

AS/NZS 4534:2006  
Reconfirmed 2017

Australian/New Zealand Standard™

**Zinc and zinc/aluminium-alloy coatings  
on steel wire**



## **AS/NZS 4534:2006**

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee MT-009, Metal Finishing. It was approved on behalf of the Council of Standards Australia on 8 June 2006 and on behalf of the Council of Standards New Zealand on 16 June 2006.

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

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**RECONFIRMATION**

**OF**

**AS/NZS 4534:2006**

**Zinc and zinc/aluminium-alloy coatings on steel wire**

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**RECONFIRMATION NOTICE**

Technical Committee MT-009 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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Galvanizers Association of Australia  
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New Zealand Metal Roofing Manufacturers

## NOTES

# Australian/New Zealand Standard™

## Zinc and zinc/aluminium-alloy coatings on steel wire

Originated, in part, as part of AS K53.1—1934 and AS K53.2—1935.  
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## PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee MT-009, Metal Finishing, to supersede AS/NZS 4534:1998, *Zinc and zinc/aluminium-alloy coatings on steel wire*.

The objective of this Standard is to specify requirements for zinc/aluminium-alloy coatings on steel wire and on fabricated wire products. The coatings are formed by the application of molten metal by hot dipping using a specialized continuous process, or by electroplating. However, in this revision of the Standard, a further range of coatings, specifically of high coating mass, has been added. The purpose of these new coatings, which first appeared in AS 2423—2002, *Coated steel wire fencing products for terrestrial, aquatic and general use*, is to provide superior protection to steel wire subjected to the more aggressive forms of corrosive environment, such as immersion in seawater.

This edition contains improved guidelines, set out in an Appendix, for the selection of appropriate coatings for the corrosion protection of steel wire.

During the preparation of this Standard cognisance was taken of ISO 7989:1988, *Zinc coatings for steel wire*. However, this international Standard could not be endorsed as an Australian Standard, as it is deficient in technical detail and is considered unsuitable by Australian industry.

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, where an ‘informative’ appendix is only for information and guidance.

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## STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

**Australian/New Zealand Standard****Zinc and zinc/aluminium-alloy coatings on steel wire****1 SCOPE**

This Standard specifies requirements for the mass, quality and testing of zinc coatings and zinc/aluminium-alloy coatings on steel wire of circular or non-circular (shaped) cross-section. The coatings are applied in a continuous process and may be formed either by the application of molten metal or by electrodeposition.

Six standard coating mass classes and a range of special coating mass classes are covered. The standard classes are intended, in general, for applications subjected to normal atmospheric corrosion conditions, whereas the special classes are specifically designed to provide acceptable durability under severe to extreme service conditions, such as for prolonged immersion in freshwater or seawater.

This Standard applies to coatings on wire at its final size, whether or not the coating has been applied after final cold working, prior to cold working, or at an intermediate stage of cold working.

Matters not relating to the coating itself are outside the scope of this Standard.

This Standard does not apply to coatings on articles that have been fabricated from uncoated steel wire and which have subsequently been coated with zinc or zinc/aluminium alloy, except where the coating has been applied in a specialized continuous process (e.g. for wire netting) as opposed to batch treatment (e.g. for nails).

**NOTES:**

- 1 Advice and recommendations on information to be supplied by the purchaser at the time of enquiry or order are contained in Appendix A.
- 2 Coatings in accordance with this Standard may not be available in every combination of wire size, coating mass class and coating type. Reference should be made to appropriate Australian Standards for the types of wire involved.
- 3 Means for determining compliance with this Standard are given in Appendix B.
- 4 Except as stated in this Clause, requirements for zinc coatings on manufactured wire articles, which have been electroplated following fabrication, are given in AS 1789.
- 5 This Standard does not specify the Preece test for coating uniformity. If this test is required, arrangements should be made between the purchaser and the supplier.

**2 REFERENCED DOCUMENTS**

The following documents are referred to in this Standard:

**AS**

1199	Sampling procedures for inspection by attributes
1199.0	Part 0: Introduction to the ISO 2859 attribute sampling system
1199.1	Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection
1242	Zinc ingots
1329	Methods for the analysis of zinc and zinc alloys
1329.1	Method 1: Determination of aluminium content—Titrimetric method



AS	
1789	Electroplated zinc (electrogalvanized) coatings on ferrous articles (batch process)
2331	Methods of test for metallic and related coatings
2331.1.4	Method 1.4: Local thickness tests—Magnetic induction and eddy current methods
2331.2.3	Method 2.3: Tests for average coating mass per unit area or for thickness—Hydrogen evolution method for zinc coatings
2331.3.1	Method 3.1: Corrosion and related property tests—Neutral salt spray (NSS) test
2505	Metallic materials
2505.6	Method 6: Wire—Wrapping test
2706	Numerical values—Rounding and interpretation of limiting values
AS/NZS	
2243	Safety in laboratories
2243.1	Part 1: Planning and operational aspects
2243.2	Part 2: Chemical aspects
2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
AS/NZS ISO	
9001	Quality management systems—Requirements
9004	Quality management systems—Guidelines for performance improvements
HB18.28	Conformity assessment—Guidance on a third party certification system for products
ISO	
9223	Corrosion of metals and alloys—Corrosivity of atmospheres—Classification
SANZ	
HB18.28	Guide 28—General rules for a model third-party certification system for products

### 3 DEFINITIONS

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

#### 3.1 Coating class

An alphanumeric notation describing the coating mass in relation to the wire size for standard coatings, but independent of wire size for special coatings (see Clauses 4.2 and 8).

#### 3.2 Coating mass

Mass of zinc coating or zinc/aluminium-alloy coating per unit surface area of steel base, expressed in grams per square metre.

#### 3.3 Electrogalvanized coating

A zinc coating (see Clause 3.7) applied to the wire by electrodeposition.

NOTE: In order to avoid confusion, it is essential that the term ‘electrogalvanized’ and any of its derivatives not be shortened to ‘galvanized’ or any of its abbreviations, such as ‘galv’, since ‘galvanized’ is conventionally employed for the hot-dip process.

### 3.4 Galvanized coating

A zinc coating (see Clause 3.7) alloyed to the steel substrate and applied to the wire by hot-dip immersion in molten zinc of at least 98% purity by mass.

### 3.5 Hot-dip coating

A coating applied by immersion of separated single strands of wire, or of a continuous length of fabricated wire product, in a bath of molten zinc or zinc/aluminium alloy.

### 3.6 Wire

A steel filament of dimensionally uniform cross-section along its length, which is either the feedstock for coating or is finish-coated with zinc or zinc/aluminium alloy.

### 3.7 Zinc coating

A coating composed essentially of zinc, with or without zinc/iron alloy formation at the zinc/iron interface, and produced in a continuous manufacturing operation by dipping (immersing) prepared and separated single strands of steel wire, or a continuous length of fabricated wire product, in a bath of at least 98% purity by mass of molten zinc, or in an electroplating bath containing a solution of an appropriate zinc salt.

### 3.8 Zinc/aluminium-alloy coating

A coating applied in a continuous manufacturing operation by dipping (immersing) either uncoated or zinc-coated separated single strands of steel wire, or a continuous length of fabricated wire product, in a bath of molten zinc/aluminium alloy containing between 4.5% and 50% aluminium. The designated nominal aluminium content is based on the resultant aluminium content of the coating, usually taken to be the nominal aluminium content of the bath.

## 4 DESIGNATION

### 4.1 General

The coating class, type and material shall be designated in sequence as follows:

- (a) The number of this Standard, i.e. AS/NZS 4534.
- (b) The coating class (see Clause 4.2).
- (c) The coating type and material (see Clause 4.3).

### 4.2 Designation of coating class

For standard coatings, the coating class shall be designated by the letter W followed by a two-digit number, as follows: W02, W05, W10, W15, W20 or W25 (see Table 1).

For special coatings, the coating class shall be identified by the letters SW followed by a number representing the specified minimum coating mass in  $\text{g/m}^2$  (see Clause 8.2).

### 4.3 Designation of coating type and material

The coating type and material shall be designated in accordance with the following:

- (a) Hot-dip zinc or zinc/aluminium-alloy coating applied at final size:
  - (i) Zinc .....Z.
  - (ii) Zinc/aluminium alloy .....ZA.
- (b) Electroplated zinc coating applied at final size .....E.
- (c) Drawn (or rolled) after hot-dip coating ..... DZ or DZA, as appropriate.
- (d) Drawn (or rolled) after electroplating ..... DE.

For zinc/aluminium-alloy coatings, the designation ZA shall include a number inserted between the letters to indicate the nominal percentage of aluminium by mass in the coating (see Clause 3.8), e.g. Z5A for 5% of aluminium.

Examples of designation:

- (i) Example 1: AS/NZS 4534/W02Z—hot-dip zinc, Class W02.
- (ii) Example 2: AS/NZS 4534/W05Z10A—hot-dip zinc/10% aluminium, Class W05.
- (iii) Example 3: AS/NZS 4534/W25E—electroplated zinc (at final size), Class W25.
- (iv) Example 4: AS/NZS 4534/W10DZ—drawn (or rolled) hot-dip zinc, Class W10.
- (v) Example 5: AS/NZS 4534/SW600Z—special coating, hot-dip zinc, 600 g/m<sup>2</sup> minimum.

## 5 WIRE MANUFACTURING PROCESS

### 5.1 Continuous coating process

#### 5.1.1 Raw materials

Zinc for replenishing the molten bath, or for electrodes for electrolysis, shall comply with the requirements of AS 1242 and shall be of 98.5% purity, or better, depending on the quality demands of the coating process.

