Selecting Stainless Steel for Optimum Performance

Sponsor:
International Molybdenum Association (IMOA)

International Molybdenum Association
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Today's Goal

Learn why some stainless steel applications look fantastic after 80 years while others look bad after 6 months

Achieve Long Term Success

- Evaluate the environment
- Select the right finish and design
- Specify the right stainless steel

Learning Objectives

Attendees will learn to:

- Evaluate the corrosiveness of the application environment based on weather patterns and exposure to corrosive pollution, salt (chlorides), and other factors
- Compare the probable relative performance of architectural metals based on the service environment
- Determine which finish options and design will provide the desired level of performance
- Select the right stainless steel for maximum performance given the environment, finish, and design

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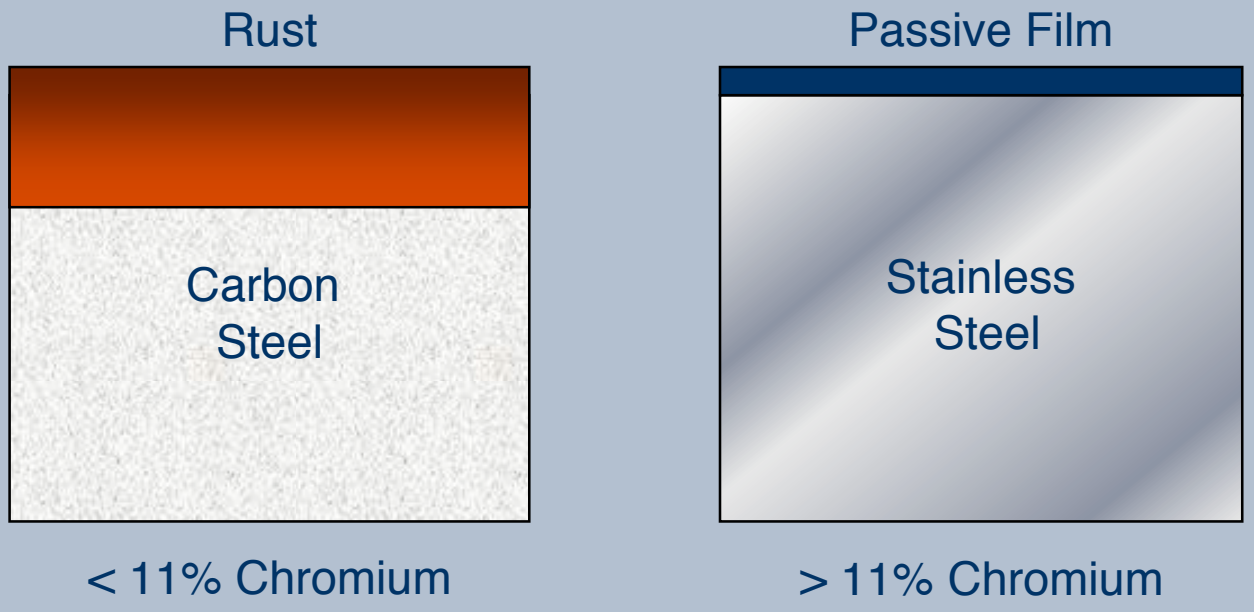
How Does A Stainless Steel Work?

Stainless steel is iron plus at least 11% chromium. If enough chromium is added, a protective passive film will form.



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Major Alloying Elements

- Iron (Fe)
- Chromium (Cr)
  - Improves corrosion resistance
- Molybdenum (Mo)
  - Improves resistance to pitting and crevice corrosion caused by salt (chlorides) and pollution
- Nickel (Ni)
  - Improves ductility, toughness, and weldability
- Nitrogen (N)
  - Improves strength and pitting and crevice corrosion resistance

Families of Stainless Steels

- Austenitic
  - 300-series (304, 316)
  - Strengthened by cold work
  - Nonmagnetic
- Ferritic
  - 400-series (430, 447)
  - Magnetic
- Duplex
  - Austenitic/ferritic (2205)
  - More corrosion resistant
  - Higher strength
  - Magnetic

Low Carbon or “L” Grades

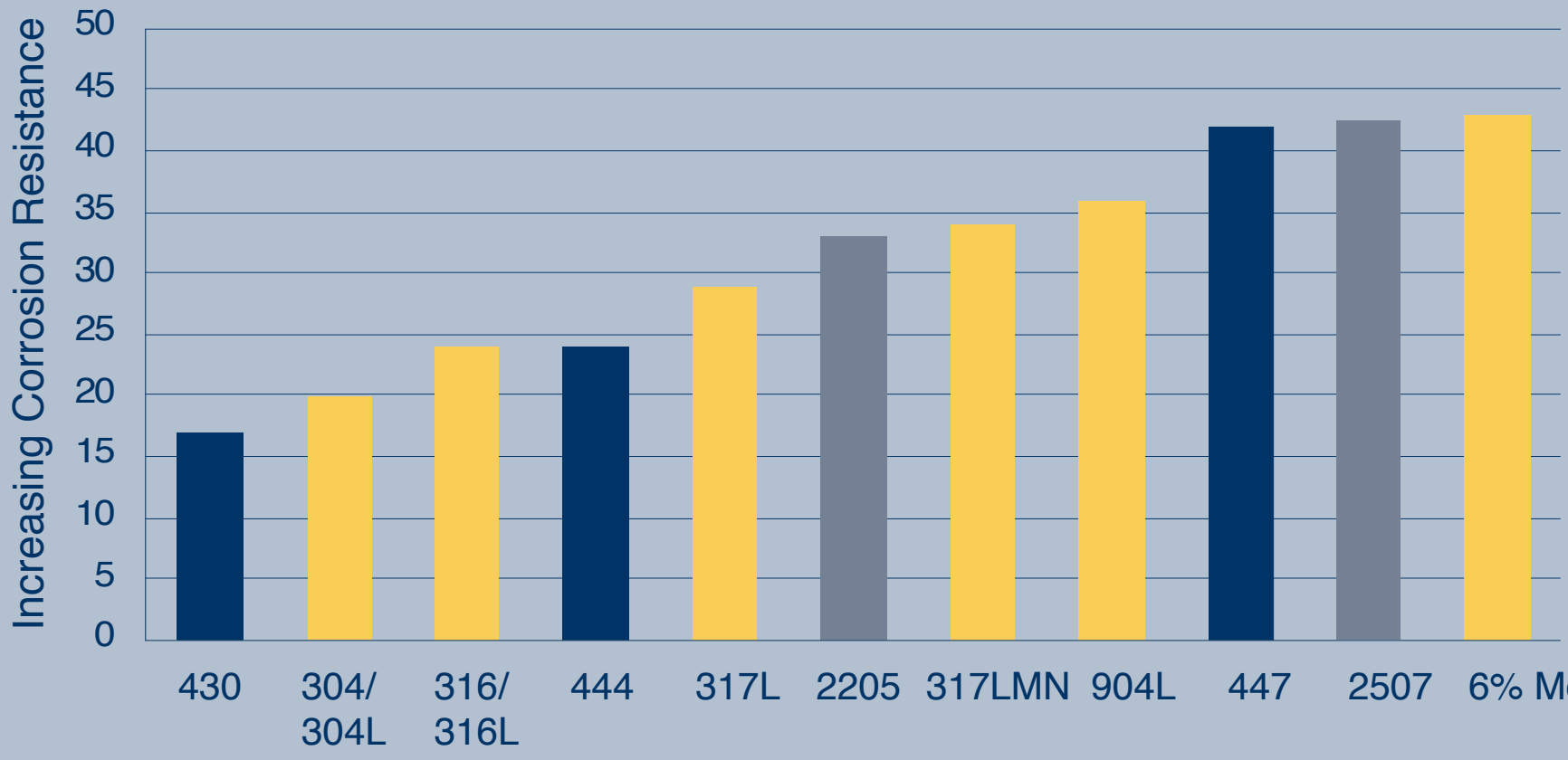
- “L” refers to low carbon levels
  - Examples: 304L and 316L
- Specify “low carbon” for welding
- When there is no price premium for low carbon stainless steel, make it your standard specification

Architectural Stainless Steels

(Nominal Chemical Composition, Wt. Pct.)

	Cr	Ni	Mo	N	C, max
430	17	---	---	0.03	0.12
304	18	9	---	0.06	0.08
316	17	11	2	0.06	0.08
2205	22	5	3	0.15	0.03

Index of Relative Pitting Corrosion Resistance



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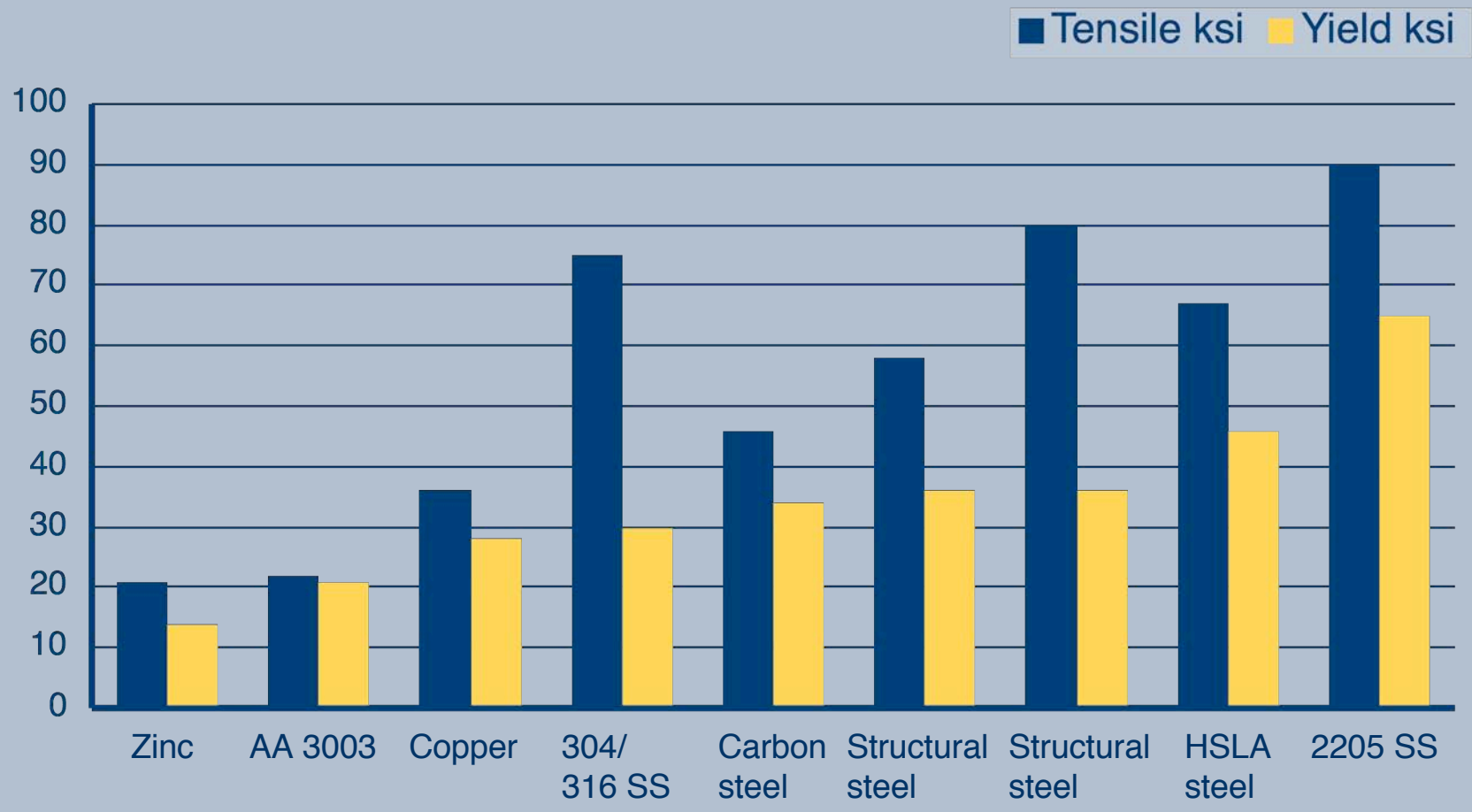
Strength Comparison



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Annual Cost of Metallic Corrosion

(US$ billions)

- Total US Cost
  - Direct cost = $296
  - Indirect cost = $255.4
  - Total cost = $551.4
- Construction*
  - Direct cost = $50
  - Indirect cost = $63.6
  - Total cost = $113.6
  - Avoidable = 20 to 25%

