AS 1548—2008

Australian Standard®

Fine grained, weldable steel plates for pressure equipment

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Australian Standard®

Fine grained, weldable steel plates for pressure equipment

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME-001, Pressure Equipment and supersedes AS 1548—1995, *Steel plates for pressure equipment*.

After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

For a summary of the major changes introduced in this edition of the Standard, refer to the Foreword

The objective of this Standard is to specify requirements for hot-rolled fully killed carbon-manganese steel plates to a maximum thickness of 150 mm for use in the construction of pressure equipment

Statements expressed 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

CONTENTS

FOREWORD

The following is a summary of the changes from AS 1548—1995:

(a) The '5' and '7' designations have been replaced by 'PT', which partially aligns with the ISO and EN designations 'P' is for pressure equipment and 'T' is for tensile strength designation as opposed to the yield strength designation used by the ISO and EN Standards Essentially, the property requirements have not changed from the previous edition.

(b) The 'R' and 'A' designations have been combined into a new normalized rolled 'NR' designation This aligns the former 'R' and 'A' interchangeability clause with ISO and EN. The definition of normalized rolling aligns with EN 10028 except that the EN Standard allows it be designated as an 'N' grade. It was thought that this would create confusion in the Australian industry and hence the 'NR' designation was formed.

The designation 'NRA' has been added to allow for the ordering of NR grades with simulated normalized test results.

(c) All grades are to be Charpy tested to exhibit some level of toughness, in line with the ISO and EN Standards. The former 'base' grades were expected to meet a certain toughness level in the pressure vessel design Standard AS 1210, based upon the performance of BlueScope Steel's grades but without any explicit requirements in AS 1548.

(d) The Charpy energy values have been changed to align with those expected in AS 1210, and with those in the ISO and EN Standards.

(e) With the removal of the '5' and '7' designations, it was decided to retain the strength requirements of the former 5-490 grade but allow NR and T to be supplied in addition to the original N. This is in line with the ISO and EN Standards.

(f) The elevated temperature tensile test values (in Table 5) have been changed to align with the ISO and EN Standards. They now represent a lower 2 standard deviation yield stress value and are not a pass/fail criteria, but are more like design values. In case of disputes, the minimum acceptable elevated temperature yield strength is set at 5% below the tabulated values. The expected removal of the safety factor penalty for non-tested elevated temperature grades from AS 1210 and AS 1228 may reduce the need for the H grade, but it is retained for purchasers who want a test result.

Elevated temperature tensile strength (R_{mT}) values have not been listed.

(g) A new grade PT540T has been included, up to 40 mm thickness, which takes advantage of the strength levels that can be achieved from thermomechanical controlled rolling. Creep rupture properties for this grade have not been included, as data is not yet available.

(h) A definition of fine grained steels has been included.

(i) Guidance on the effect of excessive stress relieving has been added.

(j) Changes to Appendices C, D and E have been made to accommodate the new designations.

(k) References to continuous mill product have been removed from the standard.

(l) C and CE limits are tighter but well within the capacity of the standard grades.

(m) For grades L20 and below, the allowable Niobium level has increased from 0.025% to 0.030%.

STANDARDS AUSTRALIA

Australian Standard

Fine grained, weldable steel plates for pressure equipment

1 SCOPE

This Standard specifies requirements for hot-rolled, fine grained, fully killed carbon-manganese steel plates to a maximum thickness of 150 mm for use in the construction of pressure equipment.

NOTE: Guidelines to purchasers on requirements that should be specified by the purchaser and those that should be agreed to at the time of enquiry or order, or both, are given in Appendix A

2 APPLICATION

This edition of AS 1548 supersedes all previous editions of the Standard, however this does not imply that material manufactured to previous editions is now invalid, nor that designs using previous grades are invalidated. It is intended that existing designs, procedures, specifications, materials etc. need not be altered in response to the publication of the new edition of this Standard. The equivalency of current and previous grades of steel to AS 1548, and the application of current grades to existing designs, specifications, procedures, etc. is described in Appendix B

3 REFERENCED DOCUMENTS

The following documents are referred to in this Standard

AS	
1210	Pressure vessels
1391	Metallic materials—Tensile testing at ambient temperature
1544	Methods for impact tests on metals
1544.2	Part 2: Charpy V-notch
1710	Non-destructive testing—Ultrasonic testing of carbon and low alloy steel plate and universal sections—Test methods and quality classification
1733	Methods for the determination of grain size in metals
2291	Metallic materials—Tensile testing at elevated temperatures
2706	Numerical values—Rounding and interpretation of limiting values
AS/NZS	
1050	Methods for the analysis of iron and steel (all parts)
1365	Tolerances for flat-rolled steel products
3992	Pressure equipment—Welding and brazing qualification
ISO	
2566	Steel—Conversion of elongation values
2566-1	Part 1: Carbon and low alloy steels
9328	Steel flat products for pressure purposes—Technical delivery conditions
9328-2	Part 2: Non-alloy and alloy steels with specified elevated temperature properties

EN

10028 Flat products made of steels for pressure purposes

10028-2 Part 2: Non-alloy and alloy steels with specified elevated temperature properties

10314 Method for the derivation of minimum values of proof strength of steel at elevated temperatures

4 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

4.1 Cast analysis

Chemical analysis determined from a test sample taken during the casting of each heat lot (see Clause 7.2).

4.2 Edge conditions

4.2.1 *Trimmed edge*

Edge produced by the removal of material by mechanical means or gas cutting.

NOTE: Also referred to as sheared, slit or gas cut edge

4.2.2 *Untrimmed edge*

Edge produced by rolling between horizontal rolls, with or without vertical edging rolls.

NOTE: Also referred to as mill or universal edge.

4.3 Fine grained steels

Fine grained steels are steels which have an austenitic grain size of number 6 or finer when tested in accordance with AS 1733. Generally steels are considered fine grained without the need for testing when the total aluminium content is greater than 0.020%, or when niobium $\geq$ 0.01%, titanium $\geq$ 0.01% or vanadium $\geq$ 0.02% are deliberately added as carbonitride formers.

NOTE: AS 1733 includes various recognized methods for grain size determination, including the McQuaid–Ehn method, and appropriate etching techniques

4.4 Longitudinal direction

Direction of the greatest extension of the steel during rolling.

4.5 Normalizing rolling

A rolling process in which final deformation is carried out in a certain temperature range leading to a material condition equivalent to that obtained after normalizing so that the specified values of the mechanical properties are retained even after normalizing.

