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# SUGGESTED ZONES OF STEEL CORROSION HAZARD IN NEW ZEALAND ATMOSPHERES

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*There seems to have been no collection of steel atmospheric corrosion rate data in New Zealand. The factors most likely to affect atmospheric corrosion in New Zealand are chloride blown inland and high relative humidities. Based on published data for these parameters, and modelled on the clauses in AS2312 which describe corrosiveness of Australian atmospheres, a set of descriptions for zones of atmospheric corrosivity in New Zealand are presented. Sketch maps have been prepared indicating the general areas covered by these corrosivity zones.*

## 1. INTRODUCTION

The recent moves in New Zealand toward increased erection of chemical plant have raised interest in establishing a code or standard covering protection of steel against corrosion in New Zealand atmospheres. N.Z. Heavy Engineering Research Association assembled a group late in 1981 to examine this question, with specific focus on whether the Australian Standard "AS2312 1980: Guide to the protection of iron and steel against exterior atmospheric corrosion" <sup>1</sup> was easily adaptable to use in New Zealand. The section on atmospheric environments in this standard was identified as needing special examination. This section classifies the corrosivity of the general climate, with the warning that microclimatic effects can over-ride this general corrosivity and should be taken into account when protective systems are considered. Classes, designated **mild**, **moderate**, **severe** and **very severe**, are based on the corrosion rate of steel. When these words are used in this paper, they specifically refer the climate at New Zealand locations to these Australian Standard classifications.

Though structural steel has been used for many years in New Zealand on railway viaducts and similar structures, there appears to be a total absence of corrosion rate data for steel in New Zealand atmospheres. It is therefore necessary to base any proposals regarding expected corrosivities in New Zealand atmospheres on theoretical principles, and ancillary data such as meteorological parameters and atmospheric salinity. The map (Figure 1) shows a proposal of this type, dividing New Zealand into a series of zones of expected corrosivity. It is not presented as a definitive answer, because detailed local knowledge should always be sought to clarify the expectation of corrosion. It is based on the principles and data discussed in the following sections, and it is hoped that it represents a fair guide to the atmospheric corrosivity toward steel which is attributable to natural effects. It must be emphasised that erecting a chemical plant at a site may disturb the local environment, normally to make it more corrosive.

## 2. JUSTIFICATION FOR DECISIONS IN ESTABLISHING ZONES

### 2.1 Atmospheric Corrosion Theory

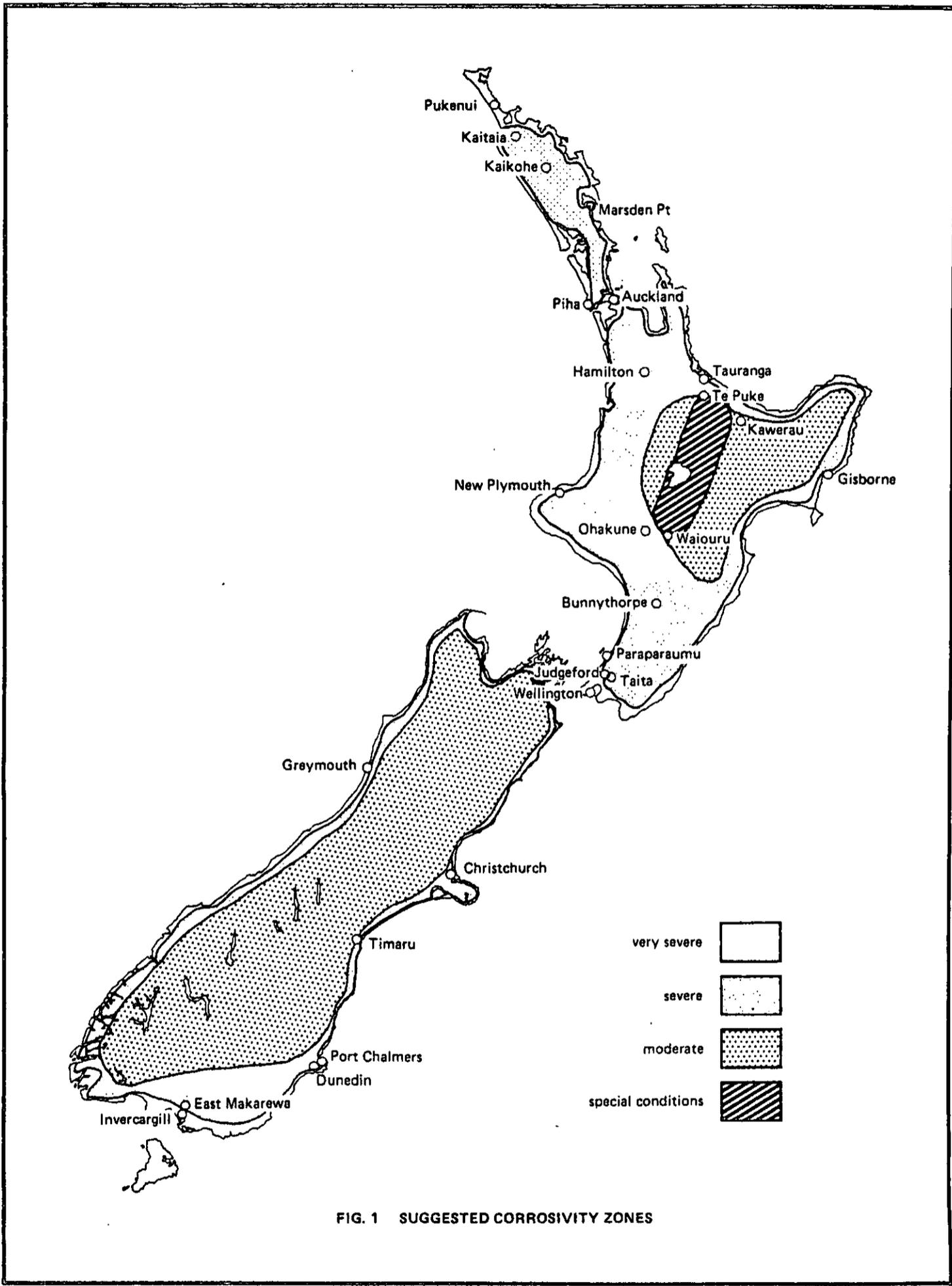
It is not intended to try to reproduce here the contents of the textbooks in this field <sup>2 3 4 5 6</sup>. It seems important, however, to set down the principles which have been regarded as important.