* May be underestimated. Does not include infrastructure and industrial construction

Photos courtesy of Allegheny Ludlum and TMR Consulting

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Two Piers, Progreso, Mexico

- Functioning pier
  - Built about 60 years ago (1937-1941)
  - Stainless rebar
- Non-functioning pier
  - Built about 30 years ago
  - Carbon steel rebar

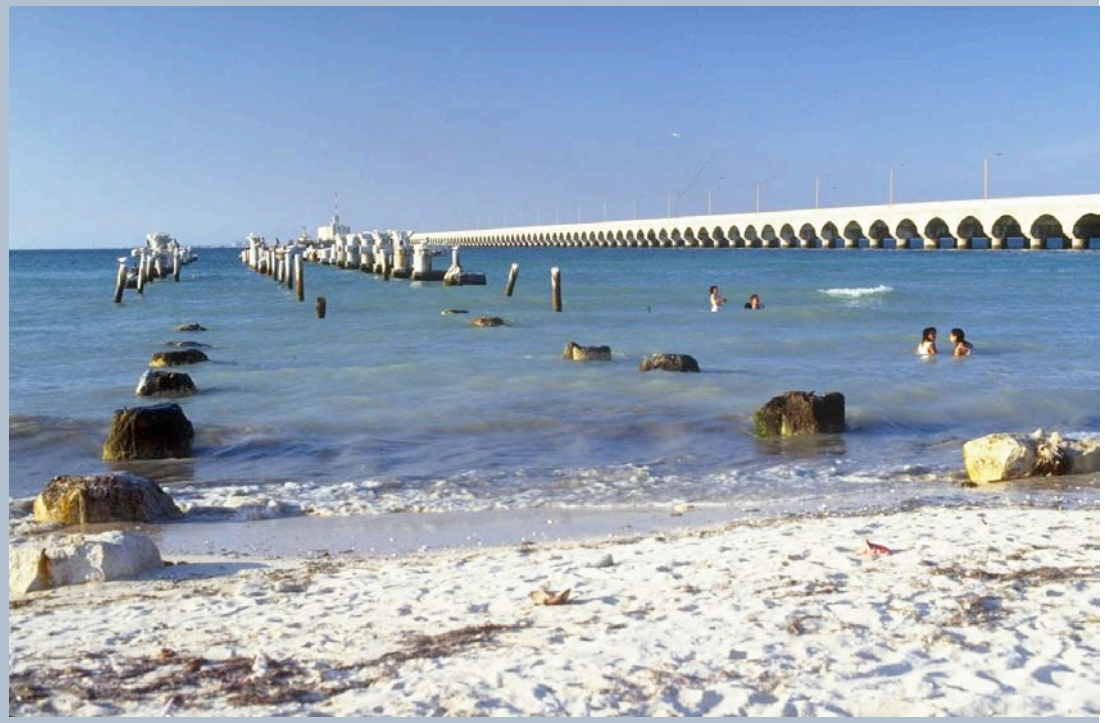

Photo courtesy of the Nickel Institute

20-Year South African Exposure Data

Average Annual Corrosion Rate (mm/yr)

Metal	Severe Marine**	Severe Marine*	Marine**	Rural*
Type 316	0.0003	0.0001	0.00003	0.00003
Type 304	0.0004	0.0001	0.00008	0.00003
Type 430	0.002	0.0006	0.0004	0.00003
Al 3003	0.019	0.005	0.005	0.00028
Copper	0.025	0.04	0.009	0.00559
Zinc	0.111	NA	0.023	0.0033
Weathering Steel	0.810	1.15	0.212	0.0229
Mild Steel	2.190	0.846	0.371	0.0432

* Low pollution, ** Moderate pollution

National Building Research Institute, South Africa

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Kure Beach, 57 Years

250 m (800 ft) from the ocean never washed

Type 304

Type 316

Photos courtesy of TMR Consulting

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Kure Beach, 48 years

Carbon steel with 60 Zn, 20 Al, 20 Mg coating 250 m (800 ft) from the ocean

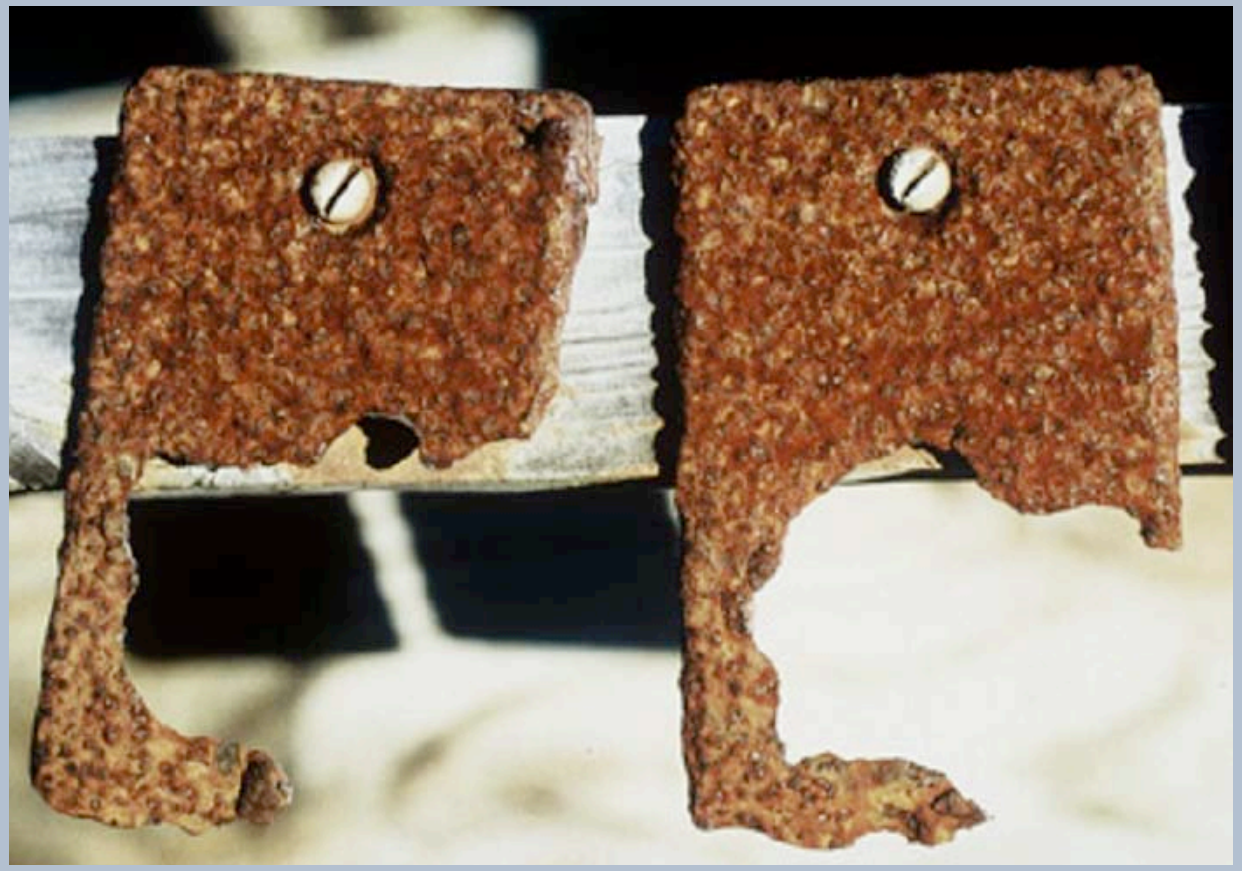

Photo courtesy of the Nickel Institute

Kure Beach, 58 years

Anodized aluminum, 250 m (800 ft) from the ocean

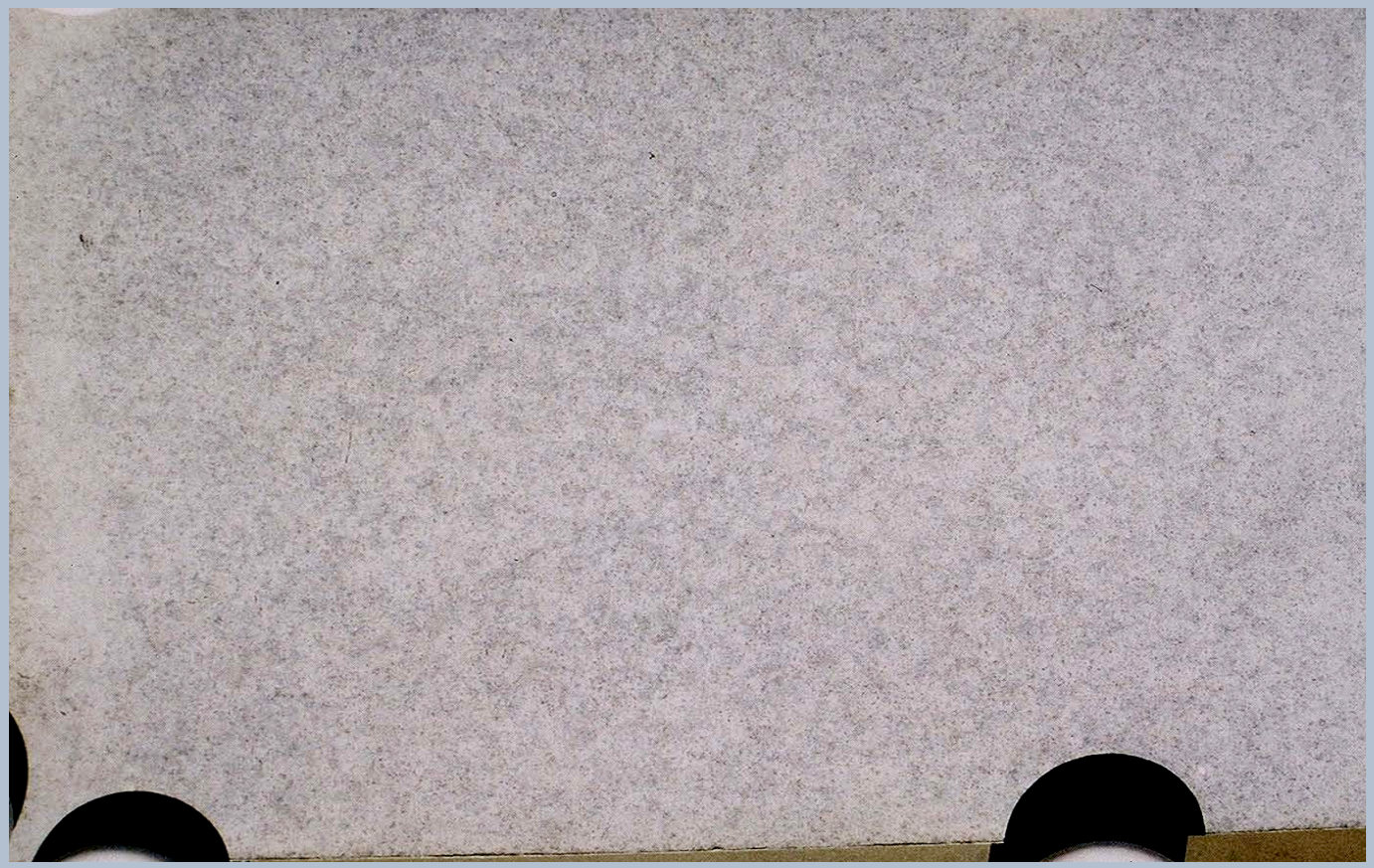

Photo courtesy of the Nickel Institute

Select Type 304

- Rural/suburban
- Urban areas
  - Low and moderate corrosivity
- Not suitable for salt exposure or moderate to high industrial pollution unless:
  - Smooth finish
  - Regular cleaning
  - Some staining between cleanings is acceptable

Photo courtesy of the US National Parks Service

Gateway Arch, St. Louis, USA

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Select Type 316

- Urban areas
  - Moderate and high corrosivity
- Industrial
  - Low and moderate corrosivity
- Marine and deicing salt
  - Low to moderate corrosivity

Frederick R. Weissman Art Museum

Photos courtesy of the Nickel Institute

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Select More Corrosion Resistant Stainless Steels

- Industrial pollution
  - Developing countries
  - High sulfur dioxides levels
  - High particulate levels
- Coastal or deicing salt
  - Splashed by or immersed in salt water
  - Corrosive, sheltered, unwashed applications
  - Significant deicing salt deposits

