Australian Standard™

Pressure equipment—Examination and testing

This Australian Standard was prepared by Committee ME/1, Pressure Equipment. It was approved on behalf of the Council of Standards Australia on 16 August 1999 and published on 5 September 1999.

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This Standard was issued in draft form for comment as DR 98310.

Australian Standard™

Pressure equipment—Examination and testing

Originated as AS 4037—1992.
Second edition 1999.

Published by Standards Australia
(Standards Association of Australia)
1 The Crescent, Homebush, NSW 2140

ISBN 0 7337 2923 1

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME/1, Pressure Equipment to supersede AS 4037—1992, *Boilers and pressure vessels—Examination and testing*.

This Standard is the result of a consensus among representatives on the Joint Committee to produce it as a Joint Australian/New Zealand Standard. Consensus means general agreement by all parties. Consensus includes an attempt to remove all objections and implies much more than the concept of a simple majority, but not necessarily unanimity. It is consistent with this meaning that a member may be included in the Committee list and yet not be in full agreement with all clauses of this Standard.

The objective of this Standard is to reduce misunderstanding, costs and delays in non-destructive examination, improve safety, prevent unnecessary duplication of tests and promote greater confidence in reciprocal acceptance of approved procedures.

This Standard is one of the 'core' documents which form part of the revised arrangement of the pressure equipment Standards under the umbrella of AS/NZS 1200, *Pressure equipment*.

The first issue of the Standard unified and replaced the requirements for the non-destructive examination methods of test and the qualification of non-destructive examination personnel specified in AS 1210, *Pressure vessels*, AS 1228, *Pressure equipment—Boilers* and AS 4041, *Pressure piping*. This revised issue is utilized by direct reference in the above Standards.

The main changes in this revision are as follows:

- Incorporation of Amendment No.1 to AS 4037—1992.
- Updated referenced documents.
- Recognition of moves to self-regulation in the pressure equipment industry.
- Replacement of inspection authority with inspection body and introduction of testing body.
- Alignment with AS/NZS 3992 and AS 4458.
- Recognition for automatic non-destructive examination (NDE).
- Introduction of time of flight diffraction (ToFD) ultrasonic examination.
- Introduction of requirements for acoustic emission.
- Editorial improvements and clarification in various areas.
- Clarification of NDE for boiler tube.
- Provision for non-destructive examination of non-metallic materials.

Statements referred in mandatory terms in notes to tables and figures are deemed to be requirements of this Standard.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out requirements for non-destructive examination (NDE) and testing of pressure equipment as specified in AS 1210, AS 1228, AS/NZS 3509, AS/NZS 3788, AS 4041 and AS 4458. It also specifies requirements for testing and qualification of non-destructive examination personnel.

This Standard provides specific details for the NDE of welded joints, acceptance criteria for weld joint imperfections, NDE of production and welder qualification test welds, NDE for construction in specific materials, NDE of specific purpose construction, forgings and castings; and reports and records.

NDE and testing of pressure equipment constructed of non-metallic or composite materials is not specified in this Standard and should be agreed by the parties concerned.

In this Standard and in other Australian or Australian/New Zealand pressure equipment Standards, 'examination' and 'testing' are quality control activities carried out by, or for, the manufacturer. 'Inspection' refers to those activities of, or for, the owner or user to determine conformity and may include some examination and testing.

1.2 APPLICATION This Standard is intended for use by designers, manufacturers, fabricators, testing bodies, NDE personnel, inspecting bodies, inspectors and all persons concerned with the non-destructive examination of pressure equipment.

This Standard may be applied to plant under pressure that is not covered by AS/NZS 1200.

1.3 REFERENCED DOCUMENTS A list of the documents referred to in this Standard is given in Appendix A.

1.4 DEFINITIONS For the purposes of this Standard, the definitions below apply.

1.4.1 Examination—a detailed review, check or assessment by visual or other non-destructive means of one or more characteristics of a given product, process or service, for conformity with the specified requirements.

NOTE: It includes various NDE methods in this Standard and examination of personnel.

1.4.2 Image quality indicator (IQI)—a device used for judging, from the appearance of its image in a radiograph, the overall quality of that radiograph.

1.4.3 Inspector—a person able to inspect pressure equipment.

1.4.4 Manufacturer—a body corporate, firm or person who manufactures pressure equipment.

NOTE: In this Standard, 'manufacturer' includes 'fabricator', 'constructor', 'assembler', 'installer' and 'erector', and is used to embrace all or some of these terms and is applicable to all locations, on or off site, where pressure equipment may be manufactured. It is recognized that different operations may be carried out by different organizations.

1.4.5 Parties concerned—the purchaser, designer, manufacturer, inspection body, testing body, NDE personnel, inspector and owner as appropriate.

1.4.6 Pressure equipment—boilers, pressure vessels, pressure piping and their components covered by AS/NZS 1200.

1.4.7 Postweld heat treatment (stress relief)—uniform heating of pressure equipment or portion thereof to a sufficient temperature, below the critical range followed by uniform cooling, to relieve the major portion of the residual stresses.

1.4.8 Shall—indicates that a statement is mandatory.

1.4.9 Should—indicates a recommendation.

1.4.10 Spot examination—the examination of samples of welds or components, expressed as a percentage of the summation of the total lengths of all such welds or the total number of components. For example, a 10 percent spot examination may be one of the following:

(a) 100 percent of the length of each weld in 10 percent of the number of welds.

(b) 10 percent of the length of each weld in 100 percent of the number of welds.

(c) An appropriate mix of percentage of each weld or percentage of number of welds so that 10 percent of the total weld length is examined.

1.4.11 Testing—carrying out one or more technical operations that consist of the determination of one or more characteristics of a given product, process or service to a specified procedure.

NOTE: It includes tests which damage or have the potential to damage products such as mechanical and pressure tests in this Standard and trials to determine performance and fitness for purpose.

1.4.12 Testing body—the body, laboratory or firm that provides testing and examination services.

NOTE: Such a body may be independent or the manufacturer.

SECTION 2 MATERIAL GROUPING

This Standard uses the material grouping system given in AS/NZS 3992 and applied throughout the pressure equipment Standards. Table 2.1 lists the material grouping for all materials.

TABLE 2.1
MATERIAL GROUPING

Material group	Material type	Typical nominal compositions or specifications	ANSI/ASME BPV-IX classification	
			P number	Group number
FERROUS MATERIALS (see Note 1)				
Carbon steel				
A1	Carbon and carbon-manganese steel (low strength) (see Note 2)	AS 1548: 7-430, 7-460 AS/NZS 1596: HU300, HA 300/1 ASTM A 106B	1	1
A2	Carbon and carbon-manganese steel (medium strength) (see Note 3)	AS 1548: 5-490, 7-490	1	2
A3	Carbon and carbon-manganese steel (High-yield strength)	API 5L: X52, X60, X65, and X70 all with carbon equivalent ≤ 0.40. AS/NZS 1594: HA350, XF 400 and XF 500.	—	—
Low alloy steel				
B	Alloy steel (alloy <¾)	C-½Mo; ½Cr-½Mo; 1Mn-½Mo	3	1, 2, 3
C	Alloy steel (¾≤ total alloy < 3)	1Cr-½Mo; 1¼Cr-½Mo; ¾Cr-¾Ni-Cu-A1	4	1, 2
D1	Alloy steel (vanadium type)	½Cr-½Mo-¼V	—	—
D2	Alloy steel (3 ≤ total alloy < 10)	2¼Cr-½Mo;	5A	1
		5Cr-½Mo; 9Cr-1Mo 9Cr-1Mo-V	5B	1 1 2
E	3½ nickel steel	3½Ni	9B	1
F	9 nickel steel	9Ni	11A	1
G	Quenched and tempered low alloy steel	ASTM A 517; AS 3597:700 PV	11B	1 to 8
High alloy steel				
H	Martensitic chromium steel	13Cr (Type 410); 15Cr (Type 429) 12Cr-1Mo-V(W)	6 —	1,2, 3, 4 —
J	Ferritic high chromium steel (11–13Cr)	12Cr-Al (Type 405) 13Cr-Low C (Type 410S)	7	1
K	Austenitic chromium-nickel steel	18Cr-8Ni (Type 304) 18Cr-12Ni-2.5Mo (Type 316) 18Cr-10Ni-Ti (Type 321)	8	1
L	High chromium steel (>25Cr)	27 Cr-1Mo (S44627)	10I	1
M	Ferritic-austenitic chromium-nickel steel	22Cr-5Ni-3Mo-N (S31803)	10H	1
NON-FERROUS MATERIALS **Aluminium and aluminium alloys**				
Al 21	Aluminium and its alloys 1000 series and 3003	Al (99.0 min) and Al-1.25Mn	21	—
Al 22	Aluminium alloys 3004 and low - strength 5000 series	Al-2.5Mg; Al-2.75Mg-0.75Mn; Al-1.2, Mn-1.0Mg	22	—
Al 23	Aluminium alloys (selected 6000 series)	Al-Mg-Si-Cr alloys	23	—
Al 25	Aluminium alloys (High strength 5000 series)	Al-4.5Mg-0.75Mn; Al-4Mg-0.5Mn	25	—

(*continued*)

TABLE 2.1 (*continued*)

Material group	Material type	Typical nominal compositions or specifications	ANSI/ASME BPV-IX classification	
			P number	Group number
Copper and copper alloys				
Cu 31	Copper (min 99.0Cu)	99.9Cu + Ag	31	—
Cu 32	Copper-zinc alloys	Cu-40Zn	32	—
Cu 33	Copper-silicon alloys	CU-3.3Si	33	—
Cu 34	Copper-nickel alloys	Cu-10Ni	34	—
Cu 35	Aluminium bronze alloys (> 5Al)	Cu-11Al	35	—
Nickel and nickel alloys				
Ni 41	Nickel and low carbon nickel	99.0Ni	41	—
Ni 42	Nickel-copper alloy	67Ni-30Cu only	42	—
Ni 43	Nickel-chromium-iron, nickel-chromium-molybdenum-iron	72Ni-15Cr-8Fe	43	—
Ni 44	Nickel-molybdenum, nickel-molybdenum-chromium-iron	55Ni-21Cr-13Mo	44	—
Ni 45	Nickel-chromium-molybdenum-copper, nickel-iron-chromium-molybdenum-copper, nickel-iron-chromium	25Ni-20Cr-6Mo-Cu	45	—
Ni 46	Nickel-chromium-silicon	35Ni-19Cr-1.3Si	46	—
Titanium and titanium alloys				
Ti 51	Unalloyed and alloyed titanium R_m ≤420 MPa	Unalloyed Ti	51	—
Ti 52	Unalloyed and alloyed titanium R_m >420 MPa	Alloyed 0.3Mo-0.8Ni	52	—
Zirconium				
Zr 61	Unalloyed Zr	99.0 Zr	61	
Zr 62	Alloyed Zr	95.5 Zr - 2.5N_b	62	

LEGEND:

R_m = specified minimum tensile strength

NOTES:

1 For these steels, an upper limit of 580 MPa applies to the actual tensile strength reported on the material certificate.

2 For these steels, an upper limit of 620 MPa applies to the actual tensile strength reported on the material certificate.

SECTION 3 NON-DESTRUCTIVE EXAMINATION METHODS—WELDED JOINTS

3.1 GENERAL Where specified by the application Standard, the non-destructive examination of welded joints shall be carried out by one or more of the methods listed in this Section. Such methods may be manual, semi-automatic or automatic. Acceptance or rejection of imperfections detected by non-destructive examination is dependent upon the construction category of the component and the type of joint under examination (see Section 8).

The basis for the selection of an NDE method (either radiographic or ultrasonic examination) should be on providing optimum detection of imperfections that require assessment in accordance with Tables 8.1 and 8.2. Both methods have advantages and disadvantages in the detection, identification and sizing of imperfections. In general, radiography shows a plan view of the imperfection and is very suitable for 'volume' type imperfections such as porosity and inclusions, and for incomplete penetration. Ultrasonic examination can be suitable for detection and sizing the height of planar imperfections such as cracks, lack of fusion and 'tight' incomplete penetration in ferritic steels, particularly in thick sections and in nozzle welds.

The acceptance Standards listed in Tables 8.1 (boilers and pressure vessels) and 8.2 (piping) allow for the above variations, and normally it is expected that only one nominated method (radiographic or ultrasonic) will be used for assessment of weld quality for this Standard. Any variation in the test method nominated shall only be permitted after consultation between the purchaser and manufacturer. However, additional tests to the nominated test method may be used for critical welds.

Abbreviations for NDE methods are as follows:

RT	Radiography.	VT	Visual.
UT	Ultrasonics.	LT	Leak testing.
MT	Magnetic particle.	ET	Eddy Current.
PT	Penetrant.	AE	Acoustic emission.

3.2 VISUAL EXAMINATION

3.2.1 Materials During construction, any material or component showing surface imperfections which exceed the allowable imperfections of the product Standard shall be rejected by the manufacturer.

3.2.2 Welds All welds shall be examined to ensure compliance with design size. The entire weld surface of all joints shall, where practicable, be visually examined for compliance with Tables 8.3 (boilers and pressure vessels) and 8.4 (piping) prior to any other non-destructive examination. Unacceptable surface imperfections shall be repaired prior to such examination (see Clauses 3.3.2 and 3.3.3).

3.2.3 Facilities Aids to visual examinations and dimensional checks, such as weld dimension gauges, templates, magnifiers (up to 10×) and lamps, shall be used where necessary. For guidance refer to AS 3978. All surfaces shall be sufficiently clean to permit adequate examination.

3.3 RADIOGRAPHIC EXAMINATION OF WELDED JOINTS

3.3.1 Application Where non-destructive examination is required and the radiographic method is selected, the extent shall be in accordance with Table 7.1, Table 7.2 or Table 7.3, as applicable.

The use of either X-ray or gamma-ray radiography is permitted, provided that each method is used under the conditions stated in this Clause (3.3).

Where it is not practicable (e.g. because of limited accessibility or special configurations) to radiograph welds completely in accordance with this Clause, the weld reinforcement limitations in Clause 3.3.2 and the requirement for film quality over the whole length of the weld may be varied, provided that the specified film density, contrast and image quality indicator (IQI) sensitivity are achieved over an approved percentage of the weld length.

Radiography may be used above the maximum thickness of 60 mm specified in Table 7.1 where this method is preferable to ultrasonic examination, e.g. welds in very thick austenitic castings.

3.3.2 Preparation of welds All welded joints to be radiographed shall comply with the following:

(a) Weld ripples or other weld surface irregularities on both the inside and outside of the weld which would mask or be confused with images of imperfections shall be dressed to an extent which permits satisfactory interpretation of the radiograph. Dressing shall be by a suitable mechanical process. (For toe dressing, gas tungsten-arc welding (GTAW) dressing may be used.) The weld surface shall merge smoothly into the parent metal for groups D1, D2, F, G, H, J and L steel components and for construction requiring detailed fatigue analysis for service conditions.

(b) The maximum height of weld reinforcement and thickness through the welded joint shall not exceed the limits given in Table 3.1.

(c) Butt joints utilizing backing strips not to be retained in service shall have the backing strips removed before radiographic testing.

3.3.3 Methods of radiographic examination Visual examination of the weld surfaces shall be carried out prior to radiographic examination to assist in the interpretation of radiographs. Radiographic examination shall be in accordance with AS 2177.1 using XR1, XR2, XR3, GR1, or GR2 methods (each for single image (S), double-wall single image (DWS), or double-wall double image (DWD)), and the following additional or specific requirements apply:

(a) *Radiographic density* The minimum radiographic density shall be 1.8 for X-ray technique or 2.0 for gamma-ray technique including a fog density of 0.3 maximum. The maximum radiographic density shall be 4.2 for all areas of the weld including parent material or to the limit of viewing facilities if density up to this value cannot give satisfactory interpretation of radiographs.

(b) *Contrast* For high-sensitivity type radiography RT(H) using gamma-rays, the contrast shall be assessed by a plaque/hole or step/hole IQI or the contrast meter (or equivalent) detailed in JIS Z3104. Adequate contrast shall be achieved by visual assessment of the IQI outline or where the JIS contrast meter is used, the requirements for special cases as specified in JIS Z3104.

(c) *Tube voltage* In X-ray techniques, the tube voltage shall not exceed the specified value given in AS 2177.1 for the weld thickness under examination.

(d) *Use of gamma-rays* Gamma-ray sources may be used provided that the Ug levels specified in AS 2177.1 are maintained and the sensitivity levels required by Figure 3.1 are achieved except as modified by Clause 3.3.4.

(e) *Additional requirements for crack-sensitive steel* Radiographic examination of welds in crack sensitive ferrous material groups D1, D2, F, G, H, J and L, (i.e. listed in Table 7.2 and materials in Table 7.3) shall be examined by XR1, XR2, or GR1 radiographic methods with the following exception: the GR2 radiographic method may be used for circumferential welds in 2.25 percent chromium, 1 percent molybdenum material in pipework up to 20 mm in thickness.

TABLE 3.1

PERMISSIBLE WELD REINFORCEMENT OF RADIOGRAPHED JOINTS

millimetres

Nominal thickness of thinner parent metal at weld (t)	Maximum height of weld reinforcement on either inside or outside (see Notes 1 and 2)	Maximum total thickness through weld (see Note 1)
≤3	1	t + 2
>3 ≤12	1.5	t + 3
>12 ≤25	2.5	t + 5
>25 ≤50	3.0	t + 6
>50	4.0	t + 8

NOTES:

1 These reinforcement limits may need to be reduced, particularly for parent metal thickness below 12 mm, to enable the radiographic density limits of Clause 3.3.3 to be satisfied.

2 For butt welds in Group G steels used in transportable pressure vessels the maximum reinforcement on each side of the joint shall be the lesser of 3 mm or 10 percent of the parent plate thickness.

3.3.4 Assessment of radiographic sensitivity Radiographic sensitivity shall be assessed by the image quality indicator (IQI) using the smallest wire, step/hole or plaque/hole visible on the film, expressed as a percentage of the weld metal thickness (see Foreword of AS 2177.2 for limitation of use of IQIs).

