ATMOSPHERIC ENVIRONMENTS I-04

Protective Coatings

PURPOSE

This section provides a general appreciation for different corrosive atmospheric environments.

INTRODUCTION

This section classifies atmospheric zones in Australia and New Zealand which affect the corrosion of steel and the life of a coating system. When selecting an appropriate protective coating system, the overall atmospheric conditions in the location of the intended structure require consideration.

A structure situated in an aggressive environment will require a much higher standard of corrosion protection than one in a benign environment. The environment can affect both the steel and the paint system. Of prime importance is the effect the environment has on the corrosion of steel. The major factors affecting atmospheric corrosion, and hence atmospheric corrosivity categories based on ISO 9223, are given in AS/NZS 2312:2002 Appendix B.

The effect the environment has on the life of the paint system is also important. It should be appreciated that corrosive environments described do not necessarily affect coatings in the same way as they affect bare steel. Environments that would not be considered to be particularly corrosive to steel, such as hot dry climates with a high amount of ultraviolet (UV) radiation, can cause early breakdown of some coatings. Tropical environments, with high humidity, rainfall, and which promote mould and fungal growth, are far more aggressive to organic coatings than the corrosion rate would suggest.

Furthermore, the colour of the paint may influence its performance in some environments. In addition to climatic effects, the local environmental effects (or microclimate) produced by the erection of a structure or installation of equipment need to be taken into account. Such on-site factors require additional consideration because a mildly corrosive atmosphere can be converted into an aggressive environment by microclimatic effects. A significant acceleration of corrosion rate can occur in the following circumstances:

a) at locations where the metal surface remains damp for an extended period, such as where surfaces are not freely drained or shaded from sunlight, and

b) on unwashed surfaces, i.e. surfaces exposed to atmospheric contaminants, notably coastal salts, but protected from cleansing rain.

Other microclimatic effects which may accelerate the corrosion of the substrate or the deterioration of its protective coating include acidic or alkaline fallout, industrial chemicals and solvents, airborne fertilisers and chemicals, prevailing winds which transport contamination, hot or cold surfaces exposed to abrasion and impact. These effects can outweigh those of the microclimatic zones described in AS/NZS 2312:2002 Clause 2.2. As a result of microclimatic effects it is very difficult, if not impossible, to predict accurately the aggressiveness of a given environment and a certain amount of educated judgement is required to assess its influence on the coating life.

ATMOSPHERIC CLASSIFICATIONS (APPLICABLE TO STEEL)

Atmospheric environments are classified into the following five atmospheric corrosivity categories based on the corrosion rates of mild steel given in ISO 9223, plus one tropical category which is not determined by corrosion rate.

Category A: Very low. Environments in this category are most commonly found inside heated or air conditioned buildings with clean atmospheres, such as most commercial buildings. They may also be found in semi-sheltered locations remote from marine or industrial influence and in heated or non-air conditioned buildings. The only external environments in Australia or New Zealand are some alpine regions although, generally these environments will extend into Category B.

Category B: Low. Environments in this category include dry, rural areas as well as other regions remote from the coast or sources of pollution. Most areas of Australia and New Zealand beyond at least 50 kilometres from the sea are in this category, which can however, extend as close as 1 kilometre from seas that are relatively sheltered and quiet. Typical areas occur in arid and rural inland regions, most inland cities and towns such as Canberra, Ballarat, Toowoomba, Alice Springs and Hamilton (New Zealand) 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). Unheated or non-air-conditioned buildings where some condensation may occur, such as warehouses and sports halls, can be in this category. Proximity to the coast is an important factor.

Category C: Medium. This category mainly covers coastal areas with low salinity. The extent of the effected area varies significantly with factors such as wind, topography and vegetation. Around sheltered areas, such as Port Phillip Bay, Category C extends beyond about 50 metres from the shoreline to a distance of about one kilometre inland. For a sheltered bay or gulf, such as near Adelaide, this category extends from the shoreline to about 3 to 6 kilometres inland. Along ocean front areas with breaking surf and significant salt spray, it extends from about 1 kilometre inland to between 10 to 50 kilometres inland, depending on the strength of prevailing winds and topography.