4.6 Plate

Hot-rolled product supplied flat with width equal to or greater than 600 mm and nominal thickness greater than 4.5 mm. Edges are either trimmed or untrimmed.

4.7 Plate as-produced

A plate rolled from a slab or rolled directly from an ingot, except that when the plate is normalized and is cut into pieces, the term refers to each individual piece of the original plate normalized separately or to a group of pieces normalized together.

4.8 Product analysis

Chemical analysis determined from a test sample of the finished material.

4.9 'Shall' and 'should'

The word 'shall' indicates that a statement is mandatory, and the word 'should' indicates a recommendation.

4.10 Testing

Mechanical tests, chemical analyses and non-destructive tests as required by this Standard or by the purchaser.

4.11 Test piece

Piece prepared for testing and made from a test specimen by some mechanical operation

4.12 Test sample

Portion of material selected from the plate as produced or from a batch (see Clause 11.3) by sampling

4.13 Test specimen

Portion or a single item taken from the test sample for the purpose of applying a particular test

4.14 Thermomechanical controlled rolling (TMCR)

Rolling procedure in which significant deformation takes place at temperatures below the normalizing range permitting little, if any, recrystallization of austenite. This appropriately conditions the austenite and consequently refines the final microstructure, conferring beneficial properties on the material.

4.15 Transverse direction

Direction at right angles to the direction of the greatest extension of the steel during rolling.

5 DESIGNATION

All plate shall be designated in the following manner:

AS 1548-PTYDAHLXZX

where

AS 1548 = number of this Standard
P = pressure vessel steel
T = tensile strength specified
Y = grade of steel
= specified minimum tensile strength, in megapascals (430, 460, 490 or 540)
D = delivery condition, as follows:
N—see Clause 6.1
NR—see Clause 6.2
T—see Clause 6.3
(See Table 1 for various TYD combinations.)
A = Testing required in the simulated normalized condition. (only applies for the NR delivery condition)
H = elevated temperature tensile testing required

NOTES:

1 Where a tensile test at elevated temperature is not required, 'H' is omitted.
2 See Table 5 for minimum lower yield or 0.2% proof stress at temperatures available.

LX = low temperature (L) impact property required, together with test temperature (X) at or below 0°C, e.g. L50 for −50°C impact tests.

NOTES:

1 Where a particular low temperature impact property is not required, 'LX' is omitted.
2 See Table 4 for minimum impact energy at test temperature.

ZX = through-thickness tensile test required (Z) together with percentage reduction of area (X), e.g. Z25 for 25% minimum average reduction of area.

NOTES:

1 Where a through-thickness test is not required, 'ZX' is omitted.
2 See Table 6 for minimum reduction of area requirements
3 Only supplied in thicknesses equal to or greater than 16 mm (see Clause 15.5)

Examples of designation:

1 AS 1548-PT490NL20 is a fully killed carbon-manganese steel having a tensile strength between 490 MPa and 610 MPa, supplied normalized, and having guaranteed impact properties at –20°C

2 AS 1548-PT430NRH is a fully killed carbon-manganese steel having a tensile strength between 430 MPa and 550 MPa, supplied normalized rolled, and having a specified elevated temperature property.

3 AS 1548-PT460TZ25 is a fully killed carbon-manganese steel having a tensile strength between 460 MPa and 580 MPa, supplied in the TMCR condition having a specified minimum average reduction of area of 25% in a through-thickness direction

4 AS 1548-PT460NRA is a fully killed carbon-manganese steel having a tensile strength between 460 MPa and 580 MPa, supplied in the normalized rolled condition, but tested in the simulated normalized condition

6 DELIVERY CONDITION

6.1 'N' designation plate

Plates specified with an 'N' designation shall be normalized by the steel manufacturer, after final rolling, in the temperature range 870°C to 930°C.

Normalized 'N' grades may be replaced by the steel manufacturer, in consultation with the purchaser, with normalized rolled 'NR' grades.

6.2 'NR' designation plate

Plates specified with an 'NR' designation shall be supplied in the normalized rolled condition as defined in Clause 4.5. Plates may also be supplied in the normalised 'N' condition at the steel manufacturer's discretion.

NOTE: This condition replaces the 'R' and 'A' interchangability clause of AS 1548—1995.

Where plates are specified with an 'NRA' designation testing shall be carried out using simulated normalized samples, at an agreed frequency, to verify compliance with the specified properties in the normalized condition

NOTE: Simulated normalized testing is intended for applications where hot forming will be carried out during fabrication, to provide assurance that the steel alloy design is capable of achieving the required mechanical properties. Such testing does not provide proof that heat treatment processes used during actual fabrication have resulted in the specified properties being achieved in the fabricated item

6.3 'T' designation plate

Plates specified with a 'T' designation shall be supplied as material produced by the TMCR process. This results in low temperature impact properties equivalent to those of normalized material and may be used as an alternative process to normalizing.

NOTE: 'T' designation plate should not be hot-formed above 620°C. If hot-forming operations are performed on a 'T' designation plate, there will be some reduction in the tensile properties of the plate and appropriate procedural tests will be needed to ensure specified properties are achieved (see Appendix C, Paragraph C1.3).

7 CHEMICAL COMPOSITION

7.1 General

The steel shall conform to the cast analysis as specified in Table 1.

NOTE: A product analysis is not required by this Standard and is performed only where specified by the purchaser (see Appendix A, Paragraph A1(k)). Details of the product analysis are specified in Table 1

7.2 Sampling and testing

Samples of the steel shall be taken from each heat lot. Where it is impracticable to obtain samples from liquid steel, analysis on samples taken in accordance with the relevant requirements for sampling from solid metal in AS/NZS 1050.1 may be reported as the cast analysis.

The method of sampling for chemical analysis shall be in accordance with AS/NZS 1050.1. The chemical composition shall be determined by methods which are accurate to not less than those defined in the AS/NZS 1050 series.

7.3 Residual elements

Elements not referred to in Table 1 shall not be intentionally added to the steel without the agreement of the purchaser.

TABLE 1

CHEMICAL COMPOSITION

Designation	Analysis type (see Clause 7)	Analysis, percent (see Notes 1, 2, 5, 6 and 7)										Carbon equivalent max. percent (see Note 3)
		C	Mn		Si	P	S	Nb		Al	Ti	
		max.	min.	max.	max.	max.	max.	min.	max.	max.	max.	
PT430 NR, N or T	Cast/ Product	0.20	0.80 (Note 8)	1.60	0.50	0.040	0.030	*	0.010 (Note 4)	0.100	0.040	0.43
PT460 N NR or T	Cast/ Product	0.20	0.90 (Note 8)	1.70	0.60	0.040	0.030	*	0.010 (Note 4)	0.100	0.040	0.43
PT490 NR, N, or T	Cast/ Product	0.20	0.90	1.70	0.60	0.040	0.030	0.010	0.050	0.100	0.040	0.46
PT540T	Cast/ Product	0.20	0.90	1.70	0.60	0.040	0.030	0.010	0.050	0.100	0.040	0.46

* No specified limit.