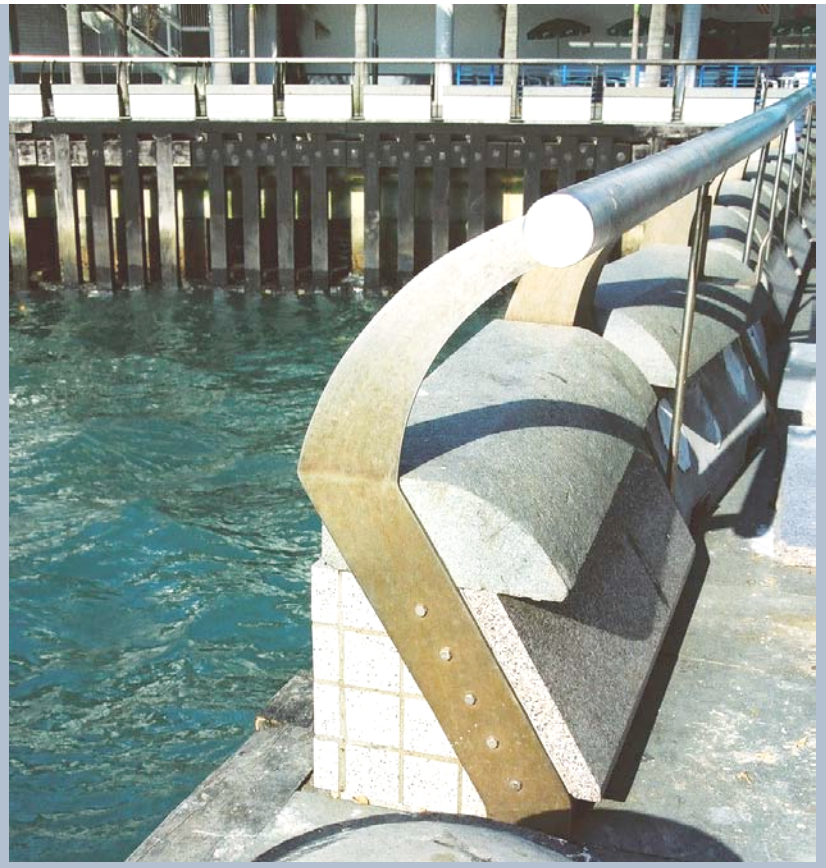

Photo courtesy of the Nickel Institute

Type 316 railings
Hong Kong Convention Center - seawater spray exposure, rough finish

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Site and Design Evaluation System

- Designed for applications where corrosion staining is not acceptable

- Do not use this system if
  - Appearance does not matter
  - Structural integrity is the primary concern

Stainless Steel Selection Scoring System

Total Score	Stainless Steel Selection
0 to 2	Type 303/304L is generally the most economical choice
3	Type 316/316L or 444 is generally the most economical choice
4	Type 317L or a more corrosion resistant stainless steel is suggested
≥5	A more corrosion resistant stainless steel such as 2205, 317LMN, 904L, super duplex, super ferritic, or a 6% molybdenum super austenitic stainless steel may be needed

Environmental Pollution

Points	Section 1: Environment (Select the highest applicable score)
	Rural
0	Very low or no pollution
	Urban Pollution (Light industry, automotive exhaust)
0	Low
2	Moderate
3	High *
	Industrial Pollution (Aggressive gases, iron oxides, chemicals, etc.)
3	Low or moderate
4	High *

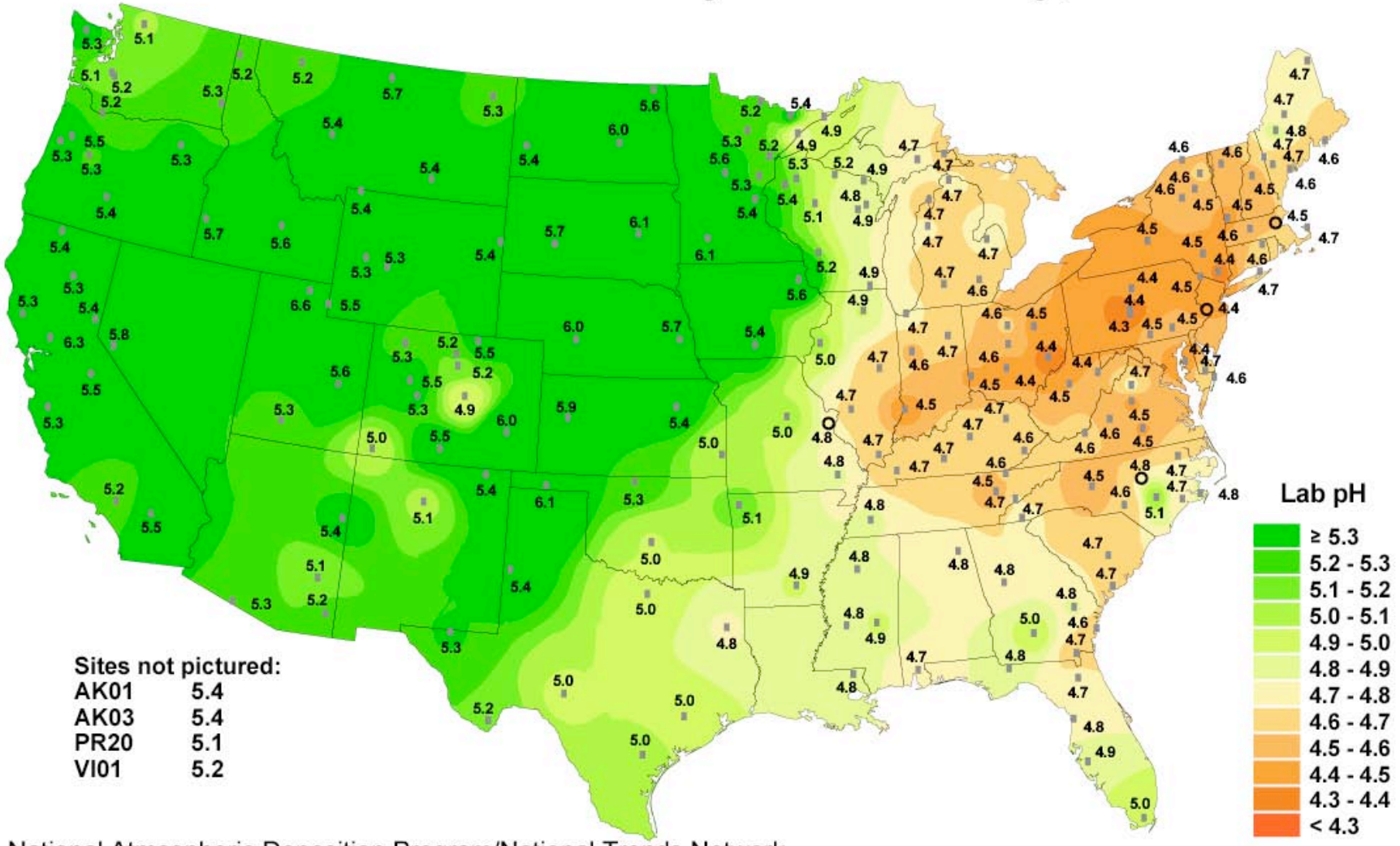
* Potentially a highly corrosive location. Have a stainless steel corrosion expert evaluate the site.

Rating Pollution Levels

City	Pollution Level	Suspended Particulate $\mu gm/m^3$	Sulfur Dioxide $\mu gm/m^3$
Beijing	High	377	90
Calcutta	High	375	49
Stockholm	Low	9	5
Pittsburgh	Moderate	40	16
Moscow	High	100	109
New York	Moderate	27	26
Rio de Janeiro	High	139	129
Chicago	Moderate	35	14

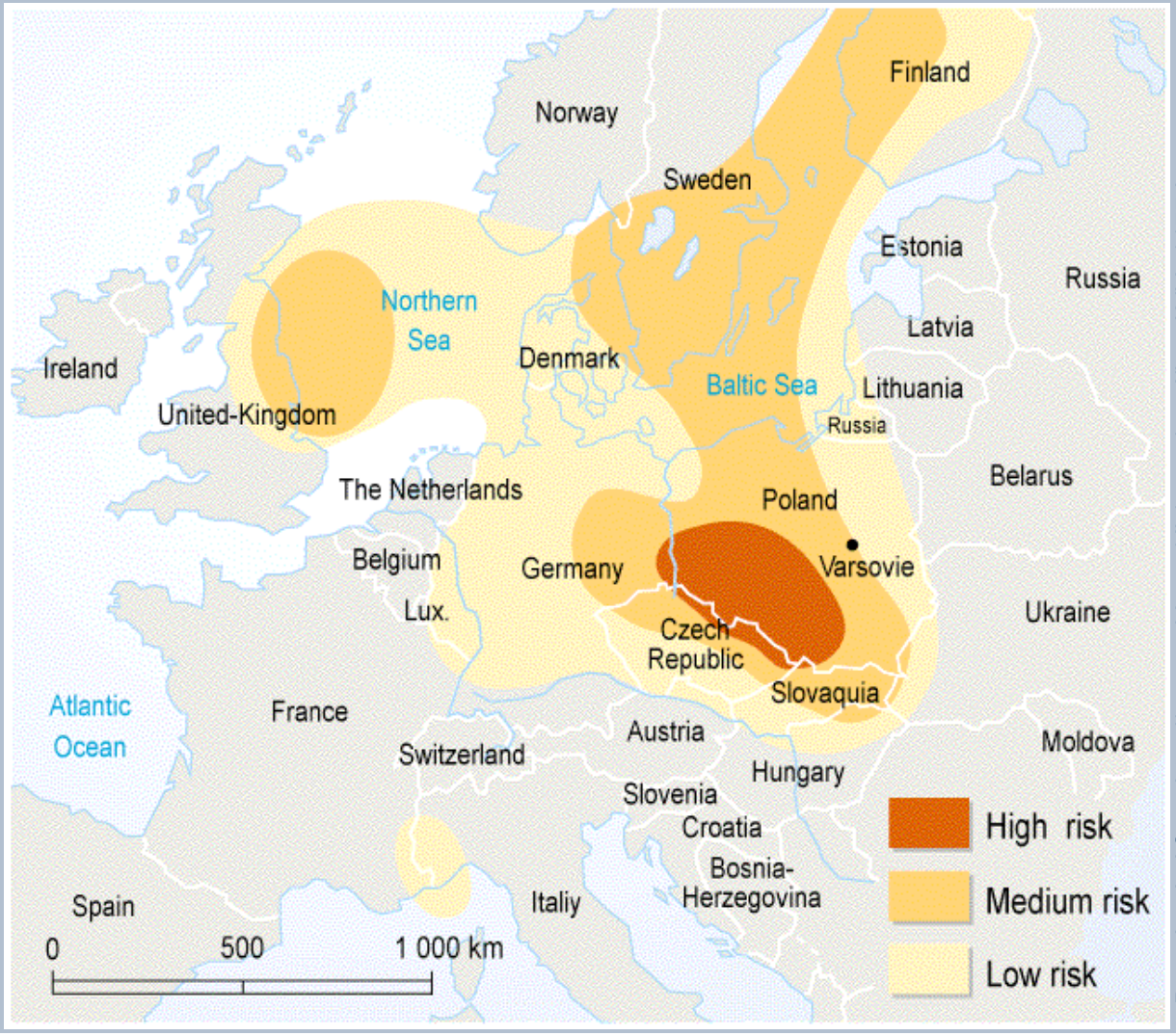
1995 Urban Pollution Levels, World Health Organization Data

Hydrogen ion concentration as pH from measurements made at the Central Analytical Laboratory, 2004



National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

European Acid Rain Map



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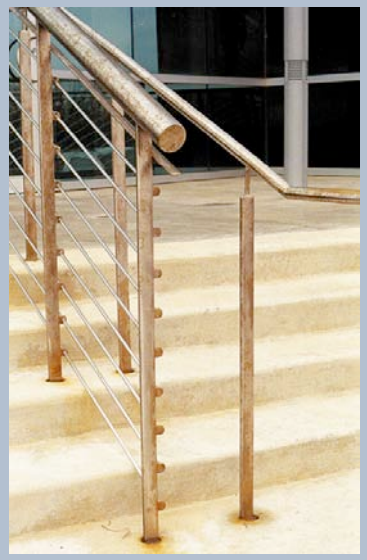
Evaluation Scores
Case Study 01