Zinc/aluminium-alloy bath replenishment shall be accomplished in such a way that the aluminium content of the zinc/aluminium alloy coating on the wire (see Clause 3.8) is within +0.5% and –0.5% of the designated nominal value. Raw material additions to the bath may contain minor levels of control elements.

#### 5.1.2 Precautions

The wire manufacturer shall take care in the coating process to avoid undue changes to the mechanical properties of the steel base, particularly in respect of embrittlement, and to avoid damage, such as scoring, of the coating itself.

NOTE: Appendix C gives advice on unavoidable changes, which may occur to the mechanical properties of softened wires, and on the effects of hydrogen embrittlement resulting from electrodeposition.

The wire manufacturer shall take every precaution to ensure that the coating is free of irregularities and defects (see Clause 6).

### 5.2 Drawing or rolling process

For wires that are cold worked after the application of the coating, due care shall be taken by the manufacturer to avoid damage to the coating, such as abrasion, scoring or chatter marks, either prior to, or at any stage of, the cold working operation.

### 5.3 Supplementary non-metallic coatings

Zinc or zinc/aluminium-alloy coatings may be covered with a supplementary adherent coating, such as chromate, paint, plastic, wax, or residual drawing lubricant.

NOTES:

- 1 Hot-dip zinc or zinc/aluminium-alloy coatings may carry a thin covering of wax, applied to reduce friction during subsequent mechanical forming treatments.
- 2 Zinc or zinc/aluminium-alloy coated wires that have subsequently been drawn normally carry a thin covering of wire-drawing lubricant.

## 6 APPEARANCE

The zinc coating or zinc/aluminium-alloy coating shall be continuous, as smooth and evenly distributed as modern industrial technology permits, and be free of defects that are detrimental to the stated use of the wire.

### NOTES:

- 1 Defects cannot be completely quantified. Where the presence, size or frequency of defects in the coating is considered to be of concern, appropriate arrangements should be made between the purchaser and the wire manufacturer or supplier. This may be achieved by the provision of acceptable type samples or methods of test.
- 2 The coating on hot-dip galvanized or zinc/aluminium-alloy-coated wire is not perfectly smooth or devoid of irregularities. It should be noted that diameter or dimensional tolerances, required by appropriate wire or wire product specifications, apply to representative uniformly coated areas of the wire.
- 3 With increasing coating mass, hot-dip coatings usually become less smooth.
- 4 Hot-dip coatings applied in a specialized continuous process to fabricated wire articles are usually not as smooth as coatings applied to single wire strands.
- 5 The finish of untreated zinc-coated wire, i.e. without a supplementary non-metallic coating (see Clause 5.3), is usually a lustrous silver colour when produced, but ages to a dull grey. Zinc/aluminium-alloy coatings age from silver, when initially produced, to a deep grey. Provided that the coating complies with the requirements of this Standard, the colour and lustre of the finish should not be considered detrimental to the performance of the coating in service.
- 6 Advice on the transport and storage of coated wire is given in Appendix D.

## 7 SELECTION OF TEST SPECIMENS FOR COATING MASS AND COATING ADHERENCE TESTS

### 7.1 General

A suitable length of wire for performing the required tests shall be cut from one or both ends of each coil selected for sampling. If the ends of the coil are damaged or otherwise abnormal, an appropriate length of wire shall be discarded before taking the test lengths. Any supplementary non-metallic coating (see Clause 5.3), which may interfere with testing, shall be removed, taking care not to damage the surface of the zinc or zinc/aluminium-alloy coating.

Lengths taken from products or articles fabricated from zinc-coated or zinc/aluminium alloy-coated wire shall be as representative as possible of the original coated wire.

Lengths taken from products or articles that have been zinc or zinc/aluminium alloy-coated after fabrication, by means of a specialized continuous operation, shall be as representative as possible of the batch involved.

Unless specified otherwise, test specimens taken from fabricated products or articles shall not be required to undergo adherence testing. However, the adhesion of the coating shall be fit for purpose.

### 7.2 Coating mass

The lengths of test specimens required for gravimetric, volumetric or non-destructive determination of coating mass are specified in Paragraphs E2.3, E3.4 or E4 respectively of Appendix E.

### 7.3 Adherence of coating

The test specimen shall be cut from the sample and shall be of sufficient length to ensure complete control of the wrapping or bending operation employed for adherence testing.

## 8 TEST METHOD AND REQUIREMENTS FOR COATING MASS

### 8.1 General

The coating mass of zinc or zinc/aluminium-alloy coatings on steel wire of circular or non-circular cross-section, as produced, shall be determined in accordance with one of the methods specified in Paragraphs E2, E3 or E4 of Appendix E. In cases of dispute, the gravimetric method (see Paragraph E2, Appendix E) shall be used as the referee test method.

The coating mass of zinc or zinc/aluminium-alloy coatings on round wire shall conform to the limits specified in Table 1 for standard coatings and as given in Clause 8.2 for special coatings. For shaped wires, an equivalent nominal diameter appropriate to Table 1 is determined using the following equation:

$$d = \frac{c}{\pi} = 0.318c$$

where

$d$  = the equivalent nominal diameter corresponding to the nominal size of the coated shaped wire, in millimetres

$c$  = the circumference of the nominal size of the coated shaped wire, in millimetres

NOTE: The 'nominal diameter' shown in Table 1 relates to the zinc or zinc/aluminium alloy-coated wire, excluding any supplementary non-metallic coating.

If coating mass determinations are carried out on products that have been fabricated from zinc-coated or zinc/aluminium alloy-coated wires, the specified minimum coating masses shown in Table 1 and in Clause 8.2 shall be reduced by 3%, and then rounded to the nearest 5 g/m<sup>2</sup>, unless specifically stated otherwise in the relevant product Standards.

### 8.2 Specific requirements for special coatings

For special zinc or zinc/aluminium-alloy coatings, the specified coating mass shall be at least 300 g/m<sup>2</sup> minimum with incremental increases of 50 g/m<sup>2</sup>; that is, 300, 350, 400, 450 g/m<sup>2</sup> minimum and so on.

NOTES:

- 1 Special SW coating masses are independent of wire size; that is, the specified coating mass does not vary with wire size.
- 2 Not every specified minimum coating mass nor wire size may be commercially available.

## 9 TEST METHOD AND REQUIREMENTS FOR COATING ADHERENCE

The adherence of the zinc coating or zinc/aluminium-alloy coating shall be tested by means of a cylindrical mandrel. For wires of circular cross-section the relationship between mandrel diameter and wire diameter shall be in accordance with Table 2. For shaped wire, unless specified to the contrary, the nominal diameter given in Table 2 shall be taken to be its overall minor dimension.

NOTES:

- 1 This test applies only to wire where the coating is clearly visible through any thin, supplementary non-metallic coating (such as wax or wire-drawing lubricant), or where no supplementary non-metallic coating exists, or where it has been carefully stripped from the wire.
- 2 The 'nominal diameter' shown in Table 2 relates to the diameter of the zinc or zinc/aluminium-alloy coated wire, excluding any supplementary non-metallic coating.

For wires of nominal diameter 7.50 mm and smaller, the adherence of the coating shall be tested by wrapping the wire at least six close turns snugly around the mandrel as specified in Table 2 (see Note 3), and in accordance with the procedure given in AS 2505.6. For wires over 7.50 mm nominal diameter, the adherence of the coating shall be tested by bending the wire through an angle of at least 90° around the appropriate mandrel specified in Table 2.

The coating shall remain firmly adherent to the steel base and shall not crack or flake to a degree that any flakes of coating can be removed by rubbing with the bare fingers.

NOTES:

- 1 Loosening or detachment of small particles of coating during the adherence test, arising from mechanical polishing of the surface of the coated wire, should not be deemed cause for rejection. Small particles of coating, formed as small globules or fragments on the surface during the coating process, may loosen or detach during the test, and this too should not be deemed to be cause for rejection.
- 2 Due care should be exercised in selecting the appropriate mandrel for the wrap or bend test since such mandrels are usually marked with radius rather than diameter.
- 3 With shaped wires carrying less than Class W10 coatings, it may be found impracticable to satisfactorily perform the wrap test as specified, when the ratio of the major dimension to the minor overall dimension is greater than 1.5. In such instances, the adherence of the coating may be tested by bending the wire through an angle of at least 90° around the mandrel appropriate to the minor dimension, which is taken as the nominal diameter.

## 10 CORROSION RESISTANCE

The corrosion resistance of zinc-coated or zinc/aluminium-alloy coated wire is dependent on a number of factors including coating thickness and the atmospheric environment to which it is subjected.

NOTE: Guidance on the selection of coatings for various corrosive environments is given in Appendix F.

## 11 ROUNDING OF TEST RESULT VALUES

The determined value of coating mass shall be rounded to the nearest 5 g/m<sup>2</sup>. For advice on the method of rounding see AS 2706.

## 12 MARKING

Except where a wire or a wire product is covered by an Australian or Australian/New Zealand Standard, which refers the coating requirements to a specific class in this Standard, each coil of wire shall be legibly and durably tagged to enable the coating to be identified with this Standard. The information on the tag pertaining to the coating shall include the following:

- (a) The number of this Standard, i.e. AS/NZS 4534.  
NOTE: Where the space is limited on the tag, manufacturers may designate the number of this Standard as AS 4534 or NZS 4534, as appropriate.
- (b) Designation of coating class (see Clause 4.2).
- (c) Designation of coating type and material (see Clause 4.3).
- (d) Manufacturer's trade identification.

NOTE: Manufacturers making a statement of compliance with this Australian/New Zealand Standard on a product, packaging, or promotional material related to that product are advised to ensure that such compliance is capable of being verified.

