

AS 3990—1993

Reconfirmed 2016

Australian Standard®

Mechanical equipment—Steelwork

This Australian Standard was prepared by Committee ME/5, Cranes (Balloted by ME/1, Boilers and Pressure Vessels; ME/4, Lift Installations; ME/5, Cranes; ME/18, Mining Equipment; ME/38, Gas and Liquid Petroleum Piping Systems; ME/43, Bulk Handling Equipment). It was approved on behalf of the Council of Standards Australia on 24 February 1993 and published on 17 May 1993.

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STANDARDS AUSTRALIA

RECONFIRMATION

OF

AS 3990—1993

Mechanical equipment—Steelwork

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Technical Committee ME-005 has reviewed the content of this publication and in accordance with Standards Australia procedures for reconfirmation, it has been determined that the publication is still valid and does not require change.

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NOTES

Australian Standard[®]

Mechanical equipment—Steelwork

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PREFACE

This Standard was prepared by the Standards Australia Committee on Cranes and balloted by the Standards Australia Committees for Boilers and Unfired Pressure Vessels, Lift Installations, Cranes, Mining Equipment, Gas and Liquid Petroleum Piping Systems, and Bulk Handling Equipment to provide a working stress method for the design of mechanical equipment steelwork. AS 1250—1981, *SAA Steel Structures Code*, which provided a working stress method, was superseded by AS 4100—1990, *Steel structures*, which provides the limit states design method.

Although the limit states design method (AS 4100) is the preferred method of designing steelwork, it is necessary to continue the working stress design method (this Standard) for certain mechanical equipment where the application Standards allow. This is particularly so for mechanical equipment where the equivalent international Standards use the working stress design method.

While the editorial style and layout have been updated, this Standard incorporates the minimum changes necessary to AS 1250—1981, *SAA Steel Structures Code*. Amendments 1 and 2 have been incorporated into the text. Section 10 has been deleted, Section 11 renumbered and new Appendices F and G added. Clauses 1.1, 2.2, 3.3.1, 3.3.5, 9.5.2, 10.1.1, 10.1.4 and 10.1.5; and Appendix C have been revised.

The issue of this Standard follows its publication as an Interim Standard in December 1991. Section 1 and Appendix G have been revised, a new Application Clause included and Reference Standards updated to current editions.

Attention is drawn to the following Standards which may be required for use in connection with this Standard:

AS

- 1110 ISO metric hexagon precision bolts and screws
- 1111 ISO metric hexagon commercial bolts and screws
- 1112 ISO metric hexagon nuts, including thin nuts, slotted nuts and castle nuts
- 1163 Structural steel hollow sections
- 1170 SAA Loading Code
 - 1170.1 Part 1: Dead and live loads and load combinations
 - 1170.2 Part 2: Wind loads
 - 1170.3 Part 3: Snow loads
- 1252 High strength steel bolts with associated nuts and washers for structural engineering
- 1275 Metric screw threads for fasteners
- 1302 Steel reinforcing bars for concrete
- 1303 Steel reinforcing wire for concrete
- 1379 The specification and manufacture of concrete
- 1391 Methods for tensile testing of metals
- 1418 SAA Crane Code
- 1554 SAA Structural Steel Welding Code
 - 1554.1 Part 1: Welding of steel structures
 - 1554.2 Part 2: Arc stud welding (steel studs to steel)
 - 1554.5 Part 5: Welding of steel structures subject to high levels of fatigue loading

- 1559 Fasteners—Bolts, nuts and washers for tower construction
- 1594 Hot-rolled steel flat products
- 1627 Metal finishing—Preparation and pretreatment of surfaces
- 1627.7 Part 7: Hand tool cleaning of metal surfaces
- 2074 Steel castings
- 2121 SAA Earthquake Code
- 2214 SAA Structural Steel Welding Supervisors Certification Code
- 2312 Guide to the protection of iron and steel against exterior atmospheric corrosion
- 2812 Welding, brazing and cutting of metals—Glossary of terms
- 3600 Concrete structures
- 3678 Structural steel—Hot-rolled plates, floorplates and slabs
- 3679 Structural steel
- 3679.1 Part 1: Hot-rolled bars and sections
- 3679.2 Part 2: Welded sections
- 4100 Steel structures
- BS
- 5135 Metal-arc welding of carbon and carbon manganese steels
- Supplement 1 (PD 3343) to BS 449,
- Part 1: Recommendations for design (withdrawn)

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STANDARDS AUSTRALIA

Australian Standard

Mechanical equipment—steelwork

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard applies to the design, fabrication, erection, repair and alteration of steelwork associated with boilers and pressure vessels, lifts, cranes, mining equipment, gas and liquid petroleum piping systems, bulk handling equipment and the like, in accordance with the working stress design method.

The Standard does not apply to the following structures and materials:

- (a) Road and railway bridges.
- (b) Steel elements, other than packers, less than 3 mm thick.
- (c) Steel for which the value F_Y used in design exceeds 450 MPa.
- (d) Cold-formed members other than those complying with AS 1163.

Steelwork may be designed to—

- (i) the limit states design method of AS 4100; or
- (ii) the working stress design method of AS 3990 (this Standard).

NOTE: It is intended that the working stress method will be phased out in Australia as it is phased out internationally.

1.2 APPLICATION This Standard is intended to apply to steelwork associated with mechanical equipment such as boilers and pressure vessels, lifts, cranes, mining equipment, gas and liquid petroleum piping systems and bulk handling equipment.

1.3 STANDARDS Unless otherwise noted, a Standard referred to in this Standard is the current edition thereof.

1.4 NEW MATERIALS OR METHODS This Standard shall not be interpreted to prevent the use of materials or of methods of design or construction not specifically referred to herein.

NOTE: It will be necessary to seek approval from the Building Authority for the use of new materials or methods.

1.5 DESIGN AND SUPERVISION

1.5.1 Design The design of a structure or the part of a structure to which this standard is applied shall be the responsibility of an engineer experienced in the design of such structures.

For the purposes of this Standard the term ‘Design Engineer’ shall mean the Engineer responsible for design and shall include his representative.

1.5.2 Supervision All stages of construction of a structure or the part of a structure to which this Standard is applied shall be adequately supervised to ensure that all the requirements of the design are satisfied in the completed structure. Supervision shall be the responsibility of either—

- (a) the Design Engineer; or
- (b) an Engineer experienced in such supervision.

For the purposes of this Standard, the term ‘Supervising Engineer’ shall mean the engineer responsible for supervision of construction and shall include his representative.

