

Australian Standard™

**High voltage switchgear and controlgear**

**Part 301: Dimensional standardization  
of terminals**



This Australian Standard was prepared by Committee EL-007, Power Switchgear. It was approved on behalf of the Council of Standards Australia on 20 July 2005.  
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Australian Standard™

**High voltage switchgear and controlgear**

**Part 301: Dimensional standardization  
of terminals**

Originated as AS 2395—1980.  
Revised and redesignated as AS 62271.301—2005.

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## PREFACE

This Standard was prepared by the Standards Australia Committee EL-007, Power Switchgear to supersede AS 2395—1980, *Terminals for switchgear assemblies for alternating voltages above 1 kV*.

The Standard covers the requirements for terminals for indoor and outdoor switchgear assemblies and ancillary equipment such as are employed in connection with the generation, transmission, distribution and utilization of electric power.

In the preparation of the Standard consideration was given to IEC 62271-301, *High-voltage switchgear and controlgear – Part 301: Dimensional standardisation of terminals*, and an ENA document on the standardization of equipment palm terminals, and acknowledgement is made of the assistance received therefrom.

IEC 62271-301 gives dimensions of terminals of cylindrical shape and the IEC sizes have been adopted herein. For terminals of rectangular shape, IEC 62271-301 gives only the diameters of and distances between holes. These dimensions have been retained herein, except for terminal numbers 12 to 14 where the 60 mm spacing does not accommodate the conductor terminal; in this case a spacing of 70 mm has been used.

Additionally two informative appendices have been added. Appendix A provides the basis for the design of terminals and justification for having hole diameter of 18 mm for terminal numbers 7 to 14. Appendix B provides recommendations for the design and preparation of joints.

### Common numbering of standards falling under the responsibility of EL-007

In accordance with the decision taken by the committee EL-007 a common numbering system will be established in order to align the numbering of Australian Standards falling under the responsibility of EL-007 with IEC standards. All high-voltage switchgear and controlgear Standards will, at their next revision (or as equivalent Standards become available in IEC), become parts of the AS 62271 (High-voltage switchgear and controlgear) series. The table below gives the relationship between future numbering and existing Standard numbers. Standards current at the time of publication of this Standard are marked with an asterisk (\*).

AS 62271 Series	High-voltage switchgear and controlgear	Old AS Number
1	Common specifications	*AS 2650
100*	High-voltage alternating current circuit-breakers	AS 2006
102*	Alternating current disconnectors and earthing switches	AS 1306 and AS 4298
103	Switches for rated voltages above 1 kV and less than 52 kV	*AS/NZS 60265.1
104	Switches for rated voltages of 52 kV and above	*AS 60265.2
106	Alternating current contactors and contactor based motor-starters	*AS 2024
110	Inductive load switching	*AS 4372
200*	AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV	AS 2086
201	AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV up to and including 38 kV	*AS 2264
202	High-voltage/low-voltage prefabricated substations	*AS 61330

<b>AS 62271 Series</b>	<b>High-voltage switchgear and controlgear</b>	<b>Old AS Number</b>
203*	Gas-insulated metal enclosed switchgear for rated voltages above 52 kV	AS 2263
301*	Dimensional standardization of terminals	AS 2395
303	Use and handling of sulphur hexafluoride (SF <sub>6</sub> ) in high-voltage switchgear and controlgear	*AS 2791
304	Additional requirements for enclosed switchgear and controlgear from 1 kV to 72.5 kV to be used in severe climatic conditions	*AS 4243
308*	Guide for asymmetrical short-circuit breaking test duty T100a	—

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STANDARDS AUSTRALIA

Australian Standard

High voltage switchgear and controlgear

Part 301: Dimensional standardization of terminals

## 1 SCOPE

This Standard specifies dimensions and configuration for terminals intended for use on indoor and outdoor switchgear assemblies such as are employed in connection with the generation, transmission and distribution of electric power. It also applies to the ancillary equipment used in conjunction with the switchgear.

## 2 APPLICATION

This Standard applies to terminals on electrical equipment and on ancillary connections such as busbars. It does not apply to terminals internal to switchgear, switchboards and similar, where the connection may be an integral part of the design.

This Standard does not require all connections on to terminals to be made with fasteners. Other methods may be more appropriate and reference should be made to AS 2067, Appendix C, for a description of these.

NOTE: The intention of the standard is to establish a set of dimensions of terminations for equipment for ease of assembly and interchangeability. In this context, it is appreciated that equipment to which the terminals are applicable will have a current rating in accordance with the particular standard to which it is tested. Service experience has indicated that despite the various metals and their alloys used in equipment terminals, it is practicable to assign nominal current ratings to terminals of various sizes and coordinate a terminal to an item of equipment having the same current rating.

