All electrical plant used in welding operations shall be correctly and adequately earthed and shall comply with AS 1674.2 or equivalent Standard.

The welding return lead from the work shall be adequate in cross-section and shall be connected correctly.

9.5.6 Storage and handling of covered electrodes Covered electrodes shall be stored and handled in the following manner and in accordance with any over-riding special precautions recommended by the electrode manufacturer:

(a) Electrodes shall be stored in their original unopened packets or cartons in a reasonably dry place adequately protected from the effect of weather.

(b) Electrodes shall be used in approximate order of receipt.

(c) Electrodes which have been wet or which have the flux covering damaged shall not be used whether dried or not.

(d) Low hydrogen electrodes shall be dried immediately before use for at least 3 h at 205°C to 260°C in a suitable oven, provided however that if they have been packaged in a hermetically sealed container they may be used without such drying to weld carbon and alloy steels within 8 h and 4 h respectively after opening such container.

(e) Low alloy electrodes transferred immediately from hermetically sealed containers to an oven at 120°C minimum may be used without further treatment, but shall be maintained at this temperature up to time of use.

9.5.7 Storage and handling of electrode wire, filler wire and flux In addition to complying with the recommendations of the filler material manufacturer, the following requirements shall be met:

(a) Electrode wire, filler wire and flux shall be stored in their original containers with proper identification of type and grade, in a dry and weatherproof location.

(b) Flux shall be dry and free from contamination from dirt, scale, rust or other foreign material. Handling shall avoid segregation of flux constituents.

(c) Agglomerated flux which has become damp shall not be redried and re-used.

(d) Flux fused in the welding process shall not be reclaimed and re-used.

(e) Electrode and filler wires shall be clean and free from dust immediately prior to welding. Where excessive oxide has formed on filler wire it shall be removed or the wire rejected.

SECTION 10 WELDING PREHEAT

10.1 GENERAL Preheating shall be employed during welding where necessary to comply with the qualified welding procedure, and to obtain welded joints of the required quality.

It is recommended that no welding be performed when the temperature of the base metal is lower than −20°C. At temperatures between 0°C and −20°C the surface of all areas within 75 mm of the point where a weld is to be started shall be heated to a temperature at least warm to the hand (estimated to be above 20°C) before welding is started.

10.2 METHOD OF PREHEATING Preheating may be carried out by any suitable method provided that it is uniform and that the temperature during welding and within at least twice the thickness of the thinner component (with a minimum of 20 mm and a recommended maximum of 100 mm) in each direction of the weld is maintained above the minimum required. The heat of welding may assist in maintaining preheat temperatures.

10.3 TEMPERATURE MEASUREMENT The preheat temperature at a distance equal to the thickness of the parent metal shall be checked by the use of temperature-indicating crayons, thermocouple pyrometers or other suitable method to ensure that the required preheat temperature is obtained immediately prior to and maintained during welding.

10.4 CONTINUITY OF PREHEAT DURING WELDING For the welding of thick alloyed steel components which require preheating in excess of 100°C by Table 10.1, it is recommended that the joint be filled to a minimum of one third of its thickness prior to allowing the joint to cool under a suitable insulation blanket, or by maintaining preheat till the welding process is recommenced.

10.5 INTERRUN TEMPERATURES Difficulty may be experienced with groups D, G and H steels, particularly with partially welded joints, if the interrun temperature is allowed to fall below the preheat temperature or 150°C. It may be desirable either to maintain the preheat temperature between runs or to heat the joint to the postweld heat treatment temperature before allowing it to cool to ambient temperature.

Consideration shall be given to the limitation of maximum preheat and interrun temperatures for various thickness of groups F and G steels to avoid detrimental effects on mechanical properties of these heat-treated steels.