NOTES:

- 1 Although the execution of design and supervision may be delegated to other acceptable persons who need not necessarily be qualified, Clause 1.5 requires that design and supervision be the responsibility of qualified and experienced persons.
- 2 The Clause does not require the Design Engineer to be responsible for supervision also unless he has been assigned this responsibility specifically. The Design Engineer and the Supervising Engineer need not be the same person.
- 3 Welding inspectors should be qualified to the requirements of AS 2214.

1.6 DEFINITIONS

1.6.1 General For the purposes of this Standard, the definitions in Clauses 1.6.2 to 1.6.4 shall apply.

NOTE: Other terms having special meanings are defined in the Clause in which they occur.

1.6.2 Administrative definitions

1.6.2.1 Approved—according to the context, approved either by the Engineer or the Building Authority.

1.6.2.2 Building Authority—a body having statutory powers to control the design and erection of buildings or structures in the area in which the building or structure concerned is to be erected.

1.6.2.3 Contractor—the person, persons or organization agreeing under a contract to execute the work.

1.6.2.4 Engineer—a person qualified for Corporate Membership of the Institution of Engineers, Australia. (See Clause 1.5.)

NOTE: The definition of ‘Engineer’ does not require that an Engineer be a Corporate Member of the Institution of Engineers, Australia.

1.6.3 Technical definitions

1.6.3.1 Beam or girder—a structural member, other than a triangulated frame, which supports load primarily by its internal resistance to bending.

1.6.3.2 Dead load—the actual weight of all permanent construction and all permanently installed plant, equipment, and services required for functional purposes.

1.6.3.3 Footing—a part of the building or structure in direct contact with and transmitting load to the supporting foundation.

1.6.3.4 Foundation—the soil, sub-soil or rock, either built up or natural, upon which a structure is supported.

1.6.3.5 Gauge—the transverse spacing between parallel adjacent lines of fasteners.

1.6.3.6 High strength bolt—a bolt manufactured to AS 1252 or an equivalent fastener.

1.6.3.7 Live load—the load assumed to arise from the intended use or purpose of a structure, including distributed, concentrated, impact and inertial forces, but excluding wind, snow and earthquake forces.

1.6.3.8 Load factor—the numerical value by which the load which would cause failure of a structure is divided, to give the maximum permissible working load on the structure.

1.6.3.9 Partition—a wall employed solely for the purpose of subdividing a storey of a building into sections and which is not intended to support any load other than its own weight.

1.6.3.10 Pitch—the centre distance between individual fasteners in a line of fasteners.

1.6.3.11 Strut—a compression member including a column or stanchion.

1.6.3.12 Substructure—the general structural base upon which the remainder of a structure is supported, comprising the footings and any retaining or like wall supported by the ground.

1.6.3.13 Tensile strength—the ultimate tensile strength of a steel or electrode as defined in the appropriate Australian Standard.

1.6.3.14 Wind forces—forces on a structure resulting from wind pressure.

1.6.3.15 Yield stress—the minimum yield stress in tension specified for the grade of steel in the appropriate Australian Standard.

1.6.4 Welding terms Welding terms shall have the meanings given in AS 2812.

1.7 NOTATION The notation used in any of the Clauses shall have the following meanings with respect to the structure, or member or condition to which the Clause is applied, unless otherwise defined elsewhere in this Standard. Unless otherwise stated, a dimension shall mean a specified dimension.

NOTE: The subscripts x , y denote the X-X and Y-Y axes of the section, respectively, X-X denotes the major principal axis, and Y-Y denotes the minor principal axis.

- A_g = the gross cross-sectional area of a concrete-encased strut neglecting any casing in excess of 75 mm from the overall dimensions of the steel section and neglecting any applied finish
- A_s = the effective cross-sectional area of a steel member
- A_w = the effective sectional area resisting shear for calculating the average shear stress or the maximum shear capacity in a member
- B = the overall width of the flange of a section
- b = the lesser clear dimension of a web panel
- b_1 = the outstand of a flange or stiffener beyond the line of connections to a web, or other line of support
- b_2 = the unsupported width of a flange or element between two adjacent faces of support or between two adjacent lines of connections to other elements of the member
- c_1, c_2 = respectively, the lesser and greater distances from the section neutral axis to the extreme fibres
- D = the overall depth of a section measured parallel to the web
- d = the clear depth of the web of a rolled I-section or channel between root fillets

- d_1 = for the web of a beam without horizontal stiffeners, the clear distance between the flanges, neglecting fillets, or the clear distance between the inner toes of the flange angles, as appropriate
- = for the web of a beam with horizontal stiffeners, the clear distance between the horizontal stiffener and the tension flange, neglecting fillets, or the inner toes of the tension flange angles, as appropriate
- d_2 = twice the clear distance from the neutral axis of a beam to the compression flange, neglecting fillets, or the inner toes of the flange angles, as appropriate
- E = the modulus of elasticity for steel, taken as 2×10^5 MPa in this Standard
- F'_c = the characteristic 28-day compressive strength of concrete as defined in AS 3600
- F_{ac} = the maximum permissible compressive stress in an axially loaded strut not subjected to bending
- F_{at} = the maximum permissible tensile stress in an axially loaded tension member not subjected to bending
- F_b = the maximum permissible stress due to bending in a member not subjected to axial force
- F_{bc} = the maximum permissible compressive stress due to bending in a member not subjected to axial force
- F_{bt} = the maximum permissible tensile stress due to bending in a member not subjected to axial force
- F_{ob} = the elastic buckling stress of a beam
- F_{oc} = the elastic buckling stress of a strut
- F_p = the maximum permissible stress in bearing in a member
- F_u = the tensile strength pertaining to the steel used in a member
- F_v = the maximum permissible average stress in shear in a member
- F_{vm} = the maximum permissible stress in shear in a member
- F_Y = the yield stress pertaining to the steel used in a member; where F_Y is used in dimensionally inconsistent expression in this Standard, its value shall be expressed in MPa (see Appendix C)
- f_{ac} = the calculated average stress in a member due to an axial compressive force
- f_{at} = the calculated average stress in a member due to an axial tensile force
- f_{bc} = the calculated compressive stress in a member due to bending about a principal axis
- f_{bt} = the calculated tensile stress in a member due to bending about both principal axes
- I_s = the second moment of area (moment of inertia) of the cross section of a pair of web stiffeners about the centre-line of a beam web, or of a single stiffener about the face of a beam web, as appropriate
- K_1 = a coefficient to allow for the reduction in thickness or breadth of the flanges between the points of effective lateral restraint. Values of K_1 are given in Table 5.5(2) for various values of N_F
- K_2 = a coefficient to allow for the inequality of the flanges. Values of K_2 are given in Table 5.5(3) for various values of M_F
- L = the span of a member
- l = the effective length of a beam or strut