NOTES:

1 The following elements may be present to the limits stated below:

Copper 0.40%

Nickel 0.50%

Chromium ..... 0.25%.

Molybdenum ..... 0.10%.

Vanadium ..... 0.030%.

Nitrogen 0.0100%.

2 The use of sulphide shape control elements for these grades is permitted.

3 Carbon equivalent (CE) is calculated according to IIW practice, using the equation:

$$CE = C + \frac{Mn}{6} + \frac{Ni + Cu}{15} + \frac{Cr + Mo + V}{5}$$

4 Niobium (up to 0.030%) may be added for L20, L40 and L50 designations

5 If percent by mass of copper exceeds 0.2%, the percent by mass of nickel shall be at least half the percent by mass of copper

6 Copper + chromium + molybdenum = 0.45% max.

7 A minimum total aluminium content of 0.020% applies to ensure a fine grain structure. This minimum aluminium content does not apply if nitrogen is additionally fixed by the addition of niobium (Nb ≥ 0.01%), titanium (Ti ≥ 0.01%) or vanadium(V ≥ 0.02%).

8 Value not applicable for thicknesses ≤8 mm

8 STEELMAKING PROCESS

The steel shall be made by the basic oxygen process or an electric process at the steel manufacturer's option. The steel making process shall be shown on test certificates.

NOTES:

1 A basic oxygen process means the process of making steel in a basic converter blown with commercially pure oxygen.

2 Additional refining by vacuum-arc-remelt (VAR), electroslag-refining (ESR) or vacuum degassing is permitted.

9 MANUFACTURING TOLERANCES

Plate thickness tolerances shall not exceed those values listed in Table 2. All other tolerances shall not exceed the permissible variations specified in AS/NZS 1365.

TABLE 2

PLATE THICKNESS TOLERANCES IN ALL EDGE CONDITIONS

millimetres

Specified width		Under tolerance	Permissible variation over specified thickness										
			Specified thickness										
			>4.5 ≤6.0	>6.0 ≤8.0	>8.0 ≤10	>10 ≤13	>13 ≤18	>18 ≤22	>22 ≤30	>30 ≤42	>42 ≤63	>63 ≤100	>100 ≤150
>600	<1000	0.30	0.40	0.40	0.50	0.60	0.70	0.80	1.00	1.30	1.90	2.90	4.20
≥1000	<1600	0.30	0.40	0.50	0.50	0.60	0.80	0.90	1.10	1.40	2.00	3.10	4.30
≥1600	<2100	0.30	0.50	0.60	0.60	0.70	0.90	1.00	1.20	1.50	2.10	3.20	4.40
≥2100	<2700	0.30	0.70	0.70	0.80	0.90	1.00	1.20	1.40	1.70	2.30	3.40	4.50
≥2700	<3300	0.30	1.00	1.00	1.10	1.20	1.30	1.50	1.60	2.00	2.60	3.60	4.50
≥3300		0.30	1.40	1.50	1.50	1.60	1.80	2.10	2.20	2.50	3.20	3.70	4.50

10 FREEDOM FROM DEFECTS

10.1 General

The plate shall be free from defects detrimental to its use for the applications specified in Clause 1.

Notwithstanding that the plate has been accepted previously, if subsequent processing reveals that it contains defects found to be detrimental, the plate shall be deemed not to comply with this Standard, provided that it has not been improperly treated after delivery.

10.2 Removal of surface defects

Injurious surface imperfections shall be removed by mechanical means provided that no region of the plate thickness is reduced below the specified thickness of the plate.

Any repair of defects by welding (see Note) shall be subject to the following conditions:

(a) The welding shall be performed using welding procedures in accordance with AS/NZS 3992

(b) The total area to be repaired shall not exceed 2% of the surface area of that face of the plate

(c) The plate thickness shall not be reduced to less than 80% of the nominal specified thickness after the complete removal of the defect and before welding.

(d) The welds shall be sound and free from defects or discontinuities and shall be filled to an excess thickness of at least 1.5 mm and then levelled by chiselling or grinding, or both, to give the repaired plate a smooth uniform surface.

(e) The position and extent of weld-repaired areas shall be marked on the plate. These marks shall be referred to on the steel manufacturer's certificate (see Clause 21(o)). If agreed upon between the steel manufacturer and the purchaser, a sketch showing the positions and dimensions of weld repairs shall be supplied by the steel manufacturer.

(f) 'N' designation plates shall be normalized, or re-normalized after weld repair, unless otherwise agreed upon between the purchaser and the supplier.

If the plate is already normalized, re-normalizing after weld repair may not be necessary unless required by the weld procedure in compliance with AS/NZS 3992.

(g) Normalizing of 'T' designation plate after weld repair is not permitted unless a retest is carried out which indicates that the relevant minimum property requirement, as specified in Tables 3, 4 and 5, is maintained. Any post-weld heat treatment of such plates shall be the subject of agreement between the steel manufacturer and the purchaser.

NOTE: Repair of defects by welding is at the purchaser's option only and is subject to agreement between the purchaser and steel manufacturer (see Appendix A, Paragraph A1(l)).

11 FREQUENCY OF SAMPLING

11.1 Room temperature tensile test

11.1.1 *Continuous mill product*

For product supplied from coils, one test sample shall be taken from one of the following locations:

(a) Sufficient distance from either end of the coil to be representative of the major portion of the coil.

(b) The middle third of the coil.

11.1.2 *Reversing mill product*

For product cast in ingots, test samples shall be taken as follows:

(a) For plate as-produced of mass 5 t or less, one test sample taken from either end of the plate.

(b) For plate as-produced of mass over 5 t, one test sample shall be taken from each end of the plate.

For product produced by continuous casting, one test sample shall be taken from either end of the plate as produced.

11.2 Charpy V-notch impact test

Where impact properties are specified ('LX' designation) by the purchaser, test samples shall be taken in accordance with Clause 11.1.

Where impact properties are not specified by the purchaser, one test sample shall be taken per thickness per heat per grade.