10.6 PREHEAT TEMPERATURE

10.6.1 Steels Preheating temperatures for steel depend on chemical composition, degree of restraint of parts being joined, the total thickness of metal at the weld, the amount of hydrogen present during welding of some steels, and the heat input. The preheating requirements listed in Table 10.1 are recommended minimum values and also apply to tack and seal welds. If the qualified welding procedure includes higher preheat, this shall be used.

10.6.2 Non-ferrous metals There are no mandatory preheating requirements for aluminium and aluminium alloys, copper and copper alloys, nickel and nickel alloys (with nickel over 66 percent) other than to comply with the qualified welding procedure. Preheating of plates over 12 mm thickness to 100°C or higher may be beneficial in improving weld profile and reducing porosity and distortion.

10.6.3 Dissimilar metal joints When materials of different material groups are welded together (including attachment of non-pressure parts) the higher preheat temperature should be applied unless the welding procedure qualification has proven that other temperatures are acceptable.

10.6.4 Different material thicknesses For joints in materials of different thicknesses, the recommended minimum preheat temperature should be that applicable to the thinner of the materials at the joint from Table 10.1 unless the welding procedure qualification has proven that another temperature is acceptable.

TABLE 10.1

RECOMMENDED PREHEAT TEMPERATURES FOR ARC WELDING OF STEEL

Material group (Note 1)	ASME P and sub-group No.	Material type	Typical specifications or nominal compositions	Recommended minimum preheat temperature, °C (Note 2) for following thicknesses (Note 3)				Notes
				≤12 mm	>12 mm ≤25 mm	>25 mm ≤50 mm	>50 mm	
CARBON, CARBON-MANGANESE AND LOW ALLOY STEELS								
A1	1.1	Carbon and carbon-manganese steel (low strength)	AS 1548: 7-430 7-460 ASTM A 106-B	0	20	40	75	6, 7
A2	1.2	Carbon and Carbon-manganese steel-(medium strength)	AS 1548: 5-490 7-490 ASTM A 106-C	20	50	80	125	7, 8
A3	—	Carbon and carbon manganese steel (High yield strength)	AS 1594: XF 400, XF 500 API 5L X52	0	25	50	75	7
B	3.1	Alloy steel (alloy <¾)	C-½ Mo ½C-½Mo 1¼Mn-½Mo	50	75	100	125	7, 8
C	4.1	Alloy steel (¾ ≤ total alloy < 3)	1 Cr-½Mo 1¼ Cr-½Mo	50	75	100	125	7, 8
D1	—	Alloy steel (vanadium type)	½ Cr-½ Mo-¼V Mn-V	200	200	200	200	7, 8
D2	5A.1 5B.1	Alloy steels (3 ≤ total alloy < 10)	2¼ Cr-1 Mo	150	200	200	200	7, 8
			5 Cr-½ Mo 9Cr-1 Mo, 9Cr-1 Mo-V	200	200	200	200	7, 8
E	9B.1	3½ Ni steel	3½ Ni	150	150	150	150	7, 8
F	11A.1	9 Ni steel	9 Ni	25	25	25	25	7, 8, 9
G	11B.1 to 11B.8	Quenched and tempered low alloy steel	ASTM A 517 AS 3597:700 PV	10 for ≤15 mm	75 for >15 mm	75	75	7, 8, 9
HIGH ALLOY STEELS								
H	— 6.1 6.2	Martensitic Chromium steels	12Cr-1Mo-V(W) 13Cr 15Cr	200	200	200	250	7,8,10
J	7.1	Ferritic high chromium steel	Types 405, 410S, 430	10	10	10	10	—
K	—	Austenitic Cr-Ni steel	Types 302, 304, 304L, 310S, 316, 316L, 321, 347	10	10	10	10	—
L	10.5	High chromium steel	Types 442, 446	200	200	200	200	7, 10
M	—	Ferritic-austenitic Cr-Ni steel	22Cr-5Ni-3Mo	10	10	10	10	—

NOTES TO TABLE 10.1:

1 For steel groups see Section 2 and Appendix B.

2 Higher or lower temperatures may be required to achieve the qualified welding procedure. In both cases, preheat, interpass and energy limitations of AS/NZS 3992 apply.

