

Australian Standard[®]

**Corrosion of metals—Dissimilar metals
in contact in seawater**



This Australian Standard® was prepared by Committee MT-014, Corrosion of Metals. It was approved on behalf of the Council of Standards Australia on 19 September 2006. This Standard was published on 17 October 2006.

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- Australian Corrosion Association
 - Australasian Institute of Metal Finishing
 - Australian Chamber of Commerce and Industry
 - Australian Electrolysis Committee
 - Australian Paint Manufacturer's Federation
 - Australian Paint Approval Scheme
 - Austroads
 - Bureau of Steel Manufacturers of Australia
 - Department of Defence
 - Division of Building, Construction and Engineering, CSIRO
 - Galvanizers Association of Australia
 - Telstra
 - United Water International
 - Water Corporation of Western Australia
 - Corrosion consultants
 - Water Services Association of Australia (WSAA)
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-

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RECONFIRMATION
OF
AS 4036—2006
Corrosion of metals—Dissimilar metals in contact in seawater

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NOTES

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PREFACE

This Standard has been prepared by the Australian members of the Joint Standards Australia/Standards New Zealand Committee MT-014, Corrosion of Metals, to supersede AS 4036—1992, *Corrosion of metals—Dissimilar metals in contact in seawater*.

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

The objective of this Standard is to provide a test method to determine the corrosion rate of dissimilar metals when immersed in stagnant artificial seawater.

The objective of this revision is to update the reference documents, to apply current editorial style and to revise the test methods for determining the corrosion of dissimilar metals in stagnant artificial seawater.

This Standard provides a test method to derive the ratings of galvanic corrosion activity of metallic couples immersed in artificial seawater, based on their current/time relationships.

It also lists the galvanic series comprising a number of individual metals and alloys after immersion for one hour and also for a 28 day period, in artificial seawater.

The Committee determined that there were no International Standards (ISO) which were suitable to be used as an Australian Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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FOREWORD

The corrosion of dissimilar metals in contact is sometimes known as bimetallic, galvanic or contact corrosion, and occurs when two such metals are in electrical contact and bridged by an electrolyte to form an electrochemical cell.

A variety of factors can influence the functioning of a dissimilar-metal corrosion cell. Although theoretical considerations can offer some guidance, they cannot provide precise information on what will happen for a range of dissimilar metals in contact under all conditions of exposure. At present, the most reliable guidance is found in published tables of the galvanic series of metals or alloys in contact in seawater, based on potential measurements or sound practical experience. The test procedure given in this Standard requires the measurement of galvanic current to give information on dissimilar metal behaviour for the determination of corrosion ratings.

It is intended that this procedure should be used by persons or organizations wishing to evaluate other dissimilar-metal couples.

STANDARDS AUSTRALIA

Australian Standard

Corrosion of metals—Dissimilar metals in contact in seawater

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies a test method to determine the degree of additional corrosion of the more anodic of two metals in direct electrical contact, when immersed under standard conditions in stagnant artificial seawater.

NOTES:

- 1 The factors controlling galvanic corrosion given in Section 3 should be taken into account when evaluating the test results in terms of expected performance in actual seawater conditions and may reduce the viability of some galvanic couple ratings given in Table B1.
- 2 The basic theory of the galvanic corrosion of dissimilar metals is given in Appendix C

The test method given in Appendix A requires the measurement of the galvanic current over a period of 28 days, and rates the amount of additional corrosion of the metal under consideration into four categories.

The Standard provides ratings for a variety of commercially-significant dissimilar metal couples (including alloys and carbon).

NOTE: Table B1 may be used to give a qualitative assessment of the performance of dissimilar metal couples when they are immersed in actual seawater.

The Standard also provides information on factors influencing galvanic corrosion and in addition, provides guidelines on controlling this corrosion.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- | | |
|--------|---|
| 1789 | Electroplated zinc (electrogalvanized) coatings on ferrous articles (batch process) |
| 2832 | Cathodic protection of metals |
| 2832.3 | Part 3: Fixed immersed structures |
| 4108 | Metal finishing—Glossary of terms in electroplating and related processes |

1.3 DEFINITIONS

For the purpose of this Standard the definitions given in AS 4108 apply.

SECTION 2 FACTORS INFLUENCING GALVANIC CORROSION

2.1 SCOPE OF SECTION

This Section considers the factors which may affect the severity of galvanic corrosion of a metal or alloy when coupled to a dissimilar metal or alloy. The severity of galvanic corrosion is directly related to the magnitude of the galvanic current flowing in the galvanic cell.

The most important factors which influence this are:

- (a) Potential difference between dissimilar metals in contact (see Clause 2.2).
- (b) Nature of the electrolyte (see Clause 2.3).
- (c) Cathode/anode area relationship.
- (d) Metallurgical condition of the metal or alloy.
- (e) Defects present in metallic coatings (see Clause 2.4).
- (f) Noble metal ion contamination in the electrolyte (see Clause 2.5).
- (g) Presence of carbonaceous materials (see Clause 2.6).
- (h) Extent of movement of electrolyte (see Clause 2.7).
- (i) Corrosion product build-up (see Clause 2.8).
- (j) Occurrence of polarity reversal (see Clause 2.9).
- (k) Temperature (see Clause 2.10).