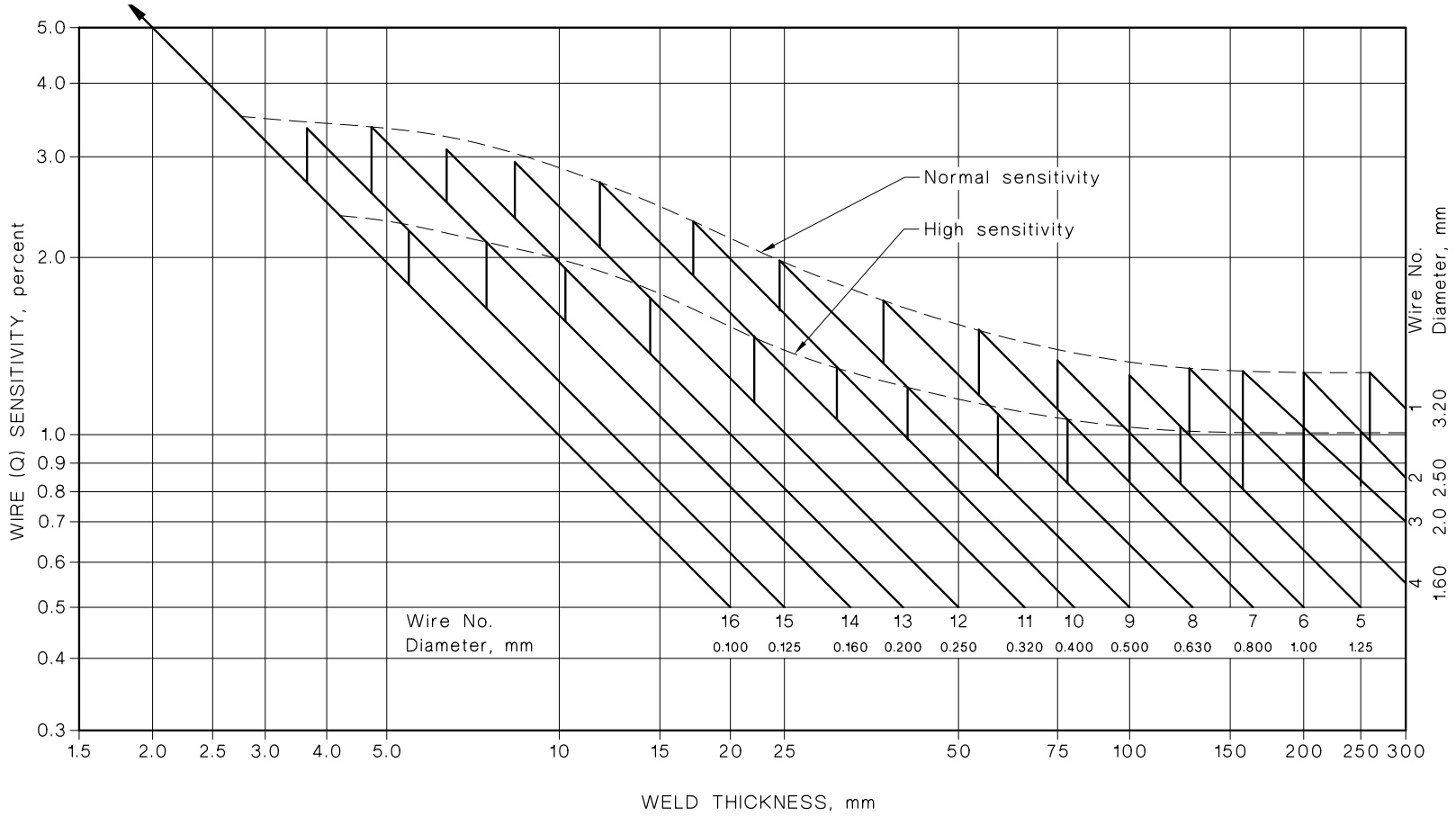
The radiographic sensitivity shall not be greater than the wire sensitivity expressed as a percentage or the wire size specified in Figure 3.1, except for the relaxations detailed in Items (a) and (b) as follows:

(a) The use of GR1 and GR2 methods using the radioisotope iridium-192 is permitted for weld metal thickness below 20 mm in material groups as covered by Table 7.1 for circumferential joints only, provided that radiographs produced by these methods give the sensitivities from IQIs located in accordance with techniques specified in Table 3.2. For weld metal thickness above 20 mm and for longitudinal seams (Type A joints) the radiographic sensitivity using the above techniques shall comply with the requirements of Figure 3.1.

For all joints in components in materials covered by Table 7.2, the IQI sensitivity shall comply with the requirements of Figure 3.1 for the weld thickness under examination and GR2 techniques shall not be used except as permitted by Clause 3.3.3(e).

(b) For joggle joints using DWS techniques on materials as listed in Table 7.1 with single weld thickness equal to or less than 6.3 mm, the sensitivities to be achieved shall be not greater than one wire size smaller than the appropriate wire size shown in Figure 3.1.

The weld thickness for use in Figure 3.1 shall be the single weld thickness at the joint which shall be equal to the nominal wall thickness plus the thickness of the allowable reinforcement on each side of the weld and shall not include the thickness of any backing ring or joggle.



NOTES:

1 The sensitivity and wire sizes shown are based on IQIs located on the source side. Where an IQI is located on the film side, the required IQI sensitivity is that given by the wire of one numerical number lower e.g. for film side wire No. 12, use wire No. 11 for determination of IQI sensitivity.

2 For step/hole and plaque/hole type IQIs, the equivalent wire type IQI sensitivity is to be determined in accordance with AS 2177.2 and is not to exceed the values shown in the above figure.

FIGURE 3.1 IQI SENSITIVITY

TABLE 3.2

IQI SENSITIVITY FOR WELD THICKNESS BELOW 20 mm

Weld thickness mm	Radiographic exposure technique	IQI location	IQI sensitivity required
> 3 ≤ 6	DWD	Source side	Wire No. 12 or thinner
> 6 ≤ 9	DWD	Source side	Wire No. 11 or thinner
> 9 ≤ 20	DWD	Source side	Wire No. 10 or thinner
> 3 ≤ 6	DWS	Film side	Wire No. 13 or thinner
> 6 ≤ 9	DWS	Film side	Wire No. 12 or thinner
> 9 ≤ 20	DWS	Film side	Wire No. 11 or thinner

LEGEND:

DWD = Double wall, double image technique

DWS = Double wall, single image technique

3.4 ULTRASONIC EXAMINATION OF WELDED JOINTS

3.4.1 Application Where non-destructive examination is required and the ultrasonic method is selected, the extent of examination shall be in accordance with Table 7.1, Table 7.2 or Table 7.3 as applicable and the following conditions shall apply:

(a) Where ultrasonic examination of group K steel weldments or weldments of thickness below 10 mm is required, the procedure shall be qualified to prove that it can detect unacceptable imperfections as listed in Tables 8.1 and 8.2.

(b) The welded joint shall be subjected to magnetic particle examination, or penetrant examination for non-magnetic materials, in accordance with Clause 3.5 or Clause 3.6 as well as the ultrasonic examination.

3.4.2 Surface preparation Surfaces over which probes are to be traversed shall comply with the requirements for preparation of surfaces specified in AS 2207. The appropriate surface preparation category (see AS 2207) shall be chosen to suit the scanning mode required.

Where scanning of butt welds can be carried out from one surface only due to joint geometry, and the reinforcement precludes full examination of the weld, the butt weld surface shall be dressed flush (AS 2207 Category SP4). The location of the dressed weld shall be marked on the surface prior to testing.

Welds shall be dressed flat (AS 2207, Category SP3) on one or both surfaces as necessary for groups D1, D2, F, G, H, J, and L steels and for electroslag welds.

3.4.3 Method of examination Examination shall be in accordance with AS 2207, methods UMA, UMB, UMC, UMD, UME, UMF, and UMG at Levels 1 or 2 for double preparation and single preparation butt welds, tee butt welds, cruciform joints and set-in and set-on branches respectively.

Option B of the variations given in AS 2207 shall apply for Level 2 examination.

Examination at Level 1 sensitivity shall be used where required in Tables 7.2 and 7.3 for welds in steel groups D1, D2, F, G, H, J and L and for electroslag welds.

As an alternative to AS 2207 and Clause 3.4.1(b) above, time of flight diffraction (ToFD) ultrasonic examination may be used provided the equipment, procedure and calibration methods comply with BS 7706 and the parties concerned agree.

NOTE: ToFD examination was recognized in the above British Standard in 1993 as a reliable and accurate means of assessment for imperfections. This method could be readily automated producing a hard copy record. It provides a longitudinal cross-sectional representation of imperfections and identifies surface-breaking imperfections. This method is currently in use in Australia.

3.5 MAGNETIC PARTICLE EXAMINATION OF WELDED JOINTS

3.5.1 Application The extent of magnetic particle examination shall be in accordance with Table 7.1, Table 7.2 or Table 7.3, as applicable.

Penetrant examination in accordance with Clause 3.6 is permissible as an alternative to magnetic particle examination, only if access restrictions preclude the use of magnetic particle method.

3.5.2 Method of examination The preparation of surfaces and the procedure for magnetic particle examination shall be in accordance with AS 1171.

Arcing at the prod contact and local overheating or burning of the surface being examined shall be avoided (see also Section 12).

3.6 PENETRANT EXAMINATION OF WELDED JOINTS

3.6.1 Application The extent of penetrant examination shall be in accordance with Table 7.1, Table 7.2 or Table 7.3, as applicable.

3.6.2 Method of examination The preparation of surfaces and the method for examination shall be in accordance with AS 2062.

3.7 OTHER METHODS Examination methods other than those listed in this Section may be more suitable for special constructions and may be used as alternatives provided that—

(a) the procedure is in accordance with a national Standard;

(b) the method is shown to be no less capable of detecting imperfections; and

(c) the parties concerned agree.

See also Sections 23 and 24.

SECTION 4 QUALIFICATION OF NON-DESTRUCTIVE EXAMINATION PERSONNEL

4.1 RADIOGRAPHIC AND ULTRASONIC EXAMINATION Radiographic and ultrasonic examination, interpretation, evaluation for compliance, and reporting shall be made by personnel having qualifications and experience for their job function acceptable to the testing body, the manufacturer and where required by the purchaser.

Operators shall have the qualifications detailed below or shall carry out their duties under the supervision of persons responsible for the examination.

NOTES: Qualifications normally acceptable for the examination of components include the following:

1 Certification by the Australian Institute of Non-Destructive Testing (AINDT) or Certification Board for Inspection Personnel (CBIP), New Zealand, in accordance with AS 3998 in the relevant non-destructive testing category together with adequate experience in the examination of welds by the relevant non-destructive examination method.

2 Acceptance as a signatory for a laboratory approved by National Association of Testing Authorities (NATA), Australia and International Accreditation New Zealand (IANZ), New Zealand, for the relevant non-destructive testing category.

3 Equivalent qualification.

4.2 VISUAL, MAGNETIC PARTICLE, DYE PENETRANT, EDDY CURRENT AND ACOUSTIC EMISSION EXAMINATION Visual, magnetic particle, dye penetrant, eddy current and acoustic emission examination shall be carried out by personnel having adequate experience and qualifications to carry out their duties.

See Section 23 for AE testing.

NOTE: Certification of personnel for some of these examination methods are available through AINDT and CBIP.

4.3 EXAMINATION OF IMPORTED COMPONENTS For equipment and components manufactured outside Australia, the manufacturer shall ensure that the quality of non-destructive examination and the qualification of the personnel carrying out the examination is comparable with the requirements of this Standard.

SECTION 5 NON-DESTRUCTIVE EXAMINATION SCHEDULE

For all pressure equipment fabrication, where non-destructive examination is a requirement of the design, a non-destructive examination schedule should be prepared by the manufacturer. Such a schedule should identify the following:

(a) The stages of manufacture of components or fabrication at which non-destructive examination, as required by this Standard, is undertaken.

(b) The amount of non-destructive testing in relation to material type thickness, welding process and type of welded joint (see Tables 7.1, 7.2 and 7.3).

(c) The method of examination and the test sensitivity level required (see Tables 7.1, 7.2 and 7.3).

NOTE: Some typical examples of non-destructive examination schedules as applied to pressure vessels and pressure piping are given in Appendix E.

SECTION 6 STAGE OF NON-DESTRUCTIVE EXAMINATION

Non-destructive examination may be carried out before or after postweld heat treatment or hydrostatic test, except as modified by the following:

(a) For F and G group steels, 100 percent magnetic particle examination (or where this is not practicable, 100 percent penetrant examination) of all welds shall be carried out after the hydrostatic test and not less than seven days after welding or postweld heat treatment, whichever is the later operation, except that for those surfaces not accessible after the hydrostatic test, the examination shall be carried out at the last possible stage of fabrication.

(b) For D1, H, J, K, and L group steels, non-destructive examination shall be carried out after postweld heat treatment.

(c) For welds made by the electroslag process, non-destructive examination shall be carried out after normalizing.

It is recommended that in-process NDE be carried out during fabrication to ensure that all obvious fabrication imperfections are removed prior to postweld heat treatment.

SECTION 7 EXTENT OF NON-DESTRUCTIVE EXAMINATION OF WELDED JOINTS

7.1 GENERAL The extent of non-destructive examination is dependent upon—

(a) class of construction;

(b) type of welded joint;

(c) parent material used in construction; and

(d) method of welding of joint under examination.

The percentage of weld to be examined for each type of joint in the construction is set out as follows:

(i) Tables 7.1 and 7.2 for boilers and pressure vessels of Classes 1, 2, 2A, 1H, 2HA and 2HB construction. The non-destructive examination for other construction classes are referred to in Clause 8.1.

(ii) Table 7.3 for piping Classes 1 and 2. Class 3 piping is exempt from all non-destructive examination except for visual.

7.2 TYPES OF WELDED JOINTS For the purposes of this Standard, welded joints are classified as one of the following Types 'A', 'B', 'C' and 'D', according to their position as indicated in Figure 7.1 for typical joint types in vessels and as indicated in Table 7.3 for piping:

(a) *Type A joints*—are longitudinal welded joints in main cylindrical shells, transitions in diameter, or in branches; or joints in positions requiring equivalent welds. This includes circumferential or any other welded joints within spherical shells, within formed or flat ends, or welds connecting spherical ends to main shells or within flat plates forming integral parts of pressure vessels.

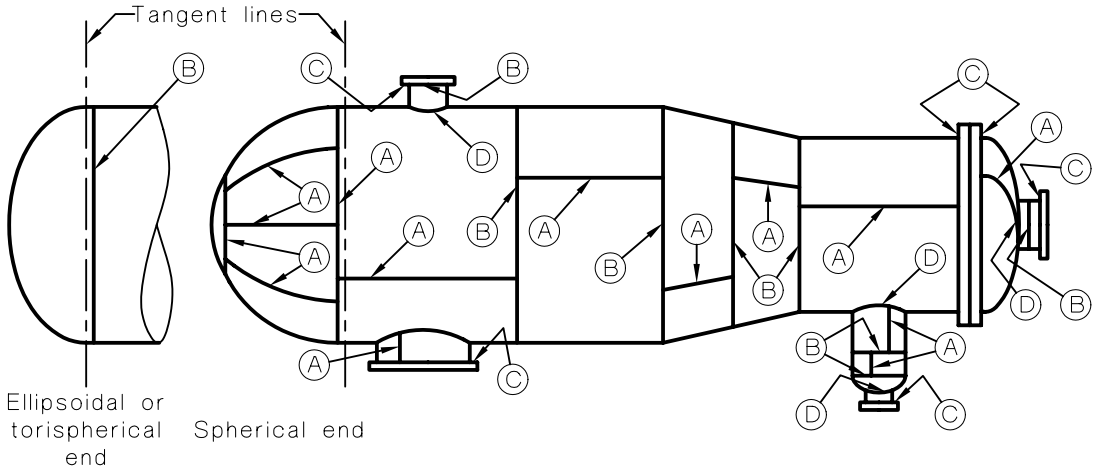
(b) *Type B joints*—in boilers and pressure vessels are circumferential welded joints within main cylindrical shells, within transitions of diameter, welds connecting diameter transition pieces to main cylindrical shells, welds connecting formed ends (other than spherical) to main cylindrical shells and circumferential welds in branches. See Tables 7.1 and 7.2 as appropriate.

In piping, Type B joints are circumferential butt welds in pipes, tubes and attachment welds of pipe fittings such as caps, reducers, tees and weldneck flanges. Some fillet welds in piping are included as Type B. See Table 7.3.

(c) *Type C joints*—are peripheral welded joints with the weld located at a corner between pressure-retaining part as in the joints connecting flanges, tube plates, or flat ends to main shells, to formed ends, to transitions in diameter, or to branches.

(d) *Type D joints*—are welded joints, connecting branches to main shells, to spheres, to transitions in diameter, to ends or to piping.

7.3 100 PERCENT EXAMINATION Where 100 percent examination is specified in Tables 7.1 to 7.3, the weld shall be subjected to the specified non-destructive testing method over its full length. Where magnetic particle or penetrant testing are specified they shall be applied to all accessible surfaces of the weld, include both sides and the heat affected zone.



NOTE: For explanation of points A to D see Clause 7.2.

FIGURE 7.1 WELDED JOINT TYPE BASED ON LOCATION

7.4 SPOT EXAMINATION When examination of less than 100 percent is specified in Tables 7.1 to 7.3, spot examination (refer definition 1.4.10) is applied.

Spot examinations are an effective method for inspection and quality control provided that the portions selected for examination are representative of the overall weld or batch of welds. Examination in accordance with this Standard will ensure with a high probability that any weld is of the specified quality. Where a higher level of confidence is required, an increased percentage examination should be employed.

The extent of the specified spot examination shall comply with the following:

(a) The percentage of weld length or welds, for the relevant welding methods nominated in Table 7.1, Table 7.2 and Table 7.3, shall be examined by the non-destructive examination method specified.

(b) At least 50 percent of the spot examinations shall include, where applicable, 'T-junctions' of circumferential and longitudinal welds.

(c) Additional spots or joints shall be examined, so that the examination includes welding produced by each welder and with each welding procedure.

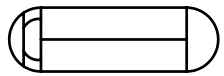
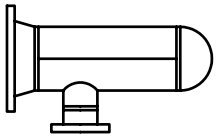
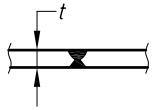
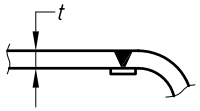
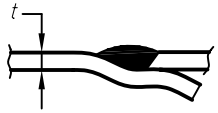
NOTE: Where more than one welder or welding procedure is used on a double-welded butt joint, a single spot examination may represent the work of such welders or welding procedures.

(d) The minimum length of spot examination shall be 300 mm when applied to a percentage of a weld length or the examination of one joint when applied as percentage of a batch of welds.

(e) The areas shall be representative of all processes employed in the manufacture.

TABLE 7.1

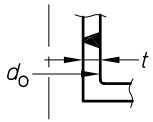
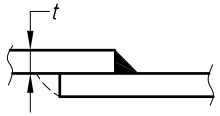
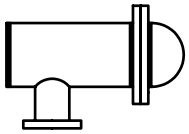
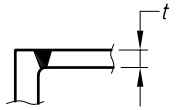
NON-DESTRUCTIVE EXAMINATION OF WELDED JOINTS—BOILERS AND PRESSURE VESSELS (See Notes 1 and 2)*—STEEL GROUPS A1, A2, A3, B, C, E, K, AND M (See Note 3)* AND NON-FERROUS METALS

Type of joint (see Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see Note 4)*							Examination method and sensitivity (see Note 21)*
					Construction Standard and class of construction							
					AS 1210					AS 1228		
					Class 1H	Class 2HA	Class 2HB	Class 1	Class 2A	Class 1	Class 2	
Type A 	1 Double-welded butt; or equivalent 	All	All	5, 6, 7, 8	100	100	10(AU) 25(M) Note 9	100	2(AU) 10(M)	100	10(AU) 25(M)	Wall thickness t mm: $t \le 10$: RT (N) $10<t\le32$: RT(N): or UT(2) + MT $32<t\le60$: RT(H); or UT(2) + MT $t > 60$: UT(2) + MT (preferred) or RT(H)
Type B 	1 As above 	≤32	All	6, 7, 8,	100	10(AU) 25(M) Notes 5, 9	10(AU) 25(M) Notes 5, 9	10(AU) 25(M) Notes 5, 9, 27	2(AU) 10(M)	100	10(AU) 25(M)	
		>32	All	6, 8	100	10(AU) 25(M) Notes 5, 9	10(AU) 25(M) Notes 5, 9	100	N.A.	100	N.A.	
	2 Single-welded butt with retained backing strip 	All	All	6, 7, 8	N.A.	N.A.	N.A.	100	2(AU) 10(M)	100	N.A.	
	3 Single-welded joggled butt 	≤16	All	6, 7, 8	N.A.	N.A.	N.A.	100	2(AU) 10(M)	N.A.	N.A.	

See end of Table 7.3 for Notes and Legend.

(*continued*)

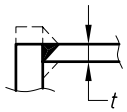
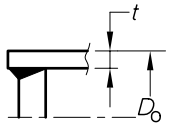
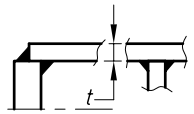
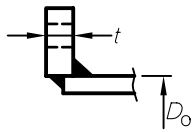
TABLE 7.1 (*continued*)

Type of joint (see Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see Note 4)*							Examination method and sensitivity (see Note 21)*
					Construction Standard and class of construction							
					AS 1210					AS 1228		
					Class 1H	Class 2HA	Class 2HB	Class 1	Class 2A	Class 1	Class 2	
Type B (*continued*)	4 Circum. butt weld in branch, pipe and tube 	≤20	All	6, 7, 8, 22	10	5	5	0	0	As per Table 7.3 for Class 1 piping	As per Table 7.3 for Class 1 piping	As per Table 7.3
		>20	≤275	6, 7, 8, 22	100	20	20	10	0			
		>20	>275	6, 7, 8	100	100	100	100	0			
	5 Circum. fillet weld in shell branch, pipe and tube 	All	All	NA	NA	NA	NA	NA	NA	NA	NA	Note: Joint only applies to Class 3 vessels.
Type C (see Note 10) 	1 Butt 	≤32	All	6, 7, 8	100	10(AU) 25(M) Note 9	10(AU) 25(M) Note 9	10(AU) 25(M) Notes 5, 9	2(AU) 10(M)	100	2(AU) 10(M)	As for A and B above
		>32	All	6, 8	100	10(AU) 25(M) Notes 5, 9	10(AU) 25(M) Notes 5, 9	100	N.A.	100	N.A.	