**TABLE 1**  
**STANDARD COATING MASSES FOR ROUND WIRE**

Nominal diameter of coated wire, mm	Minimum coating mass, g/m <sup>2</sup>					
	Class W02	Class W05	Class W10	Class W15	Class W20	Class W25
>0.19 ≤0.23	—	15	25	40	50	65
>0.23 ≤0.33	—	25	45	70	90	115
>0.33 ≤0.40	—	35	60	90	120	150
>0.40 ≤0.46	—	40	75	115	150	190
>0.46 ≤0.53	—	50	90	135	180	225
>0.53 ≤0.63	20	60	105	160	210	265
>0.63 ≤0.75	20	65	120	180	240	300
>0.75 ≤0.85	25	70	130	195	260	325
>0.85 ≤0.95	25	80	140	210	280	350
>0.95 ≤1.06	25	85	150	225	300	375
>1.06 ≤1.18	25	90	160	240	320	400
>1.18 ≤1.32	30	95	170	255	340	425
>1.32 ≤1.55	30	100	185	280	370	465
>1.55 ≤1.80	35	110	200	300	400	500
>1.80 ≤2.24	35	120	215	325	430	540
>2.24 ≤2.72	40	125	230	345	460	575
>2.72 ≤3.15	45	130	240	360	480	600
>3.15 ≤3.55	50	135	250	375	500	625
>3.55 ≤4.25	60	140	260	390	520	650
>4.25 ≤5.00	70	150	275	415	550	690
>5.00 ≤8.00	80	160	290	435	580	725
>8.00 —	80	170	305	460	610	765

## NOTES:

- 1 The class identification numbers reflect the minimum coating masses relative to Class W10. For example, the minimum coating masses for Class W05 are approximately half those for Class W10; those for Class W25 are 2.5 times those for Class W10.
- 2 Guidance for the selection of coating mass and material to suit particular external exposure conditions is given in Appendix F.
- 3 For coating mass requirements for shaped wires, see Clause 8.1

**TABLE 2**  
**RELATIONSHIP BETWEEN MANDREL**  
**DIAMETER AND WIRE DIAMETER**

millimetres

Nominal diameter ( <i>d</i> ) of coated wire	Mandrel diameter	
	Classes W02 and W05	Classes W10 and over
$\leq 3.80$	$1d$	$4d$
$>3.80 \leq 10.00$	$1d$	$5d$
$>10.00$	$2d$	$6d$

NOTE: For mandrel diameters for shaped wires, see Clause 9.



APPENDIX A  
PURCHASING GUIDELINES  
(Informative)

**A1 GENERAL**

Australian/New Zealand Standards are intended to include the technical provisions necessary for the supply of products referred to in the particular Standard, but do not purport to comprise all the necessary provisions of a contract. This Appendix contains advice and recommendations on the information to be supplied by the purchaser at the time of enquiry or order.

**A2 INFORMATION TO BE SUPPLIED BY THE PURCHASER**

The purchaser should supply the following information at the time of enquiry or order:

- (a) The number of this Standard, i.e. AS/NZS 4534.
- (b) Designation of coating class, e.g. W10 and SW600 (see Clause 4.2).
- (c) Designation of coating material and process, or type, e.g. E for electroplated zinc, Z for hot-dip galvanized (see Clause 4.3).
- (d) For zinc/aluminium alloys, the nominal percentage of aluminium by mass, e.g. Z5A for 5% aluminium (see Clause 4.3).
- (e) Any special requirements for frequency of testing.
- (f) Whether an additional test for uniformity of the coating is required. Details of test requirements should be included.
- (g) Whether a test report covering coating mass and adherence is required.
- (h) Whether it is the intention of the purchaser to inspect the coated product prior to delivery.
- (i) Any special or supplementary requirements, such as a passivation coating.

NOTE: Soldering of material having a zinc/aluminium-alloy coating, or where passivation coatings have been applied, may present difficulties and may not be practicable.

**APPENDIX B**  
**MEANS FOR DEMONSTRATING COMPLIANCE WITH THIS STANDARD**  
**(Informative)**

**B1 SCOPE**

This Appendix sets out the following different means by which compliance with this Standard can be demonstrated by the manufacturer or supplier:

- (a) Evaluation by means of statistical sampling.
- (b) The use of a product certification scheme.
- (c) Assurance using the acceptability of the supplier's quality system.
- (d) Other such means proposed by the manufacturer or supplier and acceptable to the customer.

**B2 STATISTICAL SAMPLING**

Statistical sampling is a procedure which enables decisions to be made about the quality of batches of items after inspecting or testing only a portion of those items. This procedure will only be valid if the sampling plan has been determined on a statistical basis and the following requirements are met:

- (a) The sample needs to be drawn randomly from a population of product of known history. The history needs to enable verification that the product was made from known materials at essentially the same time, by essentially the same processes and under essentially the same system of control.
- (b) For each different situation, a suitable sampling plan needs to be defined. A sampling plan for one manufacturer of given capability and product throughput may not be relevant to another manufacturer producing the same items.

In order for statistical sampling to be meaningful to the customer, the manufacturer or supplier needs to demonstrate how the above conditions have been satisfied. Sampling and the establishment of a sampling plan should be carried out in accordance with AS 1199.1, guidance to which is given in AS 1199.0.

**B3 PRODUCT CERTIFICATION**

The purpose of product certification is to provide independent assurance of the claim by the manufacturer that products comply with the stated Standard.

The certification scheme should meet the criteria described in HB 18.28 (SANZ HB18.28) in that, as well as full type testing from independently sampled production and subsequent verification of conformance, it requires the manufacturer to maintain effective quality planning to control production.

The certification scheme serves to indicate that the products consistently conform to the requirements of the Standard.

## **B4 SUPPLIER'S QUALITY MANAGEMENT SYSTEM**

Where the manufacturer or supplier can demonstrate an audited and registered quality management system complying with the requirements of the appropriate or stipulated Australian or international Standard for a supplier's quality management system or systems, this may provide the necessary confidence that the specified requirements will be met. The quality assurance requirements need to be agreed between the customer and supplier and should include a quality or inspection and test plan to ensure product conformity.

Information on establishing a quality management system is set out in AS/NZS ISO 9001 and AS/NZS ISO 9004.

## **B5 OTHER MEANS OF ASSESSMENT**

### **B5.1 General**

If the above methods are considered inappropriate, determination of compliance with the requirements of this Standard may be assessed from the results of testing coupled with the manufacturer's guarantee of product conformance.

Irrespective of acceptable quality levels (AQLs) or test frequencies, the responsibility remains with the manufacturer or supplier to supply products that conform to the full requirements of the Standard.

### **B5.2 Sampling and testing for coating mass and coating adherence**

One sample should be taken from each continuous production run of 10 tonnes or less of each wire size. The sample should be identifiable with the coil from which it was selected.

### **B5.3 Compliance**

Each production run complies with this Standard if all of the samples tested give results that comply with the specified test requirements. If any of the tested samples fail to comply with specification, the requirements of Paragraph B5.4 apply.

### **B5.4 Retests**

Should any test piece from a sample first selected not comply with the test requirements specified, both ends of the coil concerned should be sampled and retested.

NOTE: Only one end of the coil concerned needs to be retested in cases where the other end is inherently inaccessible, e.g. where the coil is on a spool.

If any of these samples fails, then all coils comprising the batch should be tested, and only those coils that pass tests are deemed to comply with this Standard. Even if both samples pass tests, two further samples should be taken from other coils in the batch. If the test pieces from both of these additional samples comply with the test requirements, the production run represented by the samples is deemed to comply with this Standard. Should either of the test pieces from these additional samples not comply with the test requirements, all coils comprising the batch should be tested, and only those coils that pass tests are deemed to comply with this Standard.

APPENDIX C  
CHANGES IN MECHANICAL PROPERTIES CAUSED BY AGEING OR  
HYDROGEN EMBRITTLEMENT

(Informative)

Wires that have been softened (annealed) during the metal-coating process may exhibit changes in mechanical properties after manufacture. The changes result from a phenomenon known as ageing, or age-hardening, and are evidenced by a lowering in ductility and an increase in tensile and yield strengths, compared with values obtained for these properties immediately after the coating process.

It is customary during the manufacture of these softened wires to carry out testing immediately after coating. At room temperature, ageing proceeds relatively slowly and many weeks may pass before ageing reaches completion. It follows, therefore, that results of mechanical tests performed by the purchaser may be at variance with those reported by the manufacturer.

Hydrogen embrittlement may affect the mechanical properties of electroplated wires that have a tensile strength greater than about 1100 MPa. Such embrittlement should be relieved, in accordance with AS 1789, by heating to about 200°C for a period of time and before any supplementary non-metallic coating is applied.

## APPENDIX D

TRANSPORT AND STORAGE OF ZINC-COATED AND  
ZINC/ALUMINIUM ALLOY-COATED WIRES

(Informative)

Attention should be paid to the conditions of transport and storage of zinc-coated or zinc/aluminium alloy-coated wire, to which no supplementary protective coating (e.g. wax, chromate) has been applied in manufacture, in order to avoid the possibility of wet-storage stain.

This unsightly stain of corrosion products, commonly known as 'white-rust', can occur on newly metallic coated wire that is transported or stored under humid, badly ventilated conditions. However, while the corrosion products may detract from the as-produced appearance of the wire, they are usually not detrimental, unless storage under the unsatisfactory conditions is prolonged.