## 3 REFERENCED DOCUMENTS

This Standard may require reference to the following documents:

AS

1100	Technical drawing
1100.201	Part 201: Mechanical engineering drawing
1110	ISO metric hexagon bolts and screws—Product grades A and B
1110.1	Part 1: Bolts
1111	ISO metric hexagon bolts and screws—Product grade C
1111.1	Part 1: Bolts
1237	Plain washers for metric bolts, screws and nuts for general purposes
1237.1	Part 1: General plan
1444	Wrought alloy steels—Standard, hardenability (H) series and hardened and tempered to designated mechanical properties
2067	Switchgear assemblies and ancillary equipment for alternating voltages above 1 kV
2338	Preferred dimensions of wrought metal products
2752	Preferred numbers and their use

AS/NZS	
1865	Aluminium and aluminium alloys—Drawn wire, rod, bar and strip
IEC	
62271	High-voltage switchgear and controlgear
62271-301	Part 301: Dimensional standardisation of terminals

## 4 DIMENSIONAL REQUIREMENTS

### 4.1 General

Terminals shall comply with the details and dimensions shown in Figures 1 to 3 and Tables 1 and 2 as appropriate, and with the requirements given in Clauses 4.2 to 4.4.

### 4.2 Surface areas of terminals

The current carrying surface(s) of terminals shall be flat or cylindrical as applicable, free from blemishes and with a surface roughness as defined in AS 1100.201 not greater than 3.2  $\mu\text{m}$ .

The contact and rear surface areas of palm terminals shall be parallel. If the rear surface is required as a current-carrying surface, this shall be specified by the purchaser.

### 4.3 Thickness of palm terminals

The palm terminal thicknesses given in Table 1 are considered to be minimum practical values for the current ratings nominated and for normal mechanical loading. Where special conditions apply, such as abnormal mechanical loading, the thickness shall be as specified by the purchaser, or where applicable shall be subject to their approval.

### 4.4 Space orientation of major and minor axes of palm terminals

The space orientation of the major and minor axes of equipment palm terminals shall be as specified by the purchaser.

## 5 ALTERNATING CURRENT RATINGS

The current ratings assigned to the terminals in Figures 1 to 3 are those specified in the various Australian standards for electrical equipment, are in accordance with the R10 series of preferred numbers in AS 2752, and reflect common usage.

The assigned values for palm terminals may be exceeded provided that the current density at the joint face, i.e. 0.17 A/mm<sup>2</sup> for aluminium or 0.32 A/mm<sup>2</sup> for copper, is not exceeded and that the joint is designed and prepared in accordance with Appendix B.

NOTE: Palm terminals having current ratings exceeding 5000 A and cylindrical terminals having current ratings exceeding 3150 A are not covered by this standard and are a matter for agreement between purchaser and manufacturer.

## 6 MATERIAL

The terminal may be made from any material acceptable to the purchaser.

## 7 TERMINAL APPLICATION

### 7.1 Terminals with rectangular shape

The recommended dimensions for rectangular terminals should be restricted to the diameters of and the distances between the hole.

The dimensions are as follows:

- (a) Hole diameters: 14 mm, 16 mm, 18 mm, and 22 mm.

(b) Distance between holes: 40 mm, 45 mm, 50 mm, 60 mm and 70 mm (centre-to-centre)

Any possible combination of these dimensions is permitted.

The distance between holes should be applied to two adjacent holes, both along the abscissa and ordinate.

### 7.2 Palm terminals (See Figures 1 and 2)

All palm terminals except numbers 6 and 11 may be used either as equipment palm terminals or as conductor palm terminals. Terminal number 7 is intended for use as conductor palm terminal with equipment palm terminal numbers 12, 13 and 14.

Terminal numbers 6 and 11 are intended for use as conductor palm terminals.

### 7.3 Cylindrical terminals (See Figure 3)

Where terminal numbers 15 to 20 are supplied on equipment, suitable adaptor palm terminals shall be provided by the equipment manufacturer if specified by the purchaser.

