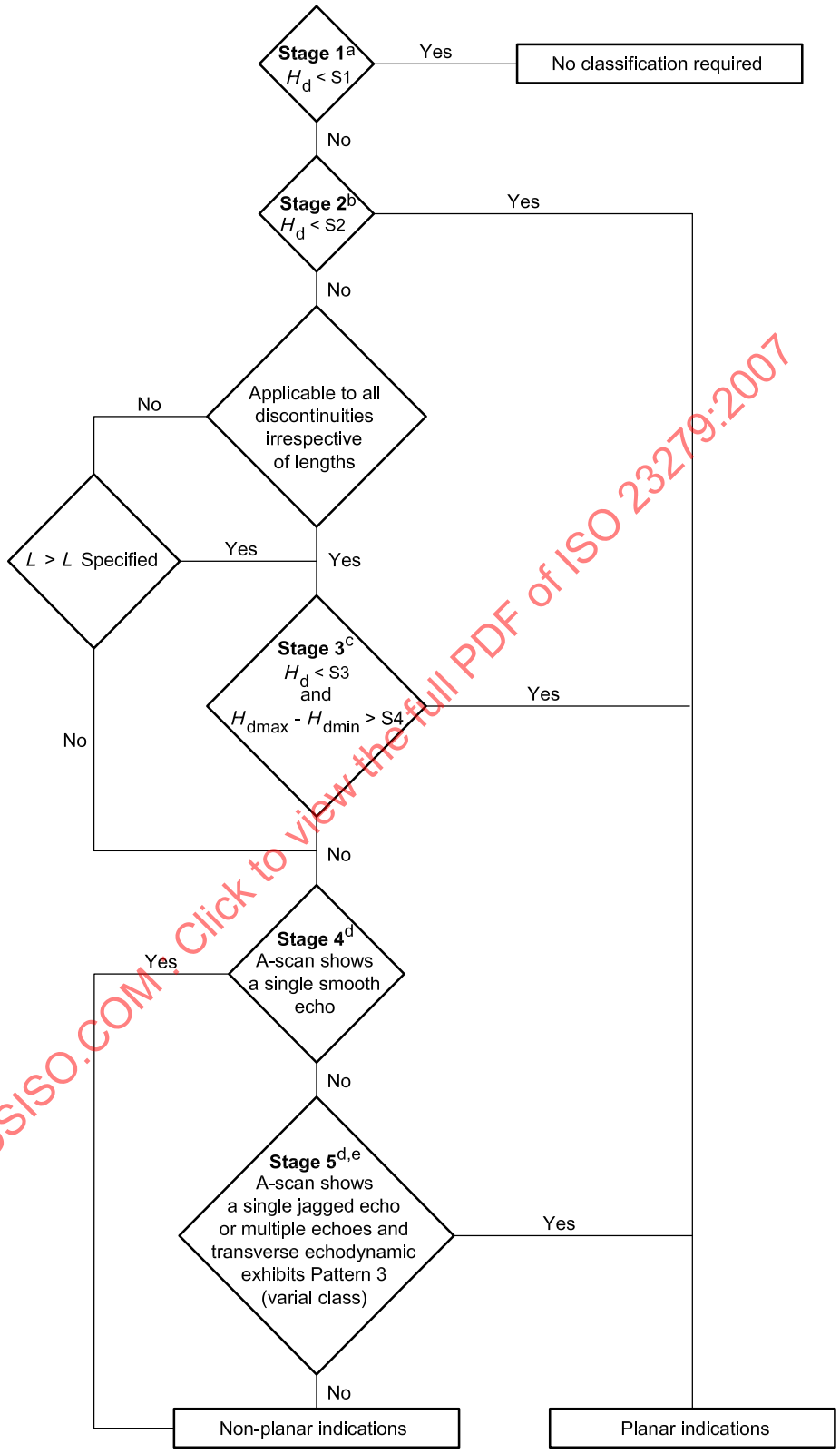
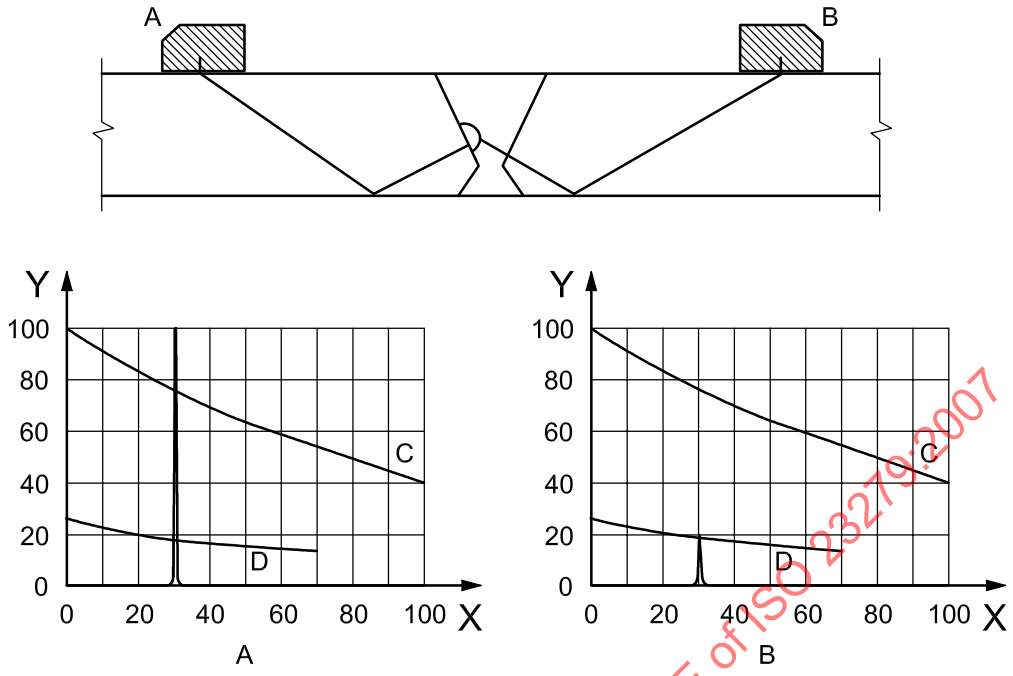