Storage under tarpaulins or polymer sheeting, since these restrict the circulation of air, or storage under conditions in warehouses or sheds where condensation may occur, especially overnight through falling temperature, is not recommended. Ideally, zinc-coated and zinc/aluminium alloy-coated wires should be stored above ground (on suitable racks, for example) and in warmed buildings, so that the relative humidity always remains low. (Zinc corrodes at a very slow rate in clean air where the relative humidity is below about 70%.)

When coils are stored under inappropriate conditions, condensation can occur and moisture can be retained between turns of wire through capillary action. Since drying is delayed by lack of circulating air within the close-packed turns, condensate retention is prolonged, and corrosion thereby promoted. In addition, moisture can gravitate to the lower parts of coils and lead to severe localized corrosion, given sufficient time in storage.

Severe localized corrosion can also occur where coils of zinc or zinc/aluminium alloy-coated wire are stored on or touching cardboard or paper products, concrete (notably where seepage can occur), or damp surfaces, cinders, clinkers, unseasoned or freshly termite-proofed timbers or harmful chemicals, such as fertilizers and fungicides.

It should be noted, however, that even under suitable transport and storage conditions, the initial lustrous silver finish of zinc or zinc/aluminium-alloy coatings will age to a dull or deep grey respectively. This change in colour and lustre is a naturally-occurring phenomenon and will not affect the performance of the coatings.

NOTE: In dry air, freshly-applied zinc is slowly attacked by atmospheric oxygen, which then reacts with carbon dioxide, with consequent dulling of lustre, to form a thin very protective layer of basic zinc carbonate. However, when new zinc coatings are exposed to high humidity especially under conditions of poor ventilation, a porous deposit of zinc oxide or hydroxide forms and this then converts to the spongy deposit of carbonate known as 'white rust'. Because of its nature, the spongy deposit provides little barrier to the access of moisture to the zinc (or alloy) metal and prolongs the time of wetness.

APPENDIX E  
DETERMINATION OF COATING MASS  
(Normative)

## E1 GENERAL

This Appendix sets out three alternative procedures for determining the mass of zinc coating or zinc/aluminium-alloy coating on steel wire, as follows:

- (a) Gravimetric determination (see Paragraph E2)
- (b) Volumetric determination (see Paragraph E3)
- (c) Non-destructive determination (see Paragraph E4).

In cases of dispute, the gravimetric determination shall be the referee method.

NOTE: The test procedures do not necessarily include all of the precautions required to satisfy health and safety aspects. In particular, care should be taken to ensure that the test procedures in Paragraphs E2 and E3 are carried out only by people who have received suitable training. Guidance in the handling and use of hazardous chemicals will be found in AS/NZS 2243.1 and AS/NZS 2243.2.

## E2 GRAVIMETRIC DETERMINATION

### E2.1 Principle

The zinc coating or zinc/aluminium-alloy coating on the specimen of wire is dissolved in inhibited acid and the resultant loss in mass is determined by comparing the masses of the specimen before and after the coating has been dissolved.

### E2.2 Stripping solution

A suitable stripping reagent may be prepared by dissolving 3.5 g of hexamethylene tetramine in 500 mL of concentrated hydrochloric acid ( $\rho = 1160 \text{ kg/m}^3$  or 32% w/w). This solution is then diluted with water to 1 litre.

NOTES:

- 1 The use of a stripping reagent prepared by using antimony trioxide ( $\text{Sb}_2\text{O}_3$ ) or antimony chloride ( $\text{SbCl}_3$ ) should be avoided, since the reaction of either with zinc may result in the evolution of the poisonous gas antimony hydride (stibine,  $\text{SbH}_3$ ).
- 2 The addition of 10 g/L of nickel chloride to the stripping solution will greatly increase the rate of dissolution of zinc/aluminium-alloy coatings.

### E2.3 Test piece

The test piece shall be such that its mass, in grams, is numerically between 4 and 20 times its diameter, in millimetres, provided that its length is at least 200 mm.

NOTE: The test specimen may be cut into several shorter lengths for ease of weighing and stripping.

### E2.4 Procedure

The test shall be conducted in accordance with the following procedure:

- (a) Where necessary, degrease the specimen with an organic solvent that does not attack the zinc or zinc/aluminium alloy, and then dry the specimen. It is important that no traces of supplementary non-metallic coating, such as paint or plastic, remain on the specimen.
- (b) Before immersion in the stripping reagent, weigh the specimen to the nearest 0.01 g.

- (c) Completely immerse the specimen in the stripping solution, which is maintained at or near room temperature until the coating is completely dissolved. The end of the dissolution process can be recognized by the cessation of the originally brisk effervescence.
- (d) Rinse the specimen in running water, and remove any loose substances adhering to the surface by rubbing with a wet wad of cotton wool or similar material, ensuring that no fibres remain attached to the surface.
- (e) Immediately dip the specimen in a suitable alcohol, e.g. methylated spirits, dry it quickly and re-weigh it to the accuracy indicated in Step (b).
- (f) For wires of circular cross-section, determine the diameter of the stripped specimen to the nearest 0.01 mm. Unless specified otherwise for shaped wires, determine the cross-sectional area and the circumference of the stripped specimen to the nearest 0.0001 mm<sup>2</sup> and 0.01 mm respectively.

### E2.5 Calculation of coating mass

The coating mass for zinc or zinc/aluminium-alloy coatings shall be calculated using one of the following equations:

- (a) For wires of circular cross-section—

$$m_A = \frac{m_1 - m_2}{m_2} \times 1960d \quad \dots \text{E2.5(1)}$$

- (b) For shaped wires—

$$m_A = \frac{m_1 - m_2}{m_2} \times \frac{7850s}{c} \quad \dots \text{E2.5(2)}$$

where

$m_A$  = coating mass, in grams per square metre

$m_1$  = mass of the specimen before stripping, in grams

$m_2$  = mass of the specimen after stripping, in grams

$d$  = the diameter of the stripped wire, in millimetres

$s$  = the cross-sectional area of the stripped wire, in square millimetres

$c$  = the circumference of the stripped wire, in millimetres

NOTES:

- The multiplying factor, 1960 (rounded), is one-quarter of the density of steel, taken as 7850 kg/m<sup>3</sup>. The composition of the coating does not enter into Equations E2.5(1) or E2.5(2). (The same equations may be employed with minimal error to determine the mass of relatively thick supplementary non-metallic coatings such as paint or plastic.)
- For zinc coatings, the equivalent average thickness (in micrometres) is obtained by dividing the coating mass (in g/m<sup>2</sup>) by 7.15 (i.e. one-thousandth of the density of zinc, in kg/m<sup>3</sup>). For zinc/aluminium-alloy coatings, the divisor will vary depending on the actual percentage of aluminium in the coating; however, as a guide, the divisor for a 5% aluminium content is 6.58.

## E3 VOLUMETRIC DETERMINATION

### E3.1 Principle

The volumetric method of determining the mass of a coating depends on the fact that a metal dissolved in an appropriate acid always releases a quantity of hydrogen proportional to the amount of metal dissolved.

#### NOTES:

- 1 1 g of zinc releases 343 mL of hydrogen at a temperature of 0°C and a pressure of 1 standard atmosphere. Under the same conditions, 1 g of aluminium releases 1246 mL of hydrogen. (1 standard atmosphere = 760 mm Hg = 1013 hectopascals).
- 2 The volumetric method may not be suitable for heavily coated wires since test pieces may become so short, and thus limit the volume of hydrogen evolved, that unacceptable errors in measuring their length may introduce large inaccuracies in coating mass determinations.
- 3 The volumetric method may not be practicable for zinc/aluminium-alloy coatings because small variations in aluminium content produce large variations in the volume of hydrogen evolved, thus introducing possible inaccuracies in calculations. An accurate determination of coating mass can only be obtained if the percentage of aluminium is known exactly, and adjustments are made to Equation E3.6(3). The amount of aluminium may be determined by reference to AS 1329.1, or by another approved method. It should be noted that the actual aluminium content of a zinc/aluminium-alloy coating may differ significantly from the designated nominal aluminium content, depending on the manufacturing process (see Clause 3.8).

### E3.2 Stripping solution

The same stripping reagent described in Paragraph E2.2 should be used.

NOTE: The stripping reagent should be replaced when the acid concentration is reduced to a level where, for example, vigorous evolution of gas lasts longer than about 80 s for a coating mass of 230 g/m<sup>2</sup>.

### E3.3 Apparatus

The apparatus is typically a 100 mL, 250 mL or 300 mL glass burette fitted with a stopcock at the top and bottom, and connected (at the bottom) to a reservoir by means of a rubber tube. The apparatus set up for the commencement of a test is illustrated in Figure E1.

The burette should be graduated to at least 1.0 mL subdivisions for a 100 mL burette and 2.0 mL subdivisions for a 250 mL or a 300 mL burette.

#### NOTES:

- 1 The graduated scale on the burette tube should commence at the bottom of Stopcock A. If the scale begins below Stopcock A, then it is important that the burette be recalibrated to take account of the volume between the stopcock and the existing zero graduation.
- 2 It is advisable to provide the burette with a bell-mouth opening, or similar, above Stopcock A, to facilitate entry of a specimen and also to accommodate the small amount of reagent displaced immediately upon its entry.
- 3 Under some circumstances (e.g. for very fine wires), the apparatus described in AS 2331.2.3 may be found more serviceable.
- 4 Care should be exercised with wires of large cross-sectional area since the impact of their mass may damage the burette.
- 5 Where small sizes of wire, (e.g. wire of less than 1.50 mm diameter or dimension) are regularly tested, it may be found useful to employ a 50 mL burette of about the same length and graduated to at least 0.2 mL subdivisions.