Much of the metropolitan areas of Wollongong, Sydney, Newcastle, the Gold Coast, Auckland and Wellington are in this category.

In South Australia, the whole of 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, this category extends between 30 and 70 kilometres inland. Such regions are also found in urban and industrial areas with low pollution levels and although uncommon in Australia and New Zealand, exist for several kilometres around major industries, such as smelters and steelworks, and in the geothermal areas of New Zealand.

Micro-environmental effects, such as those resulting from proximity to airports and sewage treatment works, may also place a site into this category. Interior environments with Category C corrosivity can occur in humid production rooms, such as food-processing plants, laundries, breweries, printing works and dairies.

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 to about 1 kilometre inland. As with Categories B and C, the extent depends on winds, wave action and topography. Industrial regions with an aggressive atmosphere may also be in this category, but in Australia and New Zealand these are only likely to be found within 1.5 kilometres of the plant. This category extends inside the plant where it is best considered as a micro-environment. Damp, contaminated interior environments such as occur in swimming pool enclosures, dye works, paper manufacturers, foundries, smelters and chemical processing plants may also extend into this category.

Category E: Very high. (E-I: Industrial E-M: Marine) This category is common offshore and on the beachfront in regions of rough seas and surf beaches. The region can extend inland for several hundred metres. (In some areas of Newcastle, for example, it extends more than half a kilometre from the coast). This category may also be found in aggressive industrial areas, where the environment may be acidic. For this reason, Category E is divided into Marine and Industrial for purposes of coating selection. Some of the damp and/or contaminated interior environments in Category D may occasionally extend into this category.

Category F: Inland Tropical. A tropical environment is found in coastal areas of north Queensland, Northern Territory, north-west Western Australia, Papua-New Guinea and the Pacific Islands, except where affected by salinity. Corrosivity in inland regions is generally low (similar to that of category B), but the aggressiveness of the environment to organic coatings means that special protection is required.

If a site is considered to be in more than one category, for example an industry on the coast in a tropical region, then a selected coating should, if possible, be capable of resisting each of the environments.

OTHER ENVIRONMENTS

Steelwork may be immersed in water, buried in soil, or exposed to other environments not specifically defined in any of the above listed categories. Structures in such environments are subject to corrosion problems often of a completely different nature to atmospheric corrosion. Not only are different coating systems sometimes used, but a number of other corrosion prevention options, such as cathodic protection or selection of different materials should be considered. The selection of such prevention methods requires specialist advice.

ADVICE ON ATMOSPHERIC CORROSION OF STEEL IN AUSTRALASIAN CLIMATES

There are a large number of factors which influence atmospheric corrosivity but the three most important are:

a) time of wetness
b) atmospheric chloride content, and
c) atmospheric sulphur dioxide content.

Time of wetness is the length of time during which the metal surface is covered by a film of water which renders atmospheric corrosion possible. It is influenced by factors such as metal mass, orientation and pollution, and is quantified to sufficient accuracy by the number of hours per year that the relative humidity is above 80% for temperatures above 0°C. Airborne salinity and sulphur dioxide content are both powerful stimulants of atmospheric corrosion and their deposition rate in non-sheltered situations is directly proportional to their concentration in the atmosphere. Airborne salt has a major influence on corrosion rates; however, sulphur dioxide has been found to play only a minor role in the corrosion of steel in Australia and New Zealand and can be neglected except when occurring near recognised point sources.

Rainfall also influences corrosion rates and has the effect of either stimulating or reducing corrosion, depending on the environment. In polluted atmospheres, the washing effect of the rain reduces corrosion, while in less polluted sites the situation is reversed and the corrosive action of rain is more important. Temperature can also have contradictory effects. Increasing temperature increases the rate of the corrosion reactions but, on the other hand, leads to more rapid evaporation, shortening the time of wetness and decreasing the corrosion rate. Unless specific corrosive chemicals are present, time of wetness, chloride and sulphur dioxide deposition are the most important factors influencing corrosion rates. If details of these factors are known, atmospheric corrosiveness can be estimated from the information in ISO 9223. However, there is some doubt as to whether such calculations can give an acceptable figure for corrosivity, especially in Australian and New Zealand. Furthermore, ISO 9223 allows estimation of corrosivity zone based on corrosion rates of other metals such as zinc.