There is virtually unanimous agreement that water in the atmosphere plays the crucial role in atmospheric corrosion. Liquid water is deposited on the surface by rain, fog, or thawing snow. In rain, there is an excess of water for the corrosion process. The water layer renews itself continuously during rainfall, and the large variations cause introduction of water-soluble components of the atmosphere (especially oxygen) which aid the corrosion. On the other hand, in prolonged rain there is washing away of accumulated salt and pollutants from the surface, and so the corrosion process may be slightly inhibited. In addition, there is washing-away of previously-formed corrosion products. These products may be sparingly soluble, so inhibiting corrosion significantly by forming a more or less continuous surface layer. The mechano-erosive action of rain is significant in this case.

The case where the surface is wetted by very small water drops (mist) is quite different. The amount of water precipitated is far smaller here, and rarely leads to major water exchange on the surface. The small water droplets are saturated with atmospheric oxygen and all other species important for corrosion which are present in the atmosphere, because of the large surface area of the drops. A continuous liquid layer is visible on 'pure' metals only after prolonged exposure to mist, and this forms by coalescence of isolated drops. If corrosion products already exist, a continuous water layer is likely to form during fog; due to the microporous structure of the predominantly crystalline corrosion product. Electrolyte layers formed during exposure to fog are thinner than those in rain, but more aggressive because of the extra corrosion stimulator content and because they are not washed off again.

Water vapour in the air is perhaps even more important than liquid water. Hygroscopic water-soluble salts, coming into contact with humid air after being dried, take up water vapour from the atmosphere to give a solution whose concentration corresponds to an equilibrium value between the water vapour partial pressure over the solution and that existing in the atmosphere. This can happen below 100% relative humidity. Particularly in atmospheres which contain large quantities of salts and in which the metal surface is more or less contaminated with them, this type of electrolyte formation is of special importance. This occurs in coastal and industrial regions; in the former because of chloride, in the latter because of sulphate formed from sulphur dioxide.

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In New Zealand, it is an appropriate first approximation to ignore industrial pollution effects due to sulphur dioxide; microclimates suffering from these effects will exist around flues, but there are no significantly industrially polluted regions of the scale commonly meant by this term when applied to European or American countries. Some winter days in Christchurch will have high SO<sub>2</sub> levels, but this is dispersed within a few days, at most.

Salt particles from the atmosphere are not the sole source of hygroscopic species at the metal surface. During corrosion reactions between metals and gaseous species (normally air pollutants), soluble hygroscopic products form, and these lead in turn to electrolyte formation. In this respect, chloride is particularly important. Relative humidities at 20°C over some saturated solutions of chlorides are as follows:

Salt	%
Zn Cl <sub>2</sub> .H <sub>2</sub> O	10
CaCl <sub>2</sub> .6H <sub>2</sub> O	32
MgCl <sub>2</sub> .6H <sub>2</sub> O	34
NaCl	77
KCl	86

Evans<sup>5</sup> has pointed out that in presence of pure sodium chloride, corrosion of iron slows below 75% RH, but in presence of sea-salt corrosion is still quite rapid at 50% RH. This is probably due to the significant magnesium and calcium contents of sea-salt, and means that tests using sodium chloride alone may not reflect actual service. Much earlier, Vernon<sup>7</sup> had shown that if steel was protected by a muslin screen from deposition of salt or dust particles, corrosion was minimal even at 99% RH. Thus, high humidities alone may not be corrosive, but the higher the humidity the greater the corrosion danger if there is any hygroscopic substance on the surface.