3 Thickness is the nominal thickness at the weld for the parts to be joined assuming a butt weld in plates of equal thickness. For other types of joint the equivalent thickness used shall be half the total thickness of all material connected at or immediately adjacent to the weld.

4 Not allocated.

5 Not allocated.

6 Where low hydrogen welding processes are used these temperatures may be reduced to that specified in the qualified welding procedure.

7 The preheat temperature shall in no case be less than that applied in the qualified welding procedure, amended as considered necessary by the manufacturer for additional thickness and in particular for root runs in pipe work.

8 Preheat temperatures are based on the use of a low-hydrogen welding process.

9 Maximum interrun temperatures should be controlled to avoid detrimental effect on mechanical properties.

10 Maximum preheat and interrun temperature should not exceed 230°C.

SECTION 11 WELDED JOINTS

11.1 CONDITIONS FOR WELDED JOINTS PRIOR TO AND DURING WELDING Immediately prior to and during welding of pressure components the following shall be observed:

(a) The joint surfaces shall be cleaned and aligned as required by Section 8.

(b) Joint preheat and interrun temperature and arrangements for delayed cooling when required shall be in accordance with the qualified welding procedure for the respective joints.

(c) Ambient air movement should be limited to that covered by the qualified welding procedure.

(d) All welding procedure variables shall be maintained in accordance with the qualified welding procedure.

To assist in maintaining conditions detailed in Items (a) (b) and (c), welding shall be carried out in a space protected from rain, snow and excessive wind and preferably from sub-zero air temperatures. Such conditions shall be observed in particular, for site fabrication.

In addition to the general requirements as listed above the cleaning procedure given in Clause 8.1(c) shall be applied prior to welding of aluminium and aluminium alloys.

11.2 STRIKING OF ARC In arc welding the arc shall be struck in the weld preparation, or on previously deposited weld metal, where metal is to be fused, or on special striking plates.

11.3 INTERRUN CLEANING After each run of welding all slag or oxide shall be removed from the whole of the weld face unless the welding procedure qualification establishes that this is not necessary. Interrun cleaning shall be carried out by any suitable means so as to prevent inclusion of impurities in the weld.

11.4 SURFACE OF FINISHED WELD Unless otherwise specified in the application Standard, the surface of finished welds shall satisfy the following:

(a) No defects exceeding the limits given in AS 4037 are permitted.

(b) The surface of the weld along and across the joint shall be reasonably smooth and free from sharp irregularities, grooves or depressions, and shall merge smoothly into the base metal surface.

(c) Where the weld is ground or machined flush, care shall be taken to avoid underflushing, or overheating. Overheating of the joint may result in the introduction of grinding cracks. Welds in pressure components with wall thickness greater than 20 mm fabricated from group D2 materials with a chromium content greater than four percent and group D1 materials shall be ground to give a smooth contour-blending between weld and parent metal ensuring the removal of all undercut prior to any postweld heat treatment.

(d) For optimum corrosion resistance or appearance, welds in stainless steels should be descaled, ground or polished depending on service requirements. Where treatment is required this shall be specified by the purchaser.

NOTE: See Appendix D for descaling.

(e) Grooves for butt welds shall be completely filled and the height of the reinforcement shall not exceed the limits nominated in Table 11.1. For joints subject to radiographic inspection, these limits shall be reduced to comply with the requirements of AS 4037.

TABLE 11.1

HEIGHT OF WELD REINFORCEMENT

Thickness of plate (t) mm	Maximum height of reinforcement on each side (see Note) mm
$t \leq 3$	1
$3 < t \leq 6$	1.5
$6 < t \leq 12$	2.5
$12 < t \leq 25$	3
$t > 25$	5

NOTE: 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.

(f) There shall be no undercutting at the toes of welds of pressure-retaining parts for the following:

(i) In vessels subject to shock loadings, e.g. transportable vessels.