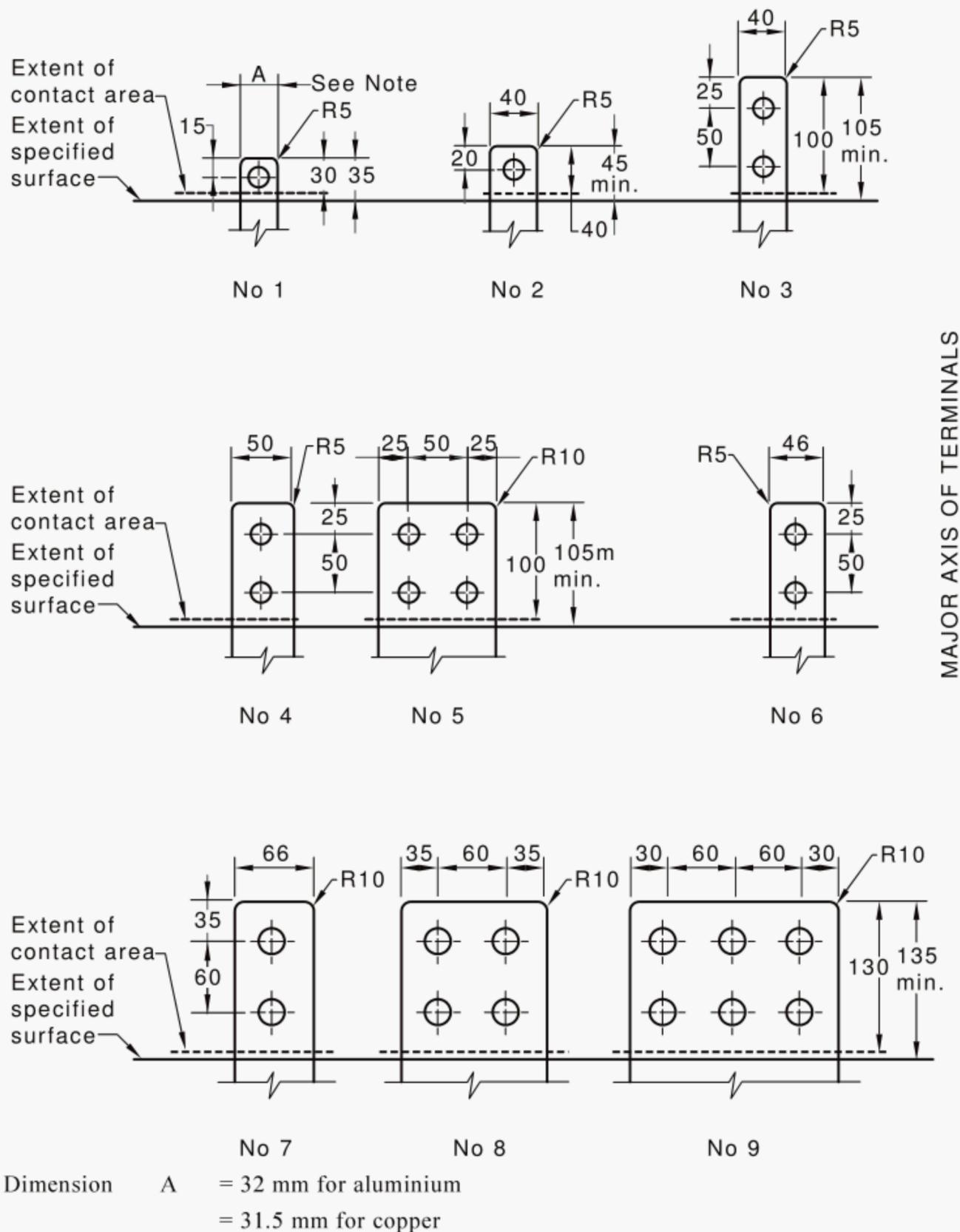


FIGURE 1 AUSTRALIAN PREFERRED PALM TERMINALS—NUMBERS 1 TO 9

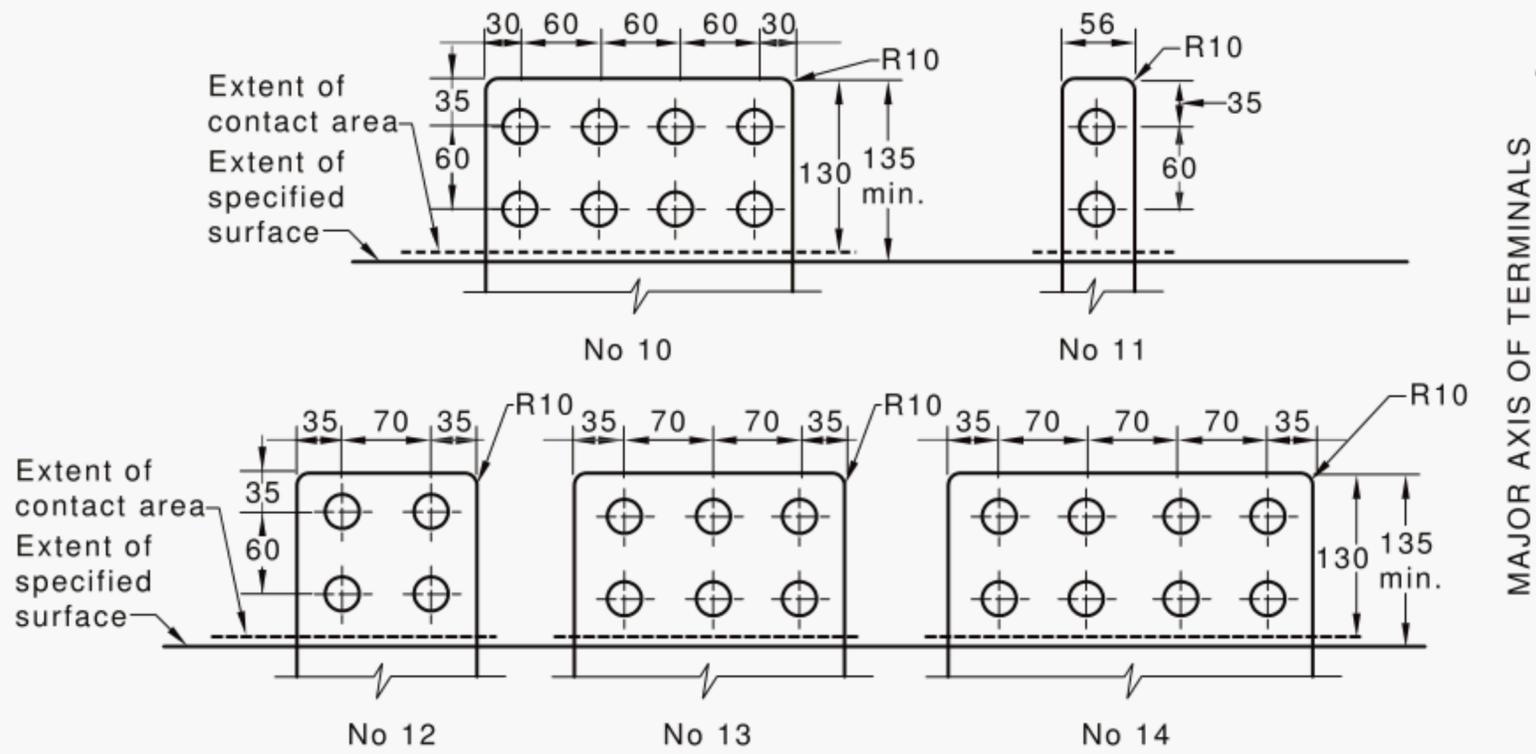


FIGURE 2 AUSTRALIAN PREFERRED PALM TERMINALS—NUMBERS 10 TO 14

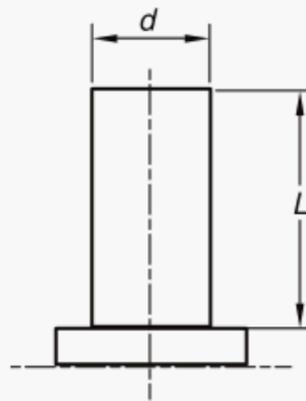


FIGURE 3 CYLINDRICAL TERMINALS—NUMBERS 15 TO 20

NOTES TO FIGURES 1 TO 3:

1. All dimensions are in millimetres.
2. For voltages of 123 kV and above, palm terminals shall have the corners rounded to the dimensions shown. Palm terminals intended for use at lower voltages need only have the sharp edges and corners rounded off. Burrs are to be removed around holes on both sides of the terminals.
3. Net areas shown for palm terminals assume that a similar palm terminal is attached, with both terminals having radii of corners as shown. Where conductor palm terminals (terminal numbers 6 and 11) are used with equipment palm terminals, the net areas are governed by their size and number.

**TABLE 1**  
**PALM TERMINAL CHARACTERISTICS**

1	2	3	4	5	6	7
Terminal number	Bolt hole diameter mm	Net contact area mm <sup>2</sup>	Minimum thickness mm		Assigned current-rating A	
			Copper	Aluminium	Copper	Aluminium
1	14	780	4	6	200	80