In contrast to the many ways an electrolyte layer can form, the disappearance of these layers can in practice be due only to evaporation or to formation of chemical reaction (corrosion) products. Water layers can evaporate from metal surfaces only at below 100% relative humidity. The evaporation process is thus dependent above all on the environmental relative humidity. A significant temperature effect is likely. Barton<sup>2</sup> reviewed a suggestion that an algorithm for time of wetness could be based on time spent at above 20°C and/or below 75% RH, but concluded it to be unsatisfactory, and that there could be no simple formula for determining time of wetness. Nonetheless, reviews such as Sereda<sup>8</sup> have discussed reasonable correlation of time of wetness to duration of periods when relative humidity exceeds a set value (which seems dependent on location, but is generally in the range 80-85%). This information is usually obtainable from meteorological records.

Increased temperature can have an unpredictable effect on corrosion. Like most chemical processes, the actual oxidation/reduction rate is higher at higher temperatures, but higher temperatures can also lead to faster evaporation of electrolyte films which halts the corrosion process. As a general rule, at a constant relative humidity a rise in temperature will raise the corrosion rate. (Cermakova<sup>9</sup> gives a fuller discussion of temperature effects.)

## 2.2 Chloride Effects on Corrosion Rates

The stimulating effect on corrosion of steel of small amounts of chloride ion has long been known, and this effect is responsible for the high corrosion rates in marine atmospheres.

Brierly has distinguished four corrosion risk zone types based on sea-salt fall-out, as follows<sup>10</sup>:

### Area I: Oceanic Islands and Coastal Areas - Heavy Fallout

Saltfall from all processes varies from a minimum of 28 kg/ha per year to more than 340. Specific well-exposed areas may receive as much as 4500. Individual 2- or 3-day storms may deposit as much as 30 kg/ha per storm. Daily salt-fall during maximum periods may be as high as 20 kg/ha per day.

Coastal areas of low-lying relief have a lower coastal fallout but a higher inland fallout. The same is also true of embayments and inland arms of the sea that penetrate the land masses. Cuspate forelands, peninsulas, and islands in areas of moderate or intense winds can be expected to have a high sea-salt fallout.

### Area II: Intermediate Coastal and Humid Inland Areas - Moderate Fallout

Saltfall from all processes varies from a minimum of about 3.4 kg/ha per year to about 28. A belt of decreasing amounts of saltfall extends from parts of the coast where offshore winds or winds that parallel the coast are dominant, to a point from 50 to 1,000 miles inland (depending on topography) where saltfall variability is reduced to a minimum. Coasts may be moderately saline, but salinity drops off very rapidly inland. Corrosion rates of ferrous metals and zinc fall off very rapidly from the coastal area to a point inland where there is little or no visible corrosion within a year.

### Area III: Subhumid and Humid Area of Uniform Low Saltfall - Light Fallout

Saltfall from all processes in such regions is less than about 5.5 kg/ha per year from atmospheric sea-salt fallout as recorded by standard measurements. The areas are located primarily in the interior of continents.

### Area IV: Arid Areas of Variable Saltfall - Light to Moderate Fallout

Sea-salt fallout is normally less than 5.5 kg/ha per year but total saltfall may locally be abnormally high due to salt laden winds from off lakes of high salinity, or to wind-blown topsoil.

## 2.3 Chloride in the New Zealand Atmosphere

Few measurements appear to have been made of this parameter. However, a map showing distribution of sodium in sweet vernal grasses around New Zealand has been published<sup>11</sup>. This map was compiled on the basis of 400 measurements made at sites distributed throughout New Zealand, and checks were subsequently made by sampling along prevailing winds at increasing distance from the sea. Four levels of sodium concentration are chosen to define five zone bands which are described in this paper as Categories I to 5 (I being the highest concentration). The degree of detail shown on the maps is considerable considering the inevitably wide spacing of analyses around the coast. The maps carry a warning that they are intended only to indicate broad patterns. Despite these reservations, the maps represent the best available information to date as a first approximation to chloride distribution in New Zealand atmospheres, assuming that where sodium occurs chloride will also be present. (Miller<sup>12</sup> has shown that at Taita in 1956-8, sodium and chloride comprised 78% of the salts in rainfall, in similar ionic ratios to those in sea water. The "sodium presence implies chloride" assumption therefore seems reasonable).