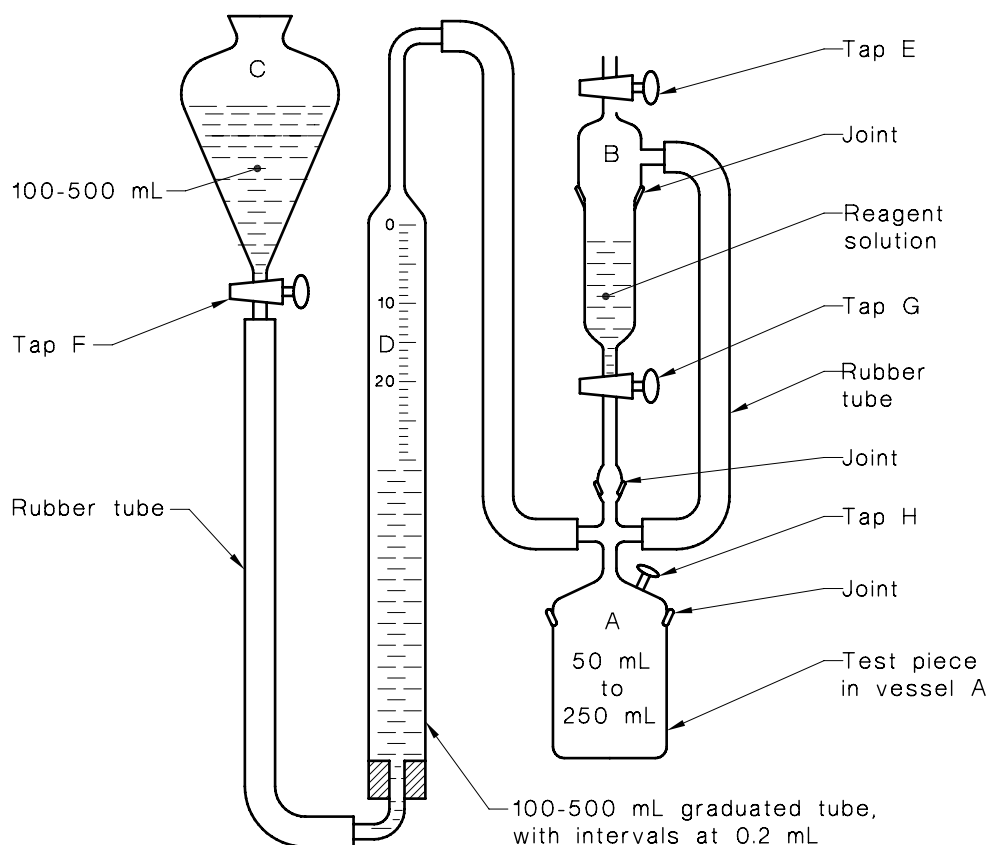


FIGURE E1 APPARATUS FOR DETERMINING COATING MASS BY VOLUMETRIC METHOD

### E3.4 Test pieces

Test pieces shall be accurately cut to the required length (with an error of less than 1%) from a straightened and undamaged length of wire. The most suitable length of each test piece is dependent on the size of burette, the size of wire cross-section and the expected mass of the coating. The lengths indicated in Table E1 for wires of circular section will usually be found convenient, and may also be used as a guide for shaped wires.

TABLE E1  
RECOMMENDED MINIMUM LENGTHS OF TEST PIECES

Coated wire diameter	Length of test piece		
	millimetres		
	For a 250 mL or 300 mL burette	For a 100 mL burette	For a 50 mL burette
$>0.45 \leq 0.85$	—	—	200
$>0.85 \leq 1.06$	—	200	150
$>1.06 \leq 1.80$	100	100	75
$>1.80 \leq 3.60$	75	75	—
$>3.60 \leq 6.00$	50	50	—

### E3.5 Procedure

The test shall be conducted in accordance with the following procedure:

- (a) Pour the acid reagent into the reservoir until it completely fills the burette, leaving a small portion in the reservoir when it is in the elevated position.
- (a) Adjust the height of the reservoir so that the acid reagent just fills the burette up to stopcock A with the bottom stopcock B closed.
- (b) Quickly drop the test piece, cut to the specified length, into the burette and immediately close stopcock A.

NOTES:

- 1 Where long test pieces are necessary, rapid entry into the burette may be difficult and it may be more convenient to drop two short pieces simultaneously through the stopcock.
- 2 Any amount of reagent displaced upwards through Stopcock A, immediately following insertion of the specimen, is disregarded since it is not relevant to the determination.

The coating rapidly dissolves and liberates hydrogen, and the test is continued until evolution of hydrogen, except for a few fine bubbles, has ceased.

- (c) Lift the reservoir from its support and place it alongside the burette until the levels of the acid reagent in the burette and in the reservoir are the same, and read off the volume of hydrogen on the burette scale.

NOTE: Where volumetric testing is being carried out simply to check that the coating conforms to specified minimum requirements, it is expedient not to balance the reagent levels between the burette and the reservoir, provided that the reservoir is higher than Stopcock A at all times. This modified procedure will result in a conservative measurement of coating masses.

- (d) At the conclusion of the test, open stopcock A and withdraw all acid reagent from the burette by lowering the reservoir to a position below stopcock B. Open stopcock B to eject the test piece and close it again. Measure the temperature, to an accuracy of  $\pm 0.5^\circ\text{C}$ , of the discharged stripping solution, since this provides a measure of the temperature of the evolved hydrogen.

NOTES:

- 1 The procedure given in Steps (a) to (e) may then be repeated for a succeeding test.
- 2 The stripping solution should be discarded when the reaction rate becomes unduly slow or its temperature unacceptably high.

- (e) Wash, wipe dry and measure the diameter of the stripped wire to the nearest 0.01 mm. For shaped wire, unless specified otherwise, the circumference shall be determined to the nearest 0.01 mm.

### E3.6 Calculation of coating mass

The coating mass for the volumetric determination shall be calculated using the following general equation:

$$m_A = \frac{V}{dl} \times f \quad \dots \text{E3.6(1)}$$

where

- $m_A$  = coating mass, in grams per square metre
- $V$  = volume of hydrogen evolved, in millilitres
- $d$  = stripped wire diameter, in millimetres
- $l$  = length of specimen, in millimetres
- $f$  = a multiplying factor (see Paragraph E3.7)

For zinc coatings the following equation applies:

$$m_A = \frac{V}{dl} \times 865 \quad \dots \text{E3.6(2)}$$

For zinc/aluminium-alloy coatings the following equation applies:

$$m_A = \frac{V}{dl} \times f_{ZA} \quad \dots \text{E3.6(3)}$$

where

$f_{ZA} = 783$  for 4% aluminium content, 764 for 5% aluminium content, 730 for 7% aluminium content and 685 for 10% aluminium content (see Paragraph E3.1 Note 3)

In the case of shaped wires, the diameter ( $d$ ) in Equations E3.6(1), E3.6(2) and E3.6(3) is replaced by  $0.318c$ . For zinc coatings, Equation E3.6(2) then becomes—

$$m_A = \frac{V}{cl} \times 2718 \quad \dots \text{E3.6(4)}$$

where

$c$  = the circumference of the stripped shaped wire, in millimetres

### E3.7 Correction for temperature and barometric pressure

The multiplying factor  $f$  or  $f_{ZA}$ , as appropriate, in Equations E3.6(1), E3.6(2) and E3.6(3) has been calculated for a temperature of 20°C and a barometric pressure of 1013 hPa. Although the values for  $f$  and  $f_{ZA}$  quoted in Paragraph E3.6 apply only under these conditions, acceptable results will be obtained if the test temperature does not vary by more than  $\pm 2^\circ\text{C}$ , and the pressure by more than  $\pm 25$  hPa.

Under test conditions that exceed these variations, the factor  $f$  or  $f_{ZA}$  should be corrected, as follows:

$$f' = f \times \frac{293}{(t + 273)} \times \frac{P}{1013} \quad \dots \text{E3.6(5)}$$

where

$f'$  = modified multiplying factor

$t$  = test temperature, in °C

$P$  = atmospheric pressure, in hPa

NOTE: The test temperature is that of the liberated hydrogen, taken to be the temperature of the stripping solution.

## E4 NON-DESTRUCTIVE DETERMINATION

A non-destructive coating-mass-measuring instrument specifically designed for metal-coated steel wire may be employed, either for continuous monitoring of coating mass during wire manufacture or for the determination of coating mass on test specimens, provided the data are suitably recorded and appropriate calibration control is maintained. For the determination of coating mass, test specimens shall be checked over a length of at least 100 mm in order to obtain a representative average value.

The test instrument and procedure shall conform to the requirements specified for eddy current determinations in AS 2331.1.4.

**E5 TEST REPORT**

The test report shall include the following information:

- (b) Name of testing authority.
- (c) Report number and date of issue.
- (a) Batch or coil identification and details of the material under test.
- (b) The test method used.
- (c) Results of the test, and a statement of compliance, or otherwise, with the requirements of this Standard.
- (d) Reference to this test method, i.e. AS/NZS 4534, Appendix E.

APPENDIX F  
GUIDANCE ON CORROSION PROTECTION  
(Informative)

## F1 SCOPE

This Appendix provides general information on the corrosion behaviour of zinc and zinc/aluminium-alloy coatings on steel wire, with emphasis on products for rural pursuits, and on the climatic and environmental conditions to which they are subjected. Indicative service lives for the range of zinc and zinc/aluminium-alloy coatings covered by this Standard are also included.

## F2 DEFINITIONS

For the purposes of this Appendix, the definitions below apply.