2	14	1430	4	6	400	200
3	14	3670	6.3	12	800	630
4	14	4670	10	12	1250	800
5	14	9300	16	12	2500	1250
6	14	4270	10	12	1250	630
7	18 or 22	7730	16	20	2500	1250
8	18 or 22	15300	16	20	3150	2000
9	18 or 22	21000		20		3150
10	18 or 22	28100		20		4000
11	18 or 22	6430		20		1000
12	18 or 22	—		20		2500
13	18 or 22	—		20		3150 (3750)
14	18 or 22	33300		20		5000

**TABLE 2**  
**CYLINDRICAL TERMINAL CHARACTERISTICS—  
COPPER AND ALUMINIUM TERMINALS**

1	2	3	4
Terminal number	Diameter <i>d</i> mm	Length <i>L</i> mm	Assigned current rating A
15	20	80	800
16	30	80	1250
17	30	125	1250
18	40	80	1250
19	40	125	2000
20	60	125	3150

NOTE: The assigned values given above are considered to be reasonable for general applications. However current-ratings for cylindrical transformer and wall bushing terminals vary with respect to application and voltage in manufacturers' literature and thus reference should be made to such literature; reference should also be made to ENA transformer drawings.

APPENDIX A  
BASIS FOR DESIGN OF TERMINALS  
(Informative)

## A1 SCOPE

This Appendix outlines the basis on which the details and dimensions shown in Figures 1 to 3 have been determined.