Figure A.1 — Flowchart procedure



Key

X amplitude, %
Y probe displacement, mm
A position 1
B position 2
C DAC
D DAC – 9 dB

Figure A.2 — Example of application of directional reflectivity criteria

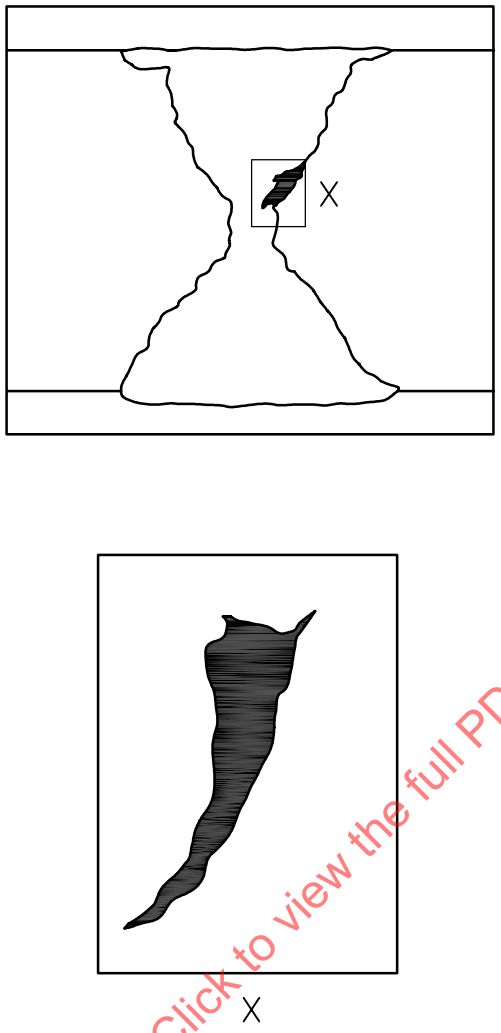
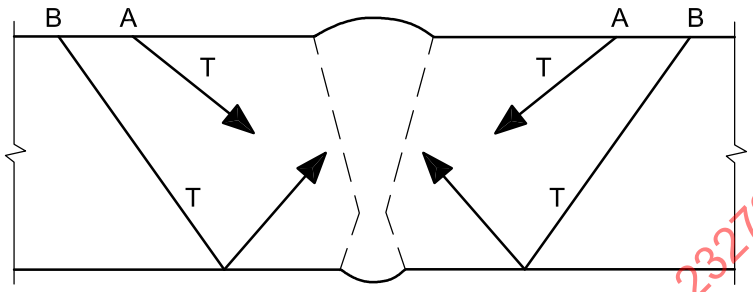


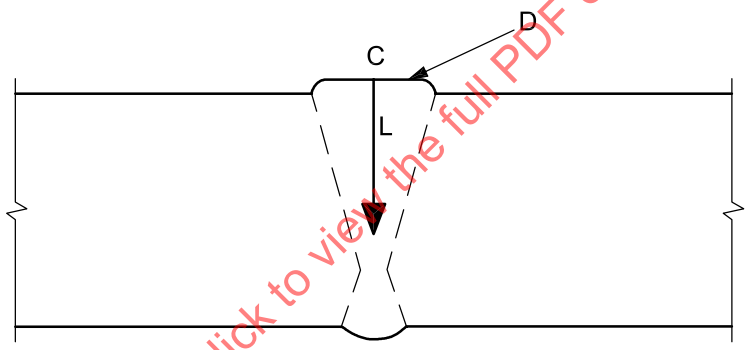
Figure A.3 — Example of hybrid indication — Inclusion and lack of fusion

Annex B
(informative)

Examination incidence



a) Transverse wave, T



b) Longitudinal wave, L

Key

A, B, C	probe positions
D	local grinding
L	longitudinal wave
T	transverse wave

Figure B.1 — Examination incidence

Annex C
(informative)

Basic echodynamic patterns of reflectors

Echodynamic patterns of reflectors can be classified into four basic types, as listed below.

a) **Pattern 1: Point-like reflector response** (see Figure C.1) At any probe position, the A-scan shows a single sharp echo. As the probe is moved, this rises in amplitude smoothly to a single maximum before falling smoothly to noise level.