* See end of Table 7.3 for Notes and Legend.

(*continued*)

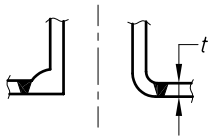
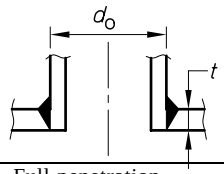
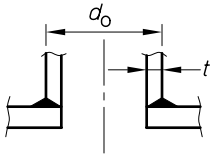
TABLE 7.1 (*continued*)

Type of joint (see Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see Note 4)*							Examination method and sensitivity (see Note 21)*
					Construction Standard and class of construction							
					AS 1210					AS 1228		
					Class 1H	Class 2HA	Class 2HB	Class 1	Class 2A	Class 1	Class 2	
Type C (see Note 10) (*continued*)	2 Full penetration-shell 	≤32	All	6, 11, 22	0	0	0	0	0	0	0	MT
		>32	All	6, 11, 12	100	10(AU) 25(M) Notes 5 & 9	10(AU) 25(M) Notes 5 & 9	100	N.A.	100	N.A.	UT for lamellar tearing only
	3 Full penetration-end 	≤32	All	6, 11, 12, 13, 22	10	10	10	0	0	10	0	MT
		>32	≥1500	6, 11, 12, 13, 22	10	10 Note 9	10 Note 9	0	N.A.	10	N.A.	
		>32	>1500	6, 11, 12, 13	100	100 Note 9	100 Note 9	100	N.A.	100	N.A.	UT for lamellar tearing only
	4 Partial penetration or fillet 	≤60	All	6, 11, 22	0	0	0	0	0	0	0	MT
		>60	All	6, 11, 22	10	N.A.	N.A.	10	N.A.	10	N.A.	
		All	Weld throat >15	6, 11, 22	10	10	N.A.	10	N.A	10	10	
	5 Circum. weld to loose or slip-on flange 	≤20	All	6, 11, 22	0	0	0	0	0	0	0	MT
		>20	≤300	6, 11, 22	100	100	100	10	0	100	0	
		>20	>300	6, 11, 22	100	100	100	100	10	100	10	

* See end of Table 7.3 for Notes and Legend.

(*continued*)

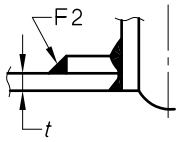
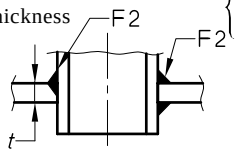
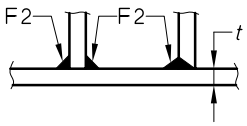
TABLE 7.1 (*continued*)

Type of joint (see Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see Note 4)*							Examination method and sensitivity (see Note 21)*
					Construction Standard and class of construction							
					AS 1210					AS 1228		
					Class 1H	Class 2HA	Class 2HB	Class 1	Class 2A	Class 1	Class 2	
Type D	1 Butt 	All	All	5, 6, 7, 8	100	100	10(AU) 25(M) Note 9	100	2(AU) 10(M)	100	10(AU) 25(M)	As for A and B above
	2 Full penetration (through shell) 	≤32	All	6, 11, 22, 23	0	0	0	0	0	0	0	MT
		>32 ≤60	All	6, 8, 11, 14, 22, 23	10	10 Note 9	10 Note 9	0	N.A.	10	N.A.	MT
		>60	≤170	6, 8, 11, 14, 22, 23	10	N.A	N.A.	5	N.A.	10	N.A.	MT
		>60	>170	6, 8, 11, 14, 22, 23	10	N.A.	N.A.	5	N.A.	10	N.A.	UT(2) + MT
	3 Full penetration (through nozzle) 	≤32	All	6, 11, 15, 22, 23	0	0	0	0	0	0	0	MT
		>32 ≤60	All	6, 8, 11, 15, 22, 23	10	10 Note 9	10 Note 9	0	N.A.	10	N.A.	MT
		>60	≤170	6, 8, 11, 15, 22, 23	10	N.A.	N.A.	5	N.A.	10	N.A.	MT
		>60	>170	6, 8, 11, 15, 22, 23	10	N.A.	N.A.	5	N.A.	10	N.A.	UT(2) + MT

* See end of Table 7.3 for Notes and Legend.

(*continued*)

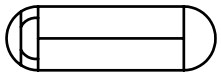
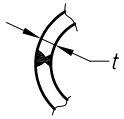
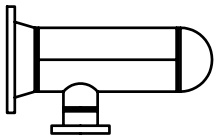
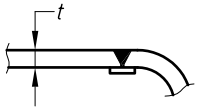
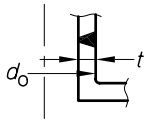
TABLE 7.1 (*continued*)

Type of joint (see Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see Note 4)*							Examination method and sensitivity (see Note 21)*
					Construction Standard and class of construction							
					AS 1210					AS 1228		
					Class 1H	Class 2HA	Class 2HB	Class 1	Class 2A	Class 1	Class 2	
Type D (*continued*)	4 Full penetration plus pad (fillet weld)  F2 = fillet weld throat thickness	≤32	All	6, 11, 14, 22	0	0	0	0	0	0	0	MT
		>32 ≤60	All	6, 8, 11, 14, 22	10	10 Note 9	10 Note 9	10	5	10	N.A.	
		>60	≤170	6, 8, 11, 14, 22	10	N.A.	N.A.	10	N.A.	10	N.A.	MT
		>60	>170	6, 8, 11, 14, 22	10	N.A.	N.A.	10	N.A.	10	N.A.	UT(2) + MT
		All	Fillet throat F2 ≤15	6, 11	0	0	0	0	0	0	0	MT
		>60	Fillet throat F2 >15	6, 8, 11	10	N.A.	N.A.	5	N.A.	10	10	
	5 Partial penetration of fillet F2 = weld throat thickness 	≤60	Weld throat F2 ≤15	6, 11, 22	0	0	0	0	0	0	0	MT
		≤60	Weld throat F2 >15	6, 8, 11, 14, 22	10	N.A.	N.A.	5	N.A.	10	N.A.	
		≤60	All	6, 8, 11, 14, 22	10	N.A.	N.A.	5	N.A.	10	N.A.	MT
	6 Attachments butt or fillet 	>60	All, with throat F2 >15	6, 8, 11	10	N.A.	N.A.	5	N.A.	10	N.A.	

* See end of Table 7.3 for Notes and Legend.

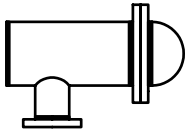
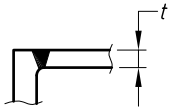
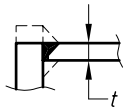
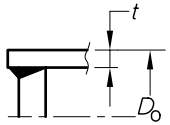
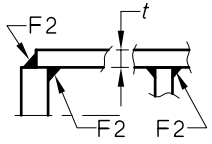
TABLE 7.2

NON-DESTRUCTIVE EXAMINATION OF WELDED JOINTS—BOILERS AND PRESSURE VESSELS (see Notes 1 and 2)*—STEEL GROUPS D1, D2, F, G, H, J and L (see Note 3)*

Type of joint (See Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see (Note 4)* Construction Standard and class of construction AS 1210 Cl 1H	AS 1210 Cl 1	AS 1228 Cl 1	Examination method and sensitivity (see Note 21)*
Type A 	1 Double-welded butt, or equivalent 	All	All	7, 16 17	100	100	100	Wall thickness t mm
Type B 	1 As above	All	All	7, 16, 17	100	100	100	$t \leq 10$: RT(H) $10 < t \leq 50$: RT(H) or UT (1) + MT
	2 Single-welded butt with retained backing strip 	All	All	7, 16, 17	100	100	100	$t > 50$: UT(1) + MT
	3 Single-welded butt with retained backing strip	(Not applicable)						
	4 Circum. butt weld in branch, piping and tubes 	≤10	All	7, 8, 16, 17	10	10	As per Table 7.3	As per Table 7.3 for class of construction
		>10	≤300	7, 8, 16, 17	20	20		
		>10	>300	7, 16, 17	100	100		

*See end of Table 7.3 for Notes and Legend. (*continued*)

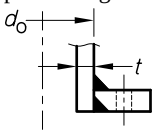
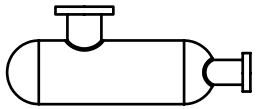
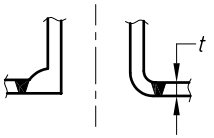
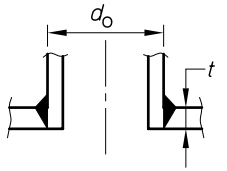
TABLE 7.2 (*continued*)

Type of joint (See Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see (Note 4)* Construction Standard and class of construction AS 1210 Cl 1H	AS 1210 Cl 1	AS 1228 Cl 1	Examination method and sensitivity (see Note 21)*
Type C (see Note 10) 	1 Butt 	All	All	7, 11, 16, 17	100	100	100	As for A above
	2 Full penetration-shell 	≤12	All	11, 12, 16, 17	100	100	100	MT
		>12	All	7, 16, 17	100	100	100	UT(1) + MT
	3 Full penetration-end 	≤12	All	7, 11, 16, 17	100	100	100	MT
		>12	All	11, 12, 16, 17	100	100	100	UT(1) + MT
	4 Partial penetration or fillet  F2 = weld throat thickness	All	All	11, 12, 16, 17	100	100	N.A.	MT
		>12	>65	12, 11, 16, 17	100	100	N.A.	UT(1) + MT
		All	Weld throat F2 ≤15	11, 12, 16, 17	100	100	N.A.	MT
		All	Weld throat F2 >15	11, 12, 16, 17	100	100	N.A.	UT(1) + MT

* See end of Table 7.3 for Notes and Legend.

(*continued*)

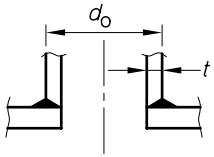
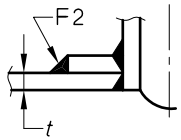
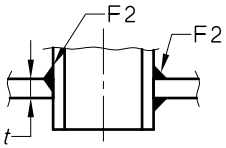
TABLE 7.2 (*continued*)

Type of joint (See Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see (Note 4)* Construction Standard and class of construction AS 1210 Cl 1H	AS 1210 Cl 1	AS 1228 Cl 1	Examination method and sensitivity (see Note 21)*
Type C (*continued*)	5 Circum. weld to loose slip-on flange 	All	All	11, 16, 17	100	100	100	MT
Type D 	1 Butt 	All	All	11, 16, 17	100	100	100	As for A above
	2 Full penetration through shell 	All	All	7, 11, 16, 17	100	100	100	MT
		>12	>65	7, 11, 14, 16, 17, 23	100	100	100	UT(1) + MT

* See end of Table 7.3 for Notes and Legend.

(*continued*)

TABLE 7.2 (*continued*)

Type of joint (See Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see (Note 4)* Construction Standard and class of construction AS 1210 Cl 1H	AS 1210 Cl 1	AS 1228 Cl 1	Examination method and sensitivity (see Note 21)*
Type D (*continued*)	3 Full penetration through nozzle 	All	All	11, 14, 16, 17, 23	100	100	100	MT
		≤12	>65	7, 11, 14, 15, 16, 17, 23	10	10	10	UT(1) + MT
		>12 ≤20			20	20	20	
		>20			100	100	100	
	4 Full penetration plus pad (fillet weld) 	All	All	11, 14, 16, 17	100	100	100	MT
		>12	>65	7, 11, 14, 16, 17	100	100	100	UT(1) + MT
		All	Fillet throat with F2 ≤15	11, 14, 16, 17	100	100	100	MT
		All	Fillet throat with F2 >15	7, 14, 16, 17	100	100	100	UT(1) + MT
	5 Partial penetration or fillet 	All	All, with throat F2 ≤15	11, 14, 16, 17	100	100	100	MT
		All	All, with throat F2 >15	7, 14, 16, 17	100	100	100	UT(1) + MT

* See end of Table 7.3 for Notes and Legend.

TABLE 7.2 (*continued*)

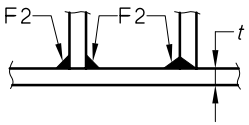
Type of joint (See Figure 7.1)	Type of weld	Nominal wall thickness (t) mm	Nominal outside diameter (d_o) or (D_o) mm	Notes*	Extent of non-destructive examination, percent (see (Note 4)* Construction Standard and class of construction AS 1210 Cl 1H	AS 1210 Cl 1	AS 1228 Cl 1	Examination method and sensitivity (see Note 21)*
Type D (*continued*)	6 Attachments butt or fillet 	All	All, with throat F2 ≤15	11, 16, 17	100	100	100	MT
			All, with throat F2 >15	7, 11, 16, 17	100	100	100	UT(1) + MT

TABLE 7.3

NON-DESTRUCTIVE EXAMINATION OF WELDED JOINTS—PRESSURE PIPING (AS 4041) (See Notes 2, 18, 19, 28)

Type of weld	Class 1 piping					Class 2 piping				
	Material groups	Nominal wall thickness *'t'* mm	Notes	Extent of NDE percent (see Note 4)	Examination method and sensitivity (see Note 21)	Material groups	Nominal wall thickness *'t'* mm	Notes	Extent of NDE percent (see Note 4)	Examination method and sensitivity (see Note 21)
A Longitudinal Butt weld (see Note 20)	A1, A2, A3, B, C, E, K, M and non-ferrous	≤10	7, 6	100	RT(N)	A1, A2, K	≤10	6, 7, 8, 22, 27	10	RT(N)
		>10 ≤60	6	100	RT(N)/UT(2) + MT		>10 ≤32	6, 8, 22, 27	10	RT(N)/UT(2) + MT
		>60	6	100	UT(2) + MT	B	≤20	6, 7, 8, 22, 27	10	RT(N)/UT(2) + MT
	D1, D2, F, G, H, J, L	≤10	7, 16, 17	100	RT(H)	C, E, M, A3	≤16	6, 7, 8, 22, 27	10	RT(N)/UT(2) + MT
		>10 ≤50	16, 17	100	RT(H)/UT(1) + MT	Non-ferrous	≤10	6, 8, 22, 27	10	RT(N) + PT
		>50	16, 17	100	UT(1) + MT					
B Circumferential Butt weld including butt weld of branch to weld neck flange	A1, A2, A3, B, C, E, K, M and non-ferrous	≤10	6, 7, 8, 22, 25	10	RT(N)	A1, A2, K	≤10	6, 7, 8, 22, 26	5	RT(N)
		>10 ≤20	6, 8, 22, 25	10	RT(N)/UT(2) + MT		>10 ≤32	6, 8, 22	5	RT(N)/UT(2) + MT
		>20 ≤32	6, 8, 22	20	RT(N)/UT(2) + MT					
		>32	6	100	RT(N)/UT(2) + MT	B	≤10	6, 7, 8, 22	5	RT(N)
							>10 ≤20	6, 8, 22	5	RT(N)/UT(2) + MT
	D1, D2, F, G, H, J, L	≤10	7, 8, 16, 17, 22, 24	10	RT(H)	C, E, M, A3	≤10	6, 7, 8, 22	5	RT(N)
							>10 ≤16	6, 8, 22	5	RT(N)/UT(2) + MT
		>10 ≤20	8, 16, 17, 22, 24	20	RT(H)/UT(1) + MT	Non-ferrous	≤10	6, 8, 22	5	RT(N)
		>20	16, 17	100	UT(1) + MT					
Fillet weld including sleeve, socket and seal weld	A1, A2, A3, B, C, E, K, M and non-ferrous	≤20	22	0	MT or PT	A1, A2, K,	All	22	0	—
		>20 <32	6, 8, 22	20						
		>32	6, 8, 22	20						
	D1, D2, F, G H, J, L	All	16, 17	100	MT or PT	B, C, E, A3, M and non-ferrous	≤20	8, 22	2	MT or PT

(*continued*)

TABLE 7.3 (*continued*)

Type of weld	Class 1 piping					Class 2 piping				
	Material groups	Nominal wall thickness '*t*' mm	Notes	Extent of NDE percent (see Note 4)	Examination method and sensitivity (see Note 21)	Material groups	Nominal wall thickness '*t*' mm	Notes	Extent of NDE percent (see Note 4)	Examination method and sensitivity (see Note 21)
C Circumferential corner weld Butt weld (see C1 of Table 7.1)	All	All	See B butt weld above			All	All	See B butt weld above		
Other butt or fillet weld between pipe and flange and flat end (see C2–C5 of Table 7.1)	A1, A2, A3, B, C, E, K, M and non-ferrous	≤20	6, 8, 22	0	—	A1, A2, A3, B, C, E, K, M and non-ferrous	≤20	6, 8	0	MT or PT
		>20 ≤32	6, 8, 22	20	MT or PT		>20 <32	6, 8	5	MT or PT
		>32	6, 8	100	MT or PT and UT for lamellar tearing only					
	D1, D2, F, G, H, J, L	≤12	7, 11, 16, 17	100	MT or PT	Not applicable				
		>12	7, 11, 16, 17	100	UT(1) + MT					
D Branch weld i.e. weld between branch and main pipe; and attachment welds (see D1–D6 of Table 7.1)	A1, A2, A3, B, C, E, K, M and non-ferrous	≤20	7, 8, 11, 14, 15, 16, 17, 22, 23	0	MT or PT	A1, A2, A3, B, C, E, K, M, non-ferrous	Weld throat ≤15	6, 8, 11, 23	0	—
		>20		10						
		Butt weld throat ≥32		20	UT(2) + MT		Weld throat >15	6, 8, 11, 14, 15, 23	5	MT or PT
	D1, D2, F, G, H, J, L	All		20	UT(1) + MT	Not applicable				

See next page for Notes and Legend.

NOTES TO TABLES 7.1, 7.2 and 7.3:

1 Boilers are inclusive of drums and headers as defined in AS 1228. For boiler tubes, refer to Table 7.3.

2 All welds shall be subjected to 100 percent visual examination and comply with the requirements of Tables 8.3 (boilers and pressure vessels) or 8.4 (piping and boiler tubes).

3 Type 410S ferritic high chromium steel (12Cr-low C) and Group M steel welded with electrodes which produce an austenitic chromium nickel steel weld deposit or a non-hardening nickel-chromium-iron deposit shall be subjected to non-destructive examination as listed for Group K steels.

4 For additional non-destructive examination, see the following Clauses:

(a) 11.1, Clad and lined construction.

(b) 11.2, High alloy steel construction.

(c) 11.3, Nickel alloys.

(d) 11.4, Unalloyed titanium or zirconium.

(e) 11.5, Quenched and tempered steels.

(f) 11.6, Dissimilar metal joints.

(g) 12.1, Temporary attachments and arc strikes—General.

(h) 13.1, Components containing lethal substances.

(i) 13.2, Components subject to external pressure.

(j) 13.3, Pneumatically tested constructions.

5 All site welds of main seams. (Types A1, B1 and C1 shall be subjected to 100 percent NDE using the specified method.)

6 NDE may be carried out before postweld heat treatment.

7 Examination of butt welds in components of less than 10 mm wall thickness may be carried out by ultrasonic means provided that the procedure demonstrates the ability to detect unacceptable imperfections as listed in Tables 8.1 or 8.2 as applicable.

8 Areas for spot or random examination shall be selected in accordance with Section 7.

9 Applicable to material Groups A1, A2, and K only. The portions of the weld not examined shall be fully examined by the magnetic particle or penetrant examination on both sides of the weld.

10 Corner welds include those at flat ends, tube plates, flat side plates, and flanges (including nozzle flanges) other than weld neck flanges.

11 Where the thickness of any part at the weld exceeds twice the minimum thickness requiring postweld heat treatment, the root run shall be subjected to 100 percent magnetic particle or penetrant examination.

12 Ultrasonic examination is only required for carbon, carbon-manganese and low alloy steels where a buttering weld technique is not used to prevent lamellar tearing.