Evidence suggests that the corrosion rates of steel and zinc cannot be reliably related as suggested by ISO 9223, and as a result, zinc corrosion rates have not been used to define zones in AS/NZS 2312:2002. Only actual corrosion rate measurements of steel carried out in Australia and New Zealand have been used to define the corrosivity zones, extrapolating such results to other areas with similar climates and geography. Therefore, corrosivity zones described in AS/NZS 2312:2002 are not identical to ISO 9223, but they are closely based on them.

The accurate measurement of corrosion rate with acceptable reproducibility is not easy. Because the factors which influence corrosion rate are variable from one year to the next, measurements made over different time periods can vary considerably. The month in which the panels are first exposed is important, as panels initially exposed in winter generally show higher corrosion rates than those initially exposed in summer.

However, climatic factors, especially rainfall, can influence this significantly. The time over which the tests are taken is critical, as rates tend to drop off with time due to the protective nature of the rust which builds up. Panels exposed at an angle corrode at a different rate to panels exposed vertically, and panels made from copper-containing steel corrode at a slightly lower rate to panels made from ordinary mild steel. The total effect of these factors is that corrosion rate experiments carried out in different parts of the world, over different time periods, using different panels, cannot be compared unless all conditions are the same. The ISO 9223 system of dividing corrosivity into five categories simplifies matters somewhat, although lines between categories are, naturally, rather arbitrary.

Table 1 shows the corrosivity zones used in AS/NZS 2312:2002, their ISO 9223 equivalent, and the expected one-year corrosion rates of steel within each category.

TABLE 1 - CORROSIVITY CATEGORIES

Corrosivity categories	ISO 9223 Category	Corrosion rate for steel - μm/year	Typical exterior environment	Examples of interior environments
A: Very low	C1	<1.3	Few alpine areas	Offices, shops
B: Low	C2	1.3 to 25	Arid/rural/urban	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 190	Sea-shore (surf)/offshore	Plating shops, chemical plants
F: Inland Tropical	-	-	Non-coastal tropics	-

NOTE: To convert corrosion rates expressed in grams per square metre per year to microns per year, divide by 7.9 (the density of steel in g/cm^3).

Table 2 lists one-year corrosion rates for mild steel for a number of sites. Where exposure times were other than one year, or copper steel was used rather than mild steel, corrections have been made to convert the results to one year, mild steel rates. Where a number of figures are available for a given site, an average result has been quoted. It should be possible using this information to estimate the atmospheric classification of other sites.