TABLE 1 : CORROSION INDICES USING ALUMINIUM WIRE ON STEEL BOLT AT SITES IN NEW ZEALAND

Location	Value	Approximate distance of site from sea, km
Pukenui-Kaitaia	11.5-15.1	1-15
Marsden Point	11.1	less than 1
Piha	15.9	0.2
Penrose, Auckland	6.5	3
Auckland City	8.3-10.3	3
New Plymouth	14.3	less than 0.2
Paraparaumu - Bunnythorpe	9.0-12.8	1-7
Judgeford	2.0-5.7	6
Timaru	Less than 3	5
Port Chalmers	9-17	less than 3
Halfway Bush, Dunedin	1.2	6
South Dunedin	2.1	less than 3
Tiwai Point	11.3-13.6	less than 3
East Makarewa	8.3	15
Orepuki	30.3	less than 0.3
Sydney	6.4	0
Sydney	6.1	0.16
Adelaide	2.3	8
Sydney	3.1	21
Wentworth Falls	1.8	80

Notes: 1. Topography and season can have marked effects on the values found in this test.

2. Australian data taken from reference 16.

Further, this approximation generally agrees with expectations on the basis of closeness to the sea and prevailing winds. Other data, for scattered sites, based on chloride content of rainwater, is as follows<sup>12 13</sup>:

	kg/ha per year
Lincoln, 1884-1888	68
Wellington (coast) 1947-1951	235
Wellington (10 km inland) 1947-51	54
Waingawa 1947-1951	40
Gore 1955-8	67
Taita 1956-8	116
Taita 1963-1971	113
Taita 1969-1974	95

Collection of a high amount of salt in rainwater in a sampling period at Taita correlated well with an approach of the ion ratio to seawater, suggesting that in peak periods much of the salt is occurring as spray direct from the sea. These peak periods also correlated well with occurrence of southerly storms<sup>14</sup>. The Taita site is about 10 km north of Wellington harbour. The prevailing wind is northerly and has to come more than 15 km from the coast over hills rising to about 360 metres. The three lowest monthly chloride levels in the 1956-8 period averaged 16 kg/ha per year. This might be regarded as a background level, and in light of Brierly's classification<sup>10</sup> implies a significant corrosion hazard at all times.

On the basis of rainwater chloride levels alone, all the sites listed in Miller<sup>12</sup> fall in Brierly's "Area I". In addition, a considerable amount of chloride arrived at the Taita catchment independent of deposition with rain in the 1969-70 period; this was attributed to wind-blown salts<sup>14</sup>. If this dry deposition was common to all sites it will push these areas of New Zealand even further into Area I. Taita, Waingawa and Gore all fall in the third-highest category of the DSIR sodium distribution maps<sup>11</sup> and Lincoln appears to fall in the next lower category. This DSIR information should provide a fair basis for the delineation of long-term average chloride levels, though the rainwater collections at Taita<sup>12</sup> suggest that short duration storms will carry a lot of chloride inland, and close to the coast it would be prudent to expect higher chloride deposition levels from time to time. If there is a correlation between chloride concentration in rainfall and sodium concentration in grass, it would appear that at least all areas in the first three categories on the DSIR map should be regarded as Area I in Brierly's classification<sup>10</sup> of chloride-promoted corrosion hazard, and that consideration should be given to putting some of the DSIR's fourth category into Brierly's Area I also.

#### 2.4 Hydrogen Sulphide in the Atmosphere

There are special problems posed by geothermal emission of hydrogen sulphide in the area bounded by Kawerau, Waiouru, Ohakune and Te Puke. Hydrogen sulphide has significant corrosive effects, both in forming sulphides with metals such as copper, nickel or silver, and in providing a source (after oxidation) of sulphur oxyanions which promote corrosion of zinc and steel, and in moist H<sub>2</sub>S all metals are subject to corrosion<sup>6</sup>. Because hydrogen sulphide is an acidic gas, it also results in surface moisture becoming more acidic, promoting corrosion. Kennett<sup>15</sup> suggested that the "normal" level of H<sub>2</sub>S in the Rotorua area is 0.01 parts per

million (about 15 µg/m<sup>3</sup>). This contrasts with the quoted level<sup>2</sup> for "normal urban atmosphere" of 1 µg/m<sup>3</sup>. Some areas of Rotorua which are labelled "gas abundant" have 7000 µg/m<sup>3</sup> H<sub>2</sub>S in their atmosphere.