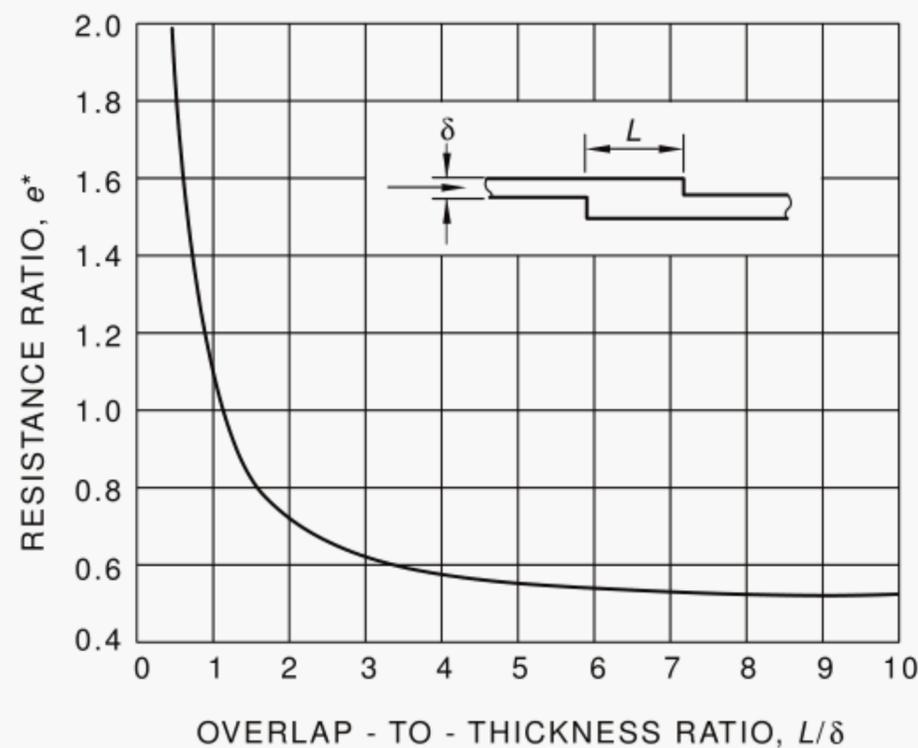
## A2 PALM TERMINALS

### A2.1 Streamline effect

Investigations have shown that the resistance of a perfect overlapping joint is higher than would be expected from the cross-section involved. This phenomenon, due to distortion of the lines of flow of current, is known as ‘streamline effect’.

Figure A1 shows how the resistance due to streamline effect of an overlapping joint of two bars can be calculated in relation to the resistance of an equal length of a single bar.

Since the  $L/\delta$  ratio of each palm terminal joint specified in this standard is greater than 5, then the ratio  $e$  is acceptable.



$$*e = \frac{\text{Total joint resistance}}{\text{Resistance of equal length of single bar}}$$

NOTE: This graph is based on graphs in the following publications:

Copper for Bushbars—Copper and Brass Information Centre.

The Alcoa Bus Conductor Handbook—The Aluminium Company of America.

FIGURE A1 RESISTANCE DUE TO STREAMLINE EFFECT OF OVERLAPPING JOINT OF TWO BARS

### **A2.2 Width of palm terminals**

Wherever possible the widths of palm terminals have been selected in accordance with the preferred sizes for wrought non-ferrous rectangular bars in AS 2338.

Where these widths cannot be achieved, it is expected that the terminals will be cast, cut from plate or forged.

### **A2.3 Hole sizes and spacings**

Hole sizes and spacings are in accordance with IEC 62271-301 except for palm terminal numbers 12 to 14, a hole spacing of 70 mm is used in one direction to provide clearance for the barrels of compression type conductor palm terminals when used thereon, and to allow conductor palm terminal number 7 to be bolted side-by-side on the palm without interference.

## **A3 CYLINDRICAL TERMINALS**

The dimensions given in Table 2 for cylindrical terminals are in accordance with IEC 62271-301.

## **A4 TERMINALS—GENERAL**

Materials are not specified in IEC 62271-301 nor is coordination given between dimensions and rated current.

## APPENDIX B

## RECOMMENDATION FOR THE DESIGN AND PREPARATION OF JOINTS

(Informative)

**B1 SCOPE**

This Appendix outlines the recommended requirements for design and preparation of terminal joints for the purpose of achieving long-term joint performance. It applies to both palm and cylindrical terminals.

**B2 JOINT DESIGN****B2.1 Factors of design**

The relevant factors to be considered are as follows:

- (a) Current density at the joint faces (see Clause 5).
- (b) Contact pressure—within the range of 5.5 MPa to 10 MPa (see Paragraph B2.2.2).
- (c) Working temperature (see Note to Paragraph B2.2.1).
- (d) Terminal materials—materials selected should have adequate conductivity and yield strength.
- (e) Bolt sizes and strengths (see Paragraph B2.2.4).
- (f) Differential expansion of materials and consequent stresses on components (see Paragraph B2.2.5).
- (g) Corrosion—selection of suitable materials and jointing compounds (see Paragraphs B2.2.3 and B3).
- (h) Bolt tightening torques (see Paragraphs B2.2.1 and B2.2.2).
- (i) Washers and pressure plates—taking into consideration the bearing strength of material and stress per bolt (see Paragraph B2.2.6).
- (j) Security of the joint locking plates or lock washers (see Paragraph B2.2.7).

**B2.2 Application guide for terminal palm joint assembly design****B2.2.1 General**

The steps set out in this Paragraph B2.2 should be followed when the appropriate bolts and washers are being chosen for joints to a particular terminal palm.