13 Fire-tube boilers constructed to AS 1228 shall have the nominated percentage of weld length subjected to ultrasonic examination. Imperfection acceptance level shall be in accordance with requirements for circumferential seams.

14 Where the thickness of the shell exceeds 32 mm, set-in branches made from plate and exceeding 300 mm outside diameter shall be examined ultrasonically for lamellar tearing.

15 For set-on branch connections, ultrasonic testing is not required where the thickness of the branch is less than 6 mm, irrespective of '*t*' thickness.

16 Non-destructive examination shall be carried out at the stage of manufacture as required by Section 6.

17 Groups F and G steels shall be subjected to magnetic particle testing in accordance with Section 6(a).

18 Class 3, piping is not subject to NDE. See Table 8.4 for acceptance criteria for visual examination.

19 Piping which is to be subjected to a pneumatic test shall have all welds that penetrate the pipe wall subject to 100 percent RT or UT at a test level appropriate to the class and material of construction and all attachment welds subjected to 100 percent MT or PT examination. Weld imperfection acceptance criteria shall be as given in Table 8.2 (see also Section 13).

20 Excluding longitudinal welds in pipes and components manufactured to a nominated standard.

21 Where either UT(1) or UT(2), plus MT is specified as an alternative to RT, such UT methods of examination are preferred to radiographic examination.

22 For welds where the fluid is lethal or where the piping is subject to severe shock, welds shall be examined by 100 percent RT(N) or UT(1) or UT(2) as applicable plus MT or PT (see also Section 13).

23 Wall thickness '*t*' is the thickness of shell or main pipe for set through branches and *t* is the thickness of the branch pipe for set on branches.

24 Examination of circumferential butt welds in material of group D2 classification with alloy content of nominal 2¼ percent chromium, 1 percent molybdenum classification may be subjected to 5 percent spot examination for DN ≤50 and such examination may be carried out using GR2 methods with IQI sensitivity in accordance with Table 3.2 or by ultrasonic method with Level 2 sensitivity.

25 For pipes DN ≤50, radiography may be reduced to 5 percent when the piping is subjected to hydrostatic testing after fabrication.

26 For pipes DN ≤65, 5 percent radiography may be omitted when the piping is subjected to hydrostatic testing after fabrication.

27 To reduce the examination to this percentage a production test plate or piping weld is required plus 100 percent MT of the balance of the weld. In the absence of a production test plate, or pipe weld 100 percent NDE is required using the nominated test method (see AS/NZS 3992 for requirements for procedure weld test pieces for plate and piping).

28 Pressure pipework is inclusive of all piping and tubing systems subject to internal pressure and covered by the Standards nominated in the Scope of this document.

LEGEND TO TABLES 7.1, 7.2 AND 7.3:

AU = joints automatically welded by the submerged arc process

d_o = nominal outside diameter of a branch or tube

D_o = nominal outside diameter of shell

M = joints welded by processes other than automatic submerge arc

MT = magnetic particle examination (see Clause 3.5); where this is not practical, or as otherwise agreed, this includes penetrant examination (PT—see Clause 3.6). See also Clause 24 re Eddy Current examination

PT = penetrant examination

DN = nominal outside diameter of piping

N.A. = not applicable

RT(N) = radiographic examination (normal sensitivity). RT(H) may also be used where RT(N) is specified (see Clause 3.3.4)

RT(H) = radiographic examination (high sensitivity); see Clause 3.3.4

t = wall thickness of thinner part at weld unless otherwise shown in these tables

UT(1) = ultrasonic examination (Level 1); see Clause 3.4.2

UT(2) = ultrasonic examination (Level 2). UT(1) may also be used where UT(2) is specified (see Clause 3.4.2)

SECTION 8 ACCEPTANCE CRITERIA FOR WELD IMPERFECTIONS REVEALED BY NON-DESTRUCTIVE EXAMINATION

8.1 GENERAL All welds in new equipment for pressure-retaining components shall comply with the imperfections acceptance levels for visual and non-destructive examination for the applicable construction category as listed in—

(a) Tables 8.1 and 8.3 for boilers and pressure vessels; and

(b) Tables 8.2 and 8.4 for piping and boiler tubing.

However, unacceptable imperfections may be assessed and approved in accordance with AS/NZS 3788, such assessment taking into consideration stress levels, weld joint and material properties and operating environment.

Equipment which has been in service and in which imperfections from initial manufacture have been detected by non-destructive examination methods listed in this Standard shall only be repaired after assessment of imperfections in accordance with the requirements of AS/NZS 3788 and when such assessment indicates that repair action is required.

Non-destructive examination of pressure vessels and boilers of a construction class not listed (in Tables 7.1 and 7.2), other than visual examination, is not a requirement of this Standard. However, when such boilers and pressure vessels are subject to NDE by radiographic examination, the following imperfection acceptance limits shall not be exceeded:

(a) Slag, metal and oxide inclusions as listed for Class 2A pressure vessels.

(b) Porosity imperfections as listed for Class 2A vessels except that individual wormholes to 12 mm in length and situated approximately parallel to weld surface are permitted.

(c) Lack of root fusion or incomplete root penetration in single-sided welds which can be permitted as specified in Table 8.2.

(d) Planar type imperfections are not permitted.

See Section 23 for acceptance criteria for acoustic emission examination.

8.2 POROSITY CHARTS Porosity charts for use in assessing the acceptability of welded joints are given in Appendix B.

8.3 SURFACE IMPERFECTIONS Surface imperfections shall be assessed by visual examination for depth of imperfections when NDE casts doubts on acceptance or rejection requirements as listed in Tables 8.3 and 8.4.

TABLE 8.1

NON-DESTRUCTIVE EXAMINATION—BOILERS AND PRESSURE VESSELS WELD ACCEPTANCE LEVELS (Note 12)*

millimetres

Imperfection	Maximum size permitted (see Note 1)*
Planar imperfections	
Cracks, lamellar tears, lack of fusion (see Note 2)*, and incomplete penetration	Nil (see Note 3)*
Slag inclusions (see Note 4)*	
(a) Individual elongated slag inclusion: —In main butt welds (Figure 7.1 Category A and B)	$l = t$, but ≤100 w & $h = t/10$ but ≤4 (see Note 5)*
—In nozzle and branch welds (see Note 6)* (Figure 7.1 Type D)	Mid-half of cross section: $l = c/4$ but ≤100, w or $h = t/4$ but ≤4 mm (see Note 5)* Outer quarters: $l = c/8$ but ≤100 of cross-section w or $h = t/8$ but ≤4 (see Note 5)*
(b) Group of aligned slag inclusion NOTE: Inclusions separated by a distance less than the length of longer, are to be regarded as one inclusion with the same overall length	Aggregate length = t in length $12t$ (see Note 21)*
(c) Other slag inclusions	$l = t/4$ but ≤3
Metal inclusions (see Appendix B for porosity charts)	
(a) Tungsten inclusions—individual	$l = t/4$ but ≤3
(b) Tungsten inclusions—grouped	5 inclusions in any 12 mm diameter circle
(c) Tungsten inclusions accompanied by oxide inclusions or open to surface	Nil
(d) Copper inclusions	Nil
Oxide inclusions (in aluminium)	
(a) Linear and planar	Nil
(b) Grouped	$l = t/4$ but ≤3
Porosity (see Appendix B for porosity charts)	
(a) Isolated spherical pores (i.e. separated from an adjacent pore by 25 or more)	$\phi = 0.3t$, but ≤6 for t ≤50 ϕ ≤10 for t >50
(b) Individual spherical pores other than isolated pores	$\phi = t/4$, but ≤3 for t ≤50 ϕ ≤4.5 for t >50
(c) Uniform spherical porosity	Total projected area on radiographic film = 2 percent of weld area (length and width). Pores with ϕ ≤0.25 may be ignored
(d) Clustered (or grouped) porosity	4 times the area of the uniform porosity in any length weld of 25 or 2 t whichever is smaller
(e) Linear porosity (aligned parallel to weld axis)	Same as for slag inclusions (c) above, but nil if associated with any lack of fusion or incomplete penetration
(f) Wormholes—isolated	l = 6; w = maximum permitted by porosity charts (see Appendix B) h = height of permissible reinforcement (see Note 7)*
(g) Wormholes—aligned	Same as for slag inclusions (c) above
Surface imperfections	See Clause 3.2 and Table 8.3

* See end of Table 8.4 for Notes and Legend.

TABLE 8.2

NON-DESTRUCTIVE EXAMINATION— PRESSURE PIPING WELD ACCEPTANCE LEVELS

millimetres

Imperfection	Maximum size permitted (see Note 13)*		
	Class 1 piping	**Class 2 piping**	**Class 3 piping**
Planar imperfections			
(a) Cracks	Nil		One crater crack not more than 4 long per weld
(b) Lack of fusion	(see Notes 2 and 3)*	Nil (see Notes 2 and 3)*	
(c) Incomplete penetration or intrusion:			
—Longitudinal butt	Nil	Nil	Nil
—Circumferential butt	h = 1.5 max. l = 3.8 in 150 (Note 14)	h = 1.5 max. l = 38 in 150 (Note 14)	$h = t/5$ (see Note 8)* l = no limitation
—Branch:			
—Middle half of cross-section		l = 40 in any 150	l = no limitation
—Outer quarters of cross-section		l = 40 in any 150	l = no limitation
Slag inclusions and other elongated imperfections			
(a) Longitudinal butt	$l = t/3$	$l = 2t$	
(b) Circumferential butt	$l = t$	$l = 2t$	
(c) Summation (see Note 9)*	$l = 2t$ in $12t$	$l = 4t$ in $12t$	
(d) w or h	2.5 but $\leq t/10$	3 but $\leq t/3$	
(e) Branch (see Note 6)*:			N.A. (see Note 10)*
—Middle half of cross-section	$l = c/4$ but ≤100 w or $h = t/4$ but ≤4	$l = c/4$ but ≤100 w or $h = t/4$ but ≤4	
—Outer quarters of cross-section	$l = c/8$ but ≤100 w or $h = t/8$ but ≤4 (see Note 5)*	$l = c/8$ but ≤100 w or $h = t/8$ but ≤4 (see Note 5)*	
(f) Other slag inclusions	$l = t/4$ ≤3	$l = t/4$ ≤3	
Metal inclusions			
(a) Tungsten inclusions—individual	$l = t/4$ but ≤3	$l = t/4$ but ≤3	
(b) Tungsten inclusions—grouped	Five inclusions grouped in a circumscribing circle with a diameter = 12	Five inclusions grouped in a circumscribing circle with a diameter = 12	N.A (see Note 10)*
(c) Tungsten inclusions—accompanied by oxide inclusions or open to surface	Nil	Nil	
(d) Copper inclusions	Nil	Nil	
Oxide inclusions (in aluminium)			
Linear and planar inclusions	Nil	Nil	N.A. (see Note 10)*
Grouped inclusions	$l = t/4$ but ≤3	$l = t/4$ but ≤3	

* See end of Table 8.4 for Notes and Legend. (*continued*)

TABLE 8.2 (*continued*)

millimetres

Imperfection	Maximum size permitted (see Note 13)*		
	Class 1 piping	**Class 2 piping**	**Class 3 piping**
Porosity (see Appendix B for porosity charts)			
(a) Isolated spherical pore	$\phi = t/3$ but ≤ 4	As for Class 1	
(b) Uniform spherical porosity	Total projected area = 2% of weld area (see Note 11)*	Total projected area = 3% of weld area (see Note 11)*	
(c) Clustered (or grouped) porosity	4 times area for uniform porosity in length of $2t$ or 25 whichever is less	4 times area for uniform porosity in length of $2t$ or 25 whichever is less	
(d) Linear porosity (aligned parallel to axis of weld)	$\phi = t/3$ but ≤ 4 and spacing between pores ≤ 4 If associated with any lack of fusion or incomplete penetration, $\phi = 0$	As for Class 1	N.A. (see Note 10)*
(e) Wormholes—isolated	$l = 6$ $w = t/3$ but ≤ 4 (see Note 11)*	As for Class 1	
(f) Wormholes—aligned	As for uniform porosity (see Note 7)*	As for Class 1	
Surface imperfections (see Clause 3.2 and Table 8.4)			

* See end of Table 8.4 for Notes and Legend.

TABLE 8.3

LIMIT OF SURFACE IMPERFECTION— BOILERS AND PRESSURE VESSELS (Note 12)*

millimetres

Imperfection	Maximum size permitted (Note 1)		
	Boilers and vessels requiring full radiography or ultrasonic examination Class 1H, Class 2HA, Class 1	**Boilers and vessels requiring spot radiography or ultrasonic examination Class 2HB, Class 2A, Class 2**	**Other boilers and vessels Class 2B and Class 3**
Surface cracks, porosity or exposed inclusion	Nil	Nil	0.5 depth but ≤t/10
Root concavity and shrinkage groove	Longitudinal joint—nil Circumferential welds with smooth root contour—depth of concavity ≤1.2 mm and weld thickness ≥t		
Undercut, underfill and underflush	Nil in: - boilers and vessels subject to shock - transportable boilers and vessels - boilers and vessels manufactured in material groups D to J - boilers and vessels requiring a detailed fatigue analysis All other boilers and vessels—h = 0.5 depth for ≤t/10 for undercut and underfill but h = 0.8 depth but ≤t/10 for underflush	0.5 depth but ≤t/10	
Overroll or overlap at weld toe	Nil (may be dressed)		
Reinforcement (Notes 17 and 18)*	t≤3, r = 1 on each side of joint 3<t ≤6, r = 1.5 on each side of joint 6<t ≤12, r = 2.5 on each side of joint 12<t ≤25, r = 3 on each side of joint t>25, r = 5 on each side of joint		t≤3, r = 1.5 on each side of joint 3<t ≤6, r = 2.0 on each side of joint 6<t ≤12, r = 3.5 on each side of joint 12<t ≤25, r = 4.0 on each side of joint t>25, r = 6 on each side of joint
Misalignment	See AS 4458		

* See end of Table 8.4 for Notes and Legend.

TABLE 8.4

LIMIT OF SURFACE IMPERFECTION—PRESSURE PIPING (See Note 1)

millimetres

Imperfection	Maximum imperfection permitted		
	Class 1 piping	Class 2 piping	Class 3 piping
Surface cracks	Nil	Nil	Nil
Surface porosity, or exposed inclusion	Where t>5 (see Note 20) Where t≤5, nil	Where t≤5 . . . . . nil Where t>5 . . . . . N.A.	Not applicable
Root concavity or shrinkage groove	Nil, except in circumferential welds with smooth root contour, depth of concavity ≤1.2, and weld thickness ≥t	(Note 8)	(Note 8)
Undercut or underfill	h = 0.5 but ≤t/10 (Note 14)	h = 0.8 but ≤t/10 (Note 14)	h = 1 but ≤t/4
Underflush	h = t/10 (Note 14)	h = 0.8 but ≤t/10 (see Note 14)	h = 1 but ≤t/4
Overroll or overlap at toe	Nil (may be dressed)	Nil (may be dressed)	Nil (may be dressed)
External reinforcement (see Notes 17 and 18)	0 <t ≤5, r = 2.0 5 <t ≤12, r = 3.0 12 <t ≤20, r = 4.0 t>20, r = 5.0 (Note 15)	As for Class 1	t ≤5, r = 3 5 <t ≤12, r = 4.5 12 <t ≤20, r = 6 t >20, r = 7.5
Penetration and protrusion in bore (Note 19)	Where bore– ≤25, h_{pe} = 1.0, >25, ≤100, h_{pe} = 2 >100, ≤200, h_{pe} = 3 >200, h_{pe} = 4	As for Class 1	Where bore– ≤100, h_{pe} = 3 >100, ≤200, h_{pe} = 4 >200, h_{pe} = 6
Misalignment	See AS 4458		

LEGEND TO TABLES 8.1, 8.2, 8.3 and 8.4

c = mean circumference of branch, in millimetres

D = diameter of largest imperfection in a group, in millimetres

h = height (in thickness direction) of imperfection, in millimetres

h_{pe} = maximum penetration in bore, in millimetres

l = length of imperfection, in millimetres

N.A. = not applicable

r = external weld reinforcement maximum, in millimetres

t = nominal thickness of thinner parent metal at the weld, e.g. pipe wall, in millimetres

w = width of imperfection, in millimetres

ϕ = diameter of imperfection, in millimetres

NOTES TO TABLES 8.1, 8.2, 8.3 AND 8.4

1 This Table is applicable to all imperfections in the welded joint including those in the fused weld metal and the heat-affected zone.

2 Where it can be demonstrated clearly that lack of fusion associated with slag inclusion does not extend beyond the boundary of the slag inclusion, the imperfection shall be treated as a slag inclusion. For single-sided welds the imperfections shown in the following figures are incomplete penetration.

3 Where ultrasonic examination is used, it is probable that imperfections of very small cross-section will be found but imperfections with height h ≤ t/30 but with a maximum height of 1.5 mm are to be disregarded provided that the length of such an imperfection does not exceed 100 mm.

4 Slag inclusions outside the limits specified are acceptable provided the total projected area does not exceed the permitted porosity in Appendix B.

5 Where radiographic examination is used, the width of the imperfection (w) is to be determined. Where ultrasonic examination is used, the height of the imperfection (h) is to be determined, except where this is not practicable, in which case the width (w) is to be determined.

6 Includes full and partial penetration welds.

7 For radiographic examination, the density through a wormhole is to be not greater than that through the thinner parent material.

8 These imperfections are not acceptable where the thickness through the weld, including any reinforcement is reduced to less than the nominal thickness.

9 Separation between acceptable imperfections shall be at least six times the length of the largest imperfection.

10 Examination for these imperfections is not required but where examination is made using one or more of the following methods—radiographic, ultrasonic, magnetic particle, penetrant, nick break or macro—the effective thickness at all parts is to be not less than $0.5t$ nominal thickness, the average thickness over a length of $12t$ is to be not less than $0.9t$, and the average thickness over the length of the weld, not less than t.

11 See the porosity charts in Appendix B, which specify 2 percent. Pores with diameter ≤0.25 mm may be ignored.

12 Boilers are inclusive of drums and headers as defined in AS 1228.

13 Where ultrasonic examination is used, it is probable that imperfections of very minor cross-section will be found but imperfections with height $h \leq t/30$ and with a maximum width of 1.5 mm are to be disregarded.

14 For welds in piping subject to severe cyclic service, h = 0 and there is to be a smooth transition between the weld and the parent metal which may reduce the thickness by the lesser of $t/15$ and 0.3 mm.

15 For welds in piping subject to severe cyclic service, r is to be reduced by 50 percent and there is to be smooth transition between the weld and the parent material.

16 For butt welds in Group G steels used in transportable vessels, the maximum reinforcement on each side shall be the lesser of 3 mm or 10 percent of the plate thickness.

17 The stop and start of each run shall merge smoothly with no pronounced hump or crater.

18 These limits may be reduced for radiographic examination to comply with the requirements of Table 3.1.

19 Localized slight excess penetration is acceptable, provided that it does not exceed in length 10 percent of the internal circumference of the pipe or tube.

20 Stop/start porosity should be limited to a maximum area of 3.0 mm^2 per 25 mm weld length (six pores of 0.8 mm diameter) for thickness greater than 5 mm up to 20 mm and a minimum area of 6.0 mm^2 for 25 mm of weld length (twelve pores of 0.8 mm diameter) for pipe thickness above 20 mm.

21 For Class 2 boilers and pressure piping and Class 2B pressure vessels, the aggregate length may be up to t in a length of $6t$.

SECTION 9 RE-EXAMINATION AND REPAIR OF WELDED JOINTS WITH IMPERFECTIONS OUTSIDE OF LEVELS OF ACCEPTANCE CRITERIA

9.1 GENERAL Unacceptable imperfections detected during examination shall be treated as given in this Section.

9.2 WELDS SUBJECT TO 100 PERCENT EXAMINATION All unacceptable imperfections shall be repaired and re-examined by the same non-destructive testing methods unless they are accepted in accordance with the requirements of Section 8.

9.3 WELDS SUBJECT TO SPOT EXAMINATION Where a spot examination discloses welding that does not comply with the requirements of Section 8, then either two additional areas shall be examined in the same length or batch of welds (as applicable) or the complete length of all welds, as represented in the examination, shall be cut out and repaired.