- M_F = the ratio of the moment of inertia of the compression flange alone to the sum of the moments of inertia of the flanges, each calculated about its own axis parallel to the axis of minimum strength of the beam, at the point of maximum bending moment
- M_p = the calculated maximum moment capacity of a beam
- M_{pc} = the calculated maximum moment capacity of a member subjected to bending and axial load
- N_F = the ratio of the total area of both flanges at the point of least bending moment to the corresponding area at the point of greatest bending moment between points of effective lateral restraint. The minimum value of N_F shall be 0.25 and flange reductions shall be limited accordingly. The removal of a flange at the end of a beam shall be neglected when calculating N_F , provided that the length of flange removed does not exceed a length equal to the flange width at midspan
- P = an axial force, compressive or tensile, in a member or part of a member
- P_{ac} = the calculated maximum load capacity of a strut
- P_Y = the calculated maximum load capacity of a tension member
- Q = a force applied transversely to a member
- R = the reaction of a beam at a support
- r_y = the radius of gyration about the y axis
- r = the radius of gyration of a section
- S = the longitudinal spacing between the centres of successive vertical stiffeners in a beam
- T = in a flanged section, the mean thickness of the flange, or the area of the flange divided by its width, or the thickness of the flange as given in AS 3679, as appropriate
- T = the flange thickness as defined in Clause 1.6. Where the flanges are unequal, T shall be calculated from the flange having the greater moment of inertia, calculated about its own axis parallel to the axis of minimum strength of the beam
- T_1 = the thickness of the flange of a section or of a plate in compression, or the aggregate thickness of plates if connected together in accordance with Section 9, as appropriate
- t = the thickness of the web of a section
- t_T = the thickness of the thinner of two components joined
- W = the total load on a beam between supports

S E C T I O N 2 M A T E R I A L S

2.1 STRUCTURAL STEEL

2.1.1 Australian Standards Except as otherwise permitted in Clause 2.1.2 below, all structural steel coming within the scope of this Standard shall, before fabrication, comply with the requirements of the following Australian Standards, as appropriate:

AS 1163 Structural steel hollow sections

AS 1594 Hot-rolled steel flat products

AS 3678 Structural steel—Hot-rolled plates, floorplates and slabs

AS 3679 Structural steel

Part 1: Hot-rolled bars and sections

Part 2: Welded sections

NOTE: See also Clause 3.3.8.

2.1.2 Other structural steels If structural steels or shapes other than those referred to in Clause 2.1.1 are used they shall comply with Australian Standards or with specifications issued by bodies accredited by the Building Authority, such as the British Standards Institution and the American Society for Testing and Materials. The maximum value of the yield stress F_Y to be used in the application of this Standard shall be 450 MPa. A steel intended to be welded shall be suitable for welding.

2.1.3 Acceptance of steels Certified mill test reports, or test certificates issued by the mill shall constitute sufficient evidence of compliance with material specifications referred to in this Standard. At the discretion of the Design Engineer, and subject to the approval of the Building Authority, it shall be permissible to use a test certificate provided by an approved testing laboratory or an affidavit from the fabricator instead of a certified mill test report or mill test certificates.

2.1.4 Unidentified steel If unidentified steel is used it shall be free from surface imperfections, and shall be used only where the particular physical properties of the steel and its weldability will not adversely affect the strength and serviceability of the structure. Unless a full test in accordance with AS 1391 is made, the yield stress F_Y of the steel for design purposes shall be taken as not exceeding 170 MPa.

2.2 FASTENERS AND ELECTRODES

2.2.1 Steel bolts, nuts and washers Steel bolts, nuts and washers shall comply with the following Standards, as appropriate:

AS 1110 ISO metric hexagon precision bolts and screws

AS 1111 ISO metric hexagon commercial bolts and screws

AS 1112 ISO metric hexagon nuts, including thin nuts, slotted nuts and castle nuts

AS 1252 High strength steel bolts with associated nuts and washers for structural engineering

AS 1559 Fasteners—Bolts, nuts and washers for tower construction

Other high strength fasteners equivalent to AS 1252 may be used.

2.2.2 Rivets All rivets shall comply with an approved Standard.

2.2.3 Electrodes All electrodes shall comply with the appropriate requirements of AS 1554.

2.2.4 High strength bolts

2.2.4.1 Storage High strength bolts, nuts and washers shall be stored in such a manner that they will not deteriorate. Bolts and nuts shall be supplied with a residual coating of light oil which shall not be removed.

NOTE: The oil coating should be retained to ensure uniform behaviour of the bolt during tightening.

2.2.4.2 Bolt length To determine the required bolt length, the minimum allowances given in Table 2.1 shall be added to the grip.

TABLE 2.1
BOLT LENGTH MINIMUM ALLOWANCES

Nominal diameter of bolt	Allowance to be added to the grip mm
M16	26
M20	30
M24	36
M30	42
M36	48

NOTES:

1 The values in Table 2.1 are generalized with due allowance for manufacturing tolerance to provide protrusion of the end of the bolt when using a heavy semi-finished hexagonal nut and one flat washer. For each additional hardened flat washer used, add 4 mm. For each bevelled washer used, add 8 mm.

Appropriate extra allowance shall be made when special thick washers or direct-tension indication washers are used. The calculated bolt length should be rounded off to the nearest suitable stock length.

2 The minimum allowance specified in Table 2.1 applies to friction-type joints or bearing-type joints where threads are permitted in the shear plane. Greater allowance may be required for bearing-type joints where threads are excluded from the shear plane. A minimum number of two free threads shall project beyond the inside bearing face of the nut in all joints.

2.3 STEEL CASTINGS All steel castings shall comply with the appropriate requirements of AS 2074.

2.4 CONCRETE Unless otherwise required by this Standard, all structural and fire-protective concrete used in association with structural steel shall comply with the appropriate requirements of AS 3600.

SECTION 3 GENERAL DESIGN REQUIREMENTS

3.1 LOADS A structure, and part of a structure, shall be designed for the loads laid down by the Application Standards and the following Standards, as appropriate:

AS 1170 SAA Loading Code

Part 1: Dead and live loads and load combinations

Part 2: Wind loads

Part 3: Snow loads

NOTE: Attention is drawn to AS 2121, SAA Earthquake Code, where it is required to take earthquake forces into account.