11.3 Elevated temperature tensile test

Where elevated temperature tensile properties are required by the grade, one test sample shall be taken per thickness per heat.

11.4 Through-thickness tensile test

Where through-thickness reduction of area properties are required by the grade, test samples shall be taken in accordance with Clause 11.1, except that two test samples are taken from one end of the plate.

12 SELECTION OF TEST SAMPLES

Samples for preparation of test pieces for room temperature tensile and impact tests and, if required, elevated temperature tensile and through-thickness tensile tests shall be taken in accordance with Clause 11.

All test samples, or the resulting test specimens or test pieces, shall be subjected to a stress-relieving treatment in accordance with Clause 16.

13 POSITION OF TEST SPECIMEN

The test specimen shall be taken midway between the centre and one edge of the plate or coil

14 ORIENTATION OF TEST PIECES

14.1 Room temperature tensile test piece

The test piece shall be prepared with its major axis in the transverse direction (see Figure 1, test piece (a))

14.2 Charpy V-notch impact test pieces

The test piece shall be prepared with its major axis in the longitudinal direction (see Figure 1, test piece (b)) unless the purchaser has specified that the major axis be in the transverse direction (see Appendix A, Paragraph A1(n)).

14.3 Elevated temperature tensile test piece

The test piece shall be prepared with its major axis in the transverse direction (see Figure 1, test piece (a))

14.4 Through-thickness tensile test pieces

The test piece shall be prepared with its major axis perpendicular to the plate surface (see Figure 1, test piece (c)).

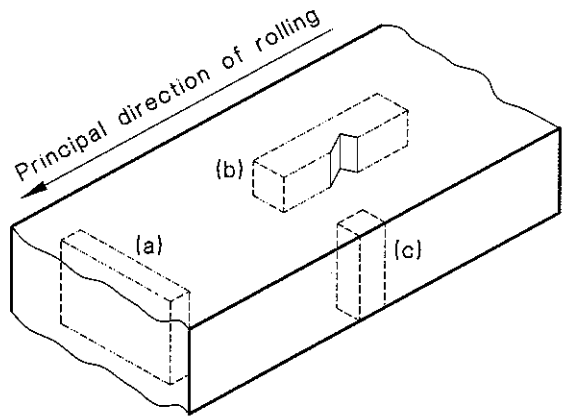

FIGURE 1 ORIENTATION OF TEST PIECES

15 PREPARATION OF TEST PIECES FOR MECHANICAL TESTING

15.1 General

Test specimens may be straightened cold before preparation of test pieces in accordance with this Clause (15). A test piece which shows defective machining or develops flaws affecting relevant mechanical properties may be discarded and another test specimen submitted.

15.2 Tensile test piece

A test piece for tensile testing shall be prepared in accordance with AS 1391

For plate less than or equal to 30 mm thick, a non-proportional test piece of the full product thickness shall be used.

For plate greater than 30 mm thick, either a proportional cylindrical test piece from as close as possible to the quarter-thickness position or a non-proportional test piece of the full product thickness shall be used

15.3 Impact test piece

The axis of the notch of the impact test piece shall be perpendicular to the rolled surface of the plate. Test pieces shall be prepared in accordance with AS 1544.2 and the following:

(a) For plate less than 7 mm thick, a full thickness test piece shall be used.

(b) For plate of specified thickness from 7 mm to less than 20 mm, standard 10 mm × 10 mm test pieces shall be machined so that they do not include material less than 1 mm beneath the surface. If the material is too thin to permit the preparation of 10 mm × 10 mm test pieces, tests shall be made on 10 mm × 7.5 mm or 10 mm × 5 mm subsidiary test pieces, as specified in AS 1544.2, provided that the test pieces do not contain material less than 1 mm beneath the surface.

(c) For plate of specified thickness from 20 mm to 32 mm, standard 10 mm × 10 mm test pieces shall be machined so that they do not include material less than 3 mm beneath the plate surface.

(d) For plate of specified thickness greater than 32 mm, standard 10 mm × 10 mm test pieces shall be machined so that the major axis of each test piece is as close as possible to the quarter-thickness position of the plate.

15.4 Elevated temperature test piece

A test piece for elevated temperature tensile testing shall be prepared in accordance with AS 2291, except that for test samples over 30 mm thick the test piece shall be taken from as close as possible to the quarter-thickness position.

15.5 Through-thickness tensile test

A test piece of 10 mm diameter for through-thickness tensile testing shall be prepared as follows:

(a) *Material of nominal thickness of 16 mm and up to and including 40 mm* A cylindrical test piece of full plate thickness is prepared by making welded extensions on the plate to be tested. This welding is carried out by suitable methods giving a sufficiently strong bond without causing any marked alteration in the mechanical properties. (Friction welding, manual metal arc welding, using properly handled low hydrogen electrodes, and stud welding are preferred methods.)

(b) *Material of nominal thickness greater than 40 mm* A cylindrical test piece of full plate thickness is prepared. This test piece may be prepared without welded extensions provided that a minimum of 6 mm on either side is used for heads or other means of fastening the test piece in the tensile testing machine.

Where specimen geometry does not allow a valid test to be performed, a 6 mm diameter test piece may be used in lieu of a 10 mm diameter test piece

16 STRESS-RELIEVING TREATMENT

16.1 General

Test samples, test specimens or test pieces shall be subjected to a stress-relieving treatment at temperature at a temperature of 600°C for a minimum of 3 hours. The furnace shall be controlled to no more than ±10°C from the set temperature.

16.2 Effect of stress-relieving on mechanical properties

Excessive post-weld heat treatment conditions (also known as stress relieving) can decreased mechanical properties. The intended time temperature parameter (P) is used to describe the effect of time and temperature used during stress relieving processes:

$$P = (273 + T_s)(20 + \log(t)) \times 10^{-3}$$

where

T_s = the stress relieving temperature, in degrees Celsius

t = the holding time, in hours

Where material is intended to undergo post-weld heat treatment, and where P for the heat treatment process is greater than 17 88 (see Note 1), the purchaser/fabricator should either:

(a) inform the steel manufacturer at the time of order so that, where agreed, appropriate additional tests can be carried out to verify whether the material properties specified in this Standard can still be regarded as valid after such treatment (see Note 2); or

(b) ensure, by carrying out appropriate procedural tests, that the specified minimum mechanical properties are retained.

The sum of holding times shall be used to calculate P for multiple stress relieving treatments

NOTES:

1 A value of 17 88 for P equates to the temperature-time conditions of 600°C and 3 hours used for the simulated stress relieving conditions applied during testing of the steel plate by the steel manufacturer, as per Clause 16.1.