Re-examination and repair shall comply with the following requirements as appropriate:

(a) Where the two additional areas examined show welding which complies with the requirements of Section 8, the entire length of all welds represented in the three examinations shall be acceptable provided that the imperfection welding represented by the first of the three examinations is removed and the area repaired by welding, or at the discretion of the Inspector allowed to remain in the welded joint.

(b) Where either of the two additional areas examined reveals welding which does not comply with the requirements of Section 8, the entire length of all welds represented in the examination shall be removed and re-welded, or at the manufacturer's option, the entire length of all welds represented shall be completely examined by the appropriate NDE method, in which case only imperfect welding need be repaired.

(c) The re-welded area, or the weld repaired areas shall be spot examined in accordance with Section 7 and shall comply with the requirements of Section 8. The report of examination of repairs or re-welds shall include the identification R1, R2, etc., to indicate that repair welding has been carried out on the area of weld represented by the examination.

In the above Items, re-examination shall be made using the same method as in the original examination.

When spot examination of a T-joint reveals unacceptable imperfections in the longitudinal seam, the additional areas examined, as required above, shall be on the longitudinal seam; and the circumferential seam shall be deemed to comply with the requirements of Section 8.

When spot examination of a T-joint reveals unacceptable imperfections in the circumferential seam, the additional areas examined, as required above, shall be on the circumferential seam; and the longitudinal seam shall be deemed to comply with the requirements of Section 8.

SECTION 10 NON-DESTRUCTIVE EXAMINATION OF PRODUCTION AND WELDER QUALIFICATION TEST WELDS

Test plates for procedure, production or welder qualification representing welds in components which will be subjected to non-destructive examination shall be given the same non-destructive examination as for the production welds.

The location of imperfections revealed in such examination in procedure or production test plates shall be clearly marked on the test plate in order that test specimens taken for mechanical testing can be selected from parts of the test plate which do not contain weld imperfections likely to cause premature failure of the test specimen.

SECTION 11 ADDITIONAL NON-DESTRUCTIVE EXAMINATION FOR CONSTRUCTION IN SPECIFIC MATERIALS

11.1 CLAD AND LINED CONSTRUCTION Clad construction includes plate having a cladding integrally bonded to the base metal or a fully attached weld overlay. Lined construction has a lining attached intermittently to the base metal.

The material thickness (*t*), specified in Tables 7.1 and 7.2 as a basis for determining non-destructive examination, is the total wall thickness for clad construction and the base metal thickness for applied lined construction.

For butt welds in clad plate and for weld overlays, the non-destructive examination specified in Tables 7.1 and 7.2 shall be carried out after the joint, including the corrosion resistance layer, is complete with the following exception: radiographic or ultrasonic examination may be carried out on the weld in the base metal before the alloy cover weld is deposited provided that—

(a) no credit for the cladding is taken into account in the design; and

(b) the corrosion-resistant alloy weld deposit is non-air-hardening.

Overlay weld deposits or welds attaching applied linings shall be subjected to 10 percent magnetic particle examination or, where this is not practicable, 10 percent penetrant examination.

Where credit for cladding is taken into account in design, all weld preparations shall be subject to the following additional non-destructive examination prior to welding to ensure that there is no separation between the cladding and the base metal:

(i) For Class 1H and 2H vessels—visual examination and penetrant examination.

(ii) For Class 2 and Class 3 vessels—visual examination.

11.2 HIGH ALLOY STEEL CONSTRUCTION Butt-welded joints in high alloy steels shall be examined as follows:

(a)	Butt welds in Type 405 steel welded with straight chromium electrodes; and Types 410, 429 and 430 steel welded with any electrode; and steels with 36 percent nickel.	100 percent radiographic examination in all thickness.
(b)	Butt welds in Type 405 steel; and Type 410 with carbon content not exceeding 0.08 percent, both welded with electrodes that produce an austenitic chromium-nickel weld deposit or a non-air hardening nickel-chromium-iron deposit.	10 percent radiographic examination when the thickness of the thinner part at the joint exceeds 38 mm.
(c)	Butt or fillet welds on all Group K and Group M steels with shell nominal wall thickness at weld exceeding 20 mm.	100 percent penetrant examination.
(d)	Butt or fillet welds on all 36 percent nickel steel welds.	100 percent penetrant examination.

11.3 NICKEL ALLOYS In materials to the following ASTM specifications, butt-welded joints shall have 100 percent radiographic examination when the thinner of the parts at the weld exceeds 10 mm, and welds not radiographed shall have 100 percent penetrant examination:

ASTM B163 (alloy 800 and 800H only), B333, B335, B407, B408, B409, B423, B424, B425, B434, B435, B443, B444, B446, B462, B463, B464, B468, B473, B511, B514, B517, B535, B536, B564 (alloy 800 and 800H only), B572, B573, B574, B575, B581, B582, B619, B620, B622 and B626.

11.4 UNALLOYED TITANIUM OR ZIRCONIUM In unalloyed titanium or zirconium material, butt-welded longitudinal and circumferential joints shall have 100 percent radiographic examination, and all welded joints shall have 100 percent penetrant examination.

11.5 QUENCHED AND TEMPERED STEELS Groups F and G steels which have their properties enhanced by heat treatment shall—

(a) have 100 percent magnetic particle examination of thermally cut edges which will not be subsequently eliminated by fusion with weld deposit;

(b) have 100 percent magnetic particle examination of all welds; and

(c) have all branch welds (Type D1, Table 7.2) examined 100 percent radiographically (at high sensitivity) or ultrasonically (at Level 1 or 2).

11.6 DISSIMILAR METAL JOINTS Butt welds of pressure-retaining parts between austenitic and ferritic steels and between ferritic-austenitic and austenitic or ferritic steels shall be subjected to 100 percent radiographic or ultrasonic examination and to 100 percent penetrant examination.

11.7 ACCEPTANCE CRITERIA The criteria of acceptance for all welds referenced in this Section shall be as specified in Section 8.

SECTION 12 ADDITIONAL NON-DESTRUCTIVE EXAMINATION FOR TEMPORARY ATTACHMENTS AND ARC STRIKES

12.1 GENERAL Areas on pressure components from which temporary attachments have been removed or where arc strikes have occurred shall be dressed smooth and examined by the magnetic particle or penetrant method in accordance with the requirements of Clauses 3.5 and 3.6 in the following circumstances:

(a) For A1, A2 and A3 steel groups, where the thickness of the parent material exceeds 32 mm or the construction is designed for low temperature operation below −20°C with a calculated average stress level exceeding 50 MPa.

(b) For B, C and E steel groups, where the thickness of the parent material exceeds 16 mm.

(c) For all constructions in groups D1, D2, F, G, H, J, L and M materials irrespective of thickness.

12.2 REPAIR OF IMPERFECTIONS Any cracking revealed by the examination in Clause 12.1 shall be removed, and the component re-examined by the same surface method to verify removal of the imperfection and retested by the same method if the area is subsequently repaired by welding.

SECTION 13 ADDITIONAL NON-DESTRUCTIVE EXAMINATION FOR COMPONENTS DESIGNED FOR SPECIFIC PURPOSE OR CONSTRUCTION

13.1 COMPONENTS CONTAINING LETHAL SUBSTANCES In constructions designed to contain lethal substances (see AS 4343) all welds that penetrate the wall of the construction shall be examined for 100 percent of their length by radiographic or ultrasonic methods. The acceptance criteria shall be as specified in Section 8 for the type and class of construction.

13.2 COMPONENTS SUBJECT TO EXTERNAL PRESSURE Components that are subject to external pressure and that have a material type and thickness requiring Class 1 construction shall have all longitudinal and circumferential welds examined as specified in Tables 7.1, 7.2 and 7.3 for Class 1 construction. The acceptance criteria shall be as specified in Section 8 for the type and class of construction.

The above requirements for non-destructive examination are not applicable to longitudinal and circumferential welds of furnace and reversal chamber wrapper plates of fire-tube boilers.

13.3 PNEUMATICALLY TESTED CONSTRUCTIONS On welded pressure components to be pneumatically tested (see Section 8), all butt-welded joints shall be subjected to the NDE requirements for Class 1 construction listed in Table 7.1, 7.2 and 7.3 as applicable. The acceptance criteria shall be as specified in Tables 8.1 and 8.2, and the following welds shall be subject to 100 percent magnetic particle or penetrant examination:

(a) All welds around openings.

(b) All attachment welds, including welds attaching non-pressure parts to pressure parts having a throat thickness greater than 6 mm.

As an alternative to the above NDE requirements in this Clause (13.3), pneumatic testing may be permitted where a critical engineering assessment identifies the conditions for safe testing and this is agreed between the parties concerned, provided that people, property and the environment are suitably protected.

13.4 EXPANSION BELLOWS Non-destructive examination of expansion bellows shall be by agreement of the parties concerned. See ASME B31.3 for guidance on piping bellows.

SECTION 14 REPORTS AND RECORDS OF WELDED CONSTRUCTIONS

14.1 APPLICATION Reports of non-destructive examination shall be prepared in accordance with the following Standards:

(a) Radiographic examination—AS 2177.1.

(b) Ultrasonic examination—AS 2207.

(c) Magnetic particle examination—AS 1171.

(d) Penetrant examination—AS 2062.

(e) Acoustic examination—Clause 23.8, of AS 4037.

14.2 INFORMATION TO BE REPORTED All reports shall contain the information specified in the Standard appropriate to the method of examination, and the following:

(a) Stage of manufacture at the time of the examination (e.g. as welded, after PWHT).

(b) Names of the personnel responsible for the carrying out of examination and the interpretation and their qualifications.

(c) Identification of the weld under examination.

(d) Descriptions and location of all significant imperfections, together with any permanent records, e.g. radiographs, scale drawings or sketches. Terminology for the description and reporting of imperfections and their location shall be in accordance with AS Z5.2.

14.3 SPECIFIC INFORMATION For radiographic examination, both the image quality indicator sensitivity required in Figure 3.1 for the relevant weld metal thickness, and the sensitivity achieved shall be included in the report.

14.4 IDENTIFICATION OF WELDS Permanent marking adjacent to welds shall be used to provide reference points for accurate location of the seam with respect to the test report unless a system is used which guarantees location of areas on the report during the lifetime of the component.

NOTE: See Appendix C for recommended weld identification.

Permanent marking shall not be used where it may have a deleterious effect on material, e.g. low temperature service or components subject to high cycle fatigue service.

14.5 RETENTION OF RECORDS A set of records (including radiographs for radiographic examination or hard copy printouts for automated methods) for each item of pressure equipment, including those for original and repair welds, together with the examination report, shall be retained for five years by the manufacturer or organization carrying out the examination.

SECTION 15 NON-DESTRUCTIVE EXAMINATION OF CASTINGS

15.1 METHOD OF EXAMINATION The methods of non-destructive examination should be agreed between the foundry and the purchaser.

Non-destructive examination may consist of radiographic, ultrasonic, magnetic particle or dye penetrant methods.

The method of examination shall be in accordance with the following Standards:

(a) Radiographic examination for ferrous materials—AS 3507.

(b) Ultrasonic examination—AS 2574.

(c) Magnetic particle examination—AS 1171.

(d) Dye penetrant examination—AS 2062.

15.2 EXTENT OF EXAMINATION Carbon, carbon-manganese, alloy and high alloy steel castings requiring a casting quality factor exceeding 0.80, and non-ferrous and nodular iron castings requiring a casting quality factor exceeding 0.90, shall, in addition to complying with the minimum requirements of the material specification, be examined in accordance with one or more of the following procedures as specified to the foundry by the purchaser:

(a) Each casting to be radiographed.

(b) Not less than three pilot castings to be radiographed until three consecutive castings manufactured by the same casting method are acceptable.

(c) Radiography to be audited at a frequency nominated by the purchaser.

(d) Ultrasonic examination to be used as a substitute for radiographic examination where agreed between the foundry and the purchaser.

(e) All ferromagnetic castings to be examined by the magnetic particle method.

(f) All non-ferromagnetic and non-ferrous castings to be examined by the dye penetrant method.

(g) One or more castings to be cut into sections where agreed between the foundry and the purchaser.

15.3 ACCEPTANCE CRITERIA Acceptability of imperfections in materials other than steel is subject to agreement between the foundry and the purchaser.

Acceptability of imperfections in steel castings shall be as follows:

(a) *Radiographic acceptance—AS 3507* Areas of casting to be butt-welded to components (e.g. valves) shall be radiographed within 50 mm of the butt-weld line and shall comply with AS 3507, Class 1 requirements. Unless otherwise specified by the purchaser, the following acceptance requirements shall apply to all sections of steel castings radiographed:

  (i) Wall thickness: ≤25 mm Class 1.

  (ii) Wall thickness: >25 mm—≤50 mm Class 2.

  (iii) Wall thickness >50 mm Class 3.

(b) *Ultrasonic acceptance—AS 2574*

  (i) Wall thickness ≤50 mm Class 2.

  (ii) Wall thickness >50 mm Class 3.

(c) *Magnetic particle and dye penetrant acceptance* Refer to Table 15.1.

15.4 REPAIRS Where castings do not comply with the above requirements, they shall be rejected with the following exception: weldable material that can be repaired by welding and retested. Welding repairs shall be retested in accordance with the requirements for the casting and using the same inspection methods which detected the imperfections, and the same acceptance limits.

15.5 MARKING Each casting shall be suitably identified by foundry heat number and serial number, when applicable.

15.6 REPORTING OF EXAMINATION The testing organization shall prepare a report giving details of any significant imperfections, their location and interpretation.

15.7 RETENTION OF RECORDS A complete set of records shall be retained in accordance with the requirements of Clause 14.5.

TABLE 15.1

ACCEPTANCE CRITERIA FOR MAGNETIC PARTICLE AND PENETRANT EXAMINATION

Category of imperfections	Acceptance criteria
Linear indication An imperfection in which one measurable dimension is at least three times greater than the other. This includes hot tears, and shrinkage cracks.	
(a) Single indication	Length ≤6 mm
(b) Multiple—Aligned or unaligned.	Spacing not less than three times the longest discontinuity which shall be 6 mm maximum.
Non-linear indication A discontinuity in which neither of the measurable dimensions is greater than three times the other. Indications appear as rounded and/or elongated clusters of magnetic particles of various sizes, scattered at random. (See Note 2).	
(a) Single indication	Maximum dimension = 6 mm
(b) Multiple—Aligned or unaligned.	Spacing not less than three times the maximum dimension of the largest indication which shall be 6 mm maximum.
(c) Indications less than 3 mm	These are irrelevant unless: - Random multiple indication density does not exceed six per 650 square millimetres. - Aligned multiple indication density does not exceed four per linear 25 mm.

NOTES:

1 Acceptable discontinuities may be reworked for appearance purposes.

2 Porosity should not be confused with dimples, pock or pustule marks.

SECTION 16 NON-DESTRUCTIVE EXAMINATION OF FORGINGS

16.1 GENERAL Ferrous forgings, when specified by the application Standard, shall be ultrasonically examined in accordance with this Section. The examination of forgings in non-ferrous materials is subject to agreement between the manufacturer and purchaser.

16.2 METHOD AND EXTENT OF EXAMINATION The procedure for ultrasonic examination shall be as follows:

(a) The preparation of forgings and the method of ultrasonic examination shall comply with AS 1065, or an equivalent national Standard.

(b) The entire volume of material shall be examined ultrasonically or as required by the material specification at some stage of manufacture, preferably after final heat treatment. If contours of the forging preclude complete ultrasonic examination after final heat treatment, the maximum permissible volume shall be examined prior to final heat treatment.

16.3 REFERENCE STANDARDS All reference blocks used for this procedure shall meet the requirements described in AS 2083. When used, reference blocks shall match, as closely as possible, the acoustic response of the material being tested.

16.4 CALIBRATION Since sensitivities will vary with the quality class chosen, the evaluation sensitivity shall be calibrated to comply with the recording limits of Table 16.1. The maximum equivalent reflector size shall be determined using a reflectivity showing either amplitude reference lines for 3, 4, 6, and 8 mm flat bottom holes or DGS diagrams (see Appendix C of AS 1065).

Scanning sensitivity shall be plus 6 dB above the evaluation sensitivity.

Instrument gain shall be adjusted for transfer, attenuation and correction for curvature.

16.5 SCANNING REQUIREMENTS Forgings shall be scanned according to the procedures given in AS 1065.

16.6 ACCEPTANCE CRITERIA Unless otherwise specified by the product Standard or the purchaser, forgings shall be examined and assessed to one of three nominated quality levels as specified in the following.

The maximum acceptable indication levels for the three different quality levels are given in Table 16.1. The appropriate quality level should be nominated by the purchaser. In the absence of such nomination, Quality Level 2 shall apply.

For the purpose of assessment, the forging shall be divided into three zones, an inner, an outer and an intermediate zone, as detailed in Figure 16.1.

16.7 INTERPRETATION OF RESULTS Additional examination procedures may be employed to resolve questions of interpretation of ultrasonic indications.

16.8 REPORTING EXAMINATION AND RECORDS The manufacturer shall prepare a report giving details of any significant indications, their locations, and interpretation.

16.9 RETENTION OF RECORDS A complete set of records shall be retained in accordance with the requirement of Clause 14.5.

TABLE 16.1
INDICATION LEVELS

Quality level	Zone of forging (See Fig.16.1)	Indication type (Note 1)				
		Individual reflector mm	Planar reflector, max. mm^2	Stringer reflector length mm	Cluster reflector, max. mm^2 (Note 2)	Loss of back wall echo dB (Note 3)
1	A	3	Not permitted	3	9	4
	B	3	Not permitted	3	9	4
	C	4	Not permitted	6	36	6
2	A	3	Not permitted	3	9	4
	B	4	150	4	9	6
	C	6	300	10	36	12
3	A	4 (Note 1)	150 (Note 4)	6 (Note 4)	36	6
	B	6	500	10	36	12
	C	8	1000	20	100	20

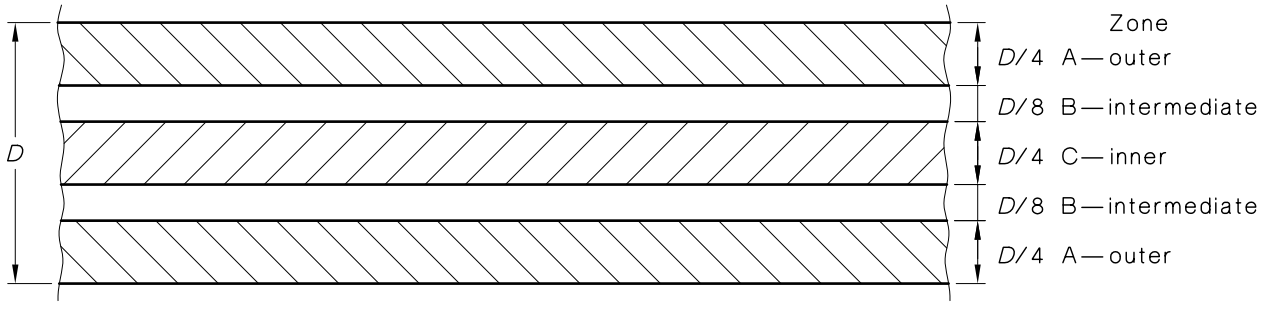
NOTES:

1 Discontinuity indications shall be classified in accordance with Appendix F of AS 1065.

2 Adjacent individual indications from 1.5 mm to 3 mm in diameter shall be separated by a distance of at least 5 *d*, where *d* is the specified maximum equivalent reflector size.

3 Compensation for curvature shall be made in accordance with Appendix D of AS 1065.

4 Cluster indications which appear on the finished surface shall be assessed by reference to the product Standard. If none is nominated, no indication shall be in excess of 3 mm in one direction and the minimum space between indications shall not be less than three times the larger indication in each case.



LEGEND:
D = Forging thickness

FIGURE 16.1 SECTIONAL VIEW OF FORGING SHOWING ZONAL SUBDIVISIONS

SECTION 17 HYDROSTATIC TESTING

17.1 GENERAL When required by the application Standard, each fabrication shall pass the standard hydrostatic test requirements as described in this Section unless the fabrication is tested in accordance with pneumatic tests (Section 18) or leak proof hydrostatic tests (Section 19 or 20).