3.2 DESIGN METHODS

3.2.1 General A structure and part of a structure shall be capable of sustaining the most adverse combination of static and dynamic forces that may reasonably be expected from all the loads specified in Clause 3.1. Except as qualified by Clause 3.2.4 or where a load factor is applicable, every part of the structure shall be so proportioned that the permissible stresses specified in this Standard are not exceeded. Where applicable, a load factor used in design shall not be less than that specified in this Standard.

A design method specified in this Standard shall be used, at the choice of the Design Engineer, as the basis for design. The stiffness, stability and serviceability of the structure shall be such that the appropriate requirements of Clause 3.3 are satisfied.

3.2.2 Simple design method The method specified herein and known as the simple design method, applies to the design of a structure, or part of a structure, in which the ends of members will not develop restraining moments adversely affecting the remainder of the structure or its parts.

- (a) *Rectangular framed structures, conventional method* For the purpose of this method of design for a rectangular framed structure, the following assumptions shall be made:
 - (i) Beams and trusses are simply supported.
 - (ii) All connections of beams and trusses are subjected to reaction shear forces applied at the eccentricity appropriate to the connection detail.
 - (iii) Members in compression are subjected to axial forces applied at the eccentricities given by applying Clause 6.4 and have the effective lengths given in Clause 6.3.
 - (iv) Members in tension are subjected to concentric axial forces applied over the net area of the section, as specified in Clause 7.3.
- (b) *Rectangular framed structures, wind connection method* If a rectangular framed structure is designed for vertical loads using (a) above, the lateral forces may be assumed to be carried by fully rigid connection action in accordance with Clause 3.2.3, Method 1, if the structure complies with the following requirements:
 - (i) Under lateral forces, the connections shall be designed elastically and shall satisfy Section 9.
 - (ii) Under vertical forces, only the welds and fasteners used in the connections shall satisfy Section 9, and the remaining elements of the cross-section shall possess sufficient deformation capacity to ensure that overstressing of the welds or fasteners cannot occur.

- (iii) Where welds or fasteners are stressed by both lateral and vertical forces the combined stresses shall satisfy the requirements of Section 9.
- (c) *Triangulated structures* For the purpose of this method of design for a triangulated structure, axial forces shall be found by assuming that all members are pin connected. Where any eccentricity occurs, all stresses arising therefrom shall be kept within the limits of this Standard.

3.2.3 Fully rigid design method The method specified herein, and known as the fully rigid design method, applies to the design of a structure, or part of a structure, in which the beam-to-strut connections have sufficient rigidity to hold the angles between the members virtually unchanged irrespective of the load.

A structure and part of a structure proportioned according to this method shall be analysed using one of the following methods:

- Method 1* Adequate elastic analysis to show that the permissible stresses specified in this Standard are not exceeded.
- Method 2* Adequate analysis to show that the load-carrying capacity is not less than that required when a load factor of 1/0.60 is applied to the loads or to the load combinations in Clause 3.3.1. Nevertheless, the deflections and other movements under working loads shall not exceed the limits imposed by Clause 3.3.5.

3.2.4 Semi-rigid design method The method specified herein, and known as the semi-rigid design method, applies to the design of a structure, or part of a structure, in which the connections between the members are capable of furnishing a dependable and known degree of flexural restraint in accordance with the recommendations of Supplement No. 1 (PD 3343), to BS 449, or as specified below.

In cases where this method of design is employed, calculations based on general or particular experimental evidence shall be made to show that the stresses in the structure are nowhere in excess of the appropriate stresses laid down in this Standard. Alternatively, where riveted or bolted connections are employed, and only steel with a yield stress not exceeding 280 MPa is used, the requirements of this Standard with respect to stresses shall be deemed to be satisfied if the design is made in accordance with Supplement No. 1 to BS 449. The design of continuous struts shall comply with Clause 6.4.

3.2.5 Experimentally based design Where a structure is of an unconventional or complex nature and the Design Engineer shows by full-scale or model tests that the limits on deflections, stability and serviceability, and stress or load factor imposed by Clause 3.2.1 are satisfied, the corresponding design requirements of this standard shall be deemed also to have been satisfied, subject to the following conditions:

- (a) In the case of a full-scale test of a prototype structure, the prototype shall be accurately measured before testing to determine the dimensional tolerances in all relevant parts of the structure. The tolerances then specified on the drawings shall be such that all successive structures shall be in practical conformity with the prototype.

Where the design is based on failure loads, a load factor of not less than 2.0, on the loads or load combinations in Clause 3.3.1 shall be used.

Loading devices shall be previously calibrated, and care shall be exercised to ensure that no artificial restraints are applied to the prototype by the loading systems.

The distribution and durations of forces applied in the test shall be representative of those to which the structure is deemed to be subjected under this Standard.

- (b) In the case where design is based on the testing of a small-scale model structure, the model shall be constructed with due regard for the principles of dimensional

similarity. The thrusts, moments and deformations under working loads shall be determined by physical measurements made when the loading is applied to simulate the conditions assumed in the design of the actual structure.

- (c) When it is desired to justify a structure or any of its parts by testing a prototype or model, prior notice shall be given to the Building Authority, and all the relevant tests shall be carried out to the satisfaction of the Authority.

3.3 OTHER DESIGN CONSIDERATIONS

3.3.1 Loading combinations Unless specified in the application Standard, e.g. AS 1418, the load combinations given in this Clause shall apply. A structure or part of a structure shall be so designed that the maximum permissible stress is not exceeded under any of the following load combinations:

- (a) $X_D + X_L$;
- (b) $0.75 (X_D + X_L + X_w)$; or
- (c) $X_D' + X_w'$;

where

X_D = dead load

X_L = live load

X_w = wind load

X_w' = wind load causing stresses of the opposite sign to the dead load

X_D' = that part of the dead load which cannot be removed from the structure

3.3.2 Stability A structure shall comply with the following requirements for stability:

- (a) The stability of a structure as a whole and of each part shall be investigated, and weight and anchorage shall be provided so that the structure or part is in equilibrium for the resultant of—
 - 1.0 times the whole of the dead load tending to prevent overturning;
 - 1.2 times the dead load, if any, tending to cause overturning; and
 - 1.4 times the static-load equivalent of other loads tending to cause overturning.

- (b) Due account shall be taken of possible variations in loading during construction and repair or other temporary conditions, so as to ensure stability at all times.