2.2 POTENTIAL DIFFERENCE BETWEEN DISSIMILAR METALS

The potential difference which exists between dissimilar metals prior to contact provides the driving force for the corrosion cell. The larger the potential difference, the greater will be the likelihood of more severe additional corrosion.

NOTE: See Paragraph C4 of Appendix C.

This additional corrosion is measured by the galvanic corrosion rate. In practice however, the deposition of corrosion products on either or both of the metals in contact can change the galvanic corrosion rate. For certain galvanic couples it is possible that a low galvanic corrosion rate can result from a high potential difference prior to contact, because of the presence of corrosion products. Although galvanic corrosion tables traditionally are based on measured potentials in seawater, and the severity of galvanic corrosion is judged to increase as the potential difference between metals increases, the measurement of galvanic current under conditions of exposure gives the best criterion for the estimation of galvanic corrosion rate.

It has been accepted that tables which are based on potentials will indicate significant galvanic corrosion tendencies if the potentials of two metals differ by more than about 200 mV. Such tables should be regarded only as a guide, since exceptions can occur. This Standard includes tables based on galvanic current measurements in stagnant artificial seawater.

In a corrosive environment, slight difference in the behaviour of a metal or alloy can occur as the result of its metallurgical condition, e.g. its state of heat treatment, or the amount of cold working and stressed and unstressed states of electroplated metals.

2.3 NATURE OF THE ELECTROLYTE

In general, the severity of galvanic corrosion depends on the following factors which affect the electrolyte:

- (a) The nature of dissolved ions, e.g. chloride ions are aggressive and hydroxide ions are often passive.
- (b) The absolute and relative concentrations of dissolved ions which can regulate the pH and the electrical conductivity of the electrolyte and the formation of precipitates in the electrolyte.
- (c) The availability of other electro-active substances, e.g. dissolved oxygen and organic inhibitors such as amines.

In marine environments, the chloride ion has a dominant role in corrosion, especially under fully-immersed or tidally-immersed conditions.

In the splash zone or at onshore locations which are subject to windborne salt-mist, the situation is much less predictable due to the vagaries of the weather. If calm, dry conditions follow a period when onshore breezes have heavily contaminated a metal structure with seawater, the drying of the structure will subject it to an electrolyte rich in dissolved chloride ions which can become concentrated to over ten times the strength of ordinary seawater. On the other hand, the contaminating salts can be gradually washed away during substantial rainfall, providing they are not already embedded in corrosion products, in which case even drenching conditions may be unlikely to dislodge them.

Because of the interactions in practice among the factors discussed in this Clause (especially pH, conductivity and oxygen-availability at the actual corrosion sites), it is difficult to generalize on the separate effects of these variables. It would be expected that a relatively high conductivity electrolyte, e.g. seawater, will support higher corrosion currents than would a lower conductivity electrolyte, e.g. rain or tapwater. In practice however, the level of conductivity may be associated, either causally or incidentally, with considerable differences in pH values and the severity of corrosion may be determined by either pH variations or by the differing corrosion products arising under the range of conditions encountered at corrosion sites.

The solubility of oxygen from the air in highly-concentrated seawater is considerably less than in ordinary seawater or fresh water, and this may offset any specific conductivity effects.

Gross conductivity fluctuations can cause incipient corrosive cells to act over smaller or larger distances and affect the distribution and intensity of corrosion. Low conductivity tends to be associated with intense action close to dissimilar metal junctions, while high conductivity can spread the corrosion over a greater distance and make the corrosion more tolerable.

Areas of electrolyte with low conductivity may not persist for long at a corrosion site if ions of the corroding metal, with high conductivity, accumulate there and avoid precipitation.

The influence of dissolved oxygen can be crucial to corrosion under galvanic conditions. Apart from solubility considerations, a differential of dissolved oxygen forming across an incipient corrosion cell may be expected to enhance any galvanic action to which the dissimilar metals may be prone. It is the metal area experiencing the lesser oxygen concentration which suffers the enhanced corrosion, and thus the amount and permeability of corrosion products and other deposits can be of overriding significance to the course and speed of galvanic action in certain cases. The continuing passivity of some metals and alloys is not always dependent on the availability of elemental oxygen (dissolved or gaseous) at the metal surface because the oxygen required to form passivating oxides can often originate from the water itself.

2.4 DEFECTS IN METALLIC COATINGS

2.4.1 General

Galvanic corrosion cells associated with defects in metallic coatings illustrate the importance of anode to cathode area ratio.

Many metals, such as chromium, tin, nickel, cadmium, zinc and aluminium, are used as protective coatings applied to a substrate metal. Some coatings are more cathodic and some more anodic than the substrate. Both cathodic and anodic metallic coatings protect by excluding the environment from the substrate, that is, they possess barrier properties. They should be as free as possible from defects such as pores or scratches.