Section	Chicago	Pittsburgh
Environment	2	2



Pittsburgh,
Type 304

Chicago,
Type 316

Photos courtesy of TMR Consulting

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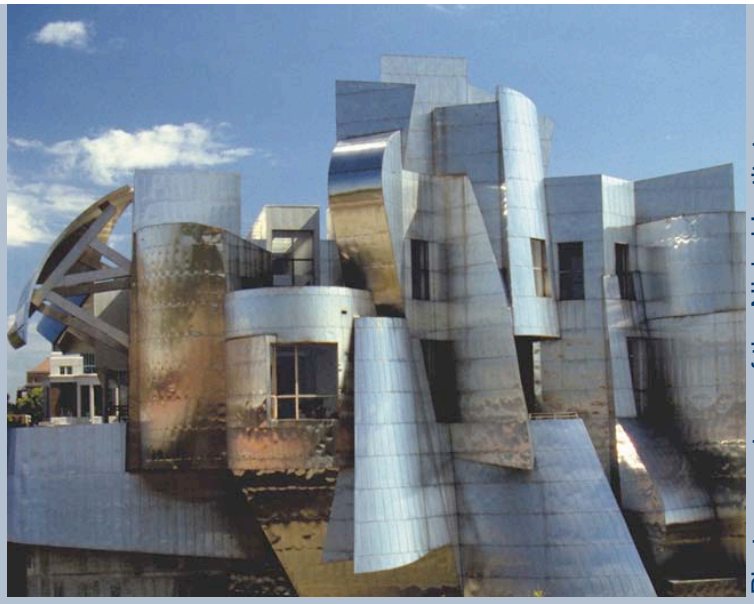
Evaluation Score
Case Study 02

Section	Museum	Window
Environment	2	2



Photos courtesy of the Nickel Institute

Weisman Art Museum, Type 316

Window frame,
Type 304

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Evaluation Scores
Case Study 03

Section	Miami Beach	Jones Beach
Environment	2	2

Photo courtesy of TMR Consulting

Miami Beach
light pole, Type 304

Photo courtesy of AISI

Jones Beach
light poles, Type 316

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Evaluation Scores Case Study 04

Section	Singapore
Environment	2

Photos courtesy of Ewing Cole, Photographer: Erhard Pfeiffer

Singapore Turf Club,
Type 316 roof

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Evaluation Scores
Case Study 05

Section	Cheung Kong	Railings
Environment	3	3

Photo courtesy of Outokumpu

Cheung Kong Center, Type 316

Photo courtesy of Nickel Institute

Hong Kong Convention Center railings, Type 316

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Evaluation Score Case Study 06

Section	Canary Islands
Environment	0

Canary Island light pole, Type 316

Canary Island railing, 2205 stainless steel

Photos courtesy of Outokumpu

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Evaluation Score Case Study 07

Section	Mapfre Tower
Environment	2

Photo courtesy of ACERINOX

Mapfre Office Tower,
Barcelona, Type 316

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Evaluation Score Case Study 08

Section	Bank Boston
Environment	4

Bank Boston, São Paulo, Brazil, Type 316

Photo courtesy of Núcleo Inox

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Evaluation Scores
Case Study 09

Section	Post	Gate
Environment	0	0

Photo courtesy of the Australian Stainless Steel Development Association

Australian Coastal fence,
Type 316 gate and Type 304 post

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Evaluation Score Case Study 10

Section	Splashed	Non Splashed
Environment	0	0

Gantry Plaza Park

Railings and Seating

New York City

Type 316

Evaluation Score Case Study 11

Section	Thames River Barrier
Environment	0

Thames River Barrier, London, England, Type 316

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Coastal or Deicing Salt Exposure

Points	Section 2: Coastal Exposure (Select the highest applicable score) If there is exposure to both coastal and deicing salt, obtain assistance from a stainless steel corrosion expert
	Coastal or Marine Salt Exposure
1	Low (> 1.6 to 16 km (1 to 10 miles) from salt water) **
3	Moderate (30 m to 1.6 km (100 ft to 1 mile) from salt water)
4	High (< 30 m (100 ft) from salt water)
5	Marine (Some salt spray or occasional splashing) *
8	Severe Marine (Continuous splashing) *
10	Severe Marine (Continuous immersion) *

* Potentially a highly corrosive location. Have a stainless steel corrosion expert evaluate the site.

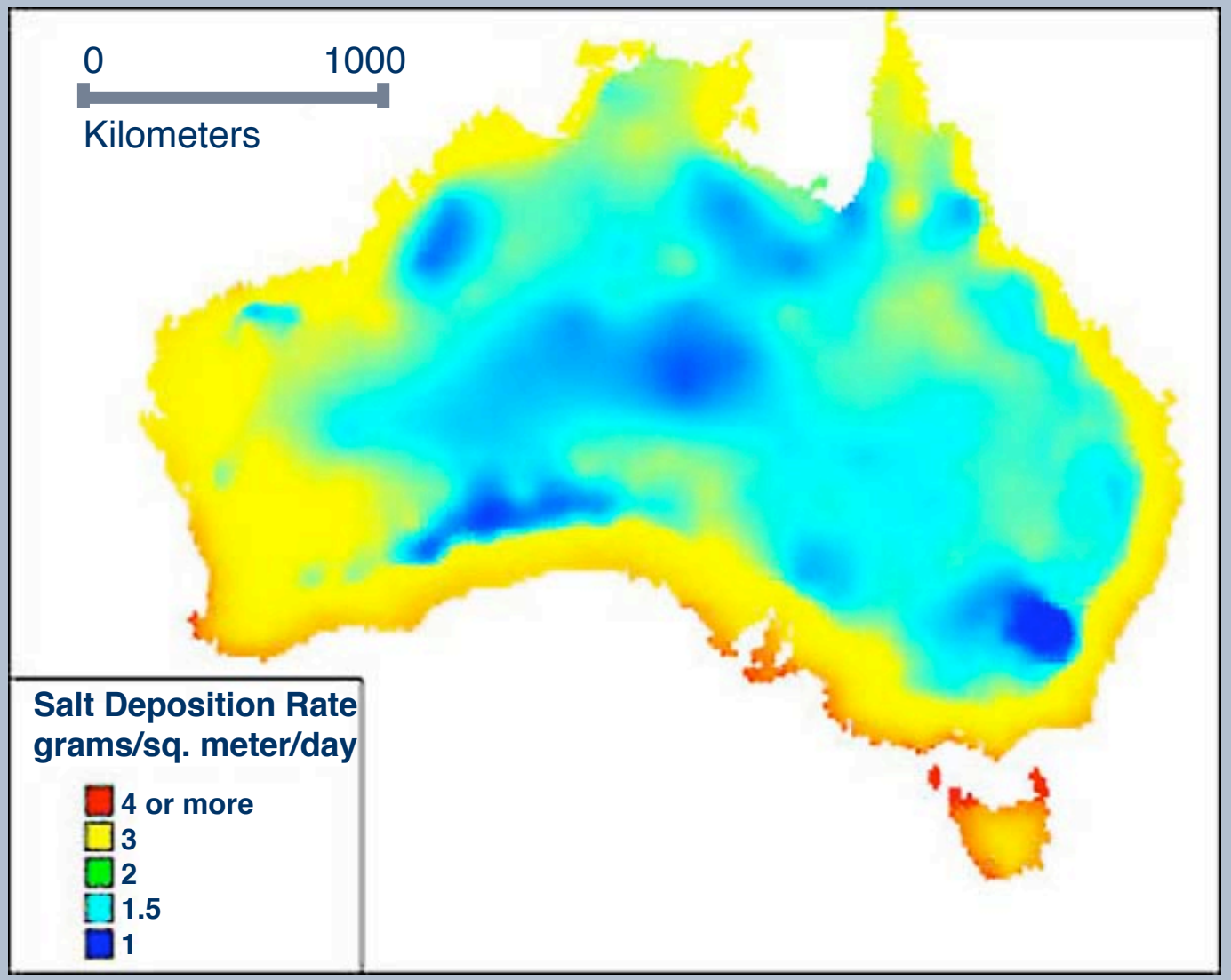
**This range shows how far chlorides are typically found from large salt water bodies. Some locations of this type are exposed to chlorides but others are not.

Points	Section 2: Deicing Salt (Chloride) Exposure (Select the highest applicable score). If there is exposure to both coastal and deicing salt, obtain assistance from a stainless steel corrosion expert
	Deicing Salt Exposure (Distance from road or ground)
0	No salt was detected on a sample from the site and no change in exposure conditions is expected.
0	Traffic and wind levels on nearby roads are too low to carry chlorides to the site and no deicing salt is used on sidewalks
1	Very low salt exposure (≥10 m to 1 km (33 to 3,280 ft) or 3 to 60 floors) **
2	Low salt exposure (< 10 to 500 m (33 to 1600 ft) or 2 to 34 floors) **
3	Moderate salt exposure (< 3 to 100 m (10 to 328 ft) or 1 to 22 floors) **
4	High salt exposure (< 2 to 50 m (6.5 to 164 ft) or 1 to 3 floors) * **

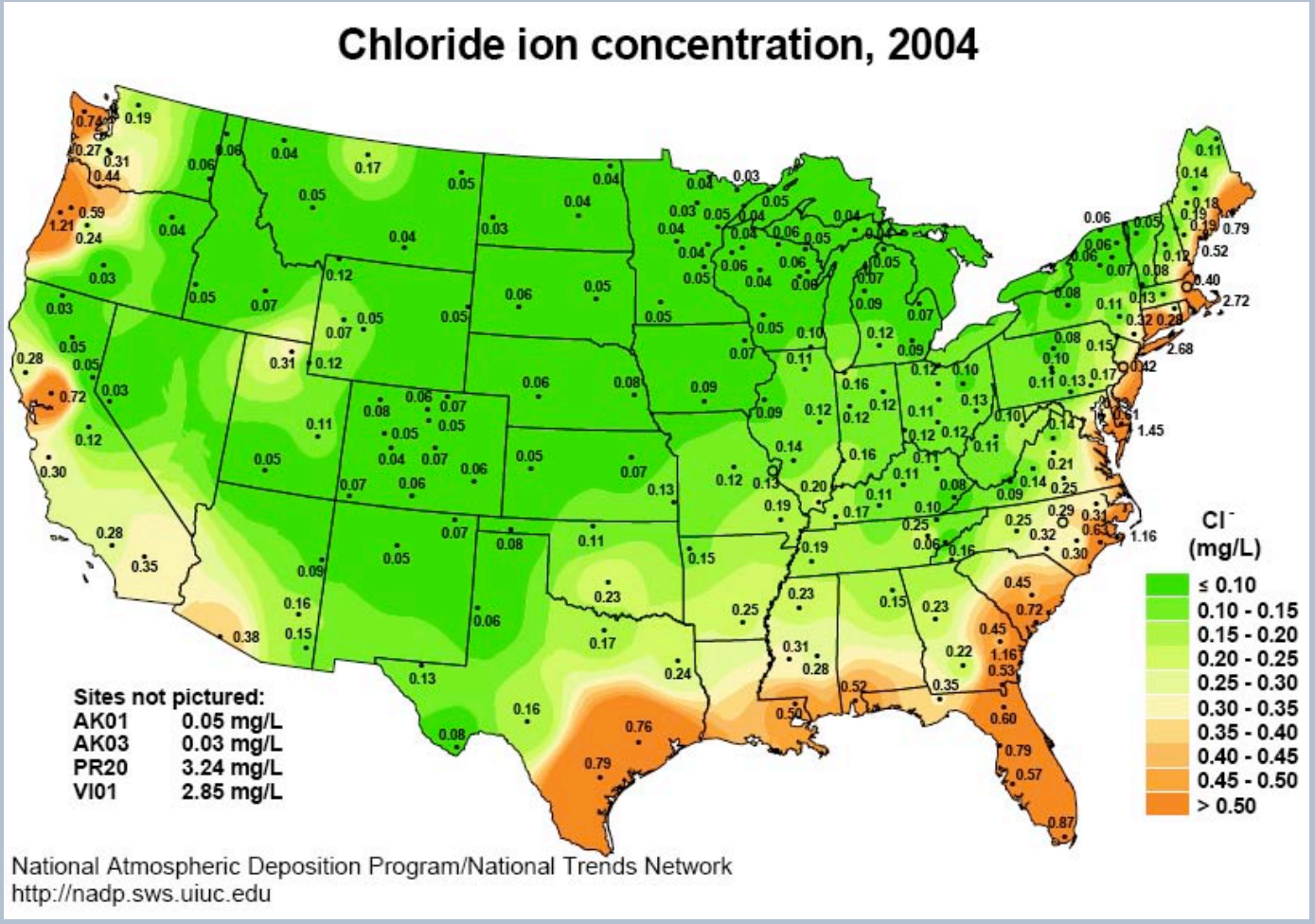
* Potentially a highly corrosive location. Have a stainless steel corrosion expert evaluate the site.