3.3.3 Lateral forces Adequate provision shall be made to resist the lateral forces that can occur during and after erection of a structure. Where the lateral forces cause twisting in a structural frame, provision shall be made to resist all resulting increases in horizontal shear but all resulting decreases in horizontal shear shall be neglected in the design.

When considering the effect of lateral forces, proper allowance shall be made for the strength and stiffness of all structural components as follows:

- (a) Where structural components such as walls, roofs, floors and other additional bracing structure are capable of transmitting all lateral forces to the substructure, it shall be deemed that the structural steelwork is not loaded by such forces.
- (b) Where these other structural components are strong enough to transmit only part of the lateral forces to the substructure, the lateral forces shall be distributed through the structural system in accordance with the relative stiffnesses of the frame and other components, and the structural steelwork shall be designed accordingly.
- (c) Where resistance to lateral forces provided by other structural components is obviously low or not ascertainable, the structural steelwork shall be designed to resist all the lateral forces and transmit them to the substructure.

3.3.4 Lateral restraining systems

3.3.4.1 General Lateral restraints required to act as intermediate lateral restraints for beams (Clause 5.9.2.2) or to reduce the effective lengths of struts shall meet the requirements of this Clause (3.3.4).

3.3.4.2 Forces A single lateral restraint shall be designed to resist a force of $0.025P$, in addition to any other forces to which it may be subjected, where P is the maximum axial force in the critical flange or chord.

3.3.4.3 Stiffness A single lateral restraint shall be designed in such a way that the transverse deflection of the critical flange or chord at the point being restrained shall not exceed $0.0025L$, where L is the span of the restrained member (Clause 5.8), when subjected to the force of $0.025P$ defined in Clause 3.3.4.2. This is equivalent of a minimum force/extension stiffness of $10P/L$.

3.3.4.4 Multiple restraints When more than one lateral restraint is used and the various restraints are uniformly distributed along the restrained member, then the force and stiffness requirements defined in Clauses 3.3.4.2 and 3.3.4.3 shall be distributed evenly amongst the various restraints; provided that the stiffness of an individual brace shall not be less than $4P/l$.

3.3.4.5 Parallel restrained members When a series of parallel members are restrained by a line of restraints, the forces and stiffnesses determined by Clauses 3.3.4.2 and 3.3.4.3 shall be summed for all members and the restraints designed for the total force and stiffness so obtained. However, for seven or more parallel members, only the seven members with the largest P values need be considered.

3.3.4.6 Attachment of restraints Lateral restraints shall be attached to a beam such that the force defined in Clause 3.3.4.2 can be transferred and such that the critical flange or chord deflection limit laid down in Clause 3.3.4.3 is not exceeded.

3.3.4.7 Critical flange or chord The critical flange or chord of a member is that part which would deflect the furthest during buckling in the absence of the restraint being designed. If an exact analysis is not available this shall be determined as follows:

- (a) When adjacent points of load application are restrained, the critical flange or chord of a beam between such points is the compression flange or chord.
- (b) When a point of gravity load application is unrestrained, the critical flange or chord is the top flange.
- (c) When the load is directly due to wind, the critical flange is the windward flange.

3.3.5 Deflection Where applicable, reference should be made to the application Standard, e.g. AS 1418, for deflection requirements. Under the most adverse loading conditions, the deflections of neither a structure as a whole, nor any of its parts, shall be such as will impair the strength or serviceability of the structure or part, or lead to damage of other building components, or be unsightly. The responsibility for selecting deflection limits used in design shall rest with the Design Engineer.

NOTE: Guidance on maximum permissible deflections in specific cases is given in Appendix A.

3.3.6 Fatigue For members subjected to frequent fluctuations of live load, the maximum permissible stress range shall be determined in accordance with Appendix B, as appropriate to the number of cycles, the class of constructional details adopted, and the materials used.

3.3.7 Corrosion protection Where steelwork in a structure is to be exposed to a corrosive environment, the steelwork shall be given adequate protection against corrosion, and the Design Engineer shall specify this protection. The degree of protection to be employed shall be determined after consideration has been given to use of the structure, climatic or other local conditions, and maintenance provisions.

NOTE: Recommendations for corrosion protection may be found in AS 2312.

3.3.8 Brittle fracture Where steelwork in a structure is welded and parts subject to tensile stress may become liable to brittle fracture, an assessment of the required notch toughness of the fabricated steel may be made using the guidance given in Appendix D of AS 1554, Part 1.

NOTE: Welded structures of steel to AS 3678 and AS 3679 are normally satisfactory but, under certain conditions, parts subjected to tensile stress may become liable to brittle fracture.

This type of failure should be considered possible when there is any combination of low temperatures and the following factors: thick plates or thick sections; reduction in the ductility of the steel connections or details giving rise to severe stress concentrations; or the possibility of undetected defects in welding such as cracks or lack of fusion or root penetration.

Specialist literature dealing with the problem of brittle fracture may also be consulted. (Refer to Welding Technology Institute of Australia Technical Note 10 'Fracture Mechanics'.)

SECTION 4 GEOMETRICAL PROPERTIES

4.1 GENERAL The geometrical properties of the gross and the effective cross-sections of a member or part of a member, shall be calculated on the following bases:

- (a) The properties of the gross cross-section shall be calculated from the specified size of the member or part.
- (b) The properties of the effective cross-section shall be calculated by deducting from the area of the gross section the following:
 - (i) The cross-sectional areas of excessive plate widths as given in Clause 4.3.
 - (ii) The sectional areas of all holes in the section, except that for parts in compression, a bolt or rivet hole shall not be a deduction. (See Clause 4.4.)

4.2 GEOMETRICAL PROPERTIES FOR CALCULATING BENDING STRESSES

It shall be permissible to calculate the bending stresses in a beam or girder by using properties equivalent to those of the effective cross-section. Such equivalent properties shall be obtained by multiplying the properties of the gross cross-section by the ratio of the effective flange cross-sectional area to the gross flange cross-sectional area.

In welded construction the flange cross-sectional area shall be that of the flange plates alone.

In bolted or riveted construction, the cross-sectional area of the flanges shall be taken as the sum of the cross-sectional areas of the flange plates, flange angles and the portion of the web and side plates (if any) between the flange angles.

4.3 PLATE THICKNESSES

4.3.1 Plate and flange outstands If the projection, b_1 , of a plate or flange beyond its connection to a web, or other line of support or the like, exceeds the relevant values given in (a), (b) and (c) below, the area of the excess flange shall be neglected when calculating the effective geometrical properties of the section.