### F2.1 Corrosivity

The ability of the atmosphere, together with its contaminants, or some other medium (e.g. seawater), to cause corrosion in a given corrosion system.

### F2.2 CRMS

Abbreviation for ‘corrosion rate of mild steel’, as used to quantify and categorize atmospheric corrosivity (see Table F1); the CRMS specifically relates to the first-year weathering of uncoated (bare), clean, mild steel coupons under monitored field test conditions, and is reported in micrometres per year ( $\mu\text{m}/\text{y}$ ) of steel converted to rust on a single surface.

## F3 CLIMATIC CONDITIONS

External (as opposed to inside buildings) atmospheric conditions for Australia may be classified into five broad categories, based on corrosion rate, plus one Tropical category which is not determined by corrosion rate.

Descriptions of the six categories are as follows:

- (a) *Category A: Very low.* Environments falling into this benign category are found in semi-sheltered regions remote from marine or industrial influence. The only Category A environments in Australia are to be found in some alpine regions, although generally such regions will fall into the low end of Category B.
- (b) *Category B: Low.* This category covers dry, rural areas as well as other regions remote from the coast or sources of pollution. Most areas of Australia located beyond at least 50 kilometres from the sea are in Category B; however, areas that are as close as 1 kilometre to relatively sheltered and quiet waters can also be in this category. Typically, Category B applies to arid regions and inland rural areas, most inland cities and towns such as Canberra, Ballarat, Toowoomba and Alice Springs, and suburbs of cities on sheltered bays, such as Melbourne, Hobart, Brisbane and Adelaide (except areas within 3 to 6 kilometres of the coast near Adelaide).

- (c) *Category C: Medium.* This category mainly covers coastal regions with low airborne salinity. The extent of affected areas varies significantly with factors such as winds, topography and vegetation. Around sheltered seas, such as Port Phillip Bay, Category C extends beyond about 50 metres from the shoreline up to a distance of about 1 kilometre inland. For a sheltered bay or gulf, such as near Adelaide, this category applies from the water's edge up to about 3 to 6 kilometres inland. Along the seafront, with breaking surf and significant salt spray, it applies to the region from about 1 kilometre inland to between 10 and 50 kilometres inland, depending on the strength of prevailing winds and topography. Much of the metropolitan areas of Wollongong, Sydney, Newcastle and the Gold Coast are in Category C. In South Australia, the whole of the Yorke Peninsula falls within this or a more severe category, and in the south-east of the state, from Victor Harbor to the Victorian border, it extends inland up to between 30 and 70 kilometres. Such regions are also found in urban and industrial areas with low pollution levels. These are relatively uncommon in Australia, but they exist for several kilometres around major industries, such as smelters and steelworks. Environmental effects, such as proximity to airports and sewage treatment works, may also put a site into this category.
- (d) *Category D: High.* This category occurs mainly on the coast. Around sheltered bays, Category D extends up to 50 metres inland from the shoreline. In areas with rough seas and surf, it extends from about several hundred metres inland, up to about one kilometre inland. Industrial regions with an aggressive acidic atmosphere may also be in this category, but in Australia these are only likely to be found within 1½ kilometres of an offending industry.
- (e) *Category E: Very High.* (E-I: Industrial; E-M: Marine) This category is common right on the waterfront in regions of rough seas or surf beaches, and its extent can be inland from the coast for several hundred metres, up to about one kilometre, depending on winds, wave action and topography. In some areas of Newcastle, for example, it extends more than half a kilometre inland. Category E may also apply to industrial areas of high corrosivity, where the atmospheric contaminants will be acidic.
- (f) *Category F: Tropical.* A tropical environment includes coastal areas of north Queensland, Northern Territory, north-west Western Australia, Papua-New Guinea and the Pacific islands, except where affected by airborne salinity. Corrosivity is generally low and is equivalent to that of Category B. However, special consideration has to be given to organic coating selection because of the effects of UV radiation and micro-organisms, or of mould.

## NOTES:

- 1 Characteristics of a tropical environment are as follows:
  - (a) Subject to high rainfall, greater than 1200 mm annually.
  - (b) Average humidity high all year round, typically 65% to 100%.
  - (c) No industrial fall-out.
- 2 Further information on the above categories is given in AS/NZS 2312.

The climatic categories have been determined from measurements of the corrosion rate of bare mild steel based on an initial one-year of outdoors exposure. A summary, together with comparable interior examples, is shown in Table F1.

It should be noted that corrosivity near the coast decreases very rapidly with distance inland, with the result that a given suburb or town can be in one, two or even three corrosion categories, depending on its proximity to the ocean and on local conditions, such as prevailing winds and polluting industry. The rapid change in corrosivity with distance inland from the sea may be gleaned from the curves shown in Figure F1.

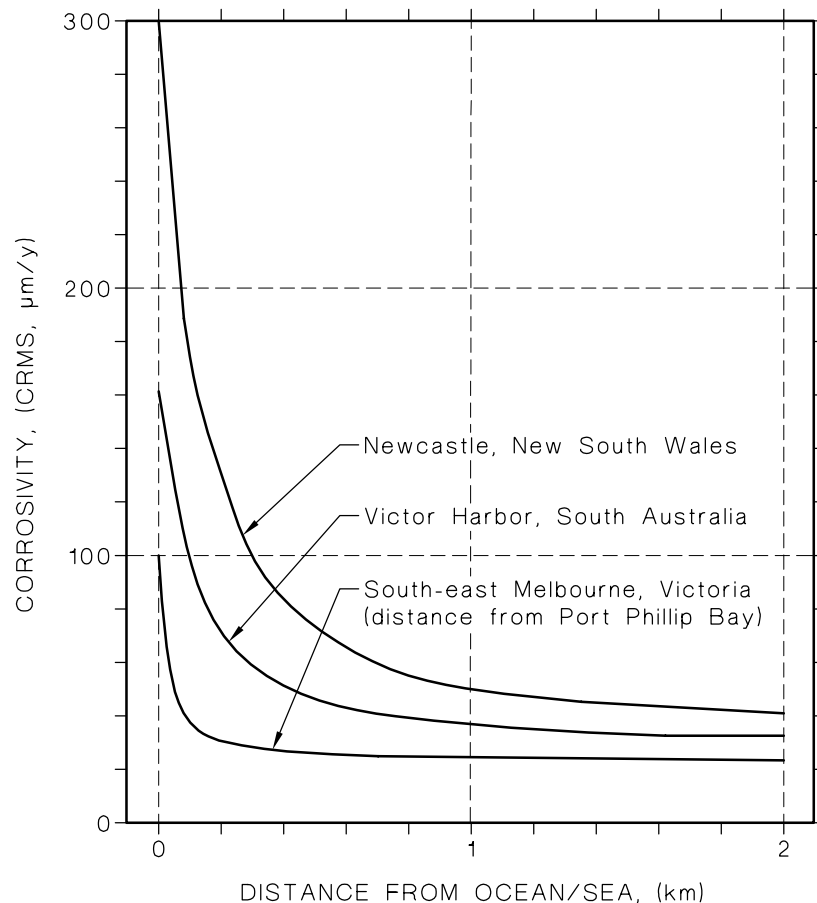
Some examples of outdoors localities and their corrosion categories, with measured corrosivities (CRMS values), are shown in Table F2.

**TABLE F1**  
**CLIMATIC CATEGORIES**

Climatic category	ISO 9223 category	Corrosivity (CRMS, $\mu\text{m}/\text{y}$ )	Typical environment (outdoors)	Typical environment (interior)
A: Very low	C1	<1.3	A few alpine areas	Offices, shops
B: Low	C2	1.3 to 25	Arid/urban/rural	Warehouses, sports halls
C: Medium	C3	25 to 50	Coastal	Food-processing plants, breweries, dairies
D: High	C4	50 to 80	Sea-shore (calm)	Swimming pools, livestock buildings
E: Very high	C5	80 to 200	Sea-shore (surf); off-shore	Plating shops, chemical plants
F: Tropical	—	—	Non-coastal tropics	

NOTES:

- For the definition of CRMS see Paragraph F2.2.
- The data in the table, except for Category F, are based on information in ISO 9223.



NOTES:

- Source: CSIRO DBCE surveys.
- For definitions of corrosivity and CRMS, see Paragraph F2.

**FIGURE F1** MEAN CURVES FOR THREE REGIONS SHOWING VARIATION IN ATMOSPHERIC CORROSIVITY WITH DISTANCE FROM THE SEA

**TABLE F2**  
**LOCATIONS, CLIMATIC CATEGORIES AND CORROSIVITIES**

Climatic category	Location	Corrosivity (CRMS $\mu\text{m}/\text{y}$ )	Climatic category	Location	Corrosivity (CRMS $\mu\text{m}/\text{y}$ )
A: Very low	Mt Buller Vic	1	C: Medium	Geelong Vic	27
				Perth (Kwinana) WA	29
B: Low	Quirindi NSW	2		Sydney (city)	32
	Cooper Pedy SA	3		Newcastle (city) NSW	35
	Dubbo NSW	4		Melb (Altona Beach), Vic	35
	Toowoomba Qld	9		Pt Kembla (jetty) NSW	45
	Scone NSW	10			
	Denman NSW	10			
	Hobart (city) Tas	11			
	Whyalla SA	13		D: High	Port Pirie SA
	Canberra ACT	14	Melb (Seaford Beach) Vic		68
	Singleton NSW	14	E: Very high	Cowley Beach Qld	142
	Adelaide (Woodville) SA	15		Newcastle Beach NSW	194
Melbourne (Clayton) Vic	18	F: Tropical	Townsville Qld	15	
Perth (Bentley) WA	19		Tully Qld	20	
Maitland NSW	20		Innisfail Qld	23	
	Brisbane (Hamilton) Qld	22			
	Sydney (Ryde) NSW	22			
	Muswellbrook NSW	23			

## **F4 FACTORS AFFECTING TERRESTRIAL CORROSION RATE**

### **F4.1 Macroclimatic effects**

The two most important atmospheric factors on corrosion rate of both steel and zinc are time of wetness and level of airborne pollutants, the most significant of the latter being chloride salts, sulfur dioxide and hydrogen sulfide.