The hydrostatic test shall be carried out at the stage of production at which welds are accessible for visual examination. Fabrications which are to be galvanized, tinned, rubber lined, or otherwise coated shall be hydrostatically tested prior to such coating. All hydrostatic tests shall be made with water or another suitable liquid. The liquid should be agreed between the parties concerned.

For large, critical, difficult to examine or high hazard level of pressure equipment, acoustic examination may be used by agreement between parties concerned to provide improved assessment of the safety during the test and in service.

17.2 TEST PRESSURE The test pressure applied to the fabrication shall be determined in accordance with the requirements of the application Standard.

The test pressure shall include any static head applying during the test on the part under consideration.

17.3 HYDROSTATIC TEST PROCEDURE

17.3.1 Safety precautions Adequate precautions against the hazards involved in pressure testing shall be taken and, in particular, the following shall apply:

(a) Water at a suitable temperature to give adequate protection against brittle fracture shall be used as a pressurizing fluid.

NOTE: To avoid the risk of freezing, it is recommended that this temperature be not less than 7°C during the hydrostatic test.

(b) The quality of water or other fluid used shall be such as to not cause unacceptable corrosion during or after the test and avoid residue of injurious solids.

NOTE: For example, potable water may be used but particular care should be taken to minimize the chloride content in water when testing austenitic stainless steel pressure equipment.

(c) The fabrication or components being tested and their connections shall be completely vented or evacuated to prevent formation of air pockets.

(d) All temporary pipes, connections, and blanking devices shall be designed and installed to withstand the appropriate test pressure. The fabrication shall be adequately supported, taking into account the weight of the testing medium to ensure adequate stability.

(e) No component undergoing pressure testing shall be subjected to any form of shock loading, e.g. hammer testing, thermal shock, or rapid application or loss of pressure.

(f) Care shall be taken to vent the equipment adequately when draining the equipment after the test.

NOTE: There is a need to avoid the risk of repeated over-pressurization. It is therefore recommended that a preliminary examination of the fabrication or component be carried out at the design pressure to determine the existence and significance of any leaks prior to the application of the full hydrostatic test pressure.

17.3.2 Application of test The test pressure shall not be applied until the fabrication and its test fluid are at about the same temperature.

The full test pressure shall be maintained for 30 minutes minimum unless otherwise specified in the application Standard and preferably for one minute per millimetre of thickness.

Prior to close examination of the vessel or component, the test pressure shall be reduced to 85–95% of the test pressure and held for sufficient time to perform the examination.

17.3.3 Measuring test pressure The test pressure shall be measured by an industrial gauge of accuracy not less than that required by AS 1349. The gauge shall be graduated as follows:

(a) For test pressures ≤3.5 MPa, to approximately twice the test pressure.

(b) For test pressures >3.5 MPa, to approximately 1.5 times the test pressure but not less than 7.0 MPa.

Means shall be provided to demonstrate that the test pressure is actually applied to the fabrication, e.g. by the use of a bleeder valve.

17.3.4 Fittings during testing Fittings and mountings shall successfully pass the tests for the appropriate design pressure, as specified in AS 1271.

17.4 TEST REQUIREMENT The fabrication shall show no visible evidence of bulging, distortion or leakage.

After the rectification of any imperfection disclosed during the hydrostatic test,the vessel shall be retested in accordance with the requirements of this Section (17).

17.5 REPORTING OF RESULTS The testing of each fabrication shall be recorded. Such records shall include as a minimum the following:

(a) Date of test.

(b) Identification of the fabrication.

(c) Test pressure.

(d) Certification by the examiner of compliance with Clause 17.4.

(e) Shell temperature at time of testing when the shell thickness exceeds twice the thickness requiring postweld heat treatment by the pressure equipment Standard (see Note 2 to Table 10.1 of AS/NZS 3992:1998).

SECTION 18 PNEUMATIC TESTS

18.1 APPLICATION Pneumatic testing should be avoided, but may be used in place of the hydrostatic test in special circumstances where—

(a) fabrications are of such design and construction, or are so supported, that it is not practicable or safe for them to be filled with liquid; or

(b) fabrications cannot be dried before being used in service or where even small traces of the testing liquid cannot be tolerated.

18.2 GENERAL PRECAUTIONS The hazards involved in pressure tests using a compressible fluid shall be considered and shall only be carried out to a documented procedure acceptable to the manufacturer and, where appropriate, to the inspection body or owner (or purchaser). The procedures are as follows:

(a) Owing to the presence of one or more undetected imperfections in the fabrication, or for some other unforeseen reasons, a major rupture of the fabrication may occur at some stage during the application of pressure. The procedure to be followed should ensure, as far as is practicable, that no person is likely to sustain injury if the vessel should fail during the testing.

(b) The test procedure shall be established during the design stage of the fabrication to ensure that when testing is carried out, the highest standards of safety are maintained throughout the test period. Adequate facilities and equipment should be provided by the manufacturer to enable these Standards to be met.

(c) The location of the fabrication relative to other buildings, plants, public roads, and areas open to the public, and all other equipment and structures in the vicinity of the vessel being tested and the time of test shall be undertaken to minimize risk in the event of failure.

(d) When practicable the volume of the vessel should be minimized, e.g. by testing individual compartments, adding seal blocks etc.

18.3 EXAMINATION OF WELDS Prior to the test, all welds shall comply with the requirements of Clause 13.3.

18.4 TEST TEMPERATURE The test temperature of the material of the fabrication shall be such as to give adequate protection against brittle fracture. Such temperature shall not be less than the material design minimum temperature for the material of construction in the as-welded or post weld heat-treated condition (as applicable) plus 20°C (see AS 1210 for material design minimum temperature for the material of construction).

The procedure used for filling and emptying the compressible fluid shall ensure that any excessive local chilling of the fabrication is not allowed to occur during pressurization and depressurization of the fabrication.

18.5 TEST PRESSURE The test pressure applied to the fabrication shall be in accordance with the application Standard.

18.6 TEST PROCEDURE

18.6.1 Test fluid Pneumatic tests shall be made with air or other suitable gas, preferably non-toxic and non-flammable.

18.6.2 Application of pressure Where the supply pressure is greater than 35 kPa a suitable pressure-reducing device shall be provided. The low pressure side of this device shall have a pressure gauge, safety valve, and pressure release cock. The safety valve discharge capacity shall be at least the maximum output of the pressure-reducing device or the pressure source. The safety valve shall be set to the preliminary leak test pressure.

During pressurization and when the equipment is under test, components shall not be subjected to shock, e.g. sudden application of pressure, hammer blows or rapid loss of pressure subsequent to pressure testing.

The pressure shall be gradually increased to not more than one half of the test pressure. Thereafter, the pressure shall be increased slowly, pausing at increments of 10 percent or less of the test pressure until the test pressure is reached. The pressure shall then be reduced to a value equal to 80 percent of the test pressure and held at this pressure for sufficient time to permit detailed visual inspection of the vessel.

To facilitate location of leakage, soapy water or other suitable medium may be used.

As an alternative to the above visual inspection, a suitable gas leak test may be used provided that the vessel will not contain lethal substances and all welded joints that will be hidden by assembly are given a visual inspection for workmanship prior to assembly.

18.7 TEST REQUIREMENTS The fabrication shall show no signs of bulging, distortion or leakage.

After the rectification of any imperfection disclosed during the pneumatic test, the vessel shall be retested in accordance with the requirements of this Section (18).

18.8 REPORTING OF RESULTS The testing of each fabrication shall be recorded. Such records shall include, as a minimum, the following:

(a) Date of test.

(b) Identification of the fabrication.

(c) Test pressure applied.

(d) Certification by the examiner that the fabrication complies with Clause 18.7.

18.9 COMBINED HYDROSTATIC/PNEUMATIC TEST In some cases it may be desirable to test a pressure vessel when it is partly filled with liquid. This combined hydrostatic and pneumatic test may be used as an alternative to the complete pneumatic test provided that—

(a) the requirements for a complete pneumatic test are met; and

(b) the liquid level is set so that the maximum stress including the stress produced by the pneumatic pressure at any point in the vessel (usually near the bottom) or in the support attachments, does not exceed 1.25 times the maximum allowable design strength for the material multiplied by the applicable joint efficiency factor.

SECTION 19 LEAK TESTS

19.1 PRELIMINARY LEAK TEST It is sometimes desirable to carry out a pneumatic leak test before the hydrostatic or pneumatic pressure test as specified in Sections 17 and 18 respectively. A suitable test may be applied without complying with the requirements applying to high pressure pneumatic testing (see Section 18).

Where the supply pressure is greater than 35 kPa or 10 percent of design pressure whichever is less, a suitable pressure-reducing device shall be provided. The low pressure side of this device shall have a pressure gauge, safety valve, and pressure release cock. The safety valve discharge capacity shall be at least the maximum output of the pressure-reducing device or the pressure source. The safety valve shall be set to the preliminary leak test pressure.

The pressure shall be increased slowly, with intervals to allow strains to equalize and for leak detection.

During pressurization and when the equipment is under test, components shall not be subjected to shock, e.g. sudden application of pressure, hammer blows or rapid loss of pressure subsequent to pressure testing.

19.2 SENSITIVE LEAK TEST A sensitive leak test shall be applied by one of the following methods when specified by the application Standard or purchaser:

(a) A sensitive leak test shall be in accordance with the gas and bubble formation test method specified in Article 10, Section V of the ASME Boiler and Pressure Vessel Code, BS 3636, or other method demonstrated to have equivalent or better sensitivity. Sensitivity shall be at least 100 mL/s.Pa under test conditions. Any sensitive leak test shall be followed by the specified pressure test.

(b) A mass spectrometer or a halide sensitivity leak test shall be in accordance with the instructions of the test equipment manufacturer. The calibrated reference leak rate shall be not greater than the specified leakage from the component. The equipment shall be calibrated against a reference leak in such a way that the leakage measured can be shown not to exceed the reference leak rate.

SECTION 20 ALTERNATIVE TESTS TO HYDROSTATIC AND PNEUMATIC TESTING

20.1 GENERAL An alternative test may be used in place of a hydrostatic or pneumatic test only where—

(a) permitted by the application Standard;

(b) the test is acceptable to the manufacturer, owner (or purchaser) and where appropriate the inspection body; and

(c) a hydrostatic or pneumatic test is not practical for the following reasons:

(i) A hydrostatic test is not practicable due to inability of foundations or supports to support the weight of test water.

(ii) A hydrostatic test would be damaging to linings or internal insulation, residual moisture would contaminate a process and cause hazard, corrosion, or failure of the process, or low metal temperature during the test would cause risk of brittle fracture.

(iii) A pneumatic test would introduce unacceptable hazard from release of stored energy. Low metal temperature during the test would increase the probability of brittle fracture.

20.2 APPLICATION The alternative test shall only apply to welds (including those made by the manufacturer of welded pipe and fittings that have not been subjected to pressure tests in accordance with Section 17 or Section 18) which have been non-destructively examined to each of the following:

(a) All longitudinal and circumferential butt-welds have been 100 percent tested by the non-destructive examination method of Section 7 and comply with the requirements of Section 8.

(b) All welds, including structural attachment welds, shall have been penetrant tested, except ferritic material shall have been magnetic particle examined.

(c) Examinations in Items (a) and (b) shall have been carried out after any heat treatment.

(d) The pressure equipment or joints to be tested shall have been sensitive leak tested in accordance with Clause 19.2.

(e) For pressure piping a flexibility analysis of the piping system shall have been made (see AS 4041).

SECTION 21 PROOF HYDROSTATIC TESTS

Where the strength of components cannot readily be calculated, the design pressure may be determined in accordance with the proof hydrostatic test procedure specified in AS 1210.

SECTION 22 SPECIAL EXAMINATIONS AND TESTS

Materials or procedures not previously used by the manufacturer or pressure equipment installed and operating under special conditions shall have special additional examinations or tests to determine suitability, where required by the parties concerned. Special examinations and tests include the following:

(a) Corrosion tests of the material (see ISO 196).

(b) Corrosion tests welded joints (see AS 2205.10.1).

(c) Chemical analysis of a component.

(d) Welded or brazed joint crack tests on suitable specimens for rigidity, restraint, cooling, or other conditions not provided for in the weld procedure qualification tests.

(e) Fatigue tests to verify service life.

(f) Special fracture toughness tests.

The method, stage and acceptance criteria for such inspections or test should be agreed by the parties concerned.

SECTION 23 ACOUSTIC EMISSION EXAMINATION

23.1 GENERAL Acoustic emission examination (AE) is based on the detection, measurement and assessment of stress waves emitted from imperfections during the application of stress by pressure, thermal or other means.

NOTES:

1 AE has been used in Australia for over 30 years and on a significant number of small to very large pressure vessels and on piping and pipelines. Experience indicates that not all tests have been satisfactory and that reliable results depend on the equipment, material and condition, test environment, equipment and method, and on the testing body and personnel.

2 For guidance see ANSI/ASME Section V, Articles 11, 12 and 13 and ASTM E569, ASTM E650 and ASTM E750.

3 For terminology see ASTM E1316.

23.2 OBJECTIVE This Section aims to provide requirements for acoustic emission examination for industry based on worldwide experience.

23.3 APPLICATION AE may be used as follows:

(a) Where required by an application Standard or specification agreed by the parties concerned.

(b) On metallic, non-metallic or mixed material pressure equipment (internal or external pressure) which is static or transportable, with or without insulation or buried or not.

(c) To detect, locate and classify emission sources i.e. locate areas where abnormally high levels of stress waves indicate possible serious imperfections, excessively stressed material or leakage. Immediate analysis of results or further local examination by other NDE methods may assist in a safe pressure test or in determining the integrity of the equipment. This integrity may be maintained if necessary with repair.

(d) During pressure testing (hydrostatic or pneumatic) as an addition to usual fabrication testing.

(e) During service for continuous or intermittent monitoring of on-stream pressure equipment to assess suspect areas.

(f) During in-service inspection, particularly for large, difficult-to-inspect pressure equipment as a main periodic inspection method, or after a serious mishap with such equipment e.g. seismic event or explosion. The equipment may be examined off or on-stream and at low to high temperatures with suitable test equipment.

(g) When it is not practicable to visually examine and assess critical areas for significant imperfections or degradation.

(h) During the test providing the pressure can be applied to closely approximate or exceed the maximum allowable operating pressure (design pressure) or exceed the maximum operating pressure experienced over a suitable period before the test.

(i) Only in accordance with a documented and qualified examination procedure and by suitably qualified and experienced acoustic emission testing body and personnel, all complying with this Standard.

23.4 PRE-EXAMINATION REQUIREMENTS The following are required prior to the test:

(a) The objective of the test.

(b) The scope or extent of the test. The main pressure retaining parts of the pressure equipment as covered by Table 7.1 should be assessed. However, flanges to branches, valves, instruments and other attached fittings should be excluded, unless otherwise agreed between parties concerned.

(c) The examination and test procedure (see Clause 23.5).

(d) The qualification of the examination procedure (see Clause 23.6).

(e) The qualification of the testing body (see Clause 23.7).

(f) The person(s) responsible for stopping or conducting the test if unexpected or unusual AE activity is detected.

(h) The timing, facilities and contractual matters.

23.5 EXAMINATION PROCEDURE A documented examination procedure shall be prepared for each item for pressure equipment or for similar equipment, and shall adequately cover each of the following:

(a) Purpose of the examination.

(b) Details of the pressure equipment (e.g. dimensions, materials, support and attachments location).

(c) Safety and emergency procedures and precautions, particularly against overstressing or leakage.

(d) Conditioning of the pressure equipment prior to examination (including test fluid).

(e) Environmental conditions and noise reduction.

(f) Pressurizing or stressing of the equipment, is to include a suitable and viable test program relating pressurization rates and specific hold levels and duration of hold periods.

(g) Sensor type, frequency, material and wave guides.

(h) Sensor locations, spacing, attachment and couplant.

(i) Test equipment including data processing and recording instruments (type and frequency).

(j) System calibration and checks. Full calibration of all equipment is required immediately prior to and immediately after each test program.

(k) Data required to be measured, assessed, recorded and reported.

(l) Pre-examination measurements.

(m) Examination program e.g. pressure, time, instrument checks.

(n) Evaluation/interpretation of results.

(o) Evaluation criteria.

(p) Post-examination cleaning.

(q) Any other supporting NDE required.

NOTE: See Clauses 23.8 and Clause 23.9 for reports and records.

23.6 QUALIFICATION OF EXAMINATION PROCEDURE The specified examination procedure shall be proven suitable by the following:

(a) The acoustic emission testing body.

(b) Demonstration that the procedure is capable of locating and assessing acceptability of imperfections or highly stressed material in the specific areas of identical or similar equipment and under similar conditions. This may be prior to or during the specific examination, as agreed. Assessment may be done directly or by ultrasonic examination or other suitable means.

(c) Review of a documented report and results of examinations and procedures carried out previously on identical or equivalent equipment or on at least two similar examinations on similar but not necessarily equivalent equipment.

(d) Verification of the procedures by the manufacturer or user of the pressure equipment.

23.7 QUALIFICATION OF TESTING BODY The body conducting the examination shall prove its suitability to the satisfaction of the pressure equipment manufacturer, owner or user, as appropriate, by providing documented evidence of the following:

(a) The body's overall business arrangement, insurance, accreditation, experience and associated bodies.

(b) The qualification and experience of personnel for the proposed examination.

(c) A summary of at least three examinations performed on equipment similar or relevant to the equipment to be examined, including outcomes and contact names.

(d) Other relevant information, e.g. copies of relevant technical papers, investigations and references.

NOTE: NATA and IANZ offer accreditation for AE examinations.

23.8 REPORT A report of the examination shall be provided to the pressure equipment manufacturer, owner or user, as appropriate, and shall include the following:

(a) Complete identification of the pressure equipment.

(b) Sketch of equipment with dimensions and sensor location.

(c) Test date(s), fluid and fluid temperature.

(d) Test sequence.

(e) Correlation of test data with acceptance criteria.

(f) Sketch showing location of any area not meeting the evaluation criteria.

(g) Any unusual effects or abbreviations before or during the examination.

(h) Other outcomes agreed initially by the parties concerned (e.g. as an extension of examination).

NOTE: This may include an assessment of pressure equipment integrity and recommendation concerning future service and operation conditions, the identification of any stimulus causing deformation, the nature of any active deformation and/or the use supplementary NDE in selected areas.

23.9 RECORD A complete record including a permanent record of AE data, shall be retained in accordance with Clause 14.5.

SECTION 24 EDDY CURRENT TESTING

24.1 GENERAL This Section provides requirements for eddy current testing.

NOTE: Eddy current testing is an NDE method by which eddy current flow is induced in the test object. Changes in the current flow caused by variation in the object at or near the surface are used to assess the integrity.

Eddy current examination, using proven techniques, equipment and personnel may be used in lieu of magnetic particle examination for the detection of surface imperfections.

24.2 METHODS The method of eddy current testing shall be one of the following:

(a) AS 2084 for eddy current testing of metal tubes.

(b) AS 4544.1 for eddy current testing for the detection of surface defects in non-ferromagnetic metallic products.

(c) Other Standards agreed by the parties concerned.

Removal of paint coatings is not required if achievement of reliable results has been established by suitable calibration, comparison models and checks. Where indications of imperfections are found, coatings shall be removed and further non-destructive examination carried out to determine the nature and extent of the imperfections found.