2.4.2 Cathodic/anode area relationship

The cathode/anode area ratio in a corrosion cell has an important effect on the galvanic corrosion rate and may influence the type of attack. In aerated electrolytes, a relatively large cathode often accelerates corrosion because of the large catchment (surface) area available for oxygen reduction. If the anode is small, or the cathode/anode ratio large, the current density will be high and rapid localized corrosion will occur. Therefore, the cathodic areas should be kept as small as possible to minimize galvanic corrosion.

2.4.3 Cathodic coatings

It is particularly important that cathodic metal coatings be free from pores or defects, as a small area of exposed substrate will act as an anode, with a resultant large cathode to anode area relationship. This can result in a localized area of high current density and the subsequent intense galvanic corrosion of the substrate (see Figure 2.1).

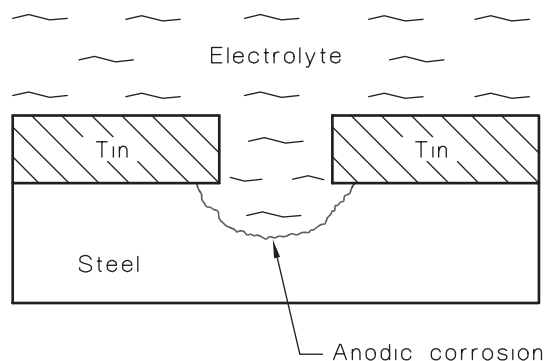


FIGURE 2.1 THE EFFECTS OF A DEFECT IN A CATHODIC METAL COATING (TINPLATE IN SEAWATER)

Examples of cathodic metal coatings are tin, nickel or copper over a substrate of steel. The usual method to minimize the number of pores in a cathodic metal coating is to increase the coating thickness.

2.4.4 Anodic coatings

If a defect occurs in an anodic metal coating, a small area of exposed substrate will act as a cathode, whilst the coating will act as the anode. The exposed substrate is sacrificially protected by the anodic metal coating and the galvanic corrosion of the anodic coating will proceed at a slow rate because of the low cathode/anode area ratio (see Figure 2.2).

An example of an anodic coating is zinc on a steel substrate. The corrosion rate of anodic coatings may be reduced and the coating life extended by the build-up of corrosion products on the coating.

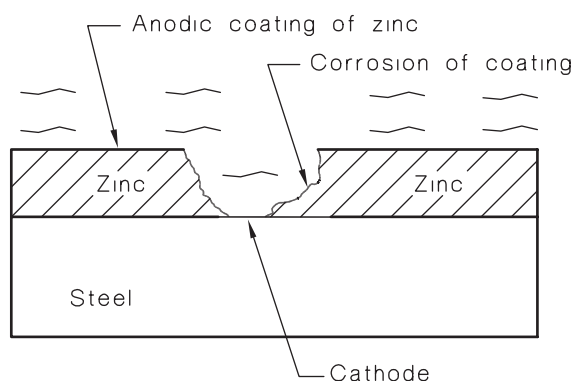


FIGURE 2.2 THE EFFECTS OF A DEFECT IN AN ANODIC METAL COATING
(GALVANIZED STEEL IN SEAWATER)

2.5 NOBLE (CATHODIC) METAL ION CONTAMINATION

Accelerated corrosion of metals can result from the deposition from solution of cathodic metal onto a more anodic metal surface. For example, in a system conveying water, small amounts of copper ions dissolved by the water from copper or copper alloy components, may be deposited in the system as metallic copper on such anodic metals as zinc, aluminium, or ferrous alloys. Galvanic couples of microscopic size formed in this way are likely to produce severe pitting in the more anodic metal adjacent to the cathodic metal (e.g. copper) deposit, when in contact with water.

2.6 CARBONACEOUS MATERIALS

Substances with high carbon contents such as graphite, coke and rubber and carbonaceous lubricants, can initiate or accelerate the galvanic corrosion of a metal, e.g. carbonaceous lubricants used in mechanical working operations.

2.7 MOVEMENT OF ELECTROLYTE

Most situations involving the corrosion of dissimilar metals in contact occur in aqueous solutions under conditions where the primary cathodic reaction is the reduction of dissolved oxygen according to reactions given in Paragraph C3(b) of Appendix C. Factors which influence the availability of oxygen at these sites may then govern the extent of corrosion. Conditions of high flow or agitation generally result in more aggressive corrosion rates than quiescent or stagnant conditions which restrict oxygen supply. However, the presence of oxygen at the anode may promote the formation of oxide films and diminish or inhibit further corrosion.

2.8 NATURE OF CATHODE REACTIONS

If the cathode has no oxide film, reduction of dissolved oxygen occurs readily and metals such as platinum, gold, silver and copper act as an efficient cathodes. However, if reduction takes place on a stable oxide film, the reaction tends to be slower and metals such as titanium, chromium and stainless steel tend to act as inefficient cathodes. As a result, such metals can cause less galvanic corrosion than would be expected from their position in the galvanic series.

NOTE: The galvanic corrosion of steel joined to stainless steel will be less than if it was in contact with copper, at whose surface reduction is much faster.