In the light of these potentially high local levels of corrosion-promoting gases, special measures are needed in protection of metals against corrosion in these areas. Some such measures are discussed in the paper by Kennett.

#### 2.5 Corrosion Rate Measurements in New Zealand Atmospheres

No published data on corrosion loss from steel panels appears to exist for New Zealand atmospheres, and little information on non-ferrous metal corrosion rates in New Zealand exists (most of it inferential rather than from direct weight loss measurements.) The aluminium wire on steel bolt test<sup>16</sup> appears to have been the most widely used test of atmospheric corrosivity in New Zealand, with most of the testing having been performed by Alcan (NZ) Ltd and the Ministry of Energy during planning of routes for transmission lines. The data for New Zealand presented in Table I is the percent weight loss of the aluminium wire after 90 days, and mostly represents previously unpublished results supplied by the Ministry of Energy. These results permit some placing in context of overseas exposures, but they must not be regarded as an unequivocal prediction method for steel corrosion rates.

Zinc corrosion rate data of the type used to generate a corrosion map for UK<sup>17</sup> was collected at some New Zealand sites in the early 1970s, but the results were never published. However if they become available, zinc corrosion rate measurements should not be regarded as satisfactory predictions of steel corrosion rates. Evidence of the unreliability of zinc corrosion rates as indicators of steel corrosion rates may be found in an ASTM study<sup>18</sup> which found a ratio of steel loss to zinc loss from panels exposed for two years ranged over seven sites categorized as "rural" from 10.3 to 22.0, averaging 17.9, but over the 12 sites categorized as "marine" from 25.2 to 364.0, averaging 93.6.

#### 2.6 Corrosion Rates in Australian Atmospheres

Table II is adapted from AS2312<sup>1</sup> and represents corrosion rates measured on low-carbon steel panels during exposure tests. Martin and King<sup>19</sup> have tested steel corrosion in different environments in seven Australian cities, using standardised coupons exposed vertically. They found that the corrosivity of the Melbourne atmosphere had approximately halved over the decade 1968-1978. No attempted explanation of this was made. Samples examined after distinct wet and dry periods showed reduced sulphur and chlorine surface levels after wet periods, which they attributed to washing-out by rain. King, Martin and Moresby<sup>20</sup> have provided a map showing how corrosion rates of steel vary over an area around Melbourne.

As an indication of atmospheric corrosivity, the Australian data in reference 16 has been reproduced in Table I. It will be observed that in general these values are much lower than for locations in New Zealand. It is again emphasised that no direct correlation exists between this aluminium wire on steel bolt test and the corrosion rate of steel, but this evidence points to the Australian corrosion rates being expected to be lower than in New Zealand.

#### 2.7 Meteorological Data for Australian and New Zealand Cities and Towns

Table III lists some meteorological parameters for Australian cities<sup>21</sup> and New Zealand cities and towns<sup>22</sup>. Study of the source of the data for NZ suggests that the

TABLE II : AVERAGE CORROSION RATE PER SIDE FOR VERTICAL EXPOSURE, LOW-CARBON STEEL

Exposure site	Environment	Corrosion rate, $\mu\text{m}/\text{yr}$			
		Years exposed			
		1	2	5	10
NEW SOUTH WALES					
Port Kembla (Steelworks)	Coastal marine/severe industrial	35	27	23	18
Appin	Rural/mild	19	17	12	9
Nebo Colliery	Rural/mild	13	9	8	7
Sydney Suburban (Rydalmere)	Urban/severe industrial	54	39	25	18
Sydney City (Pyrmont)	Urban/light industrial	31	22	13	9
Dubbo	Rural/arid	4	4	3	2
VICTORIA					
Melbourne (Clayton)	Urban/light industrial	30	23	14	9
Geelong	Coastal marine/severe industrial	40	31	21	14
SOUTH AUSTRALIA					
Port Pirie	Coastal marine/severe industrial	74	56	39	33
Adelaide	Urban/light industrial	31	25	15	9
Whyalla (BHP)	Arid/severe industrial	14	10	6	5
WESTERN AUSTRALIA					
Perth	Urban/light industrial	27	21	13	10
Kwinana	Coastal marine/severe industrial	45	39	38	25
Mount Newman	Rural/arid	3	2	2	1
QUEENSLAND					
Brisbane	Urban/marine	28	19	12	8
Townsville	Urban/tropical	15	11	6	5
Tully	Coastal/tropical (high rainfall)	25	17	9	7
Hodgson Vale	Rural/arid	8	5	3	2
TASMANIA					
Burnie	Coastal marine/severe industrial	29	23	18	15
Hobart	Severe industrial	71	59	47	33
Hobart	Urban-rural/mild	17	13	8	6

9am RH value is a fair measure of the mean RH value for the New Zealand locations. This is an important point, because while most meteorological stations record 9am humidity, only a restricted number record humidity around the clock, and so designers will often have only 9am humidity values on which to base decisions.