** The range shows how far this chloride concentration has been found from small rural and large high traffic roads. Test surface chloride concentrations.

Australian Chloride Deposition Map



Salt (Chloride) Concentration in the Air



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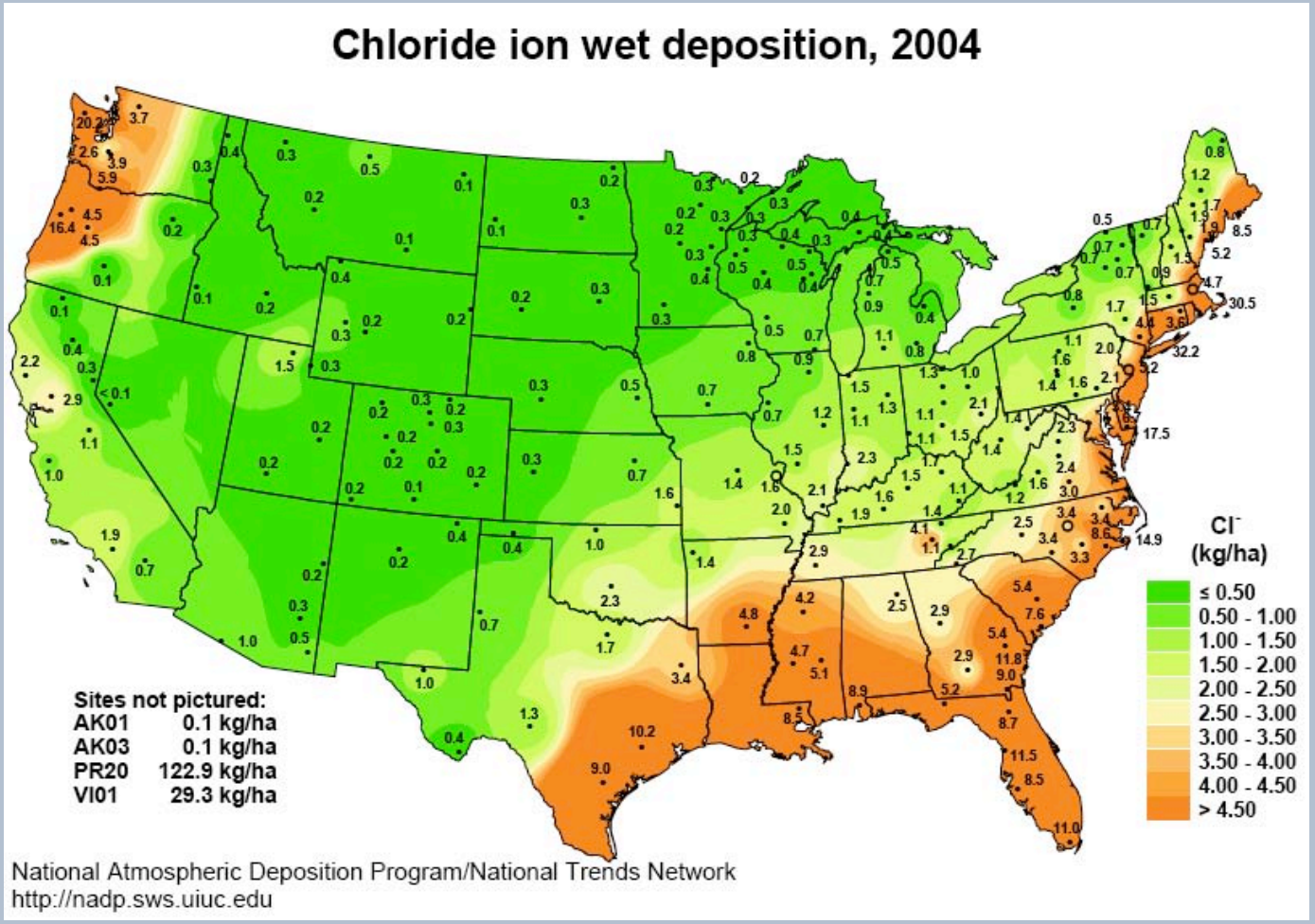
Salt (Chloride) Concentration in the Rain



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Local Weather Patterns

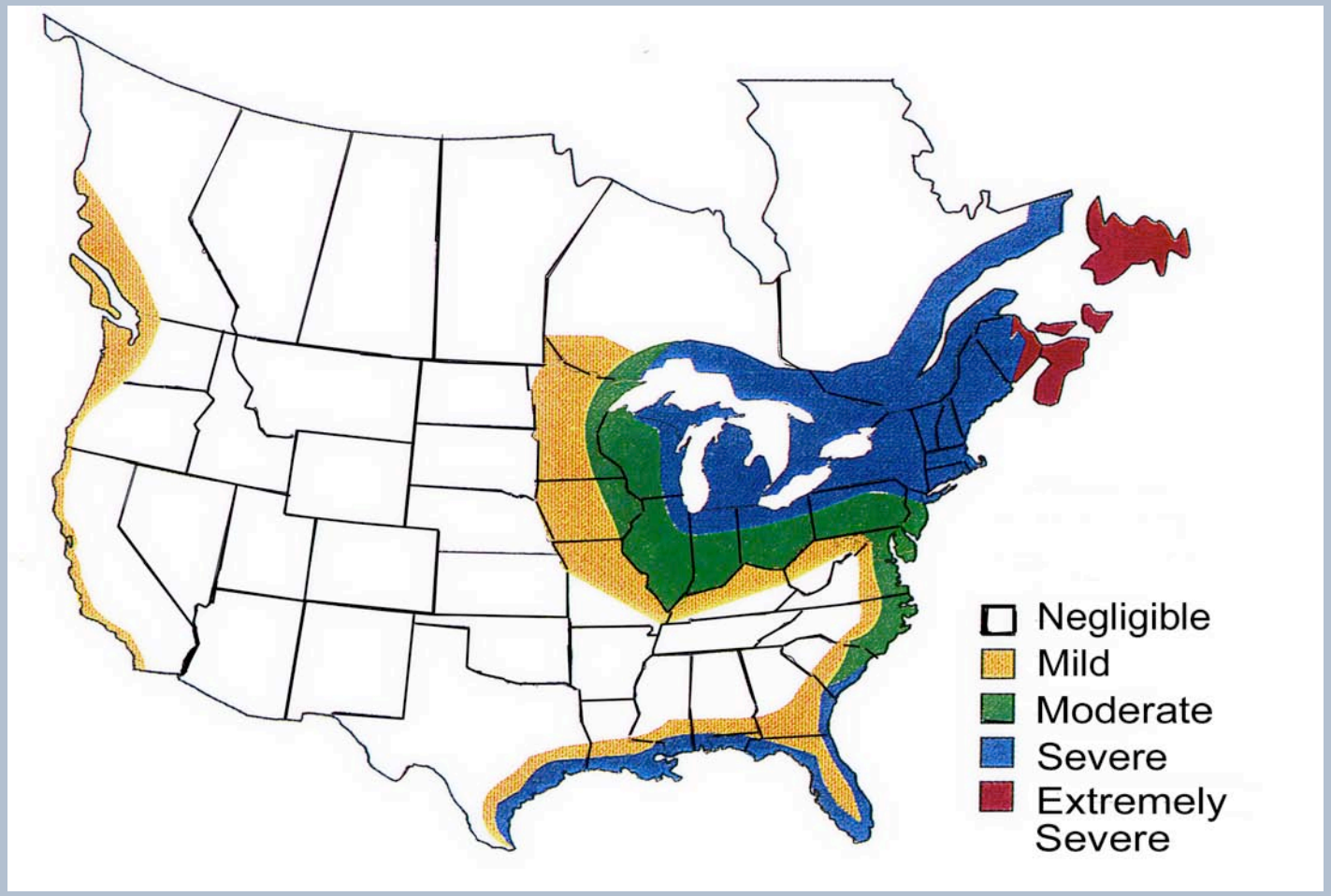
Points	Section 3: Local Weather Pattern (Select only one)
-1	Temperate or cold climates, regular heavy rain
-1	Hot or cold climates with typical humidity below 50%
0	Temperate or cold climate, occasional heavy rain
0	Tropical or subtropical, wet, regular or seasonal very heavy rain
1	Temperate climate, infrequent rain, humidity above 50%
1	Regular very light rain or frequent fog
2	Hot, humidity above 50%, very low or no rainfall ***

*** If there is also salt or pollution exposure, have a stainless steel corrosion expert evaluate the site.

Critical Temperature/Humidity Combinations for Salt (Chloride) Corrosion

Critical	Critical Humidity Level, %		
Temperature °C (°F)	Sodium Chloride	Calcium Chloride	Magnesium Chloride
25 (77)	76	30	50
10 (50)	76	41	50
0 (32)	---	45	50

United States and Canadian Corrosion Map



The Catalyst, Issue No. 2, 1997, ARMCO Inc.

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Corrosion Map for Mexico

Extremely severe

Severe

Moderate

Mild

Negligible

Map downloaded from http://www.corrosion-doctors.org

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Corrosion Map for Central America

- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

Map downloaded from http://www.corrosion-doctors.org

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Corrosion Map for Cuba

Extremely severe

Severe

Moderate

Mild

Negligible

Map downloaded from http://www.corrosion-doctors.org

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Corrosion Map for Venezuela

Map downloaded from http://www.corrosion-doctors.org

- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

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Brazilian Corrosion Map

Map downloaded from http://www.corrosion-doctors.org

- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

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Corrosion Map for Argentina

Map downloaded from http://www.corrosion-doctors.org

- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

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Corrosion Map for Chile

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- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

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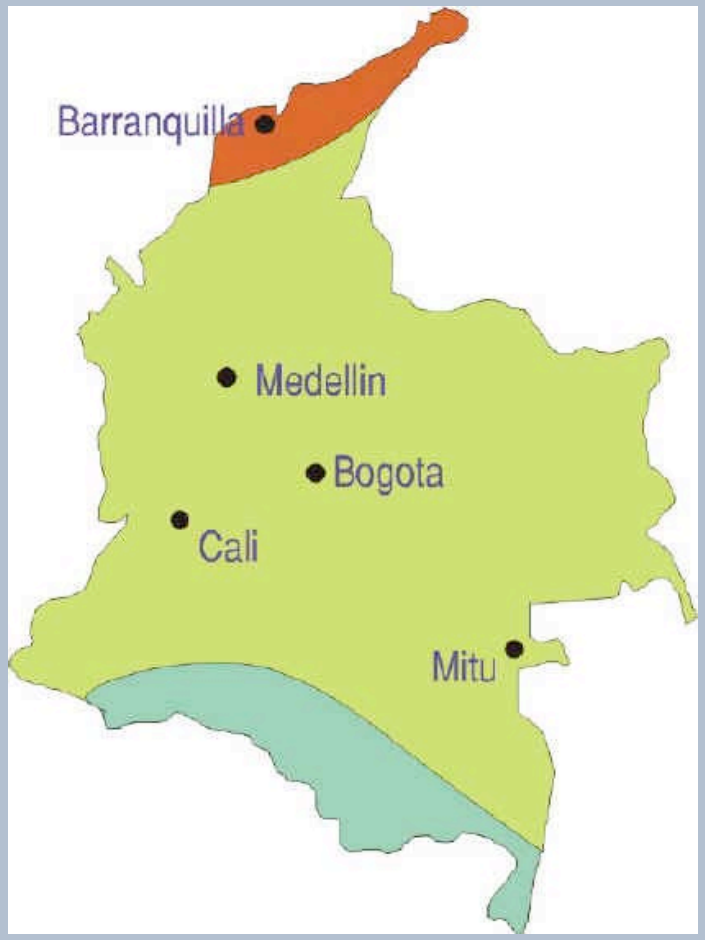
Corrosion Map for Columbia



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- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