2 Performance of Item(a) does not remove the need to carry out any procedural tests specified by the relevant construction Standard

17 TESTING PROCEDURES

17.1 Tensile test

A tensile test shall be made on each test piece prepared from each test sample taken in accordance with Clause 11.1

The tensile test shall be carried out in accordance with AS 1391. The rate of straining when approaching the yield point shall be within the limits of the conventional straining rate as defined in AS 1391.

Elongation results shall be reported on a gauge length determined by the following equation:

$$L_o = 5.65\sqrt{S_o}$$

where

L_o = gauge length

S_o = cross-sectional area of the test piece before testing. Conversion of results from a non-proportional gauge length shall be in accordance with ISO 2566-1.

17.2 Charpy V-notch impact test

One impact test in accordance with AS 1544.2, shall be performed on each of three test pieces prepared from each test sample taken in accordance with Clause 11.2 and AS 1544.2.

Impact testing temperature shall be as listed in Table 4.

17.3 Elevated temperature tensile test

The elevated temperature tensile test shall be made on the test piece prepared from the test specimen taken in accordance with Clause 11.3.

The tensile test shall be carried out in accordance with AS 2291.

Where elevated temperature testing is agreed, the purchaser should nominate ONE ONLY of the elevated temperatures listed in Table 5, at which testing is required.

17.4 Through-thickness tensile test

The through-thickness tensile test shall be carried out in accordance with AS 1391. The percentage reduction of the cross-sectional area after fracture is determined as shown in Clause 18.4.

18 MECHANICAL TEST REQUIREMENTS

18.1 Room temperature tensile tests

When determined in accordance with Clause 17.1, upper yield stress, tensile strength and percentage elongation of a test piece shall be in accordance with Table 3.

18.2 Charpy V-notch impact tests

When determined in accordance with Clause 17.2, the absorbed energy of a test piece with its major axis in the longitudinal direction shall be in accordance with Table 4.

Where the purchaser specifies that the test pieces are to be prepared with their major axes in the transverse direction (see Clause 14.2), the test requirements are the subject of agreement between the purchaser and the steel manufacturer (see Appendix A, Paragraph A1(n)).

18.3 Elevated temperature tensile test

When determined in accordance with Clause 17.3, the greater of the lower yield stress or the 0.2% proof stress shall be no more than 5% lower than the nominal minimum value listed in Table 5.

18.4 Through-thickness tensile test

The percentage reduction of the cross-sectional area after fracture shall be determined by the following equation:

$$Z = \frac{S_o - S}{S_o} \times 100$$

where

Z = percentage reduction or cross-sectional area after fracture

S_o = original cross-sectional area of the test piece

$$= \frac{\pi d^2}{4}$$

d = diameter of the test piece

S = cross-sectional area after fracture

$$= \frac{\pi}{16}(a+b)^2$$

where

a and b are the measurements of two perpendicular diameters, the fracture is elliptical in shape, and a and b correspond to the axes of the ellipse

The percentage reduction of cross-sectional area requirement shall be as shown in Table 6.

18.5 Retests

Notwithstanding the requirements in Clauses 18.1, 18.2, 18.3 and 18.4, should a test piece fail to comply with these Clauses, retests may be carried out in accordance with Clause 19. Except when the material is to be reprocessed, a maximum of three heat treatments, including any heat treatments prior to retests, shall be permitted.

19 RETESTS

19.1 Room temperature tensile tests

If a retest tensile test is taken, one or both of the following procedures shall be adopted:

(a) Two additional tests in accordance with Clause 17.1 shall be made on test pieces from samples taken from a position as near as practicable to the failed sample. If both these additional test pieces comply with Clause 18.1, then the product complies with this Standard.

(b) The product which failed shall be reprocessed, e.g. heat-treated, and another complete set of tests shall be performed in accordance with Clause 17. If the reprocessed test pieces comply with Clause 18.1, and, if applicable, Clauses 18.2, 18.3 and 18.4, then the product complies with this Standard.

19.2 Charpy V-notch impact tests

If a retest impact test is taken, one or both of the following procedures shall be adopted:

(a) Three additional test pieces from the original sample shall be tested in accordance with Clause 17.2. The results shall be added to those previously obtained and a new average calculated. If the average value of the six tests is not less than the specified minimum average, and not more than one result of the six tests is below the specified individual test value, then the product complies with this Standard.

(b) The product which failed shall be reprocessed, e.g. heat-treated, and another complete set of tests shall be performed in accordance with Clause 17. If the reprocessed test pieces comply with Clauses 18.1 and 18.2 and, if applicable, Clauses 18.3 and 18.4, then the product complies with this Standard.

19.3 Elevated temperature tensile test

If a retest elevated temperature tensile test is taken, one or more of the following procedures shall be adopted:

(a) Two additional tests in accordance with Clause 17.3 shall be made on test pieces from samples taken from a position as near as practicable to the failed sample. If both these additional test pieces comply with Clause 18.3, then the product complies with this Standard.

(b) Two further test samples shall be taken at random from the remainder of the test batch. If the test pieces from both these additional samples comply with Clause 18.3, then the remainder of the test batch complies with this Standard.

(c) Test samples shall be taken from each as-produced plate and shall be individually tested in accordance with this Standard. If the test piece from the additional sample complies with Clause 18.3, then the as-produced plate complies with this Standard.

(d) The product which failed shall be reprocessed, e.g. heat-treated, and another complete set of tests shall be performed in accordance with Clause 17. If the reprocessed test pieces comply with Clauses 18.1 and 18.3 and, if applicable, Clauses 18.2 and 18.4, then the product complies with this Standard.

The remainder of the test batch complies with this Standard provided it is reprocessed in the same manner as the above reprocessed plate and complies with the requirements of Clauses 18.1 to 18.4, inclusive and as applicable.

19.4 Through-thickness tensile test

If a retest is taken, one or more of the following procedures should be adopted:

(a) Make two additional test pieces from samples taken from a position as near as practical to the failed sample. If both additional test pieces comply with Clause 18.4, then the product complies with this Standard.

(b) Sample two plates at random from the remainder of the test batch. If the test pieces from both additional plates comply with Clause 18.4, then the remainder of the test batch complies with this Standard.

(c) Take two test samples from each as-produced plate of steel and individually test them in accordance with this Standard. If both the test pieces from the plate comply with Clause 18.4, then the as-produced plate complies with this Standard.

(d) The as-produced plate which failed should be reprocessed, e.g. heat-treated, and another complete set of tests should be performed. If the reprocessed test pieces comply with Clauses 18.1 to 18.4, inclusive and as applicable, then the product complies with this Standard.