(ii) In construction subject to high cycle fatigue service, in particular pressure vessels manufactured to AS 1210 Class 1H or 2H construction which require a full fatigue analysis.

(g) Unless specified in Item (f) undercut associated with welds shall not exceed 0.5 mm or 10 percent of material thickness for longitudinal joints, whichever is the lesser except that this figure may be increased to 1 mm maximum depth for circumferential butt weld seams in groups A1 and A2 and A3 materials. Where undercut is to be removed, care shall be taken to ensure that material is not reduced below design thickness for pressure vessel construction and below pipe minimum wall thickness for piping or tubing.

(h) The arris of exposed ends of set through branches or manhole necks shall be rounded to at least 3 mm radius or chamfered at 45 degrees to at least a 3 mm flat.

11.5 PEENING OF WELDS In components made of steel in groups A1, A2 and A3 with design minimum temperatures not lower than −10°C, and in other permissible instances, the weld metal may be peened when it is considered necessary to control distortion or reduce residual stresses. Peening shall not be substituted for mandatory thermal stress relief. Peened butt welds shall be completely ultrasonically examined while other welds which have been peened shall be completely examined by adequate non-destructive examinations.

NOTE: Appendix E provides information on a suggested practice on peening of welds.

11.6 REMOVAL OF TEMPORARY ATTACHMENTS AND ARC STRIKES Temporary attachments shall be removed prior to any pressurization unless they have been designed to the same standard as permanent attachments.

Where attachments and arc strikes are to be removed, the technique used shall be such as to avoid impairing the pressure part proper. Such removal shall be by chipping, grinding or flame cutting followed by chipping or grinding.

Areas from where temporary attachments and arc strikes have been removed shall be examined as specified in AS 4037.

11.7 WELD REPAIRS Repairs to welds shall be carried out in accordance with the requirements of Section 13.

11.8 THERMAL STRAIGHTENING Straightening or modifying the shape of pressure parts by flame or other heating methods is permitted provided that the manufacturer has established that the procedure has no deleterious effect on the safety and performance of the final product.

Thermal straightening is based on local heating causing local compressive yielding due to reduced yield strength and restraint due to adjacent cooler higher yield strength metal. On cooling the heated area shrinks and causes local bending of thick parts or flattening of thin distorted parts. Water or air blast may be used on A1, A2, A3, B, C, K and M group materials to localize quenching and increase straightening effect.

Heat treatment of pressure parts after straightening shall be in accordance with the requirements of Section 6 for the relevant hot or cold forming process for the material groups used in fabrication. Welds which have been heated or severely strained during straightening shall be subjected to non-destructive examination in accordance with the requirements of AS 4037 for the class of construction involved. Such examination shall be carried out after straightening.

When requested by the purchaser, written procedures covering the above shall be recorded and made available for inspection. Such procedures shall address the following when service conditions indicate that such properties could effect the reliability of the component:

(a) Metallurgical examination, e.g. that intergranular carbide precipitation has not occurred in stainless steels.

(b) Use of a simulated test piece which may be subjected to microexamination, Charpy testing or other agreed test.

11.9 STRUCTURAL WELDING Components that are not welded to pressure-retaining components shall be welded in accordance with the requirements of AS/NZS 1554.1.

SECTION 12 NON-WELDED JOINTS

12.1 GENERAL All joints shall be leak tight and have sufficient strength to withstand internal pressure and axial forces and external forces.

12.2 THREADED JOINTS Screw threaded joints may be used for the connection of pipes and fittings to pressure components, and to each other, within the limits specified in the design Standards.

Threads shall be cut clean and true to their full length and depth and shall comply with any gauging requirements of the relevant specification.

Where threaded joints are likely to seize or corrode, sealing shall be arranged to prevent threads from coming in to contact with the contained fluid. Where a sealing gasket is used, it shall be fitted so that inadvertent blockage of a passageway is not possible.