NOTE: It can be assumed that the sizes and values given in Tables B1 to B3 and B5 to B7 will give a satisfactory joint assembly for two palms together, either one or both aluminium or copper, at working temperatures up to 90°C when the initial tightening torques are applied at any temperature down to 0°C. Commercial bolts (see Table B4) are not of sufficient strength to withstand the thermal expansion of aluminium palms over this complete temperature range.

**B2.2.2 Contact pressure**

From terminal palm contact area, number of bolts and size of bolts, determine a bolt load that gives a satisfactory initial joint contact pressure. Table B1 gives satisfactory values for steel bolts. Table B2 gives satisfactory values for M12 aluminium alloy bolts for aluminium alloy palm terminals.

The values of torque given in Table B1 are for lubricated stainless steel and galvanized steel bolts.

The torque values given in Table B2 are for lubricated aluminium alloy bolts. However the relevance of the value  $2.4 \times 10^{-4}$  for  $k$  needs to be checked for bolts of a particular manufacture.

For torques applicable to unlubricated and/or uncoated bolts, the bolt manufacturer's literature should be consulted.

For palm terminal numbers referred to in Tables B1 and B2 see Figures 1 and 2.

### **B2.2.3** *Corrosion*

Consider choice of bolt material in terms of atmospheric and electrolytic corrosion.

### **B2.2.4** *Bolt strength*

Choose a bolt strength grade to give an initial appropriate factor of safety based on initial bolt loading (see Tables B3 to B6).

### **B2.2.5** *Differential expansion*

Consider additional bolt loading caused by differential temperature expansion of bolt, washers and palms (see Paragraph B2.2.8) and check the resultant bolt loads and factors of safety. Assumptions may be made, however, in accordance with the Note to Paragraph B2.2.1, that all the bolt tables in this Appendix except Table B4, commercial bolts, grade 4.6 to AS 1111.1, give a satisfactory joint design.

**TABLE B1**  
**BOLT SIZE, LOAD AND JOINT CONTACT PRESSURE FOR PALM**  
**TERMINALS—STEEL BOLTS**

1	2	3	4	5	6	7
Palm terminal number	Number of bolts per joint	Bolt nominal size	Torque applied to nut <i>T</i> N.m	Bolt load <i>P</i> kN	Joint contact area  mm <sup>2</sup>	Joint contact pressure  MPa
1	1	M12	20	8	780	10
2	1	M12	20	8	1430	6
3	2	M12	45	18	3670	10
4	2	M12	45	18	4670	8
5	4	M12	45	18	9300	8
6	2	M12	45	18	4270	8
7	2	M16	90	28	7730	7
7	2	M20	110	28	7730	7
8	4	M16	90	28	15300	7
8	4	M20	110	28	15300	7
9	6	M16	90	28	21000	8
9	6	M20	110	28	21000	8
10	8	M16	90	28	28100	8
10	8	M20	110	28	28100	8
11	2	M16	90	28	6430	9
11	2	M20	110	28	6430	9
12	4	M16	90	28	—	7
12	4	M20	110	28	—	7
13	6	M16	90	28	—	7
13	6	M20	110	28	—	7
14	8	M16	90	28	33270	7
14	8	M20	110	28	33270	7

**TABLE B2**  
**BOLT LOAD AND JOINT CONTACT PRESSURES FOR ALUMINIUM PALM**  
**TERMINALS—M12 ALUMINIUM ALLOY BOLTS**

1	2	3	4	5	6
Palm terminal number	Number of bolts per joint	Torque applied to nut <i>T</i> N.m	Bolt load <i>P</i> kN	Joint contact area  mm <sup>2</sup>	Joint contact pressure  MPa
3	2	38	13	3670	7
4	2	38	13	4670	6
5	4	38	13	9300	6
6	2	38	13	4270	6

NOTE TO TABLE B1 AND B2: The required torques may be obtained from the following torque/bolt load relationship:

$$T = k p d$$

where

$T$  = the torque, in newton metres

$k$  = a constant of  $2 \times 10^{-4}$  for both stainless steel and galvanized steel bolts and a constant of  $2.4 \times 10^{-4}$  for aluminium alloy bolts where the torque is applied to the nut and suitable lubricant is applied to the sliding surfaces (see Paragraph B3.4)

$p$  = the bolt load, in newtons

$d$  = the bolt diameter, in millimetres.

**TABLE B3**

**GALVANIZED PRECISION BOLTS GRADE 8.8 TO AS 1110.1**

1	2	3	4	5	6	7
Bolt nominal size	Tensile stress area  mm <sup>2</sup>	Applied load  kN	Tensile strength ( $R_m$ ) 800 MPa		Stress at permanent set limit ( $R_{p0.2}$ ) 640 MPa	
			Min. breaking load kN	Factor of safety	Proof load kN	Factor of safety
M12	84.3	8	67.4	8.4	54.0	6.8
		18	67.4	3.7	54.0	3.0
M16	157	28	126	4.5	100.2	3.6
M20	245	28	196	7.0	156.8	5.6

NOTE: The term  $P_{p0.2}$  refers to 0.2 percent proof stress.