- (a) Flanges and plates in compression with unstiffened edges $256T_1/\sqrt{F_Y}$.
- (b) Flanges and plates in compression with stiffened edges $20T_1$ to the inner face of the stiffening.

Stiffened flanges shall include flanges composed of channel or I-sections or of plates with continuously stiffened edges.

- (c) Flanges and plates in tension $20T_1$.

In this Clause, T_1 shall be taken to be the thickness of the plate, irrespective of whether the plate is a flange or other part of the member.

4.3.2 Flanges and plates—Unsupported widths Where a plate is connected to other parts of a built-up member along lines generally parallel to the longitudinal axis of the member, the width, b_2 , (see Clause 1.6) shall not exceed the following:

- (a) For plates in uniform compression $\frac{1440}{\sqrt{F_Y}} T_1$.

However, where the width exceeds—

$\frac{560}{\sqrt{F_Y}} T_1$ for welded plates which are not stress-relieved;

$\frac{800}{\sqrt{F_Y}} T_1$ for other plates; or

$\frac{635}{\sqrt{F_y}} T_1$ for cold-formed hollow section members.

the excess width shall be assumed to be located centrally, and its sectional area shall be neglected when calculating the effective geometrical properties of the section.

- (b) For plates in uniform tension $100T_1$.

However, where the width exceeds $60T_1$, the excess width shall be assumed to be located centrally, and its sectional area shall be neglected when calculating the geometrical properties of the section.

In this Clause, T_1 shall be taken to be the thickness of the plate, irrespective of whether the plate is a flange or a web of the member.

4.3.3 Circular hollow sections If a circular hollow section is used as a strut or a beam, the effective geometrical properties of the section shall be calculated using the specified outside diameter and a value for wall thickness which shall be the lesser of—

$$\frac{23 \times 10^3}{F_y(D/t)} t \text{ and } t$$

where

D = the specified outside diameter of the section

t = the specified wall thickness of the section

NOTE: For fabricated tubes, design criteria can be found in Section 3.5 of Column Research Council—‘Guide to Design Criteria for Metal Compression Members’, Ed. B. G. Johnston, 2nd Ed., John Wiley, New York 1966.

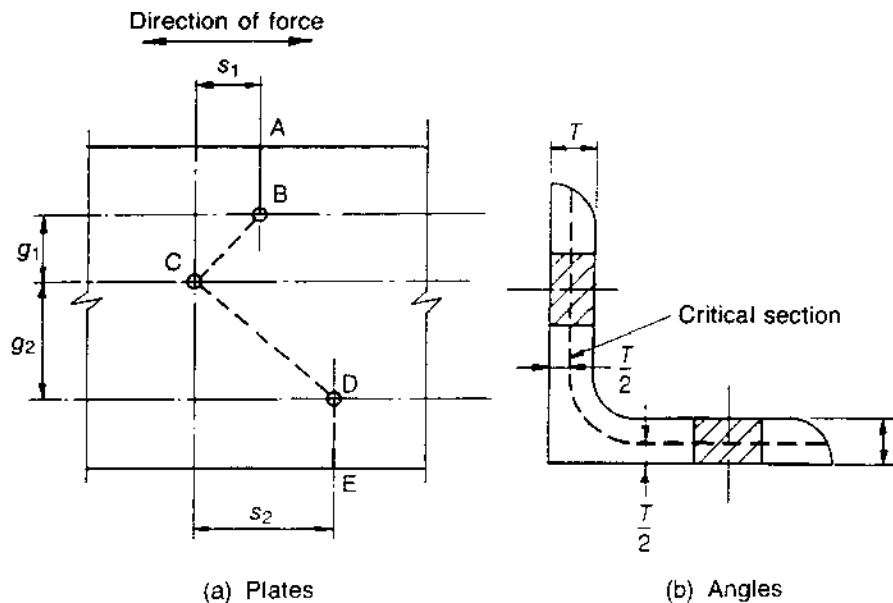
4.4 HOLES

4.4.1 Effective diameters In calculating the area to be deducted for rivets, bolts or pins the diameter of the hole shall be used.

For countersunk holes the effective diameter of a hole shall be assumed to be the cross-sectional area of the hole, including the countersunk portion in the plane containing the axis of the hole, divided by the thickness of the material holed.

4.4.2 Combinations of holes Except as specified below, the area to be deducted from the gross cross-sectional area of a member, when making deductions for combinations of holes, shall be the sum of the sectional areas of the holes in that cross-section at right angles to the direction of stress in the member in which such sum is a maximum.

Where bolt or rivet holes are staggered, the area to be deducted shall be the sum of the sectional areas of all holes in a chain of lines extending progressively across the member, less $s^2T/4g$ for each line extending between holes at other than right angles to the direction of stress, where s , g and T are respectively the staggered pitch, gauge and thickness associated with the line under consideration (see Figure 4.4.2(a)). The chain of lines shall be chosen to produce the maximum such deduction. For non-planar sections, such as angles with holes in both legs, the gauge, g , shall be the distance along the centre of the thickness of the section between hole centres (see Figure 4.4.2(b)).



Chain ABCDE:

$$\text{Deduction} = (\text{Sum of sectional areas of holes B, C and D}) - \left(\frac{s_1^2 T}{4g_1} + \frac{s_2^2 T}{4g_2} \right)$$

FIGURE 4.4.2. STAGGERED PITCH, s , AND GAUGE, g

4.5 SECTIONAL AREAS OF BOLTS, SCREWED TENSION RODS AND RIVETS

4.5.1 Bolts and screwed tension rods The gross area of cross-section of a bolt or a screwed tension rod shall be taken as the area of cross-section of the body of the bolt or tension rod. The effective area of cross-section in tension shall be taken as the stress area.

The effective area of cross-section in shear shall be taken as the gross area of the cross-section or the core area as appropriate.

NOTE: Stress areas are calculated using a diameter equal to the shank diameter less 0.9382 times the thread pitch which are tabulated in AS 1275. Stress areas are tabulated in AS 1275.

4.5.2 Rivets The nominal diameter of a rivet shall mean the specified diameter cold before driving. The gross area of a rivet shall be taken to be the cross-sectional area of the rivet hole as specified in Clause 4.4.1 excluding any countersunk portion.