The use of a thread compound having lubricating, sealing and adequately stable properties for the intended service is recommended to facilitate tightening during assembly of threaded joints, and to promote long-term pressure tightness. A thread compound shall not be used for joints which are specifically designed to be assembled dry.

The length of thread engagement shall be in accordance with the appropriate Standard, and shall in no case be less than four effective threads.

Threaded joints may be sealwelded provided they are free from cutting, sealing or preserving compounds which may be detrimental to the weld.

12.3 FLANGED JOINTS Flanged joints may be used for joining pipe, fittings and vessel components within the limits of the design Standards.

Faces of adjoining flanges shall align within one degree of the design plane when measured across any diameter. Each adjoining bolt hole shall align within 3 mm.

NOTE: See also Appendix F for recommended tolerances.

The surfaces to be clamped shall be clean and undamaged.

A tightened bolt shall have complete threading through the nut or threaded attachment. Temperature-resistant lubricants shall be applied to threads of bolting intended to operate at high temperature. Any compound or lubricant used on threads shall be suitable for the service conditions and shall not react with the service fluid or the piping material.

Bolting torque, tensioning and sequence shall be appropriate to the bolt, flange and gasket.

The contact faces of the flanges of bolted and gasketed flanged joints shall bear uniformly on the gasket, and the gasket shall be compressed in accordance with the design principles appropriate to the type used.

During assembly of flanged joints in which one flange has mechanical properties which differ widely from the other flange, special care shall be taken that the bolts are tightened to an appropriate predetermined stress or torque.

Gaskets shall comply with the design and be compatible with the service requirements.

12.4 FLARED, FLARELESS AND COMPRESSION JOINTS When permitted by the design Standard, flared, flareless and compression joints may be used for the connection of pipe and fittings.

Fittings and joints shall be compatible with the pipe, and fittings shall be assembled and applied as recommended by the manufacturer.

The gripping member of a flareless fitting shall grip or bite into the outer surface of the pipe with sufficient strength to hold the pipe against axial force, but shall not appreciably distort the inside diameter of the pipe. The gripping member shall form a pressure seal against the body of the fitting.

Where a bite type fitting is used, a spot check shall be made for adequate depth of bite and condition of the pipe, by disassembling and reassembling at least one joint. Grip type fittings tightened in accordance with the manufacturer's instructions need not be disassembled for testing.

12.5 CAULKED JOINTS When permitted by the application Standard, caulked joints maybe used for the connection of pipes and fittings.

Material used to caulk a joint shall be appropriate for the fluid, temperature and pressure.

12.6 SPECIAL FITTINGS Special fittings may be used for the connection of pipe when permitted by the design Standard.

Special fittings and couplings shall be installed in accordance with the manufacturer's instructions.

SECTION 13 WELD NON-DESTRUCTIVE EXAMINATION AND REPAIR

13.1 GENERAL All welds shall be assessed by non-destructive examination and production test plates where required by the design and class of construction.

13.2 NON-DESTRUCTIVE EXAMINATION For all pressure components where non-destructive examination is a requirement of design, or nominated by the purchaser, a non-destructive examination schedule is required in accordance with the requirements of AS 4037. Visual examination shall be carried out on all welds and shall meet the requirements for limits of surface imperfections as listed in AS 4037.

When non-destructive examination is required on components and test plates, it shall be carried out at the stage of manufacture and using the methods specified for the type of joint listed in AS 4037. All other conditions as listed in this Standard shall apply, in particular imperfection acceptance limits and the action required for rectification of welds.

When spot examination is required, it shall be carried out in accordance with AS 4037. It is strongly recommended that such examination be carried out progressively to detect any unacceptable imperfections and obviate the need for subsequent excessive additional non-destructive examination.

13.3 REPAIR TO WELDS AND COMPONENTS Where a portion of a weld or component is found by visual, non-destructive examination, or hydrostatic testing to be unacceptable, local repair or rewelding of the joint shall be carried out to rectify the unacceptable imperfection.