**TABLE B4**

**GALVANIZED COMMERCIAL BOLTS GRADE 4.6 TO AS 1111.1**

1	2	3	4	5	6	7
Bolt nominal size	Tensile stress area  mm <sup>2</sup>	Applied load  kN	Tensile strength ( $R_m$ ) 400 MPa		Yield point stress ( $R_{eL}$ ) 240 MPa	
			Min. breaking load kN	Factor of safety	Yield load kN	Factor of safety
M12	84.3	8	33.7	4.2	20.3	2.5
M20	245	28	98.0	3.5	58.8	2.1

**TABLE B5**  
**STAINLESS STEEL BOLTS**

1	2	3	4	5	6	7
Bolt nominal size	Tensile stress area  mm <sup>2</sup>	Applied load  kN	Tensile strength ( $R_m$ ) 615 MPa		Yield point stress ( $R_{p0.2}$ ) 308 MPa	
			Min. breaking load kN	Factor of safety	Proof load kN	Factor of safety
M12*	84.3	8	52.0	6.5	26.1	3.3
		18	52.0	2.9	26.1	1.5
M16*	157	28	96.5	3.5	48.4	1.7
M20†	245	28	150.7	5.4	58.8	2.1

\* Applies to bolts manufactured from American Iron and Steel Institute (AISI) grade 305 stainless steel by the cold-forging process with threads formed by cold rolling. The proof loads and subsequent factors of safety do not take account of the increase due to cold working and are therefore absolute minimum values.

† Applies to bolts machined from grade 303 stainless steel to AS 1444. This is a free machining grade steel and is chosen for M20 bolts because facilities for cold rolling of threads larger than M16 do not exist in Australia. These bolts would not attain any increase in strength owing to the manufacturing process.

**TABLE B6**  
**ALUMINIUM ALLOY BOLTS**

1	2	3	4	5	6	7
Bolt nominal size  mm	Tensile stress area  mm <sup>2</sup>	Applied load  kN	Tensile strength ( $R_m$ ) 289 MPa		Yield point stress ( $R_{p0.2}$ ) 241 MPa	
			Min. breaking load kN	Factor of safety	Proof load kN	Factor of safety
M12	84.3	12.9	23.1	1.8	20.3	1.6

NOTE: Applies to bolts manufactured from alloy 6061 temper T6 complying with AS/NZS 1865.

### B2.2.6 Bearing strength

Check the maximum compressive stress on the palm material and choose an appropriate load spreading washer or plate. For aluminium palms with steel bolts, heavy duty flat washers in accordance with Table B7 should be used to prevent plastic deformation of the aluminium. With two aluminium palms and aluminium alloy bolts, standard flat washers may be used. For copper palms, no special load spreading provision is necessary. Care should be taken to avoid forming a magnetic loop through bolts and touching washers or through bolts and plates if joint assemblies other than those recommended in this Standard are used.

**TABLE B7**  
**HEAVY DUTY FLAT GALVANIZED STEEL WASHERS**

millimetres							
1	2	3	4	5	6	7	8
Nominal size	Inside diameter		Outside diameter		Thickness		
	max.	min.	max.	min.	nom.	max.	min.
12	13.5	13	44	43	6	6.29	5.71
16	18	17	55	54	6	6.29	5.71
20	22	21	55	54	6	6.29	5.71

NOTE: The washers should be in accordance with AS 1237.1 except for dimensions.

### B2.2.7 Security of joint

Locking of the bolt and nut should be provided by locking plates with flat washers. With pressure plates or bare palms, helical spring washers or tab washers may be used. Standardized dimensions of locking plates are given in Table B8.

**TABLE B8**  
**STAINLESS STEEL LOCKING PLATES**

millimetres				
1	2	3	4	5
Nominal size	Hole diameter	Length	Width	Thickness
12	14	82	22	1.0
16	18	104 or 114 (Note 2)	28	1.0
20	22	116 or 126 (Note 2)	35	1.0

NOTES:

- 1 The plates should be to Grade 304 of AS 1444.
- 2 Dependent upon hole spacing in palm terminal.

### B2.2.8 Basis of application guide

The application guide takes into account the loads, strengths and thermal expansions of the materials and components recommended to make a joint assembly. It is based simply on the following:

- (a) Modulus of elasticity  $E = \frac{\Delta p L}{e A}$
- (b) The coefficient of thermal expansion  $\alpha = \frac{e}{L t}$

From (a) and (b) above, for a simple structure

$$\Delta p = \frac{L \alpha t}{L / E A}$$

where

- $E$  = modulus of elasticity  
 $\Delta p$  = increase in bolt load  
 $L$  = dimension of object  
 $e$  = elastic or thermal extension of object

- $A$  = cross-sectional area of object  
 $\alpha$  = coefficient of thermal expansion  
 $t$  = temperature rise.