Very few areas of New Zealand have predominant winds blowing out to sea. Strong winds (exceeding 15 knots) will have the greatest effect on the distance inland that chloride ions are carried, and the map in reference 23 shows that the only parts of New Zealand which have their strong winds blowing from the land to the sea are the east coasts of North and South Islands between East Cape and the Kaikoura Peninsula.

It is immediately apparent from Table III that the New Zealand climate is generally characterised by higher humidity and rainfall and lower temperatures than in Australia. In some localities in New Zealand, if the approximation (time of wetness) = (time RH exceeds 85%) is true and the data in Table III is a fair reflection of mean RH, there must be at least 50% time of wetness in some winter months. (See, for example, Kaitaia, Hamilton, Wellington and Christchurch). None of the Australian data remotely approaches such values. The net result of this is a considerable increase in the amount of water available to participate in corrosion reactions, and so in the presence of comparable amounts of corrosion stimulators such as chloride, considerably greater corrosion of exposed steel could be anticipated in New Zealand than in Australia. This ignores the effect of temperature - the enhanced sunshine hours in Australia, especially with respect to the southern half of the South Island of New Zealand, and the lower relative humidities will probably result in shorter times of wetness after rain in Australia, though during time of wetness the corrosion rate may be higher.

Some other points from the data in Table III should perhaps also be discussed briefly. The rainfall in Greymouth is sufficiently high all year round to remove deposited chloride from exposed surfaces, but there is very high humidity all year round so that chloride deposited onto steel surfaces which are sheltered from rainwashing is likely to make corrosion especially high. Winter rainfall in Kaitaia may be sufficiently high to provide some chloride washing out effect in winter (and thus some deceleration of corrosion), but the high humidities again mean sheltered surfaces will be very susceptible to corrosion.

Brisbane and Sydney have wetter summers and drier winters than the North Island of New Zealand, in the sense of rainfall. Martin and King<sup>19</sup> claimed that an algorithm for a time of wetness index, based on rainfall, evaporation and number of frosty nights, allowed rationalisation of the discovery that Sydney, Perth, and Brisbane were more corrosive than Canberra, Adelaide, Melbourne and Hobart. No derivation of this algorithm was given. It is of the form

$$\text{time of wetness} = \frac{(\text{Rainfall})^2 + (\text{number of frosty nights})}{(\text{Evaporation})}$$

Martin and King's values of this time of wetness index for some Australian cities are shown in Table IV; also shown are index values for some New Zealand locations (using data from New Zealand Meteorological Service<sup>24</sup>) calculated on the same basis, which indicate that if the algorithm is valid all of the North Island NZ locations listed have meteorological factors making them more prone to corrosion than any of the Australian cities listed. On the basis of this index, Christchurch and Invercargill might be expected to have similar tendency to corrosion due to atmospheric water to those of Melbourne and Hobart.

### 3. PROPOSALS FOR CORROSIVITY ZONES FOR NEW ZEALAND IN LINE WITH AS2312

This section has been compiled on the assumption that zone names should parallel those used in AS2312. It appears to be an unstated intention of the Australian Standard that the worst case in each area is legislated for, so that beneficial effects of rainwashing are downrated. It is virtually impossible to avoid unwashed areas when structural steel is used outdoors. This approach, of legislating for worst cases, has been continued in preparing this NZ comparison.

#### 3.1 Very Severe

The Australian Standard proposed two types of **very severe** zone: "tropical" and "coastal marine". The Australian "coastal marine" classification required certain humidity levels and restricted the area to a specific distance from the coast. Such a distance restriction seems very unwise in New Zealand, and it would perhaps be more prudent to say that the very severe zone exists in a 2km (minimum) band right around the NZ coast, and includes all areas falling in DSIR categories 1 and 2 for sodium distribution no matter how far inland they reach. In view of the high salt content of southerly winds reaching the south coasts of both North and South Islands, it is probably prudent to regard the very severe band as 15km wide in these areas. The examples given in the Australian Standard clearly show that it may be assumed for this classification that New Zealand has no "tropical" areas.