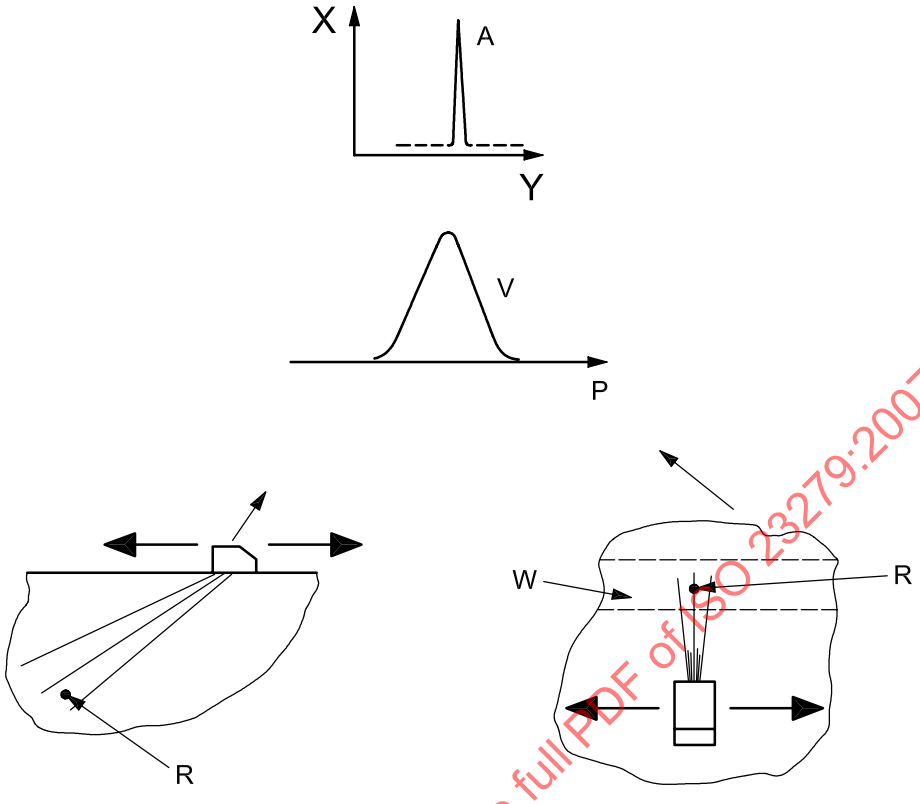
b) **Pattern 2: Extended smooth reflector response** (see Figure C.2) At any probe position, the A-scan shows a single sharp echo. When the ultrasonic beam is moved over the reflector, the echo rises smoothly to a plateau and is maintained, with minor variations in amplitude of up to 4 dB, until the beam moves off the reflector, when the echo will fall smoothly to noise level.

c) **Pattern 3: Extended rough reflector response** There are two variants of this pattern, depending upon the angle of incidence of the probe beam on the reflector:

   — **Pattern 3a: Near normal incidence** (see Figure C.3) At any probe position, the A-scan shows a single but ragged echo. As the probe is moved, this may undergo large ($> \pm 6$ dB) random fluctuations in amplitude. The fluctuations are caused by reflection from different facets of the reflector, and by random interference of waves scattered from groups of facets.

   — **Pattern 3b: Oblique incidence, "travelling echo pattern"** (see Figure C.4) At any probe position, the A-scan shows an extended train of signals ("subsidiary peaks") within a bell-shaped pulse envelope. As the probe is moved, each subsidiary peak travels through the pulse envelope, rising to its own maximum towards the centre of the envelope, and then falling. The overall signal may show large ($> \pm 6$ dB) random fluctuations in amplitude.

d) **Pattern 4: Multiple reflector response** (see Figure C.5) At any probe position, the A-scan shows a cluster of signals which may or may not be well resolved in range. As the probe is moved, the signals rise and fall at random, but the signal from each separate reflector element, if resolved, shows Pattern 1 response.



a) Typical occurrence in through thickness direction

b) Typical occurrence in lateral (length) direction

Key

A A-scan
P probe position
R reflector
V variation in peak signal amplitude
W weld
X amplitude
Y range

Figure C.1 — Pattern 1 ultrasonic response