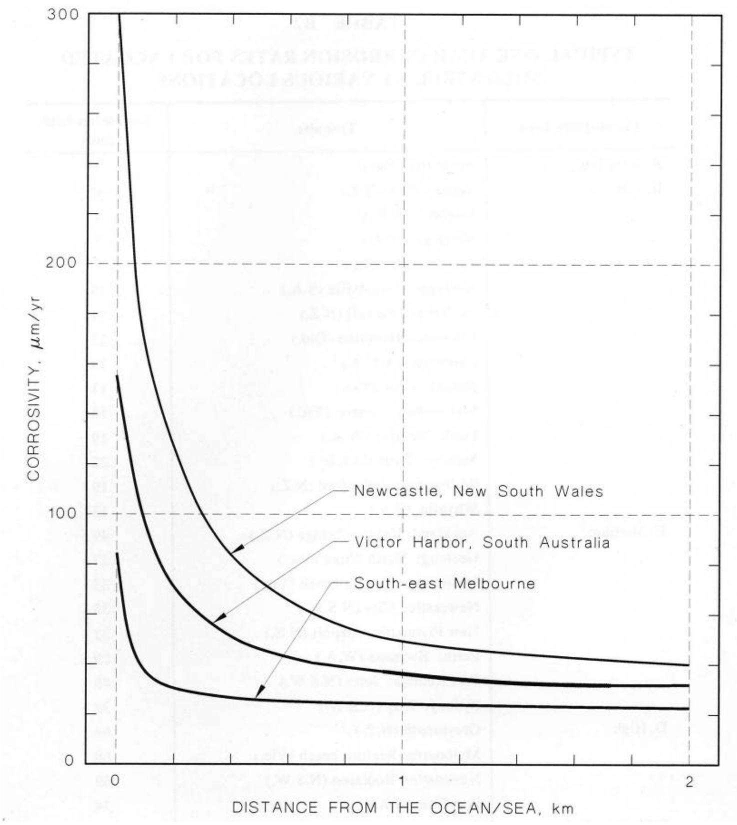
It is to be recognised that corrosion rates near the coast drop off rapidly with distance inland and a given suburb or town can be in one, two or even three corrosion zones depending on its proximity to the ocean. Furthermore, the effect of the sea varies according to locality. Around a sheltered bay, such as Port Phillip Bay, the marine influence (ISO Category 3) extends about 0.5 km inland, while along the New South Wales coast, for example, it may extend inland 20 km or more. Figure 1, based on work carried out by the CSIRO in Newcastle (New South Wales), Melbourne (Victoria) and Victor Harbor (South Australia), illustrates the impact of distance from the coast and particular locale on the corrosion rate of steel.

TABLE 2 - ONE YEAR CORROSION RATES FOR UNCOATED MILD STEEL AT VARIOUS LOCATIONS

Atmospheric classification	Test site		Corrosion rate - µm/yr
A: Very low	Mt Buller (Vic)		1
B: Low	Arthurs Pass (NZ)		6
	Dubbo (NSW)		4
	Newman (WA)		3
	Toowoomba (Qld)		9
	Adelaide: Woodville (SA)		15
	Auckland: Parnell (NZ)		21
	Brisbane: Hamilton (Qld)		22
	Canberra: (ACT)		14
	Hobart: City (Tas)		11
	Melbourne: Clayton (Vic)		18
	Perth: Bentley (WA)		19
	Sydney: Ryde (NSW)		22
	Wellington: Judgeford (NZ)		19
	Whyalla (SA)		13
C: Medium	Auckland: Harbour Bridge (NZ)		49
	Geelong: North Shore (Vic)		27
	Melbourne: Altone Beach (Vic)		35
	Newcastle: City (NSW)		35
	New Plymouth: Airport (NZ)		31
	Perth: Kwinana (WA)		29
	Port Kembla: Jetty (NSW)		45
	Sydney: City (NSW)		32
D: High	Greymouth (NZ)		64
	Melbourne: Seaford Beach (Vic)		68
	Newcastle: Boolaroo (NSW)		63
	Port Pirie (SA)		74
E-M: Very high (marine)	Cowley Beach (Qld)		142
	Newcastle Beach (NSW)		194
F: Inland Tropical	Goroka (P.N.G.)		4
	Innisfail (Qld) -	sheltered	17
	-	open	25
	Port Moresby (PNG)		17
	Rabaul (PNG)		13
	Townsville (Qld)		15
	Tully (Qld)		20

Note: 1. These corrosion rate figures do not take into account micro- or macro- environmental regions which may occur within each location.

Note: 2. For further information on corrosion rates, contact CSIRO Division of Building, Construction and Engineering (Highett) in Australia, and BRANZ (Wellington) in New Zealand.



GRAPHS DERIVED FROM MEASURED DATA SHOWING VARIATION OF ONE YEAR CORROSION RATE OF MILD STEEL WITH DISTANCE FROM THE OCEAN

Note: 1. For south east Melbourne the distance is from Port Phillip Bay.
Note: 2. The Panels used to carry out the tests were exposed vertically.

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