24.3 PERSONNEL Personnel carrying out eddy current testing shall be as specified in Clause 4.2.

24.4 RECORD A complete record of testing and results shall be retained in accordance with Clause 14.5.

APPENDIX A
LIST OF REFERENCED DOCUMENTS
(Normative)

AS	
1065	Non-destructive testing—Ultrasonic testing of carbon and low alloy steel forgings
1171	Non-destructive testing—Magnetic particle testing of ferromagnetic products, components and structures
1210	Pressure vessels
1228	Pressure equipment—Boilers
1271	Safety valves, other valves, liquid level gauges, and other fittings for boilers and unfired pressure vessels
1349	Bourdon tube pressure and vacuum gauges
1548	Steel plates for pressure equipment
2062	Non-destructive testing—Penetrant testing of products and components
2083	Calibration blocks and their methods of use in ultrasonic testing
2084	Non-destructive testing—Eddy current testing of metal tubes
2177	Non-destructive testing—Radiography of welded butt joints in metal
2177.1	Part 1: Methods of test
2177.2	Part 2: Image quality indicators (IQI) and recommendations for their use
2205	Methods of destructive testing of welds in metal
2205.10.1	Method 10.1: Corrosion test for welded austenitic stainless steel
2207	Non-destructive testing—Ultrasonic testing of fusion welded joints in carbon and low alloy steels
2574	Non-destructive testing—Ultrasonic testing of steel castings and classification of quality
3507	Non-destructive testing—Radiography of steel castings and classification of quality
3597	Structural and pressure vessel steel—Quenched and tempered plate
3978	Visual inspection of components and products
3998	Non-destructive testing—Qualification and certification of personnel—General engineering
4041	Pressure piping
4343	Pressure equipment—Hazard levels
4458	Pressure equipment—Manufacture
4544	Non-destructive testing—Eddy current testing for detection of surface flaws
4544.1	Part 1: In non-ferromagnetic metallic products
Z5	Glossary of metal welding terms and definitions
Z5.2	Part 2: Terminology of and abbreviations for fusion weld imperfections as revealed by radiography

AS/NZS	
1200	Pressure equipment
1594	Hot-rolled steel flat products
1596	Storage and handling of LP Gas
3509	LP Gas fuel vessels for automotive use
3788	Pressure equipment—In-service inspection
3992	Pressure equipment—Welding and brazing qualification
ISO	
196	Wrought copper and copper alloys—Detection of residual stress—Mercury(I) nitrate test
ANSI/ASME	
BPV-V	Boiler and pressure vessel code Section V—Non-destructive examination
BPV-IX	Boiler and pressure vessel code Section IX—Welding and brazing qualification
API	
5L	Specification for line pipe
ASME	
B31.3	Process piping
ASTM	
A105	Specification for carbon steel forgings for piping applications
A106	Specification for seamless carbon steel pipe for high-temperature service
A234	Specification for piping fittings of wrought carbon steel and alloy steel for moderate and elevated temperatures
A333	Specification for seamless and welded steel pipe for low-temperature service
A335	Specification for seamless ferritic alloy steel pipe for high-temperature service
B163	Specification for seamless nickel and nickel alloy condenser and heat-exchanger tubes
B333	Specification for nickel-molybdenum alloy plate, sheet and strip
B335	Specification for nickel-molybdenum alloy rod
B407	Specification for nickel-iron-chromium alloy seamless pipe and tube
B408	Specification for nickel-iron-chromium alloy plate, rod and bar
B409	Specification for nickel-iron-chromium alloy plate, sheet and strip
B423	Specification for nickel-iron-chromium-molybdenum-copper alloy (UNS N08825 and N08221) seamless pipe and tube
B424	Specification for nickel-iron-chromium-molybdenum-copper alloy (UNS N08825 and N08821) plate, sheet and strip
B425	Specification for nickel-iron-chromium-molybdenum-copper alloy (UNS N08825 and N08821) rod and bar
B434	Specification for nickel-molybdenum-chromium-iron alloy (UNS N10003) plate, sheet and strip
B435	Specification for UNS (N06002, N06230, and R30556) plate, sheet and strip

ASTM

B443	Specification for nickel-chromium-molybdenum-columbium alloy (UNS N06625) plate, sheet and strip
B444	Specification for nickel-chromium-molybdenum-columbium alloys (UNS N06625) pipe and tube
B446	Specification for nickel-chromium-molybdenum-columbium alloy (UNS N06625) rod and bar
B462	Specification for forged and rolled UNS N08020, UNS N08024 and UNS N08026, UNSN08367 and UNS R20033 pipe flanges, forged fittings and valves and parts for corrosive high-temperature service
B463	Specification for UNS N08020, UNS N08026 and UNS N08024 alloy, plate, sheet and strip
B464	Specification for welded UNS N08020, N08024 and N08026 alloy pipe
B468	Specification for welded UNS N08020, N08024 and N08026 alloy tubes
B473	Specification for UNS N08020, UNS N08024, and UNS N08026 nickel alloy bar and wire
B511	Specification for nickel-iron-chromium-silicon alloy bars and shapes
B514	Specification for welded nickel-iron-chromium alloy pipe
B517	Specification for welded nickel-chromium-iron alloy (UNS N06600, UNS N06025 and UNS N06045) pipe
B535	Specification for nickel-iron-chromium-silicon alloy (UNS N08330 and N08332) seamless and pipe and tube
B536	Specification for nickel-iron-chromium-silicon alloy (UNS N08330 and N08332) plate, sheet and strip
B564	Specification for nickel alloy forgings
B572	Specification for UNS N06002, UNS N06230, UNS 12160 and UNS R30556 rod
B573	Specification for nickel-molybdenum-chromium-iron alloy (UNS N10003) rod
B574	Specification for low-carbon-nickel-molybdenum-chromium alloy rod
B575	Specification for low-carbon nickel-molybdenum-chromium alloy plate, sheet, and strip
B581	Specification for nickel-chromium-iron-molybdenum-copper alloy rod
B582	Specification for nickel-chromium-iron-molybdenum-copper alloy plate, sheet, and strip
B619	Specification for welded nickel and nickel-cobalt alloy pipe
B620	Specification for nickel-iron-chromium-molybdenum alloy (UNS N08320) plate, sheet, and strip
B622	Specification for seamless nickel and nickel-cobalt alloy pipe and tube
B626	Specification for welded nickel and nickel-cobalt alloy tube
E569	Standard practice for acoustic emission monitoring of structures during controlled stimulation

ASTM	
E570	Practice for flux leakage examination of ferromagnetic steel tubular products
E650	Standard for mounting piezoeletric acoustic emission sensors
E750	Standard practice for characterizing acoustic emission instrumentation E1-1993 R(1993)
E1316	Standard terminology for non-destructive examinations
BS	
3636	Methods for proving the gas tightness of vacuum or pressurized plant
7706	Guide to calibration and setting up of the ultrasonic time of flight diffraction (ToFD) technique for th detection, location and sizing of flaws.
JIS	
Z3104	Methods of radiography and classification for steel welds

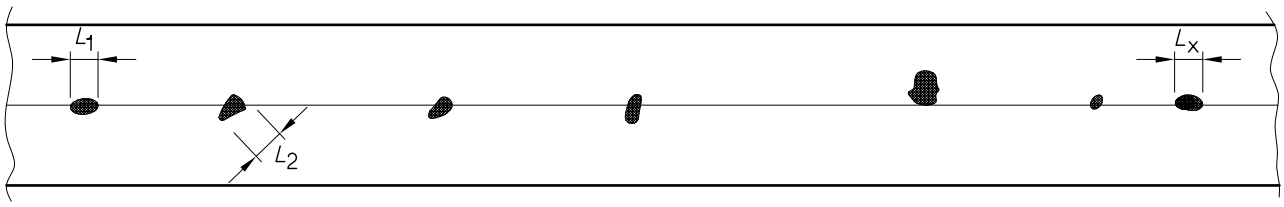
APPENDIX B
POROSITY CHARTS
(Normative)

B1 APPLICATION The following porosity charts (Figures B1 to B8) are for use in assessing the acceptability of welded joints by showing the maximum acceptable concentration of the porosity in butt welds of varying thickness of ferritic austenitic and non-ferrous metals when they are examined by radiographic means.

B2 BASIS The charts are intended to be a practical interpretation of the requirements for porosity given in Tables 8.1 and 8.2. They are to full scale and show an area of the weld as viewed in a radiograph but do not include the parent metal. The distributions shown are not necessarily the patterns that may appear on the radiograph, but are typical of the concentration and size of porosity permitted.

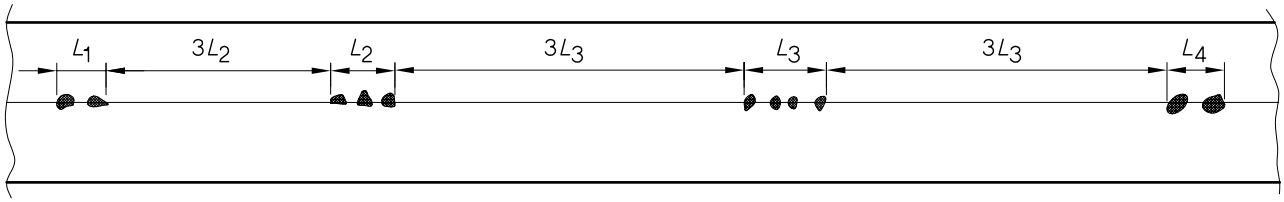
B3 THICKNESS The thickness *t* referred to in the charts is the lesser of the thickness of the weld of the pressure-retaining part or of the thinner of the parts being joined. Where a full penetration weld includes a fillet weld, the thickness of the fillet weld throat shall be included in thickness *t*.

B4 VARIATION FOR DIFFERENT WELD WIDTHS Where the width of weld differs from that shown in the charts, the maximum acceptable number of pores is directly proportional to the weld width.



Sum of L_1 to L_x shall be less than t in a length of $12t$.

FIGURE B1 ALIGNED POROSITY



Sum of group length shall be less than t in a length of $12t$.

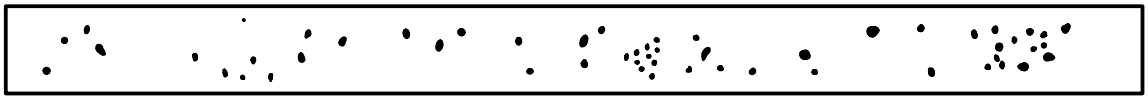
Maximum group lengths:

L = 6 mm for t < 20 mm
L = 1/3 t for 20 mm ⩽ t ⩽ 60 mm
L = 20 mm for t > 60 mm

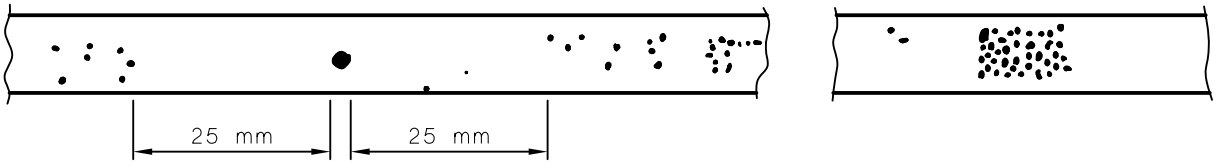
Minimum group spacing:

$3L$ where L is the length of the longest adjacent group being evaluated.

FIGURE B2 GROUPS OF ALIGNED POROSITY



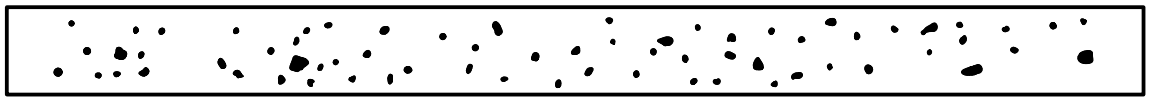
ASSORTED POROSITY
Typical concentration and size permited
in any 150 mm length of weld



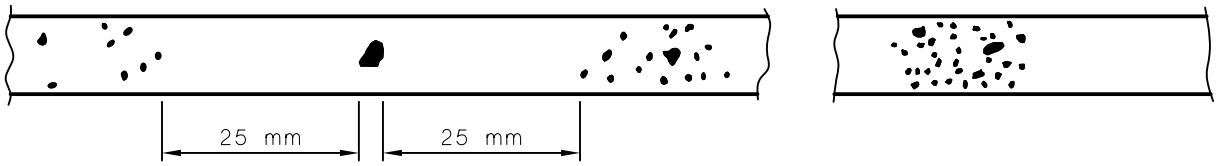
ISOLATED POROSITY
Maximum size in accordance with Table 8.1

CLUSTER POROSITY

FIGURE B3 CHARTS FOR 3 mm ≤ t ≤ 6 mm



ASSORTED POROSITY
Typical concentration and size permited
in any 150 mm length of weld

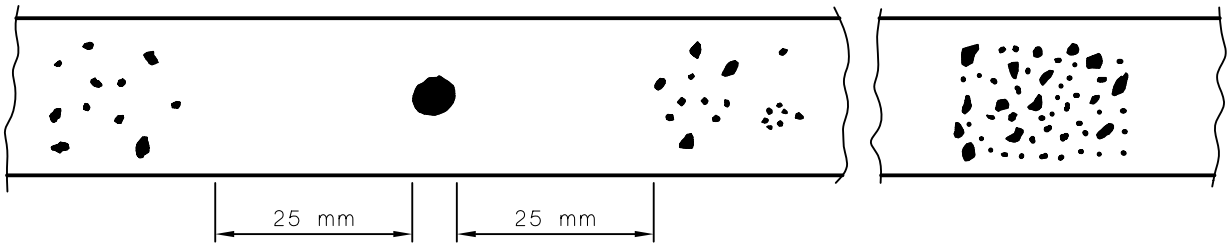


ISOLATED POROSITY
Maximum size in accordance with Table 8.1

CLUSTER POROSITY

FIGURE B4 CHARTS FOR 6 mm < t ≤ 10 mm

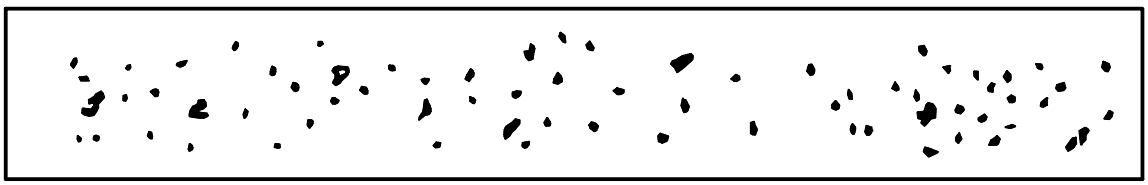
ASSORTED POROSITY
Typical concentration and size permited
in any 150 mm length of weld



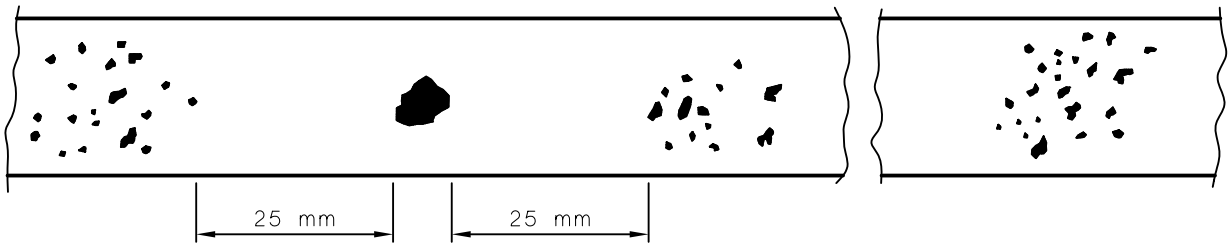
ISOLATED POROSITY
Maximum size in accordance with Table 8.1

CLUSTER POROSITY

FIGURE B5 CHARTS FOR 10 mm < $t \leq$ 20 mm



ASSORTED POROSITY
Typical concentration and size permited
in any 150 mm length of weld



ISOLATED POROSITY
Maximum size in accordance with Table 8.1

CLUSTER POROSITY

FIGURE B6 CHARTS FOR 20 mm < $t \leq$ 50 mm

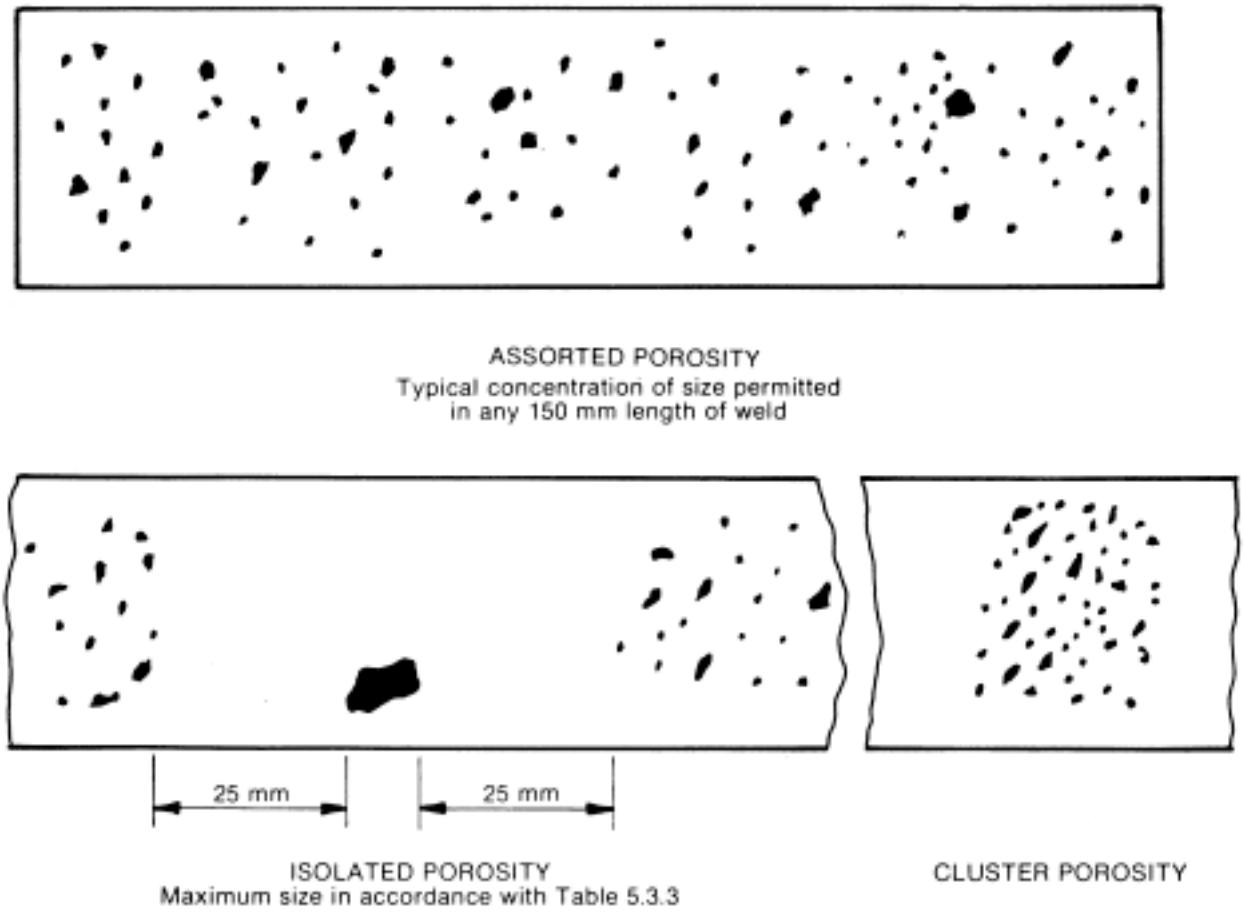
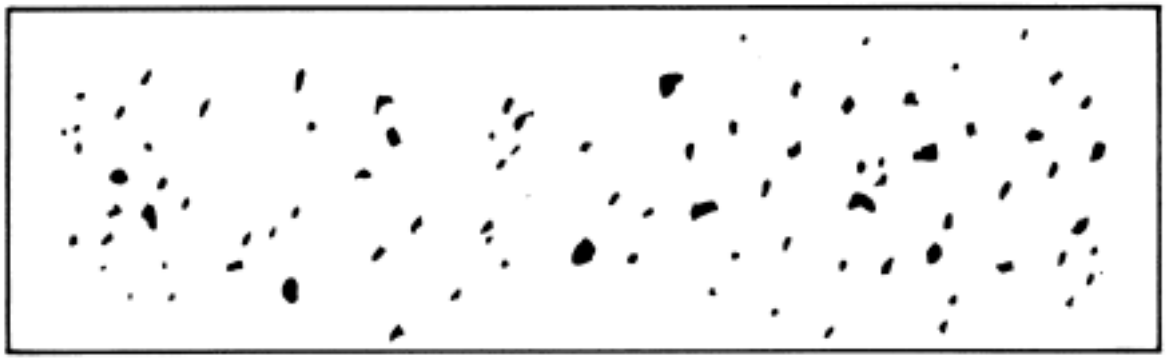
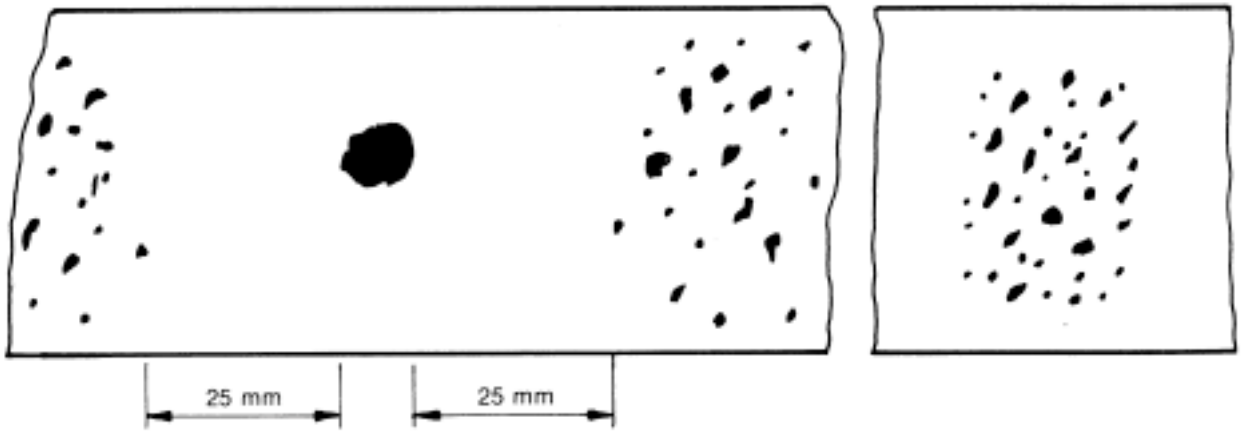