#### 3.2 Severe

The Australian Standard sets a requirement of a high level of industrial fallout and some marine influence in establishing a **severe** category. The best compromise in New Zealand, in the absence of industrial fall-out problems, seems to be to categorise the corrosion-stimulating characteristics of this type of region in terms of Category 3 sodium distribution in the DSIR map, while retaining the Australian requirements of over 1000mm per annum rainfall and humidity averaging over 50 percent, with periods above 80 percent. The Australian Standard did not put a lower limit on distance from the coast, and indeed gives as an example of this type of region places further than 500m from the shoreline in Melbourne and Kwinana. The enhanced humidity in New Zealand and the high frequency of onshore winds probably makes such a close approach to the coast unwise in New Zealand, and it would seem sensible to adopt a minimum distance of 2km from the coast until firmer data on corrosion rates close to coasts is available. DSIR category 5 areas within 2 to 15km from the coast and category 4 areas with rainfall above 1000mm p.a. also come into this zone.

#### 3.3 Moderate

For a **moderate** zone, the Australian Standard set criteria for rainfall, humidity and distance from the coast; such areas are "away from heavy industrial activity". It seems sensible to retain the rainfall and distance from coast criteria, and to combine these with existence of category 4 or 5 level of sodium on the sodium distribution map.

#### 3.4 Mild

If the criteria of annual rainfall less than 500 mm and average humidity values below 55%, as used in this Australian Standard, are applied to New Zealand, no meteorological station in New Zealand lies in a **mild** environment; the closest to this category is the Central Otago area where, though average annual rainfalls are often below 400mm, average relative humidities are rarely less than 70%. The areas with the lowest humidities (still in the

TABLE III : METEOROLOGICAL PARAMETERS FOR AUSTRALIAN AND NEW ZEALAND TOWNS AND CITIES

	Sunshine hours	Rainfall			9am R.H.			Temperature		
		Total annual mm	Feb mm	Aug mm	Mean annual	Mean Feb	Mean Aug	Mean Annual	Mean Feb	Mean Aug
Brisbane	2737	1157	161	48	66	69	66	20.5	24.7	15.9
Sydney	2445	1215	115	81	69	70	68	17.4	21.9	13.1
Melbourne	2080	661	50	50	69	63	75	14.8	19.9	10.6
Perth	2883	879	11	138	62	51	71	18.2	23.7	13.5
Adelaide	2518	531	21	62	56	44	70	17.1	23.0	12.1
Hobart	2153	633	42	49	67	62	73	12.4	16.7	8.9
Kaitaia	2108	1430	94	165	81	78	86	15.3	19.4	11.8
Auckland	2102	1268	94	142	77	73	82	15.3	19.8	11.4
Hamilton	2003	1197	81	117	80	76	85	13.0	17.8	9.2
New Plymouth	2110	1584	104	150	78	77	79	13.4	17.4	10.0
Gisborne	2215	1034	61	117	73	68	80	13.8	18.7	9.7
Wellington	2020	1271	84	124	81	79	84	12.4	16.4	8.8
Greymouth	1694	2488	202	191	83	84	82	12.1	16.0	8.8
Christchurch	1984	626	43	53	77	73	85	10.9	16.1	6.5
Dunedin	1689	772	61	46	74	72	78	10.9	14.9	7.3
Invercargill	1631	1042	79	66	83	80	87	9.5	13.4	6.1

range 64-65% as an annual mean) are to the east of the Southern Alps, and have rain levels around 850mm/annum. The Australian Standard appears to imply that if the 500mm rainfall/55% average humidity criteria are exceeded, the category **mild** cannot be applied, and consequently in Figure 1 there is no **mild** zone.

### 3.5 Special Conditions

There will obviously be a variability in the corrosion rates across the corrosivity zones. This will be of most importance in the **very severe** zones. For example, corrosion of steel (and galvanised steel) can be seen from observation of buildings to be more pronounced on the Petone foreshore than further up the Hutt Valley. The zone definitions in the Australian standard prevent further subdivision of corrosivity zones, but some note should be taken of the extreme conditions which exist very close to many beaches and harbour fronts. Areas at risk can be identified by frequent heavy salt deposition onto cars and windows. In such areas there is a special danger of corrosion at breaches of protective coatings, and so a need for special care in the preparation, application and maintenance of these coatings. BS 5493:1977<sup>25</sup> which provided a pattern for most of AS2312:1980, takes account of this by defining a zone called "sea water splash zone, or frequent salt spray" for which specific recommendations are made. No such differentiation is made in the Australian Standard, but because of the closeness to coastlines of many structures in New Zealand, note 3 was added into the preamble of the proposed environmental classifications for New Zealand in Section 4. This Section offers possible wording for an amended Section 2 of the Australian standard to make it applicable to New Zealand conditions.

The local variability of natural emission of sulphurous gases in the region approximately bounded by Waiouru, Ohakune, Te Puke and Kawerau makes it impossible to categorise this area for corrosion to steel purposes. It is likely to require coatings at least with **severe** ratings.