The remainder of the test batch complies with this Standard provided it is reprocessed in the same manner as the above reprocessed plate and complies with the requirements of Clauses 18.1 to 18.4, inclusive and as applicable.

20 IDENTIFICATION

Each plate, as delivered, shall be legibly marked in a convenient position with the following:

(a) Steel manufacturer's name or identification mark.

(b) Grade designation (see Clause 5).

NOTE: If full designation cannot be used, markings should be adequate to identify plates with the steel grade to this Standard.

(c) The plate or identification number (to include reference to serial number and cast number).

(d) The longitudinal direction of rolling (see Clause 4.3), shall be shown by an arrow or by marking parallel to the longitudinal direction.

(e) Other markings as specified on the order (see Appendix A, Paragraph A1(g)).

The plate shall be marked by either die-stamping or painting/inking (see Appendix A, Paragraph A1(g)).

For impact tested grades, the dies used for stamping shall be of the low-stress stamping type.

Where die-stamping is used, the location of the marking shall be approximately 300 mm from the edge of the material with its actual position indicated by paint/ink marking.

Where paint/ink is used for markings, the paint/ink shall not be based on compounds of lead, copper, zinc or tin.

NOTES:

1 If the marked portion of the material is subsequently removed, then the markings are to be transferred on each remaining portion of the material.

2 Steel manufacturers who place the number of this Australian Standard on plates, on packaging or on literature relating thereto are advised to ensure that the plates are manufactured to comply with this Standard.

21 TEST CERTIFICATE

The steel manufacturer shall supply a certificate stating the following:

(a) An identification number, e.g. purchaser's order number.

(b) Designation number (see Clause 5).

(c) Identification number of the plates or coils (to include reference to serial number and cast number)

(d) Process of steel manufacture and process of casting.

(e) Cast analysis in respect of all elements specified in Table 1.

(f) Product analysis, where required on the order, in respect of all elements specified in Table 1

(g) Room temperature tensile properties.

(h) Details of plate heat treatment, i.e soaking time and temperature. This record shall include any heat treatment in the reprocessing of plates (see Clause 19).

(i) Details of heat treatment of the test sample, test specimen or test pieces, i.e soaking time and temperature

(j) For elevated temperature tensile-tested plates, the temperature at which the test was made and the lower yield stress or 0.2% proof stress values obtained.

(k) For through-thickness tested plates, the percentage reduction of area results obtained.

(l) For impact-tested plates, the temperature at which the impact tests were made, the size of the test piece and the results obtained.

(m) A statement that the plates comply with the requirements of this Standard, i.e. AS 1548.

(n) Where applicable, a statement that the plates also comply with the supplementary requirements of the order.

(o) If the plate contains any welded areas (see Note, Clause 10.2), as indicated by surface markings on the plate.

The test certificate shall be authorized by a person responsible for the supervision of the testing program and shall bear that person's signature or the name and the section/department of such a person. An approved electronic signature is satisfactory for 'on-line' certification.

22 INTERPRETATION OF SPECIFIED LIMITING VALUES

22.1 General

For the purpose of assessing compliance with this Standard, the specified limiting values herein shall be interpreted in accordance with the 'rounding method' described in AS 2706, i.e. the observed or calculated value shall be rounded to the same number of figures as in the specified limiting value and then compared with the specified limiting value. As an example, for specified limiting values of 2.5, 2.50, and 2.500, the observed or calculated value would be rounded to the nearest 0.1, 0.01 and 0.001, respectively.

22.2 Tensile properties

The determined value of tensile strength shall be rounded to the nearest 10 MPa, the determined value of the upper yield stress shall be rounded to the nearest 5 MPa, and the determined value for the elevated temperature tensile test shall be rounded to the nearest 2 MPa.

TABLE 3

TENSILE TEST REQUIREMENTS FOR PLATE

Designation	Minimum upper yield stress value, MPa				Tensile strength	Minimum elongation on a gauge length of $5.65\sqrt{S_o}$
	Thickness, mm					
	≤16	>16 ≤40	>40 ≤80	>80 ≤150	MPa	%
PT430NR, N and T	300	280	270	250	430 to 550	22
PT460NR, N and T	305	295	275	265	460 to 580	21
PT490NR, N and T	360	340	330	320	490 to 610	20
PT540T	450	420	—	—	540 to 670	18

TABLE 4

CHARPY V-NOTCH IMPACT TEST REQUIREMENTS

Designation	Impact designation	Test temperature	Minimum absorbed energy, J					
			Size of test piece					
			10 mm × 10 mm		10 mm × 7.5 mm		10 mm × 5 mm	
		°C	Individual test	Average of 3 tests	Individual test	Average of 3 tests	Individual test	Average of 3 tests
PT430	None	0	23	31	18	25	16	22
	L0	0	38	51	29	40	27	34
NR, N and T	L20	−20	35	47	28	38	25	33
	L40	−40	33	45	27	36	23	32
PT460	None	0	23	31	18	25	16	22
	L0	0	38	51	29	40	27	34
NR, N and T	L20	−20	35	47	28	38	25	33
	L40	−40	33	45	27	36	2	32
	L50	−50	31	42	25	34	22	30
PT490	None	−20	43	55	35	44	30	39
	L20	−20	43	55	35	44	30	39
NR, N and T	L40	−40	33	45	27	36	23	32
	L50	−50	31	42	25	34	22	30
PT540T	None	−20	43	55	35	44	30	39
	L20	−20	43	55	35	44	30	39
	L40	−40	33	45	27	36	23	32
	L50	−50	31	42	25	34	22	30

NOTES:

1 For thicknesses less than 7 mm, full thickness impact requirements shall be those listed for 10 × 5 mm test pieces, except where alternative values are negotiated between the purchaser and the steel manufacturer.

2 Lower temperature impact designations may be substituted for higher temperature designation plates without additional testing, e.g. a PT460NL50 plate may be supplied where a PT460NL20 plate is specified.

3 Where impact test properties are not specified by the purchaser, (i.e. where impact designation is 'None"), required values may be used for equipment design purposes.