FIGURE B7 CHARTS FOR 50 mm $< t \leq$ 100 mm



ASSORTED POROSITY
Typical concentration and size permitted
in any 150 mm length of weld



ISOLATED POROSITY
Maximum size in accordance with Table 5.3.3

CLUSTER POROSITY

FIGURE B8 CHARTS FOR t >100 mm

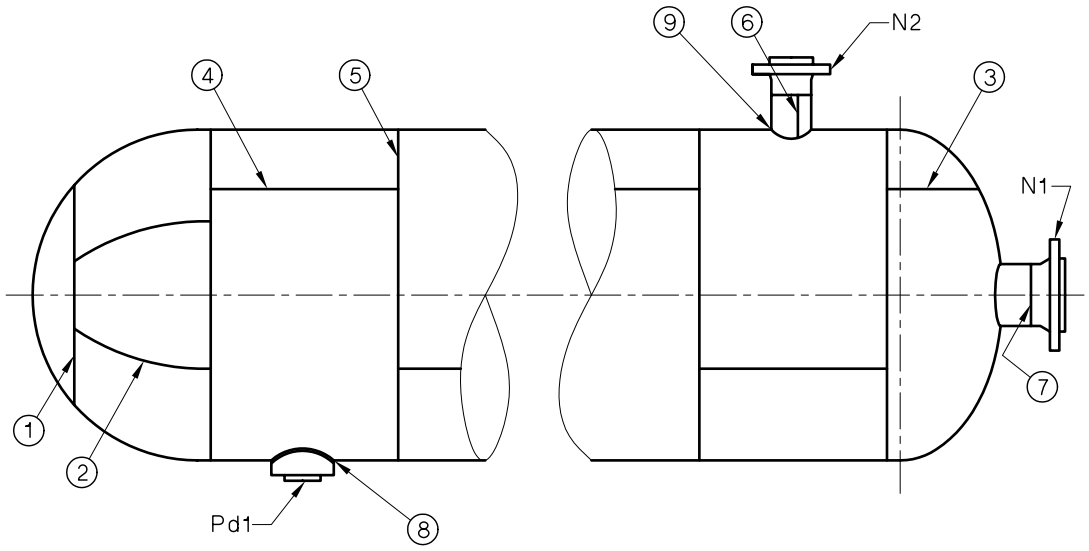
APPENDIX C
SYSTEM OF WELD JOINT IDENTIFICATION
(Informative)

This Appendix illustrates examples of the recommended method of weld joint identification for correlation with non-destructive examination reports. Figure C1 identifies the weld joints used in pressure-vessel construction.

As non-destructive testing is frequently carried out on pressure equipment sections prior to final assembly (e.g. Class 1 pressure vessel or boiler drum strakes are frequently examined prior to assembly), the final diagram showing the correlation of non-destructive examination areas to the as-built component is the responsibility of the manufacturer.

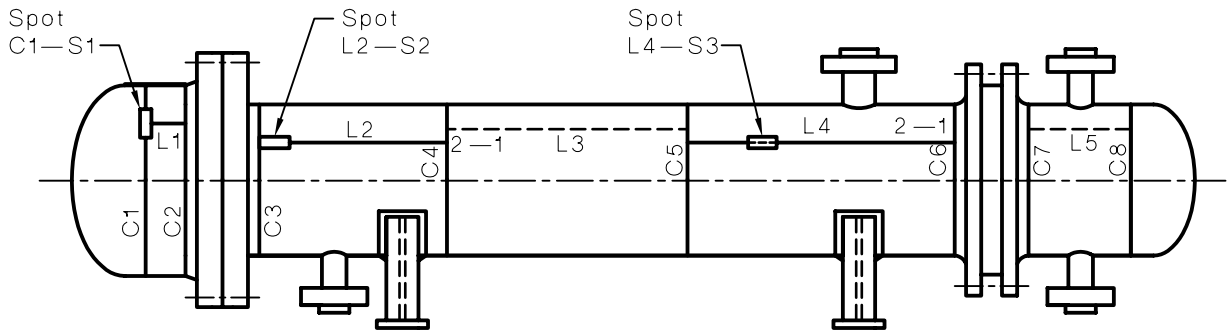
Figure C2 illustrates an example of the marking of welds for the spot radiographic examination of a pressure vessel.

Figure C3 illustrates an example of the marking of welds for full radiographic examination. Strakes already radiographed which are reversed during assembly can result in the reversal of the radiograph identification, e.g. 1-9 or 9-1.



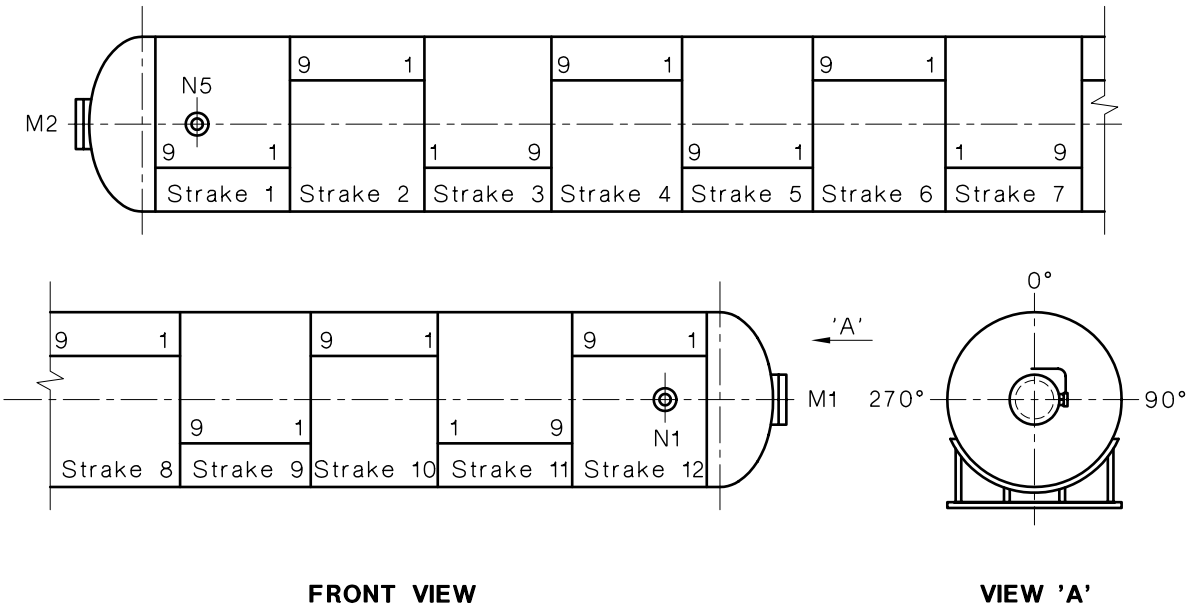
LEGEND:
1 = dollar plate weld in hemispherical end—mark D1, D2, etc., where D = dollar plate
2 = petal to petal weld in hemispherical end—mark P1, P2, etc., where P = petal
3 = transverse weld in ellipsoidal or torispherical end—mark E1, E2, etc., where E = end
4 = longitudinal weld in shell—mark L1, L2, etc., where L = longitudinal weld
5 = circumferential weld in shell—mark C1, C2, etc., where C = circumferential weld
6 = longitudinal weld in rolled plate nozzle—mark N2–L1, etc., where N = nozzle
7 = circumferential weld in nozzle neck—mark N1–C1, etc.
8 = pad to shell weld—mark Pd1–S1, etc., where Pd = pad and S = shell
9 = nozzle to shell or end weld—mark N2–S1, etc.

FIGURE C1 IDENTIFICATION OF WELD JOINTS IN PRESSURE VESSELS



NOTE: Spot radiographs are identified by butt weld number and spot number S1, S2, S3, etc.

FIGURE C2 SPOT RADIOGRAPHIC EXAMINATION OF PRESSURE VESSEL—RECOMMENDED MARKING



NOTE: For circumferential welds, area 1-2 straddles the 0° centre-line and progression is towards 90° centre-line. M = manhole

FIGURE C3 FULL RADIOGRAPHIC EXAMINATION OF PRESSURE VESSEL—RECOMMENDED MARKING

APPENDIX D
NOT ALLOCATED

APPENDIX E
NON-DESTRUCTIVE EXAMINATION SCHEDULE
(Informative)

E1 GENERAL This Appendix gives a typical form for recording details of a non-destructive examination schedule for a pressure vessel (see Figure E1) and pressure piping (see Figure E4).

To assist in the explanation of the requirements of this schedule, two examples of its application are given in this Appendix (Figures E2 and E3).

An example of a typical NDE schedule for piping is given in Figure E4.

E2 FIRST EXAMPLE OF THE APPLICATION OF NDE SCHEDULE A pressure vessel consists of two strakes, 20 mm in thickness, connected to two dished ends, 25 mm in thickness, with the following additional details applicable to design and construction.

Design code:	AS 1210 Class 2A	
Materials of:	Shell and ends AS 1548-7-460	
Construction:	Nozzle neck ASTM A106 Gr B Group A1 steel	
Specification:	Nozzle flanges ASTM A105	
	Slip-on type maximum thickness 40 mm	
Welding method:	Longitudinal seams:	Submerged arc
	Circumferential seams:	Submerged arc (2 off)
	Nozzles to shell:	Manual metal arc (10 off)
	S/O flange to shell	Manual metal arc

For the above example, the non-destructive examination schedule would be as shown in Figure E2.

E3 SECOND EXAMPLE OF THE APPLICATION OF THE NDE SCHEDULE Assuming the same pressure vessel as in Figure E2 with the additional requirements that the vessel is to contain lethal substances. Clause 13.1 requires 100% examination of all welds which penetrate the vessel wall and the NDE schedule would be as shown in Figure E3.

NON-DESTRUCTIVE EXAMINATION SCHEDULE
PRESSURE VESSEL

TITLE OF COMPONENT _____ DRAWING NO. _____

CONSTRUCTION CODE _____ CLASS _____ VESSELS SERIAL NO. _____

Specific purpose or construction methods	Applic-able	Not applic-able	Construction in specific materials	Applic-able	Not applic-able
Lethal contents (Clause 13.1)			Clad or lined construction (Clause 11.1)		
External pressure (Clause 13.2)			High alloy construction (Clause 11.2)		
Pneumatic test (Clause 13.3)			Nickel alloy construction (Clause 11.3)		
Severe cyclic or shock service			Titanium or zirconium construction (Clause 11.4)		
			Quenched and tempered steels (Clause 11.5)		
			Dissimilar metal joints (Clause 11.6)		

Item	Type of joint					
Material group						
Applicable '*t*' thickness (mm)						
Test method						
Test sensitivity						
Percent examination						
Stage of examination						
Joint numbers						

NOTES: _____

Prepared by _____

For _____

FIGURE E1 TYPICAL NON-DESTRUCTIVE EXAMINATION SCHEDULE—PRESSURE VESSEL

NON-DESTRUCTIVE EXAMINATION SCHEDULE
PRESSURE VESSEL

TITLE OF COMPONENT PRESSURE VESSEL DRAWING NO. B 1000 / REV A

CONSTRUCTION CODE AS 1210 CLASS 2A VESSELS SERIAL NO. B 100

Specific purpose or construction methods	Applic-able	Not applic-able	Construction in specific materials	Applic-able	Not applic-able
Lethal contents (Clause 13.1)		X	Clad or lined construction (Clause 11.1)		X
External pressure (Clause 13.2)		X	High alloy construction (Clause 11.2)		X
Pneumatic test (Clause 13.3)		X	Nickel alloy construction (Cause 11.3)		X
Severe cyclic or shock service		X	Titanium or zirconium construction (Clause 11.4)		X
			Quenched and tempered steels (Clause 11.5)		X
			Dissimilar metal joints (Clause 11.6)		X

Item	Type of joint (Table 7.1)					
	A1	B1	C6	D2		
Material group	A1	A1	A1	A1/A2		
Applicable 't' thickness (mm)	20	20	< 20	< 38		
Test method	RT	RT	NIL	NIL		
Test sensitivity	N	N	-	-		
Percent examination	2	SEE NOTES	-	-		
Stage of examination	AS WELDED	AS WELDED	-	-		
Joint numbers	L1, L2	C1, C2, C3	-	-		

NOTES: 2% for automatic welding; 10% for manual welding.

Prepared by

For

FIGURE E2 FIRST EXAMPLE OF A NON-DESTRUCTIVE EXAMINATION SCHEDULE—PRESSURE VESSEL

NON-DESTRUCTIVE EXAMINATION SCHEDULE
PRESSURE VESSEL

TITLE OF COMPONENT PRESSURE VESSEL DRAWING NO. B 1000 | REV B

CONSTRUCTION CODE AS 1210 CLASS 2A VESSELS SERIAL NO. B100

Specific purpose or construction methods	Applic-able	Not applic-able	Construction in specific materials	Applic-able	Not applic-able
Lethal contents (Clause 13.1)	X		Clad or lined construction (Clause 11.1)		X
External pressure (Clause 13.2)		X	High alloy construction (Clause 11.2)		X
Pneumatic test (Clause 13.3)		X	Nickel alloy construction (Clause 11.3)		X
Severe cyclic or shock service		X	Titanium or zirconium construction (Clause 11.4)		X
			Quenched and tempered steels (Clause 11.5)		X
			Dissimilar metal joints (Clause 11.6)		X

Item	Type of joint (TABLE 7.1)					
	A1	B1	C6	D2		
Material group	A1	A1	A1	A1/A2		
Applicable 't' thickness (mm)	20	20	≤20	≤38		
Test method	RT	RT	MT	UT		
Test sensitivity	N	N	—	LEVEL 2		
Percent examination	100	100	100	100		
Stage of examination	AS WELDED	AS WELDED	AS WELDED	AS WELDED		
Joint numbers	L1, L2	C1, C2, C3	ALL JOINTS	ALL JOINTS		

NOTES:

Prepared by

For

FIGURE E3 SECOND EXAMPLE OF A NON-DESTRUCTIVE—EXAMINATION SCHEDULE—PRESSURE VESSEL

TYPICAL NON-DESTRUCTIVE EXAMINATION SCHEDULE—LARGE BORE PIPING

Contract No.:			Client:			Contract:			Unit No.:		Rev. No.:		
System: Large bore integral and BEP piping			Prepared by:			Approved by:			Date:				
Weld Loc. No.	System	Description	O/D mm	Mtl Thk @ weld mm	Material specification	Joint type	Dwg. or sketch No.	WPS No. and (revision)	%NDE (sensitivity)				
									Visual	MPI	RT	UT	PT
FW001	HRSG	Spool 300-MSHS-EHB-1025-T5/3 to Spool 300-MSHS-CCD-101-T5/1	323.9	9.53	ASTM A335 P11 ASTM A106 GrB	B	01025-01 (B) 01001-01 (C)	To be qualified	100	N/A	100 (N)	N/A	N/A
FW002	HRSG	Reducer 300-MSHS-CCD-1001-T5/1 to Escape pipe 200-MSHS-BCA-1004-P5	88.9	5.49	ASTM A234 WPB ASTM A105	B	01001-01 (C) 11008 (A)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW003	HRSG	Reducer 300 MSHS-CCD-1001-T5/1 to connect. Pipe 80-MSHS-CCD-1021-P5	88.9	5.49	ASTM A234 WPB ASTM A105	B	01001-01 (C) 11008 (A)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW004	SHP	Spool 300-MSHS-CCD-1001-T5/2 to Elbow-300-MSHS-CCD-1001-T5/3	323.9	9.53	ASTM A106 GrB ASTM A234 WPB	B	01001-01 (C) 01001-02 (A)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW005	SHP	Spool 300MSHS-CCD-1001-T5/3 to Elbow 300-MSHS-CCD-1001-T5/4 to	323.9	9.53	ASTM A106 GrB ASTM A234 WPB	B	01001-02 (A)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW006	SHP	Reducer 300-MSHS-CCD-1001-T5/6 to Spool 300-MSHS-CCD-1001-T5/7	323.9	9.53	ASTM A234 WPB ASTM A106 GrB	B	01001-02 (A) 01001-03 (C)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW007	SHP	Tee reducer 300-MSHS-CCD-1001-T5/7 to Spool 150-MSHS-CCA-1010-T5/1	168.3	7.11	ASTM A234 WPB ASTM A106 GrB	B	01001-03 (C) 01010-01 (B)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW008	SHP	Spool 300-MSHS-CCD-1001-T5/8 to Tee reducer 300-MSHS-CCD-1001-T5/9	323.9	9.53	ASTM A106 GrB ASTM A234 WPB	B	01001-03 (C)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW009	SHP	Reducer 300-MSHS-CCD-1001-T/5/9 to Escape Pipe 250-MSHS-BCA-1008-P5	114.3	6.02	ASTM A234 WPB ASTM A105	B	01001-03 (C) 11009 (A)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW0010	SHP	Elbow 300-MSHS-CCD-1001-T5/9 to Spool 300-MSHS-CCD-1001-T5/10	323.9	9.53	ASTM A234 WPB ASTM A106 GrB	B	01001-03 (C) 01001-04 (C)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW0011	SHP	Spool 300-MSHS-CCD-1001-T5/12 to Elbow 300-MSHS-CCD-1001-T5/12	323.9	9.53	ASTM A106 GrB ASTM A234 WPB	B	01001-04 (C)	142 (B)	100	N/A	100 (N)	N/A	N/A
FW0012	SHP	Sppo 25-MSHS-CCA-1002-T5/1 to Sockolet 300-MSHS-CCD-1001-T5/4	33.4	3.38	ASTM A106 GrB ASTM A105	D	01002-01 (B) 01001-02 (A)	186 (1)	100	5	N/A	N/A	N/A
FW0013	SHP	Spool 25-MSHS-CCA-1002-T5/2 to Sockolet 300-MSHS-CCD-1001-T5/7	33.4	3.38	ASTM A106 GrB ASTM A105	D	01002-01 (B) 01001-03 (C)	186 (1)	100	5	N/A	N/A	N/A
FW0014	SHP	Spool 25-MSHS-CCA-1002-T5/1 to Valve MOV-10205	33.4	3.38	ASTM A106 GrB MOV-10205	D	01002-01 (B)	186 (1)	100	5	N/A	N/A	N/A

FIGURE E4 EXAMPLE OF A NON-DESTRUCTIVE EXAMINATION SCHEDULE OF PIPING