For pressure equipment manufactured to hazard level A of AS 4343, the fabrication inspection body shall be informed of repairs on pressure equipment subject to external fabrication inspection.

The body's agreement shall be obtained for materials base metal groups A1, A2, A3, K and M for depth of repair on both sides of weld of more than 20 mm and length more than 300 mm. For base metal groups D, E and J for the depth of 10 mm and length more than 200 mm and for base metal groups F, G and H for all repairs.

In the case of pressure equipment manufactured to a hazard level other than A, a relevant consent should be granted by the inspector to the manufacturer to carry out repair welding as necessary. All repairs shall be recorded and such records made available to the fabrication inspection body on request.

A relevant consent should be granted and documented by the person responsible for weld quality.

Defects shall be removed by chipping, machining, arc or flame grooving to form a groove satisfactory for the depositing of sound weld metal. Repair welding shall be carried out by qualified welders using welding procedures qualified to the requirements of AS 3992.

Those portions of welds in which defects detected by non-destructive examination have been repaired, shall be re-examined in accordance with the requirements of AS 4037.

All weld repairs shall be carried out prior to postweld heat treatment, unless otherwise permitted by Section 14.

13.4 PRODUCTION TEST PLATES Production test plates shall be prepared and welded in accordance with the requirements of the application Standard and heat treated and tested in accordance with the requirements of AS 3992. Production test plates containing unacceptable defects revealed by non-destructive examination shall be treated in accordance with the requirements of AS 3992 for welded production test plates.

SECTION 14 HEAT TREATMENT

14.1 GENERAL Postweld heat treatment is intended to do either or both of the following:

(a) Reduce residual stresses and improve resistance to brittle fracture, stress corrosion or in some cases, fatigue or control distortion on subsequent machining.

(b) Achieve or restore the material properties required for the design and service conditions.

14.2 TYPES OF HEAT TREATMENT The following types of heat treatment may be required prior to, during or after welding of pressure equipment to cover the requirements of Clause 14.1.

(a) Postweld heat treatment (stress relief) of joints as required by Clauses 14.3 to 14.9.

(b) Normalizing heat treatment as required after electroslag welding (see Clause 14.14) or after forming of welded joints (see Section 6).

(c) Solution anneal heat treatment as applied to austenitic and ferritic-austenitic steels of groups K and M (see Clause 14.10).

(d) Quenching and tempering heat treatment as may be applied to groups F and G steels (see Section 6).

14.3 PRESSURE EQUIPMENT REQUIRING POSTWELD HEAT TREATMENT The following pressure equipment shall be given the appropriate heat treatment at the stage of manufacture as listed in Clause 14.4:

(a) Postweld heat treatment (in accordance with Clauses 14.4 to 14.9 inclusive):

(i) Pressure equipment with wall thickness exceeding that given in Table 14.1 except for permitted exemptions as noted in Clause 14.11.

(ii) Transportable vessels as required for the design of transportable vessels in accordance with AS 1210.

(iii) Low temperature equipment in carbon, carbon-manganese and alloy steel and intended for service at design temperatures where postweld heat treatment is required in accordance with the low temperature material requirements of AS 1210 and AS 4041, for the relevant material, thickness and operating stress.

(iv) Pressure equipment intended for service with any substance liable to cause stress corrosion or where specified by the purchaser.

(v) Pressure equipment specified for which postweld heat treatment has been found necessary for the qualification of the welding procedure;

(vi) Pressure equipment of carbon, carbon-manganese and alloy steels where more than two welded joints meet (see ‘location of joints’ in AS 1210).

(vii) Pressure equipment or parts of vessels containing welds which have been hot or cold formed after welding and require postweld heat treatment in accordance with Section 6 of this Standard.

(b) Normalizing (in accordance with Clause 14.14):

(i) Pressure equipment containing electroslag welds.