4.6 MAXIMUM SLENDERNESS RATIOS The maximum slenderness ratio of a beam, strut or tension member given in Table 4.6 shall not be exceeded. In this Clause, l is the effective length of the member (see Clauses 5.9 and 6.3) and the radius of gyration, r , shall be based on the effective section defined in Clause 4.1.

TABLE 4.6
MAXIMUM SLENDERNESS RATIOS

Member	Maximum slenderness ratio l/r
(a) A strut carrying compressive forces from dead load or from dead load and live load (b) A discontinuous single-angle strut, single bolted or riveted	180
(c) A beam (d) A strut carrying compressive forces resulting only from wind load (e) A tension member carrying force from dead or live load where the minimum tensile force is less than 10 percent of the maximum tensile force	300

NOTE: The above limits may be exceeded for tension members if deflection stresses and vibrations are not excessive.

SECTION 5 DESIGN OF BEAMS

5.1 GENERAL The calculated stress in a member shall not exceed any of the appropriate maximum permissible stresses given in Clauses 5.2, 5.3, 5.4 and 5.6 for bending, in Clause 5.10 for shear, and in Clause 5.11 for bearing, except that Clause 5.4 shall not apply in the following cases:

- (a) a beam bent about its axis of minimum strength;
- (b) an I-beam or channel with equal flanges and with a value of l/r_y less than $960/\sqrt{F_Y}$;
- (c) a rectangular hollow section beam with B/D and t/T both greater than 0.15 (this includes hollow sections to AS 1163).

5.2 MAXIMUM PERMISSIBLE STRESS The maximum calculated stress due to bending in a member shall not exceed the maximum permissible stress F_b , determined by Equation 5.2(1) or 5.2(2):

For solid round and square bars, and for solid rectangular bars bent about the axis of minimum strength—

$$F_b = 0.75 F_Y \quad \dots 5.2(1)$$

For all other beams—

$$F_b = 0.66 F_Y \quad \dots 5.2(2)$$

5.3 MAXIMUM PERMISSIBLE COMPRESSIVE STRESS The maximum calculated compressive stress due to bending in any part of a beam shall not exceed the maximum permissible stress F_{bc} , which shall be the greater of—

$$F_{bc} = 0.60 F_Y,$$

and the value determined by Equations 5.3.(1), 5.3.(2), 5.3.(3) or 5.3.(4) as appropriate:

$$F_{bc} = \left(0.72 - \frac{0.12}{256} \times \frac{b_1}{T_1} \sqrt{F_Y} \right) F_Y \quad \dots 5.3(1)$$

$$F_{bc} = \left(0.72 - \frac{0.12}{560} \times \frac{b_2}{T_1} \sqrt{F_Y} \right) F_Y$$

for welded flanges or plates which are not stress-relieved $\dots 5.3(2)$

$$F_{bc} = \left(0.72 - \frac{0.12}{800} \times \frac{b_2}{T_1} \sqrt{F_Y} \right) F_Y$$

for other flanges or plates $\dots 5.3(3)$

$$F_{bc} = \left(0.72 - \frac{0.12}{635} \times \frac{b_2}{T_1} \sqrt{F_Y} \right) F_Y \quad \dots 5.3(4)$$

for cold-formed rectangular hollow section members.

where

b_1 = the outstand of the flange or plate of thickness T_1 in compression (see Clause 4.3.1)

b_2 = the unsupported width of the flange or plate *between faces of support which is of thickness T_1* and in compression (see Clause 1.6 and Clause 4.3.2).

5.4 MAXIMUM PERMISSIBLE STRESS IN A BEAM BENT ABOUT THE AXIS OF MAXIMUM STRENGTH

5.4.1 Equal-flange I-beams or channels For an I-beam or channel with equal flanges bent about the axis of maximum strength, the maximum calculated stress shall not exceed the maximum permissible stress F_b , given directly in Tables 5.4.1(1), 5.4.1(2) 5.4.1(3), 5.4.1(4) for a yield stress F_Y of 250 or 350 MPa*, or calculated from Equation 5.4.3(1) or 5.4.3(2), as appropriate, and an elastic flexural-torsional buckling analysis.

In Tables 5.4.1(1), (2), (3) and (4)—

T = the flange thickness as defined in Clause 1.6.

NOTE: Tables 5.4.1(1), (2), (3) and (4) have been derived from Clauses 5.4.3 and 5.5.

5.4.2 Laterally unsupported angle sections For a laterally unsupported angle section, the maximum stress F_b , may be calculated from Equation 5.4.3(1) or 5.4.3(2) and an elastic flexural-torsional analysis.

NOTE: Alternatively, it is permissible to use either the approximate solutions or the tabulated load capacities for laterally unsupported angles in the ‘Safe Load Tables for Structural Steel’ (published by The Australian Institute of Steel Construction.)

5.4.3 Other sections The maximum calculated stress due to bending in a beam not otherwise covered by Clauses 5.4.1 and 5.4.2 shall not exceed the maximum permissible stress F_b , determined by Equation 5.4.3(1) or 5.4.3(2), as appropriate:

Where F_{ob} is equal or less than F_Y —

$$F_b = \left[0.55 - 0.10 \frac{F_{ob}}{F_Y} \right] F_{ob} \quad \dots 5.4.3(1)$$

Where F_{ob} is equal to or greater than F_Y —

$$F_b = \left[0.95 - 0.50 \sqrt{\left(\frac{F_Y}{F_{ob}} \right)} \right] F_Y \quad \dots 5.4.3(2)$$

In Equations 5.4.3(1) and 5.4.3(2) above, the maximum stress F_{ob} in the beam at elastic buckling, shall be calculated in accordance with Clause 5.5 or by an elastic flexural-torsional buckling analysis.

* See Appendix C.