TABLE 5

ELEVATED TEMPERATURE TENSILE TEST VALUES

Designation (see Note 2)	Thickness mm		Nominal minimum lower yield stress or 0.2% proof stress, MPa (see Note 1) Temperature, °C								
			50*	100	150	200	250	300	350	400	450
PT430	≥3	≤16	290	273	253	232	213	196	181	170	160
NRH,NH or TH	>16	≤40	271	255	236	217	199	183	169	159	150
	>40	≤80	261	246	228	209	192	176	163	153	144
	>80	≤150	242	228	211	194	178	163	151	142	134
PT460	≥3	≤16	295	277	257	236	216	199	184	173	163
NRH, NH or TH	>16	≤40	285	268	249	228	209	192	178	167	157
	>40	≤80	266	250	232	213	195	179	166	156	145
	>80	≤150	256	241	223	206	188	173	160	150	141
PT490	≥8	≤16	348	327	303	278	255	236	217	204	192
NRH, NH or TH	>16	≤40	329	310	287	263	242	222	205	193	182
	>40	≤80	319	300	278	255	234	216	199	187	176
	>80	≤150	310	291	269	248	227	210	193	182	172
PT540TH	≥8	≤16	436	409	379	348	319	296	271	256	245
	>16	≤40	407	382	353	325	298	276	253	239	230

* Values at 50°C are not subject to test

NOTES:

1 Values given in this Table correspond to the lower trend curve determined according to EN 10314 with a confidence limit of around 98% (2 standard deviations below the mean)

2 Where elevated temperature testing is not specified by the purchaser, values listed are informative for design purposes. If tensile strength properties require confirmation, then an 'H' grade should be specified.

TABLE 6

THROUGH-THICKNESS REDUCTION OF AREA REQUIREMENTS

Through-thickness designation	Percentage reduction of area (minimum)	
	Individual test	Average of 2 tests
Z15	10	15
Z25	20	25
Z35	30	35

APPENDIX A

PURCHASING GUIDELINES

(Informative)

A1 INFORMATION TO BE SUPPLIED BY THE PURCHASER

The purchaser should supply the following information to the steel manufacturer at the time of enquiry or order, or both, after making due reference to the explanation, advice and recommendations contained in this Appendix:

(a) Product form required, i.e. plate

(b) Quantities and delivery instructions (dates, schedules, delivery point).

(c) Dimensions of the plate, the thickness, width, length and masses of bundles

(d) Type of edge required, i.e. trimmed or untrimmed edge (see Clause 4.2).

(e) Any other limitations in respect of packaging.

(f) Designation of grade, including the number of this Standard, in accordance with Clause 5

(g) Any additional markings or method of marking when different to painting (see Clause 20)

(h) Whether it is the intention of the purchaser to inspect the steel at the steel manufacturer's works (see Paragraph A4).

(i) Any information concerning processing or end use that may affect the material design.

NOTE: Examples of relevant applications may include sour service, corrosive service, use in corrosive environments, etc

(j) Whether the steel is to be ultrasonically tested (see Paragraph A2).

(k) Whether a product analysis is required, and the frequency of the analysis (see Clause 7.1).

(l) Whether defects may be repaired by welding (see Note, Clause 10.2)

(m) Whether elevated temperature testing is required (see Paragraph A5).

(n) Whether test pieces for impact tests are to be prepared with their major axes in the transverse direction (see Clause 14.2) and, if so, the test requirements to comply with Clause 18.2.

NOTE: Any special or supplementary requirements of this Standard are to be subject to agreement between the purchaser and the steel manufacturer at the time of enquiry or order, or both, and stated on the order.

(o) Whether through-thickness testing is required (see Clause 18.4).

(p) Whether simulated normalized testing is required for 'NR' designated grades (see Clause 6.2).

A2 ULTRASONIC TESTING

If ultrasonic testing of plates is required by the purchaser, the method of test to be used and the limits of acceptance should be determined at the time of enquiry or order, or both, between the purchaser and the steel manufacturer

The test method and grade should be in accordance with AS 1710.

A3 INDEPENDENT TESTS

In the event of a dispute as to the compliance of the plate with the requirements of this Standard, the purchaser and the steel manufacturer should agree to have a test carried out by an independent laboratory, as a referee, whose results should be accepted as final. A laboratory accredited by JAS-ANZ for this field and class of testing is recommended.

A4 INSPECTION

If it is the purchaser's intention to undertake any of the following procedures at the steel manufacturer's works, this should be notified at the time of enquiry or order, or both. These procedures should be accomplished in a manner which will not interfere with the operation of the works. The procedures are as follows:

(a) Inspecting the steel

(b) Selecting and identifying the test samples.

(c) Witnessing the tests being made.

The steel manufacturer should afford all reasonable facilities to satisfy the purchaser that the plates are in accordance with the Standard.

A5 ELEVATED TEMPERATURE PROPERTIES

If elevated temperature properties are required by the purchaser, this may be achieved by carrying out the test. One testing temperature (see Table 5) should be agreed upon at the time of enquiry or order, or both, between the purchaser and the steel manufacturer.

A6 ADDITIONAL TESTS

Once material is supplied by the steel manufacturer, should the purchaser (distributor or end user) require any further testing to satisfy conformance with a new designation, such as NL40 and NH, the test pieces for such testing need not be stress-relieved unless the finished vessel (component) is to be stress-relieved after fabrication.

APPENDIX B

EQUIVALENCE OF CURRENT AND PREVIOUS GRADES

(Normative)

B1 GENERAL

As the essential chemistry and processing methods in this Standard are unchanged from previous editions, current grades are deemed to be equivalent to previous grades to AS 1548, as shown in Table B1

TABLE B1

EQUIVALENCE OF CURRENT AND PREVIOUS GRADES

Current grade and designation to AS 1548	Previous grade and designation to AS 1548—1995 (and earlier editions)
PT 490 N	5-490 N and NH
PT 490 NR	5-490 R, RH, A, and AH
PT 490 T	5-490 T and TH
PT 430 N	7-430 N and NH
PT 430 NR	7-430 R, RH, A, and AH
PT 430 T	7-430 T and TH
PT 460 N	7-460 N and NH
PT 460 NR	7-460 R, RH, A, and AH
PT 460 T	7-460 T and TH
PT 490 N	7-490 N and NH
PT 490 NR	7-490 R, RH, A, and AH
PT 490 T	7-490 T and TH
PT 540 T	(no equivalent)

B2 REFERENCES TO THIS STANDARD

Where existing Standards, procedures, specifications etc. refer to a previous edition of this Standard, the current edition is deemed to be equivalent.

Where existing Standards, procedures, specifications etc. refer to a previous grade to AS 1548, the equivalent current grade to AS 1548 is deemed to comply with the previous grade

For existing welding procedures which are qualified for use with previous grades to AS 1548, the use of the equivalent current grade to AS 1548 need not be considered a change in essential variables, and need not be re-qualified.