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Corrosion Map for China

Extremely severe

Severe

Moderate

Mild

Negligible

Map downloaded from http://www.corrosion-doctors.org

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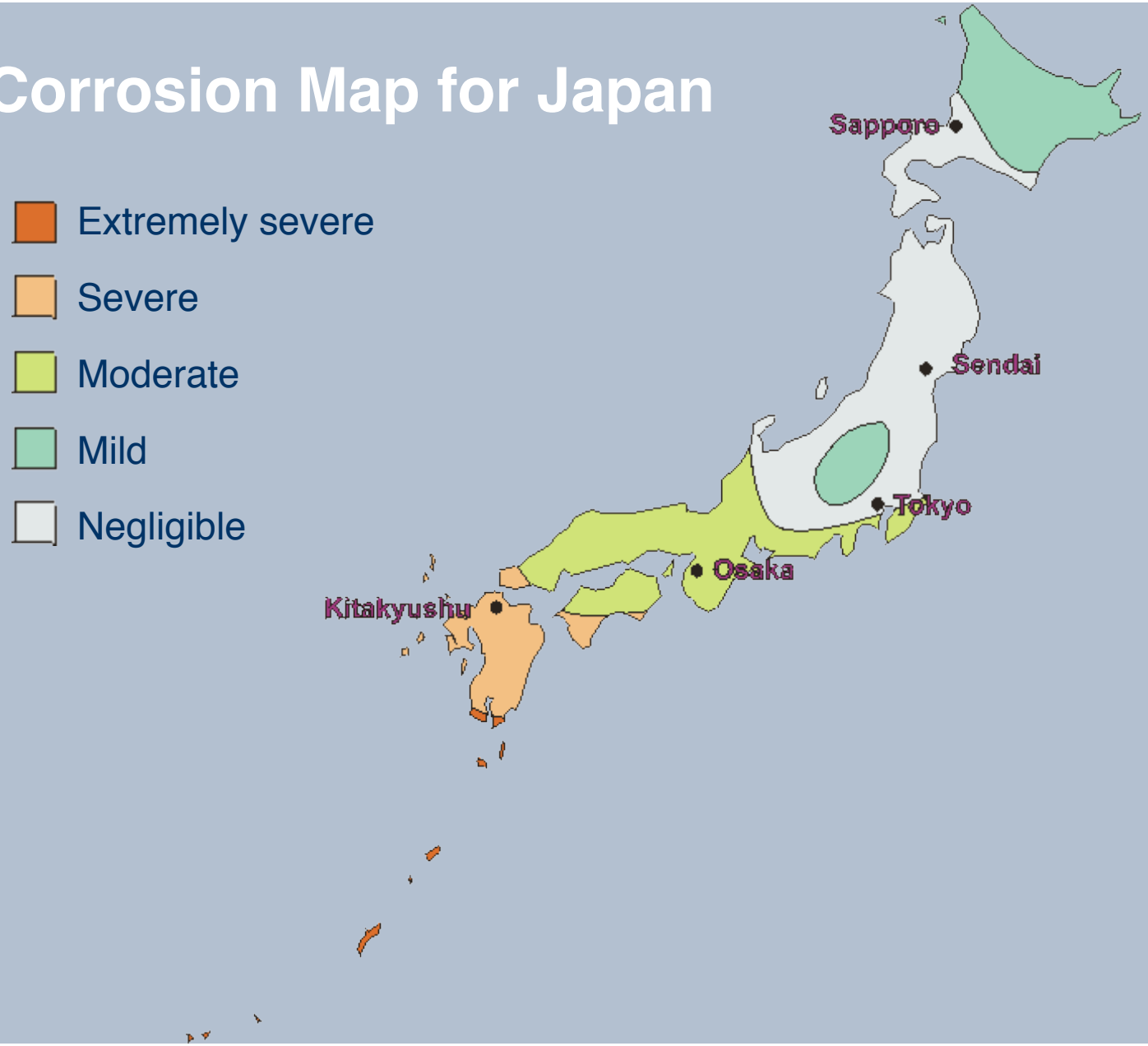
Corrosion Map for Japan



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Corrosion Map for India

- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

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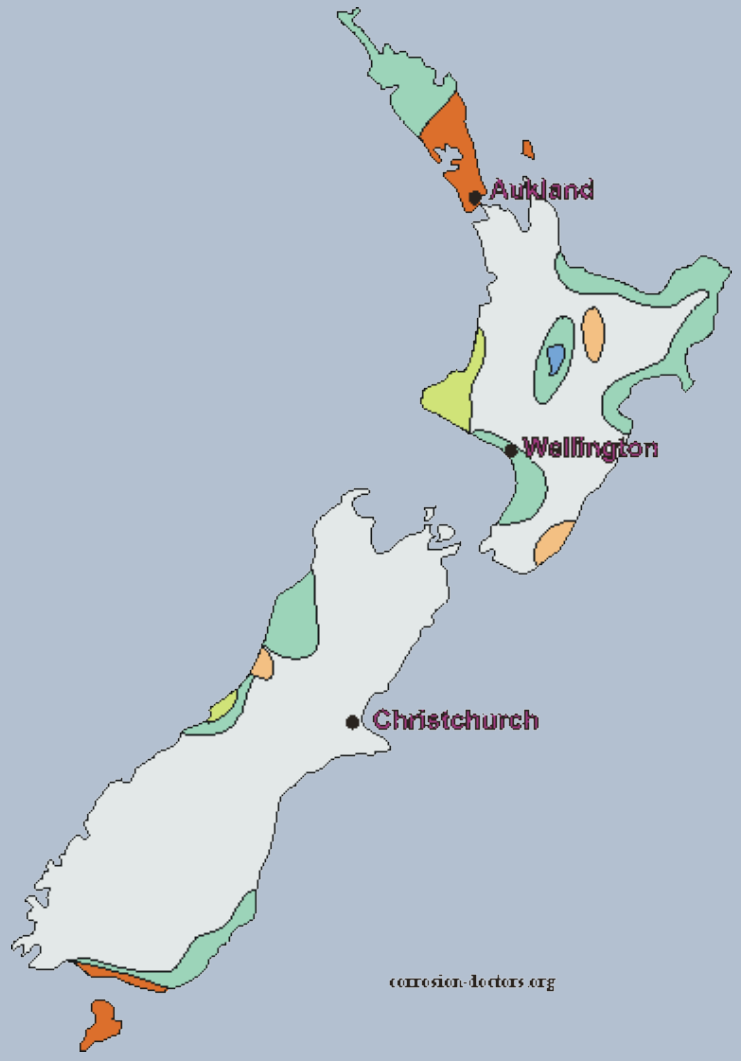
Corrosion Map for New Zealand



- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

Map downloaded from http://www.corrosion-doctors.org

Corrosion Map for Portugal

- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

Map downloaded from http://www.corrosion-doctors.org

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Corrosion Map for Spain

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- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

Corrosion Map for Great Britain

Extremely severe

Severe

Moderate

Mild

Negligible

Map downloaded from http://www.corrosion-doctors.org

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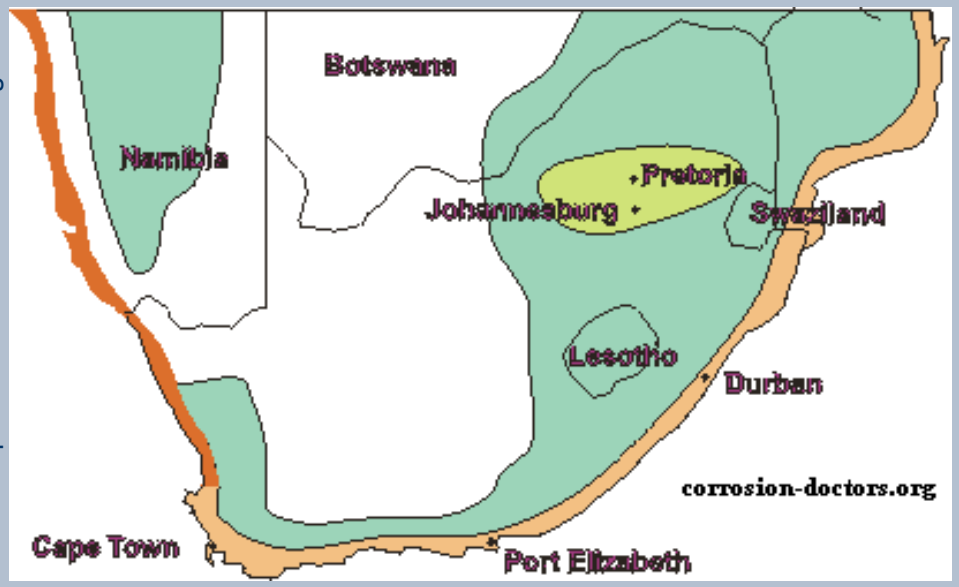
Corrosion Map for South Africa

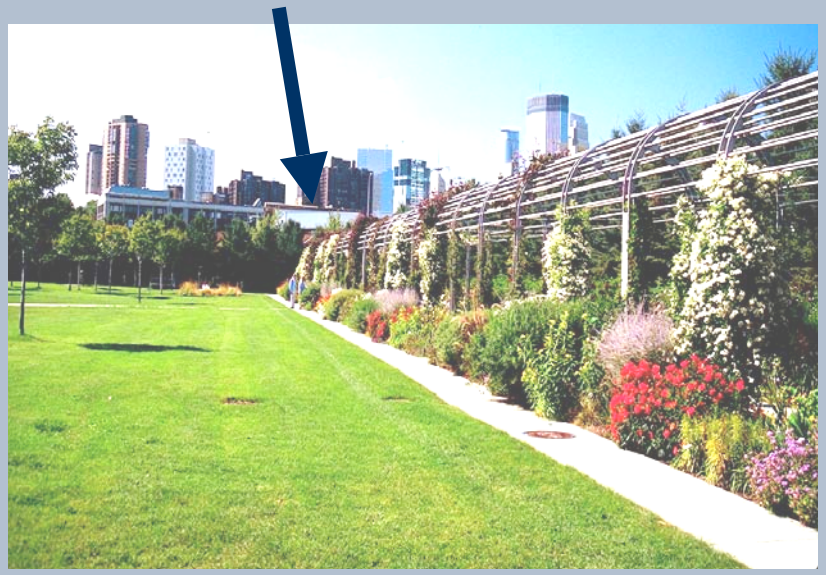


- Extremely severe
- Severe
- Moderate
- Mild
- Negligible

Type 304 Stainless Steel Arbor

- Deicing salt exposure
- Rough, sand blasted finish
- Sculpture park
- Minneapolis, USA

Truck on elevated highway



Photos courtesy of Nickel Institute

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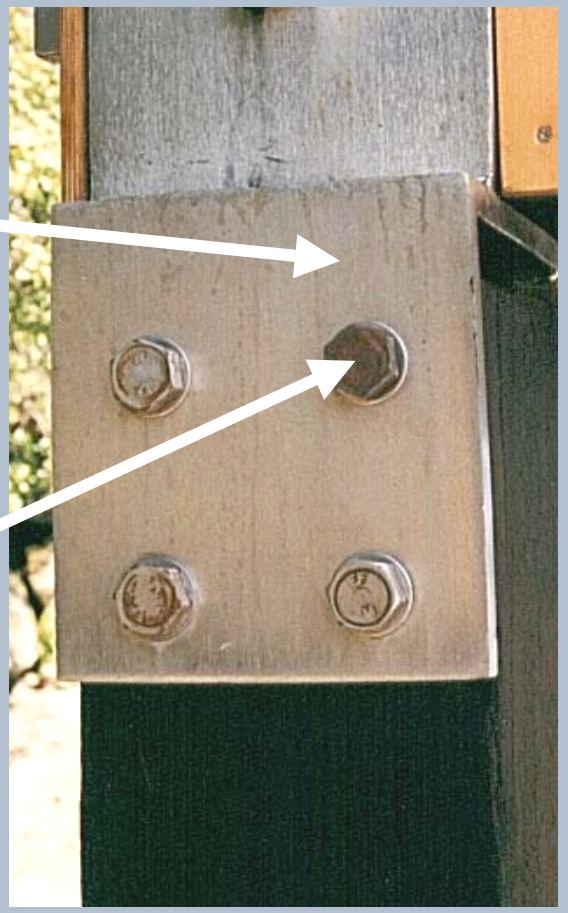
Coastal Applications

Type 316

Type 304



Photos courtesy of Austral Wright Metals

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Singapore Turf Club

Architect: Ewing Cole

Photo courtesy of Ewing Cole

Type 316 roof
2D finish

Curved 400 meter long building and walkway canopies

Standing seam roof

Modular design kept costs down

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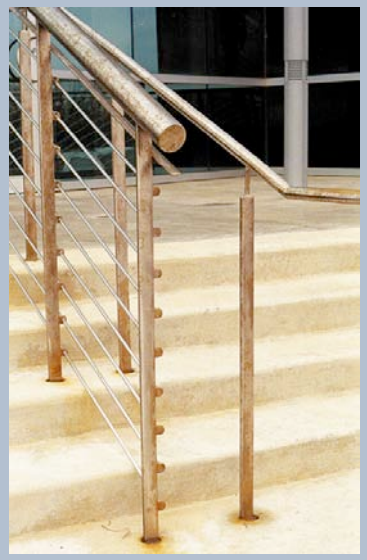
Evaluation Scores Case Study 01