Time of wetness is the length of time during which the metallic surface is covered by a film of water that renders atmospheric corrosion possible. It is influenced by factors such as metal mass, exposure orientation and pollution, and can be quantified to sufficient accuracy in terms of the number of hours per year that the relative humidity is above 80% for temperatures above 0°C.



On a global scale, airborne chlorides (essentially sodium chloride), sulfur dioxide and hydrogen sulfide are all powerful stimulants for atmospheric corrosion, and their deposition rate in situations that are exposed to the elements (i.e. situations that are non-sheltered and rain washed) is directly proportional to their concentration in the atmosphere.

Saline aerosol (spray and mist) has a profound influence on corrosion rate, especially near the ocean. Zinc is relatively rapidly attacked in the vicinity of surf beaches, for instance.

The most corrosive pollutant in air is sulfur dioxide which, in combination with time of wetness, causes abnormally high corrosion rates of zinc. In Australia, however, sulfur dioxide and also hydrogen sulfide have been found to play only a minor role in corrosion and can be neglected, except when occurring near recognized (usually microclimatic) sources, such as certain fossil fuel-burning industries or facilities (sulfur dioxide) and rotting vegetable matter, as in wetlands, or sewage treatment works (hydrogen sulfide).

In marine environments, and those affected by industrial or similar pollution, dew is likely to be contaminated with impurities that are corrosive to the metallic coating. In such circumstances, the corrosivity of the contaminant may be more important than the degree of moisture condensation.

Rainfall influences corrosion rate and has the effect of either stimulating or reducing corrosion, depending on the environment. In polluted or coastal atmospheres, the washing effect of rain reduces corrosion, while at less polluted sites or those well away from the ocean the situation is reversed and the corrosive action of rain is more important.

Temperature influences corrosion rate, but can have contradictory effects: increasing temperature accelerates the rate of the corrosion reactions, but, on the other hand, leads to more rapid evaporation, thus shortening the time of wetness and decreasing the corrosion rate.

Zinc coatings develop a carbonate barrier layer to protect the steel and also sacrificially protect locations where discontinuities have occurred in the coating, often through damage. However, airborne chlorides, sulfur dioxide and hydrogen sulfide combine with, and change the behaviour of, this barrier layer. Being fairly soluble, the resultant altered compounds are dissolved by rain-water, thus leaving the coating itself relatively unprotected, and it quickly corrodes.

#### **F4.2 Microclimatic and other effects**

In addition to (macro)climatic effects, the local environment (or microclimate) and the circumstances of use of the coated wire may present an influence, and therefore need to be taken into account, if the duration of corrosion protection sought is to be realized. For example, a wire employed in a climate, classified as mildly corrosive, may have its useful life significantly shortened if due consideration has not been taken of corrosive fumes from a nearby effluent-treatment plant, or from proximity to a busy highway or airport; in other words, microclimatic effects may have transformed a Category B environment, for example, into a localized Category C.

Factors that can significantly affect the corrosion rate of coated steel wire are as follows, and are provided for guidance:

- (a) *Initial exposure conditions* Constant rainfall and/or high humidity, especially under hot conditions, over the first few days of exposure can cause a higher initial corrosion rate of a relatively new zinc coating, since its protective carbonate layer may not have had time to form sufficiently (also see Item (g) below and the Note contained in Appendix D).

- (b) *Protection from rain* The corrosion rate in applications exposed to airborne salt and other contaminants, but shielded from rain, can be many times greater than would occur in rain-washed situations. This applies particularly to areas affected by fertilizer or insecticide drift and sea mist, where a zinc coating may become exhausted in 60% of the time when protected, compared with that when rain washed.
- (c) *Prolonged dampness* Corrosion will be promoted under conditions where the wire remains damp for extended periods of time, such as where it is protected from the warming effects of the sun, where it is in contact with wet vegetation, or where it is subject to moisture retention or condensation. Examples include the lower wires in fences, which are often shrouded in grass, and those sections of wire passing through timber posts. Wires that are exposed to spray from bore water are especially vulnerable to corrosion since prolonged dampness and salinity are influences different from the general atmospheric conditions in the vicinity.
- (d) *Galvanic corrosion* Galvanic corrosion of the coating on the wire can occur where the wire is in direct metallic contact with, or in very close proximity (less than about 1 mm) to, a dissimilar, more noble (cathodic), metal in the presence of, or covered by, moisture. Examples of galvanic corrosion are as follows:
- (i) A piece of copper or uncoated (bare) steel attached to the coated wire will accelerate attack of the metallic coating. Similarly, but less obviously, stainless steel, zinc/aluminium alloy or aluminium will promote corrosion of zinc coatings, and this will be most evident under severe marine (Category E) exposure conditions.
  - (ii) Accelerated attack of the coating will occur on wire netting that has been buried in soil containing remnants of rusted netting from an earlier fence.
- (e) *Burial in soils* It should not be assumed that coated wire buried in soils in Category B (Low) regions will be immune to corrosion, because the soil may contain salts and its moisture content may be reasonably high, thus providing a good electrolyte. For example, the clay pans in the vicinity of Birdsville in the arid, far south-west of Queensland are alkaline and very corrosive. (Also see Item (d)(ii)).
- (f) *Organic and other chemical attack* Metallic coated wires should not be employed or stored in contact with cardboard or paper products, damp concrete or other moist surfaces, cinders, clinkers, unseasoned or freshly termite-proofed (e.g. copper-chrome-arsenate (CCA) treated) timbers, or harmful chemicals (e.g. lime, fertilizers and fungicides) or chemical vapours.
- (g) *Barrier film removal* Both zinc and zinc/aluminium alloy-coated wires rely for their durability on a thin barrier film of oxides and/or carbonates that forms on the surface during the early stages of their service. Any agent, such as an abrasive or chemical (e.g. fertilizer), which tends to modify or remove the protective film, will seriously reduce the useful life of the wire. Wind erosion, where airborne sand or grit abrades the coating, is a common cause of reduced coating life in arid regions. Other common causes of film removal by abrasion are rubbing by livestock, notably at the top wires of a fence, and the to-and-fro sliding of wire within posts, as a result of livestock activity for example.
- (h) *Animal enclosures* Organic vapours, chemical substances, high levels of moisture, and contaminated fluids (e.g. urine), in and around enclosures for animals, must be considered when specifying products for their use.

- (i) *Prevailing winds* Contamination can be transported, usually unsuspectedly, from one region to another by winds, and so this aspect requires consideration. For instance, CSIRO has reported that the apparently well-dispersed emissions from the high stacks of certain coal-burning electric power stations effectively doubled the corrosivity at localities up to 80 kilometres away.
- (j) *Fire* The effects of grass and scrub fires, where structural damage is perceptibly less than with major bush fires, on the corrosion resistance of metallic coatings cannot be quantified because the conditions of exposure, notably temperature reached and times at temperature, are far too variable. As an indication, however, temperatures as high as 1100°C have been recorded in fires in thick, dry tussock grass. Damage to the metallic coating commences at about 400°C (zinc melts at 420°C, zinc/5% aluminium alloy at 382°C), becoming progressively worse until, at about 1000°C, the coating is transformed into a flaky white oxide, affording no corrosion protection at all.

NOTE: At temperatures over about 500°C strained fencing wires, especially high tensile ones, will be irreparably damaged and, at 700°C, softened, resulting in localized stretching. 'Hot spot' high temperatures may be very localized, leading to breaks because stretching is then concentrated within short lengths of wire.

## F5 FACTORS AFFECTING AQUATIC CORROSION RATE

The corrosion of metallic coatings in water is largely controlled by impurities present in the water. Freshwater streams and rivers contain dissolved atmospheric gases, eroded soil, decaying organic matter, living micro-organisms, and salts dissolved from the ground over or through which the water has run or seeped. Seawater contains most of these, but its salt content, notably sodium chloride, is very much higher. As an indication, freshwater has a total salt content of up to typically 0.05%, whereas seawater contains about 3.5%. The salinity of brackish waters, such as bore water, varies with circumstances, but 0.5% would not be unusual.

As in atmospheric exposure, the corrosion resistance of the metallic coating in freshwater depends on its initial ability to form a protective barrier layer by reacting with the environment. Water hardness is an important variable. The corrosion rate of zinc in hard water may be 15 µm/year (100 g/m<sup>2</sup> per year), but in soft water it can be ten-times higher. The reason for this is that hard waters deposit calcium-based protective scales on the coating, stifling attack. Soft water is actually more corrosive than seawater, since the latter also forms protective scales on zinc.

The life of the coating in seawater depends on a large number of factors, such as whether the wire is partly or wholly immersed, the velocity of water flow, the time of wetness (for intermittent immersion), wave action, silt or sand movements, water temperature, mechanical abrasion, and the presence of any unnatural contaminants. Even relatively gentle abrasion of the wire increases the corrosion rate because corrosion products are removed, thereby constantly presenting fresh surfaces for attack; examples of abrasion are the sliding of equipment, such as ropes, over aquatic enclosures, and situations where wires are allowed to rub against each other, perhaps through wave action, thus fretting the surface of the coating.