B3 APPLICATION TO EXISTING DESIGNS

Where an existing design specifies a previous grade to AS 1548, the equivalent current grade may be used

Where an existing design specifies a previous grade to AS 1548, and where the elevated tensile strength values (shown in Table 4) for the equivalent current grade (shown in Table B1) are higher than specified for the previous grade, the existing design may be suitably re-rated to take advantage of the higher values. The method for re-rating of existing designs, including the method for determining the maximum allowable design strength, shall comply with the applicable design Standard (e g AS 1210).

The interchange of current grades (see Appendix D) when applied to previous designs is the subject of agreement between the parties concerned.

APPENDIX C

INFLUENCE OF FABRICATION AND HEAT TREATMENT ON MECHANICAL PROPERTIES

(Informative)

C1 INFLUENCE OF HOT-FORMING ON MECHANICAL PROPERTIES

C1.1 General

Refer to Clause 16.2 regarding the need to discuss heat treatment with the steel manufacturer where the intended time temperature parameter (P) exceeds the recommended value

C1.2 All 'N' and 'NR' designations

Hot-formed items can be assumed to retain the mechanical properties specified in Tables 3, 4 and 5 provided that—

(a) the material is not heated above 620°C during forming; or

(b) the following provisions are complied with:

(i) The steel is formed by a single hot-forming operation where the item is heated to within the normalizing temperature range and the forming is done within this range

(ii) Where more than one hot-forming operation is involved, the item is allowed to cool below the transformation temperature, i.e. 725°C, prior to the final hot-forming operation upon which the steel is reheated to within the normalizing temperature range and subsequently hot-formed within this range.

(iii) The steel is normalized during the heat treatment cycle for the fabrication methods, e.g. after electroslag welding. A total of one normalizing and two re-normalizing treatments are permitted on these plates/finished fabrication.

(iv) A total maximum of three normalizing (re-normalizing) treatments are permitted on plates and finished vessels.

In general, prolonged soaking, especially at temperatures in excess of 930°C, which may adversely affect mechanical properties, should be avoided.

Where these provisions are not followed, it cannot be assumed that the specified mechanical properties are retained. In such cases appropriate procedural tests should be carried out so the fabricator can ensure that the specified mechanical properties are achieved and that the overall condition of the steel is not adversely affected.

C1.3 All 'T' designations

Where hot-forming operations are performed on 'T' designation plates, some reduction in yield strength and tensile strength will occur and an increase in Charpy transition temperature can be expected. Under such circumstances, the fabricator must ensure, by carrying out appropriate procedural tests, that the mechanical properties specified in Tables 3, 4 and 5 are achieved and that the overall condition of the steel is not adversely affected

C2 INFLUENCE OF COLD-FORMING ON MECHANICAL PROPERTIES

While cold work affects the mechanical properties, the acceptable limits of cold work, where included in the relevant application Standard, should be observed. Where necessary, the properties may be restored by appropriate heat treatment.

C3 INFLUENCE OF HOT-FORMING OR COLD-FORMING ON CREEP RUPTURE PROPERTIES

The values listed in Appendix E can be assumed to apply to items which are hot-formed or heat-treated, or both, in accordance with the requirements of Paragraph C1 2(a) and (b), and to items cold-formed in accordance with Paragraph C2.

C4 INFLUENCE OF WELDING ON PROPERTIES

Some steel properties may be affected by high heat input welding processes. The use of qualified welding procedures will normally address this issue.

'T' designation plates should not be used with electroslag welding

APPENDIX D

INTERCHANGEABILITY OF STRENGTH GRADES

(Informative)

D1 GENERAL

Interchangeability of some strength grades may be considered acceptable based on the criteria specified in this Appendix, and subject to the approval of the purchaser

D2 INTERCHANGEABILITY OF CURRENT GRADES

Grades specified in this Standard may be interchanged as follows:

(a) Grade PT460 plate may replace Grade PT430 plate in currently approved designs without the need for special re-approval of the design

(b) Welding procedures qualified on Grade PT430 plate may be used for Grade PT460 plate without the need for requalification but within other essential variables, provided that where the design strength used in determining the dimensions of scantlings is based on the mechanical properties of Grade PT460 plate, the transverse tensile strength of the weld metal in the procedure test was not less than 460 MPa, or the transverse tensile strength, where the specimen broke in the parent metal outside the weld, was not less than 437 MPa.

(c) Welding procedures qualified on Grade PT490 plate may be used for Grade PT460 plate without the need for requalification but within other essential variables

APPENDIX E

CREEP RUPTURE PROPERTIES

(Informative)

The values listed in the Table E1 are mean values of the estimated scatter range of ±20% from the test data of various countries. The latest Australian test data falls within 20% scatter range of these mean values ISO and EN Standards do not specify creep values for C-Mn-Nb steels In Table E1, the values of PT490 grade are lowered in some cases (still within 20% scatter range) as they are obtained by using approximately 95% factor on PT430/PT460 grade values in this Table. For the same reason, values for 250 000 hours for PT490 grade are not specified.

It is considered that these values may reliably be used for design purposes.

TABLE E1

CREEP RUPTURE PROPERTIES

Temperature °C	Stress for creep rupture, MPa									
	10 000 hours		30 000 hours		100 000 hours		150 000 hours		250 000 hours	
	PT490	PT430 PT460	PT490	PT430 PT460	PT490	PT430 PT460	PT490	PT430 PT460	PT490	PT430 PT460
380	264	277	241	251	211	219	198	207	N/A	192*
390	243	255	218	228	187	196	176	184	N/A	167*
400	222	233	197	206	165	173	152	160	N/A	143*
410	203	213	177	185	145	151	131	137	N/A	121*
420	184	193	156	164	123	129	111	116	N/A	101*
430	165	173	137	144	104	109	94*	98*	N/A	84*
440	147	154	118	124	88	92	78*	82*	N/A	71*
450	130	136	102	107	74	78	67*	70*	N/A	60*
460	113	118	87	91	64	67	57*	60*	N/A	50*
470	95	102	75	79	54	57	48*	50*	N/A	—
480	85	89	65	68	46	48	(38)*	(39)*	N/A	—
490	74	77	56	59	—	—		—	N/A	—
500	65	68	49	51	—	—		—	N/A	—

NOTES:

1 Values marked with an asterisk involved extended time extrapolation. Values given in parenthesis involved extended stress extrapolation.

2 These values are obtained from EN 10028-2:1992 and ISO 9328-2:1991.

3 No values are currently available for PT540T.

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