Section	Chicago	Pittsburgh
Environment	2	2
Deicing salt	3 or 4	2
Weather	-1	-1



Pittsburgh, Type 304

Chicago, Type 316

Photos courtesy of TMR Consulting

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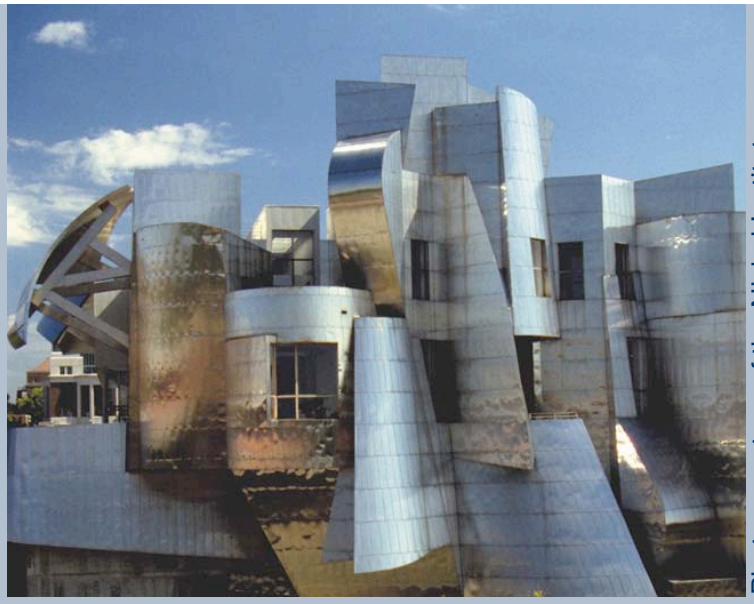
Evaluation Scores Case Study 02

Section	Museum	Window
Environment	2	2
Deicing salt	3	3
Weather	-1	-1



Photos courtesy of the Nickel Institute

Weisman Art Museum, Type 316

Window frame, Type 304

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Evaluation Scores
Case Study 03

Section	Miami Beach	Jones Beach
Environment	2	2
Coastal salt	3	3
Weather	1	-1

Photo courtesy of TMR Consulting

Miami Beach
light pole, Type 304

Photo courtesy of AISI

Jones Beach
light poles, Type 316

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Evaluation Score Case Study 04

Section	Singapore
Environment	2
Coastal salt	3
Weather	-1

Photos courtesy of Ewing Cole, Photographer: Erhard Pfeiffer

Singapore Turf Club,
Type 316 roof

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Evaluation Scores
Case Study 05

Section	Cheung Kong	Railings
Environment	3	3
Coastal salt	3	5
Weather	0	0

Photo courtesy of Nickel Institute

Hong Kong Convention Center railings, Type 316

Photo courtesy of Outokumpu

Cheung Kong Center, Type 316

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Evaluation Score
Case Study 06

Section	Canary Islands
Environment	0
Coastal salt	3 to 5
Weather	1

Canary Island light pole, Type 316

Canary Island railing, 2205 stainless steel

Photos courtesy of Outokumpu

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Evaluation Score Case Study 07

Section	Mapfre Tower
Environment	2
Coastal salt	3
Weather	1

Mapfre Office Tower,
Barcelona, Type 316

Photo courtesy of ACERINOX

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Evaluation Score
Case Study 08

Section	Bank Boston
Environment	4
Coastal salt	0
Weather	1

Bank Boston, São Paulo,
Brazil, Type 316

Photo courtesy of Núcleo Inox

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Evaluation Scores
Case Study 09

Section	Post	Gate
Environment	0	0
Coastal salt	4	4
Weather	0	0

Photo courtesy of the Australian Stainless Steel Development Association

Australian Coastal fence,
Type 316 gate and Type 304 post

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Evaluation Score Case Study 10

Section	Splashed	Non Splashed
Environment	0	0
Coastal salt	7	3
Weather	-1	-1

Gantry Plaza Park

Railings and Seating

New York City

Type 316

Evaluation Score Case Study 11

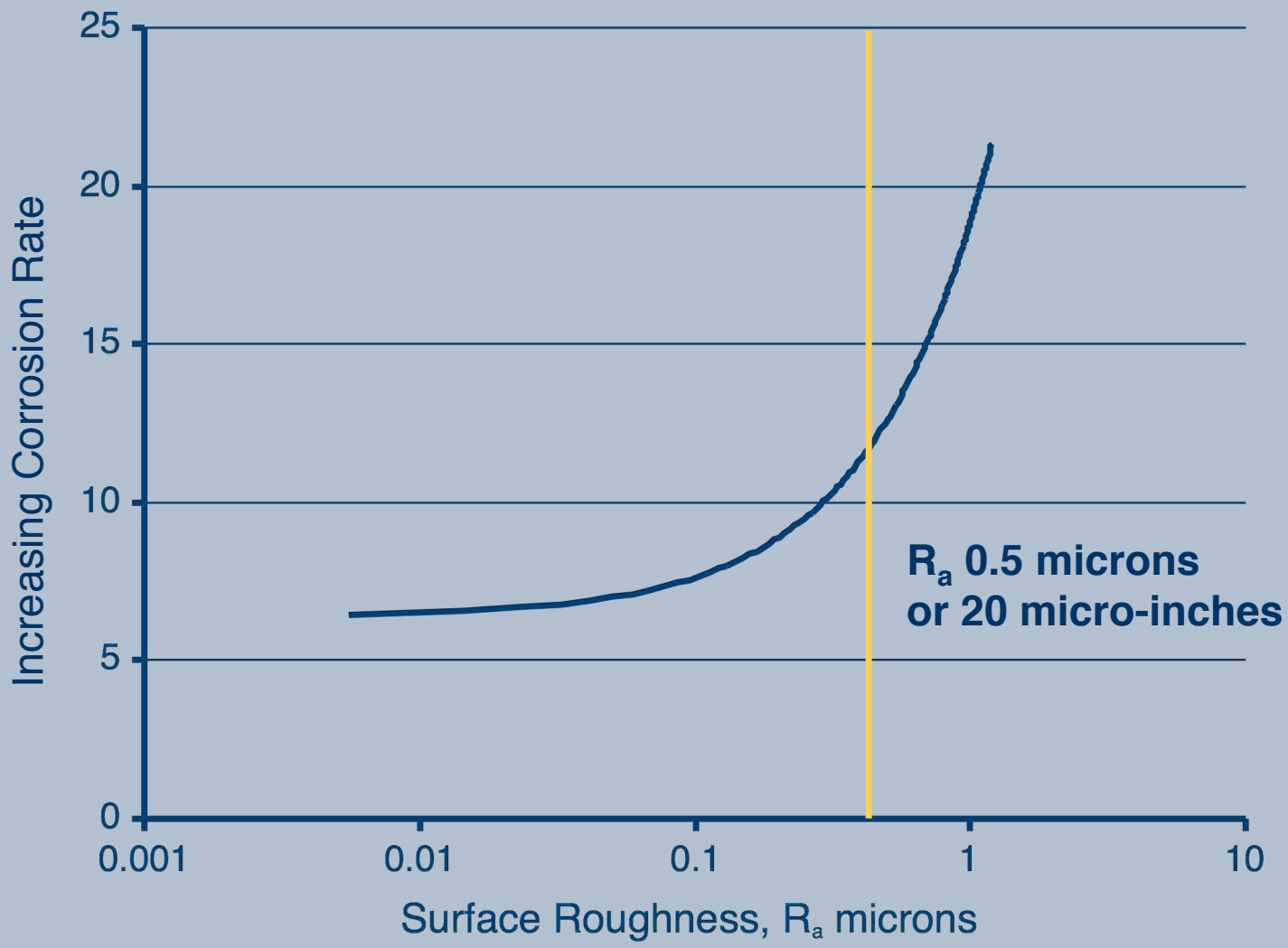
Section	Thames River Barrier
Environment	0
Coastal salt	5
Weather	0

Thames River Barrier, London, England, Type 316

Design Considerations

Points	Section 4: Design Considerations (Select all that apply)
0	Boldly exposed for easy rain cleaning
0	Vertical surfaces with a vertical or no finish grain
-2	Surface finish is pickled, electropolished, or roughness ≤ R_a 0.3 μm (12 μin)
-1	Surface finish roughness R_a 0.3 μm (12 μin) < X ≤ R_a 0.5 μm (20 μin)
1	Surface finish roughness R_a 0.5 μm (20 μin) < X ≤ R_a 1 μm (40 μin)
2	Surface finish roughness > R_a 1 μm (40 μin)
1	Sheltered location or unsealed crevices***
1	Horizontal surfaces
1	Horizontal finish grain orientation

*** If there is also salt or pollution exposure, have a stainless steel corrosion expert evaluate the site.



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Type 316 railings beside a beach

Specifying the surface roughness is as important as selecting the right stainless steel.