TABLE 5.4.1(1)
MAXIMUM PERMISSIBLE BENDING STRESSES, F_b (MPa),
IN EQUAL-FLANGE I-BEAMS OR CHANNELS

with $F_Y = 250$ MPa and $\frac{T}{t} > 2.0$ or $\frac{d_1}{t} > 85$

l/r_y	D/T														
	8	10	12	14	16	18	20	25	30	35	40	50	60	80	100
50	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165
60	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165
70	165	165	165	165	165	164	162	159	157	156	155	154	154	153	153
80	165	165	165	161	158	156	154	150	147	146	145	143	142	142	141
90	165	165	159	155	151	148	146	141	138	136	134	132	131	130	129
100	165	160	154	149	145	141	138	133	129	126	124	121	120	118	118
110	163	156	149	144	139	135	131	125	120	117	114	110	108	105	104
120	160	151	144	138	133	129	125	117	111	106	102	97	95	92	90
130	156	147	140	134	128	123	119	109	101	95	92	87	84	81	79
140	153	144	136	129	123	117	113	100	92	87	83	78	75	71	70
150	150	140	132	124	118	112	105	93	85	79	75	70	67	64	62
160	147	137	128	120	113	105	99	86	78	73	69	64	60	57	56
170	144	133	124	116	108	99	93	81	73	67	63	58	55	52	50
180	141	130	121	112	102	94	88	76	68	62	58	53	50	47	45
190	138	127	117	107	97	89	83	71	64	58	54	49	46	43	41
200	136	124	114	102	93	85	79	67	60	54	51	46	43	39	38
210	133	121	110	98	89	81	75	64	56	51	48	43	40	36	35
220	130	118	106	94	85	77	72	61	53	48	45	40	37	34	32
230	128	116	102	90	81	74	68	58	51	46	42	37	35	31	30
240	126	113	98	87	78	71	66	55	48	43	40	35	32	29	28
250	123	109	95	84	75	68	63	53	46	41	38	33	31	27	26
260	121	106	92	81	73	66	60	51	44	39	36	32	29	26	24
270	119	103	89	78	70	64	58	49	42	38	34	30	27	24	23
280	116	99	86	76	68	61	56	47	41	36	33	29	26	23	21
290	114	97	83	73	65	59	54	45	39	35	32	27	25	22	20
300	112	94	81	71	63	57	52	44	38	33	30	26	24	21	19

NOTE: Values above solid line may be reduced by Clause 5.3.

TABLE 5.4.1(2)
MAXIMUM PERMISSIBLE BENDING STRESSES, F_b (MPa),
IN EQUAL-FLANGE I-BEAMS OR CHANNELS

with $F_Y = 340 \text{ MPa}$ and $\frac{T}{t} > 2.0$ or $\frac{d_1}{t} \geq 72.9$

l/r_y	D/T														
	8	10	12	14	16	18	20	25	30	35	40	50	60	80	100
50	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224
60	224	224	224	224	222	220	218	215	213	211	211	209	209	208	208
70	224	224	218	213	209	206	203	199	196	194	193	191	190	189	189
80	224	215	208	202	197	193	190	184	180	178	176	174	172	171	170
90	218	207	199	192	186	181	177	170	165	162	159	156	154	152	151
100	211	200	191	183	176	171	166	157	150	144	140	135	132	129	128
110	205	193	183	174	167	160	155	141	132	126	122	117	114	111	109
120	199	186	175	166	158	150	141	127	118	112	107	102	99	96	94
130	194	180	168	158	148	138	130	115	106	100	96	90	87	84	82
140	189	174	162	150	137	128	120	105	96	90	86	80	77	74	72
150	184	169	155	141	128	119	111	97	88	82	78	72	69	65	64
160	179	163	148	133	121	111	103	90	81	75	71	65	62	59	57
170	174	158	140	125	114	104	97	84	75	69	65	59	56	53	51
180	170	153	133	119	107	98	91	78	70	64	60	55	51	48	46
190	166	146	127	113	102	93	86	73	65	60	56	50	47	44	42
200	161	140	121	108	97	88	82	69	61	56	52	47	43	40	38
210	157	134	116	103	92	84	77	66	58	52	48	43	40	37	35
220	153	129	111	98	88	80	74	62	55	49	46	41	37	34	32
230	148	124	107	94	84	77	70	59	52	47	43	38	35	32	30
240	143	120	103	90	81	73	67	56	49	44	41	36	33	30	28
250	138	115	99	87	78	70	65	54	47	42	39	34	31	28	26
260	134	111	96	84	75	68	62	52	45	40	37	32	29	26	24
270	130	108	92	81	72	65	60	50	43	38	35	30	28	24	23
280	126	104	89	78	70	63	57	48	41	37	33	29	26	23	21
290	122	101	86	76	67	61	55	46	40	35	32	28	25	22	20
300	119	98	84	73	65	59	54	44	38	34	31	26	24	21	19

NOTE: Values above solid line may be reduced by Clause 5.3.

TABLE 5.4.1(3)
MAXIMUM PERMISSIBLE BENDING STRESSES, F_b (MPa),
IN EQUAL-FLANGE I-BEAMS OR CHANNELS

with $F_Y = 250$ MPa and $\frac{T}{t} \leq 2.0$ or $\frac{d_1}{t} \leq 85$

l/r_y	D/T														
	8	10	12	14	16	18	20	25	30	35	40	50	60	80	100
50	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165
60	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165
70	165	165	165	165	165	165	165	165	164	163	163	162	161	161	160
80	165	165	165	165	165	163	161	158	155	154	153	151	151	150	150
90	165	165	165	162	159	156	154	149	147	145	143	141	140	139	139
100	165	165	161	157	153	150	147	142	138	136	134	132	130	129	128
110	165	163	157	152	147	144	141	135	130	127	125	122	120	118	117
120	165	159	153	147	142	138	135	128	123	119	116	113	110	106	105
130	163	155	148	143	137	133	129	121	115	111	106	101	98	94	92
140	160	152	145	138	133	128	124	115	107	101	96	91	87	84	82
150	157	149	141	134	128	123	119	108	99	92	88	82	79	75	73
160	155	145	138	130	124	119	114	100	91	85	81	75	71	67	66
170	152	142	134	127	120	114	108	94	85	79	74	68	65	61	59
180	149	140	131	123	116	109	102	88	80	73	69	63	59	56	54
190	147	137	128	120	112	104	97	83	75	69	64	58	55	51	49
200	144	134	125	116	108	99	92	79	70	64	60	54	51	47	45
210	142	131	122	113	103	95	88	75	66	61	56	50	47	43	41
220	140	129	119	109	99	91	84	71	63	57	53	47	44	40	38
230	138	126	116	105	95	87	80	68	60	54	50	44	41	37	35
240	135	124	113	101	91	83	77	65	57	51	47	42	39	35	33
250	133	121	110	98	88	80	74	62	55	49	45	40	36	33	31
260	131	119	106	94	85	77	71	60	52	47	43	38	34	31	29
270	129	117	103	91	82	75	69	58	50	45	41	36	33	29	27
280	127	114	100	88	79	72	66	55	48	43	39	34	31	27	25
290	125	112	97	86	77	70	64	53	46	41	38	33	29	26	24
300	123	109	94	83	74	68	62	52	45	40	36	31	28	25	23

NOTE: Values above solid line may be reduced by Clause 5.3.