Examples of articles immersed in seawater, in order of decreasing corrosion rate, are as follows:

- (a) Gabion netting for sea wall stability (splash zone; wave action and tidal immersion).
- (b) Netting or fabric employed in aquatic installations.
- (c) Lobster pot netting (relatively long periods of total immersion at depth).

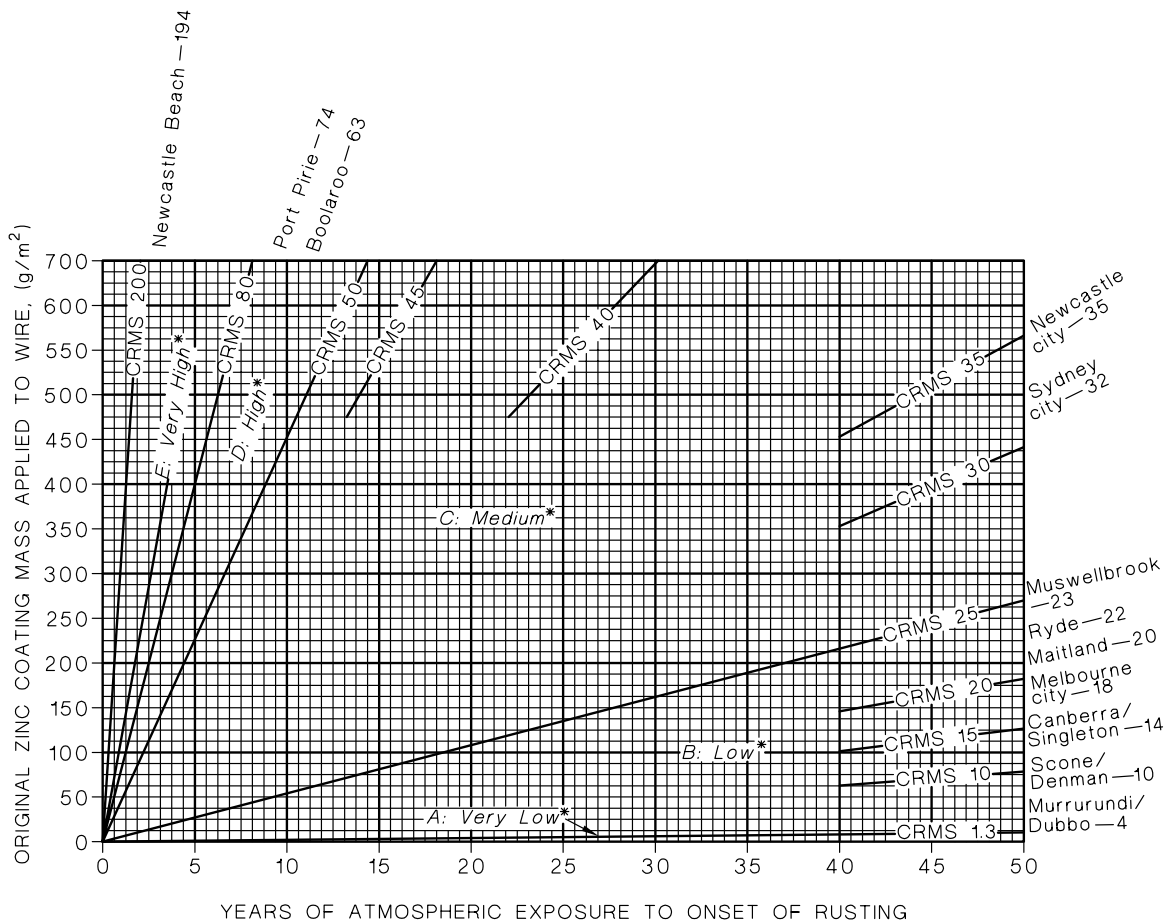
## F6 INDICATIVE COATING DURABILITY

### F6.1 General

Because of the variables described in Paragraphs F3, F4 and F5, it is extremely difficult to predict with a high level of confidence the corrosivity of a given exposure situation. Be that as it may, it is obviously possible to provide a reasonable indication of life expectancies of zinc coatings, and to a lesser extent, zinc/aluminium-alloy coatings.

### F6.2 Zinc coating durability under atmospheric conditions

For guidance, indicative values of zinc coating life to the onset of rusting (about 10% of surface rust) of the steel substrate are given in Figure F2.



LEGEND:  
 CRMS = see Paragraph F2  
 \* = Climatic category (see Para. F3, and Table F1 and F2)

FIGURE F2 ATMOSPHERIC, NON-SHELTERED, EXPOSURE DURATION TO ONSET OF (STEEL) RUSTING ON ZINC-COATED WIRES

It is important to note that the indicated lives should be employed with caution and their use should always be tempered by experience and local knowledge, since corrosion rates can vary appreciably over relatively short distances and even with minor changes in topography.

Complete depletion of the originally applied zinc coating can be expected in typically 1½ times the duration to the onset of rust formation.

NOTES:

- 1 It should be noted that the characterization of an environment (into corrosion categories) is based on the corrosion rate of mild steel (CRMS) alone. The relationship between the corrosion rates of mild steel and zinc is not linear; the corrosion rate of a zinc coating under benign conditions can be typically only one-fiftieth (1/50) that of mild steel, but in very corrosive environments, such as near the ocean, the rate can be as great as one-fifth (1/5).
- 2 The seemingly anomalous positions of the CRMS traces in Figure F2 are due to this shift in mild steel/zinc relativity. Even after the zinc coating has been totally depleted, steel wires will still retain adequate strength for a considerable period of time.
- 3 Figure F2 is based on data from several studies conducted by CSIRO at regions in South Australia, Victoria and New South Wales. The studies involved exposure for one or two years of bare mild steel coupons, as well as galvanized steel coupons in some cases, thus allowing a comparison to be made of relative corrosion rates. Galvanized wires are reported to corrode more quickly (about 50% greater) than galvanized sheet, and so the CSIRO-derived data have been adjusted accordingly.

### F6.3 Zinc/aluminium-alloy coating durability under atmospheric conditions

The most common zinc/aluminium alloy for wire contains 5% aluminium. A considerable amount of research is under way with this particular, relatively recently developed, alloy to establish its durability under the various climatic and environmental conditions.

It is known, however, that the mechanism of corrosion is such that, initially, the rate of attack of a zinc/aluminium-alloy coating is greater than that of a zinc coating, but after a relatively short period of time (the period depending on the corrosion regime to which it is exposed), its corrosion rate diminishes until it is much less than that for zinc. In simple terms, the zinc component of the zinc/aluminium-alloy coating corrodes preferentially until such time as the outer surface becomes aluminium-rich; as the level of aluminium rises at the exposed face owing to depletion of zinc, the rate of attack slows appreciably because, effectively, the atmosphere 'sees' only aluminium, and aluminium itself is very corrosion resistant because of its inherent, very protective, oxide film. Depending on circumstances, the onset of steel rusting may be delayed significantly and even beyond the point where negligible metallic coating apparently remains.

Controlled trials have shown that zinc/5% aluminium-alloy coatings offer distinct advantages over zinc-only coatings where atmospheric attack is naturally aggressive, that is, in the High and Very High climatic categories, and also where higher local corrosivities have been generated through the use of substances such as fertilizers and pesticides.

Studies under Australian (external atmospheric) field conditions, complemented by laboratory salt-spray testing to AS 2331.3.1, have shown that zinc/5% aluminium-alloy coatings on wire offer from about two up to about three times greater protection, per unit coating mass, than do zinc coatings. The higher value (i.e. about three times) is realized at high to very high levels of corrosivity, such as those in close proximity to surf beaches.

#### F6.4 Metallic coating durability under aquatic conditions

It is not possible to provide realistic predictions of coating life for zinc-coated wire immersed in freshwater or seawater, given the very broad range of conditions that may apply. However, the information shown in Tables F3 and F4 may prove useful.

Similar information or guidance on the service life of zinc/5% aluminium-alloy coatings cannot be given, since the durability achieved is very much dependent on the conditions of use.

##### NOTES:

- 1 Because of the very diverse range of existing and potential aquatic applications for both zinc and zinc/aluminium-alloy-coated wires, it is important that purchasers seek technical advice from wire manufacturers on the most appropriate coating designation for their proposed use.
- 2 Depending on the circumstances of use and the nature of the aquatic environment, a zinc/5% aluminium-alloy-coated wire may exhibit greater corrosion resistance than a zinc-coated wire, the coating mass being the same in both cases.

**TABLE F3**  
**INDICATIVE COATING MASS LOSSES FOR**  
**ZINC-COATED WIRE IN SEAWATER**

Position	Approx. coating mass loss, g/m <sup>2</sup> per month of constant wetness
Quiet water (e.g. bays)	20
Splash zone (e.g. breakwaters)	60
Offshore (10 km)	
—immersed at 1-2 m depth	50
—immersed at 10 m depth	70
Turbulent water*	90

\* 2 m below low-tide mark and 300 m offshore from surf beach.

**TABLE F4**  
**INDICATIVE COATING MASS LOSSES FOR**  
**ZINC-COATED WIRE IMMERSSED IN FRESHWATER**

Water hardness	Approx. coating mass loss per month of immersion, g/m <sup>2</sup>
Hard	10
Soft	100

## NOTES

## NOTES



## NOTES

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### **Standards Australia**

Standards Australia is an independent company, limited by guarantee, which prepares and publishes most of the voluntary technical and commercial standards used in Australia. These standards are developed through an open process of consultation and consensus, in which all interested parties are invited to participate. Through a Memorandum of Understanding with the Commonwealth government, Standards Australia is recognized as Australia's peak national standards body.

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