In an assembly of two palms with bolts and washers (see Figure B1), a composite formula which takes account of the various components of the assembly is as follows:

$$\Delta p = \frac{t(L_{W1}\alpha_{W1} + L_{P1}\alpha_{P1} + L_{P2}\alpha_{P2} + L_{W2}\alpha_{W2} - L_B\alpha_B)}{\frac{L_B}{A_B E_B} + \frac{L_{W1}}{A_{W1} E_{W1}} + \frac{L_{P1}}{A_{P1} E_{P1}} + \frac{L_{P2}}{A_{P2} E_{P2}} + \frac{L_{W2}}{A_{W2} E_{W2}}}$$

where

- $\Delta p$  = increase in bolt load  
 $L$  = length (see Figure B1)  
 $E$  = modulus of elasticity  
 $A$  = area of cross-section of area of interface as applicable  
 $\alpha$  = coefficient of thermal expansion  
 $t$  = temperature rise  
 $B$  = bolt  
 $W1$  = washer 1 (see Figure B1)  
 $W2$  = washer 2 (see Figure B1)  
 $P1$  = palm 1 (see Figure B1)  
 $P2$  = palm 2 (see Figure B1)

NOTE:  $A_w$  and  $A_v$  represent effective (bearing) areas at the washer/palm interface.

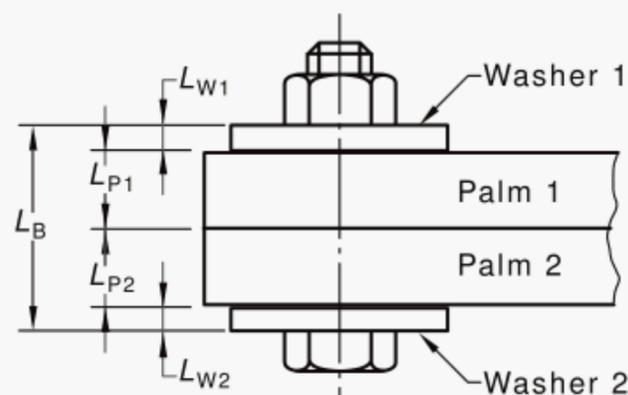


FIGURE B1 ASSEMBLY OF TWO PALMS WITH BOLT AND WASHERS

### B3 JOINT PREPARATION

#### B3.1 Copper-to-copper joints

Contact faces for copper-to-copper joints should be flat and clean but need not be highly polished or machined. Cleaning may be carried out using solvent to remove all grease and emery cloth or a wire brush to remove the oxide layer. Contact faces may then be coated with jointing compound or other suitable grease and the joint made.

Contact faces may also be tin coated or electroplated with nickel or silver if required.

### **B3.2 Aluminium-to-aluminium joints**

Aluminium, as soon as it is exposed to air, forms an invisible oxide film which has high electrical resistance. It is essential that this film be removed before a joint is made and precautions be taken to prevent the oxide re-forming either before or during the life of the joint. Thus, for all jointing of aluminium conductors other than welding, the preparation of the contact face is vital to the proper making of the joint as also are the precautions which have to be taken to prevent aluminium oxide re-forming which would result in serious deterioration of performance in service.

Proprietary brands of special jointing compounds specially designed for use with aluminium are available. Some compounds include materials which remove or break down the oxide film on the contact face of the aluminium and the compound will not deteriorate under a wide temperature range and is weather-resistant. Such compounds may also be used in making compression type joints with stranded aluminium conductors.

A commonly used practice is as follows:

- (a) The contact faces must be flat and free from blemishes and should first be cleaned with solvent, a clean wire brush or emery cloths to remove all grease and dirt.
- (b) A coating of the special aluminium jointing compound is then applied and the joint faces abraded with emery cloth or a wire brush, so that the oxide film is removed under the compound and is prevented from re-forming. Other special proprietary compounds designed to remove the aluminium oxide layer by chemical reaction may be used. Care should be taken that the joint faces are not then contaminated or disturbed prior to bolting-up.
- (c) The joint is then assembled, the bolts tightened with a torque wrench as prescribed and any surplus compound squeezed from the joint wiped off.

The manufacturer's instructions in the use of these compounds should be followed when making the joint.

### **B3.3 Copper-to-aluminium joints**

Joints between aluminium and copper conductors can be prepared and made by the same methods as given in Paragraph B3.2. Where the joints are for use outdoors, consideration may be given to tin coating the copper face, preferably by hot-dip tinning and this should extend 12 mm beyond the joint area.

Experience has shown, however, that tin coating is not essential. The copper/aluminium joint should, where practicable, be arranged so that the aluminium is installed above the copper to prevent water-borne copper salts being deposited on the aluminium and possibly causing electrolytic corrosion.

### **B3.4 Lubrication of threads**

To reduce the amount of 'scatter' in bolt tensions achieved by the application of a given torque, the bolt threads and the nut/washer bearing face should be liberally coated with jointing compound. Where jointing compound is not applied to the joint faces, e.g. copper-to-copper joints, other suitable grease type lubricants may be used.

NOTES

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