## 4. PROPOSED ENVIRONMENTAL ZONE DEFINITIONS FOR NEW ZEALAND USE OF AS2312:1980

These definitions have been compiled using, where possible, the terms and nomenclature of AS2312. These definitions are designed to replace Section 2.2 in that Standard, and so the clauses are numbered accordingly. The map referred to in Note 5 in the following is Figure 1 of this paper.

### 2.2 ATMOSPHERIC CLASSIFICATIONS (APPLICABLE TO STEEL)

#### Notes

1. Microclimates may alter the following classifications and need to be taken into account when protective systems are being considered.
2. The N.Z. Department of Scientific and Industrial Research single factor maps (published in 1962) for "available" sodium in unfertilised soils, which show five different bands according to sodium level, have been used to indicate likely chloride levels as long-term averages. Band 1 has the highest sodium level, Band 5 the lowest.
3. Frequent heavy salt deposits on cars and windows near seaside locations are an indication of special danger of corrosion at weak points in protective coatings.
4. Special conditions, due to geothermal release of sulphurous gases, occur in inland Bay of Plenty. Local advice should be sought regarding the likely degree of protection needed at any locality.

5. To assist designers and specifiers in assessing where each of the following classifications occur, a map is provided. Local knowledge will be as important a guide to the corrosivity of the atmosphere at any particular location as will be the map.

#### 2.2.1 Mild

No area of New Zealand can be described as having a **mild** classification as originally intended in the Australian Standard.

#### 2.2.2 Moderate

- (a) More than 15km from coast.
- (b) In band 5, or rainfall generally less than 1000mm p.a. and in band 4.

The effect of this type of environment on the integrity of coatings will not be very great, although grime deposited on the surface and not removed can affect the decorative appearance of coatings.

Typical areas of New Zealand which fall in this classification are the central North Island plateau, inland Hawkes Bay, and most of the South Island east of the Southern Alps not closer than 15km to the coast, except for Otago and Southland.

#### 2.2.3 Severe

- (a) More than 2km from coast, except more than 15km from the south coast of North Island or South Island.
- (b) In band 3, 4 or 5.

Most of inland North Island is in this category.

#### 2.2.4 Very Severe

Within 2km of the coast, or within 15km of the south coast of either North or South Island, or in band 1 or 2. See also note 3, above.

Bands 1 and 2 (subject to heavy chloride deposition) are particularly pronounced around the Taranaki coastline and along the west coast of the North Island from the Waikato River mouth to Dargaville, and in Westland. In these areas they are as much as 12km wide. Where winds blow predominantly off the land to the sea, such as around Gisborne and Hawkes Bay, the area with a **very severe** classification is only that immediately adjacent to the sea. The broader-band areas, such as at the south of both islands and around Taranaki, are characterised by frequent strong winds blowing off the sea to the land.

## 5. CONSEQUENCES OF THIS CLASSIFICATION

It was stated in the introduction that the impetus for preparing an assessment of the New Zealand macroclimate with respect to steel corrosion was the moves toward erection of chemical plant. All of the sites in the Taranaki, Marsden Point, Tiwai Point and Aramoana areas which have been discussed as probable sites for these plants fall in the **very severe** category proposed in this paper. It is impossible to stress too heavily that the microclimatic conditions can change the actual corrosion rates; for example, Bishop and Winnett<sup>26</sup> report a virtual reduction to zero rates of steel bridge member corrosion by enclosing the bridge members in ventilated boxes which prevent access of corrosive dusts. Nonetheless, all exterior steelwork for plants at the above sites must clearly be protected by the highest quality systems.

TABLE IV : TIME OF WETNESS INDEX VALUES TAKEN FROM KING AND MARTIN<sup>19</sup> FOR AUSTRALIAN CITIES FOR COMPARISON AGAINST NEW ZEALAND LOCALITIES (NZ DATA FOR 1979)

	February	August
Brisbane	173	22
Sydney	93	59
Melbourne	13	48
Perth	0.5	256
Adelaide	2	54
Hobart	13	63
Kaikohe	342	370
Otara (Auckland)	362	616
Tauranga	213	289
Hamilton	338	209
Palmerston North	34	385
Wellington	68	1476
Christchurch	11.6	106
Invercargill	28	126

It is stressed again that the classification applies to mild steel. Other metals such as zinc (thus galvanised steel) and aluminium have different corrosion mechanisms from mild steel. Though the same factors (water or chemicals in the atmosphere) affect the corrosion of virtually all metals, the different corrosion mechanisms mean that the relative importance of these factors varies from metal to metal. The corrosivity guidelines set out in this paper may therefore be a starting point for guidelines to corrosivity toward metals other than mild steel, but must not be adopted without thorough consideration of the corrosion mechanism, and performance in use, of these metals. The zones of greatest risk, in particular, would probably differ substantially for other metals from those for mild steel.

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