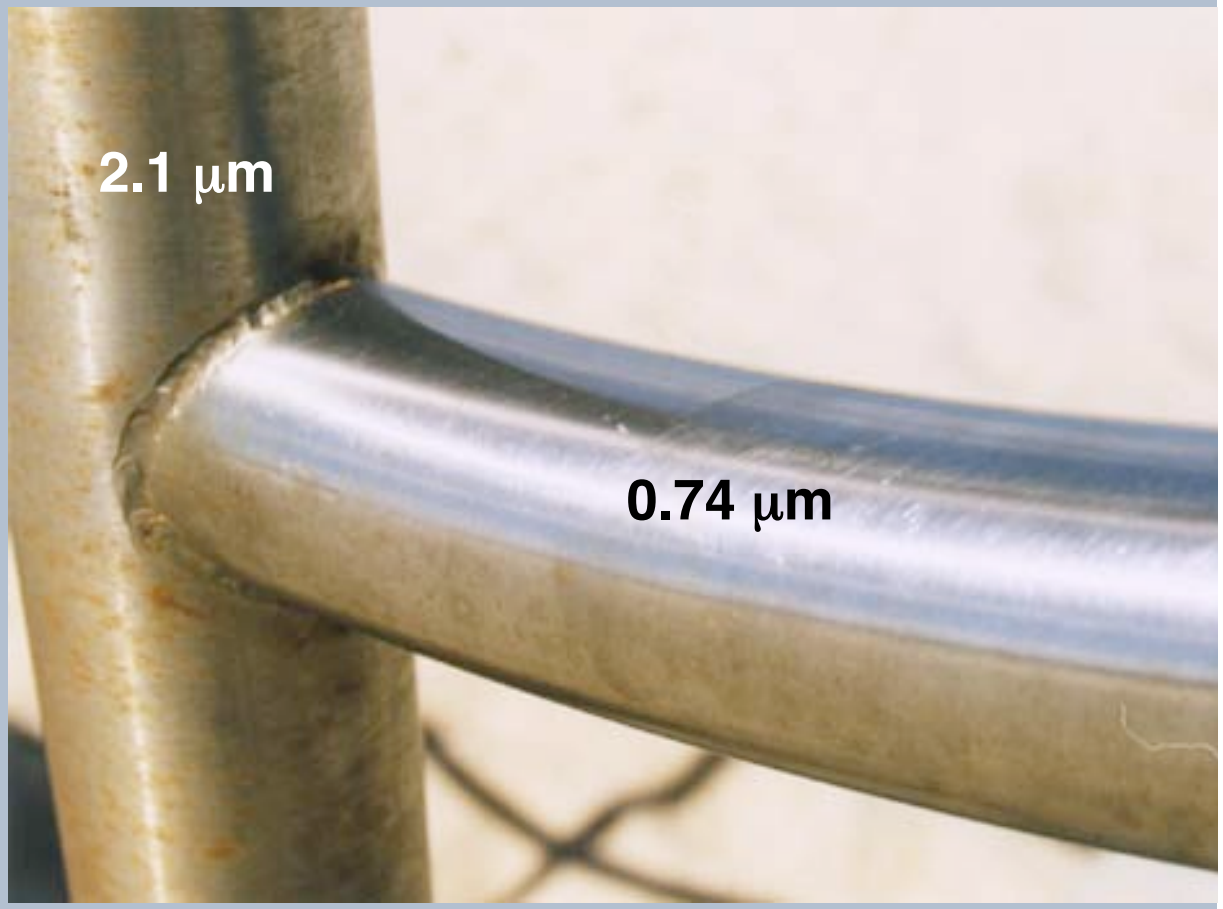

Photo courtesy of Austral Wright

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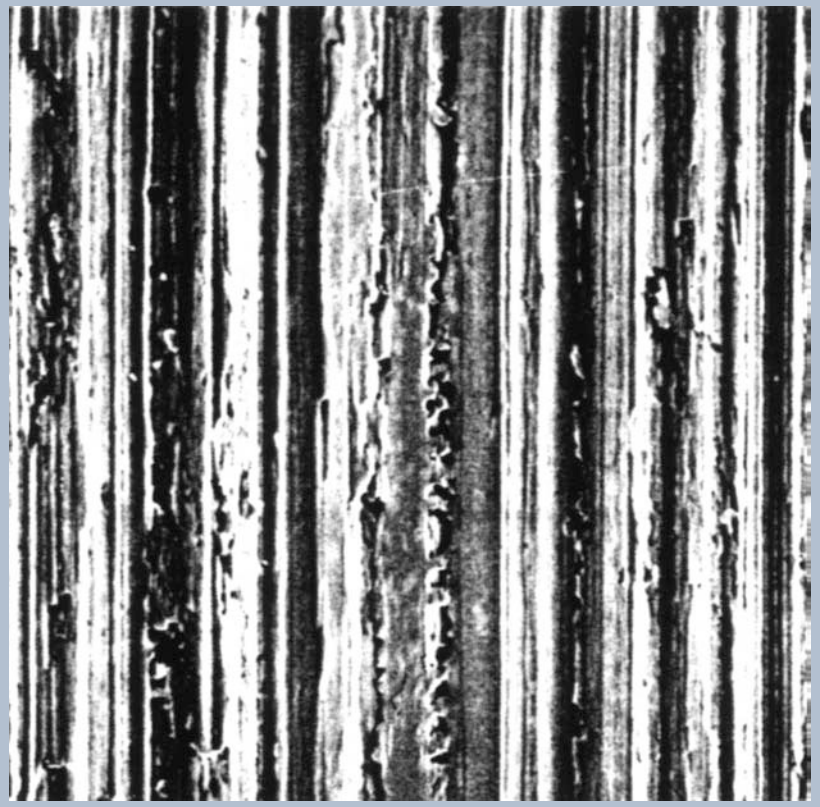
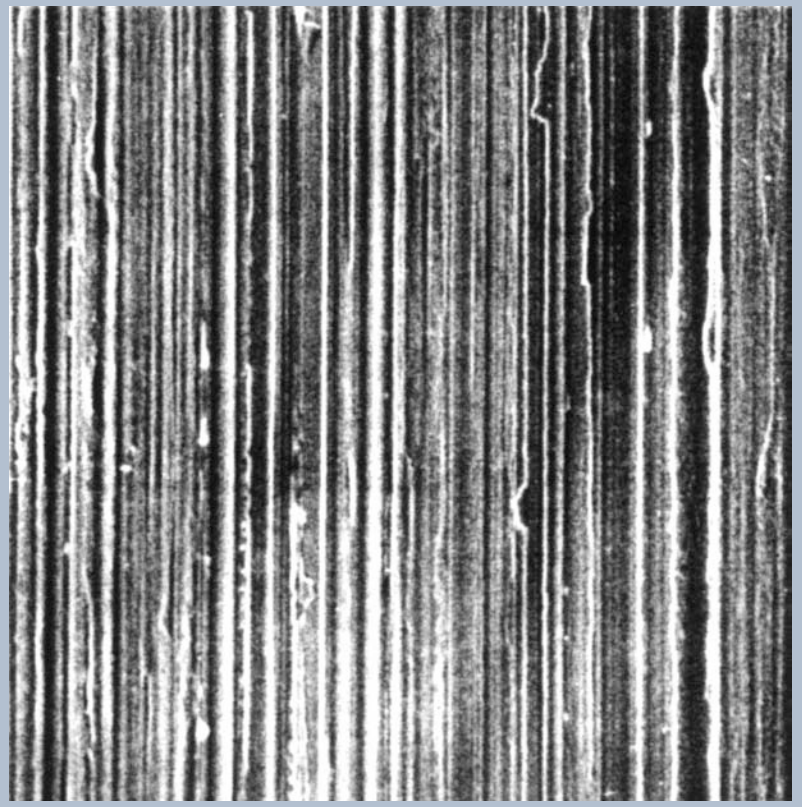
No. 4 Finish, Dry Polished, Aluminum Oxide Abrasive



R_a 0.7 microns

No. 4 Finish, Wet Polished, Silicon Carbide Abrasive



> R_a 0.3 microns

Photos courtesy of Outokumpu

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Typical Sheet Surface Roughness Range

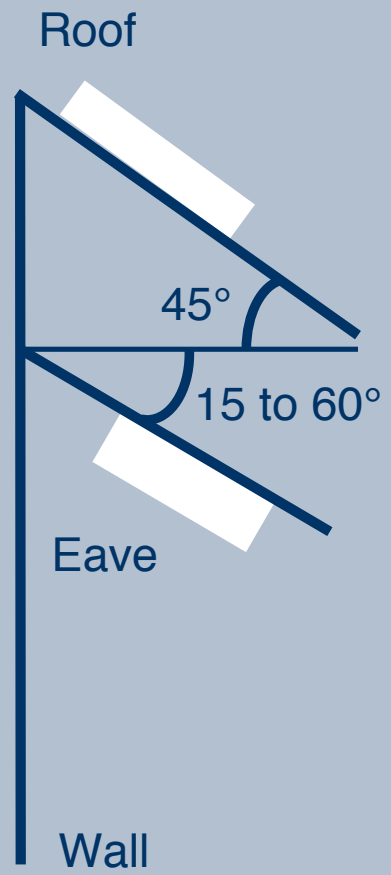
Finish	2D	2B	BA	No. 3	No. 4	Hair-line	No. 7	No. 8	Super No. 8
R_a Micro-inch	5 - 39	2.4 - 20	0.5 - 4	10 - 43	7 - 25	5.5 - 8.0	2.4 - 8	0.8 - 4	0.4 - 0.8
R_a Micron	0.13 - 1.0	0.06 - 0.5	0.01 - 0.10	0.25 - 1.1	0.18 - 0.64	0.14 - 0.2	0.06 - 0.2	0.02 - 0.10	0.01 - 0.02

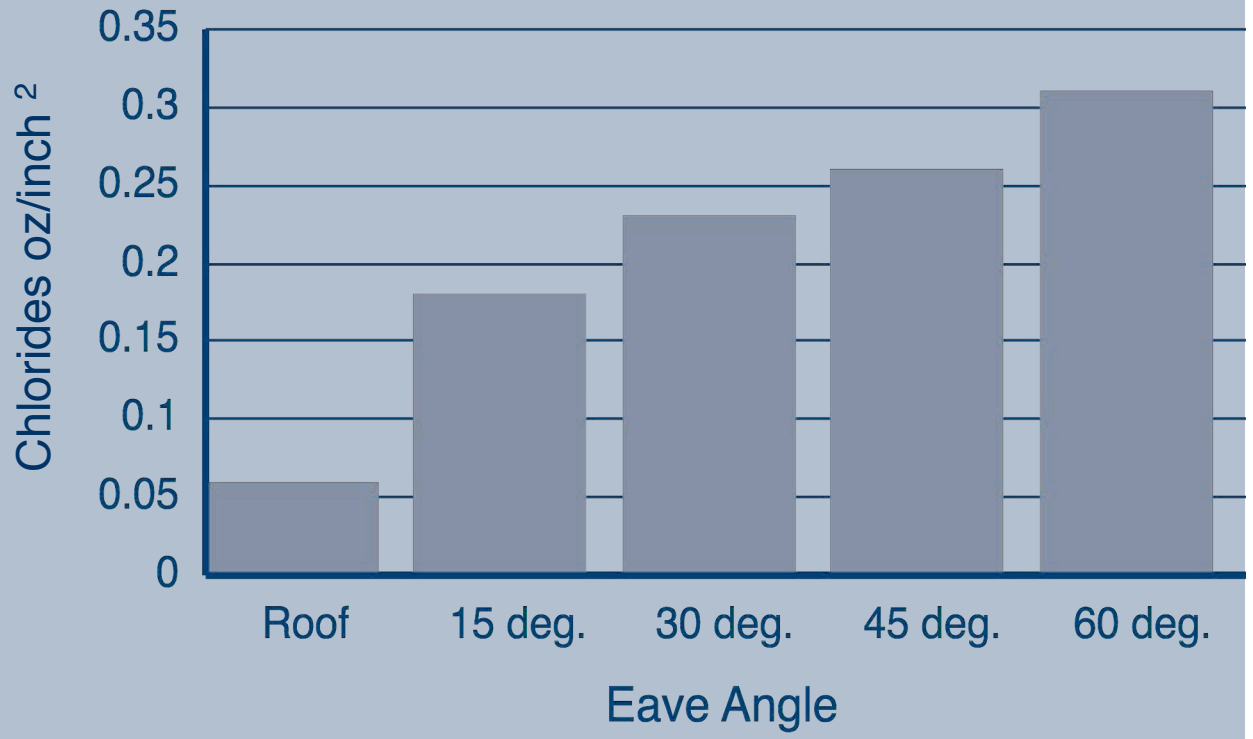
Based on a Nickel Institute survey of North American and European suppliers which determined the surface roughness range that might be typically supplied for each finish. The surface roughness range will vary with thickness.

Tighten Specifications

- Flatness
  - Require stretcher or tension leveling
- Chemistry
  - Sulfur ≤ 0.005 for exterior and swimming pool applications
- Iron Contamination
  - Require iron free certification in compliance with ASTM A 380
- Exterior and Swimming Pool Finishes
  - Surface roughness ≤ R_a 20 micro-inches

Chloride Accumulation In Sheltered Locations





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Sheltered Components

Increased corrosion risk

Photos courtesy of JSSA and ASSDA

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Sites for Crevice Corrosion

If the design will be exposed to salt (chlorides) and moisture, avoid crevices or seal them to prevent corrosion

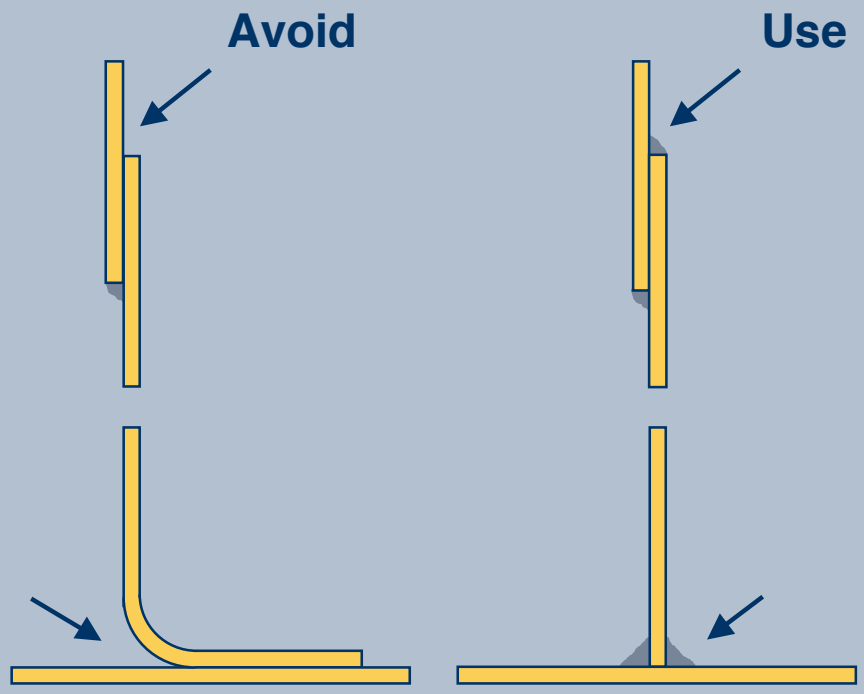

Photo courtesy of Nickel Institute

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Type 316 Light Fixture

- Highly polished light fixture
- Unsealed crevices accumulated salt and water causing corrosion
- Eliminate corrosion by cleaning the fixture and sealing the crevices

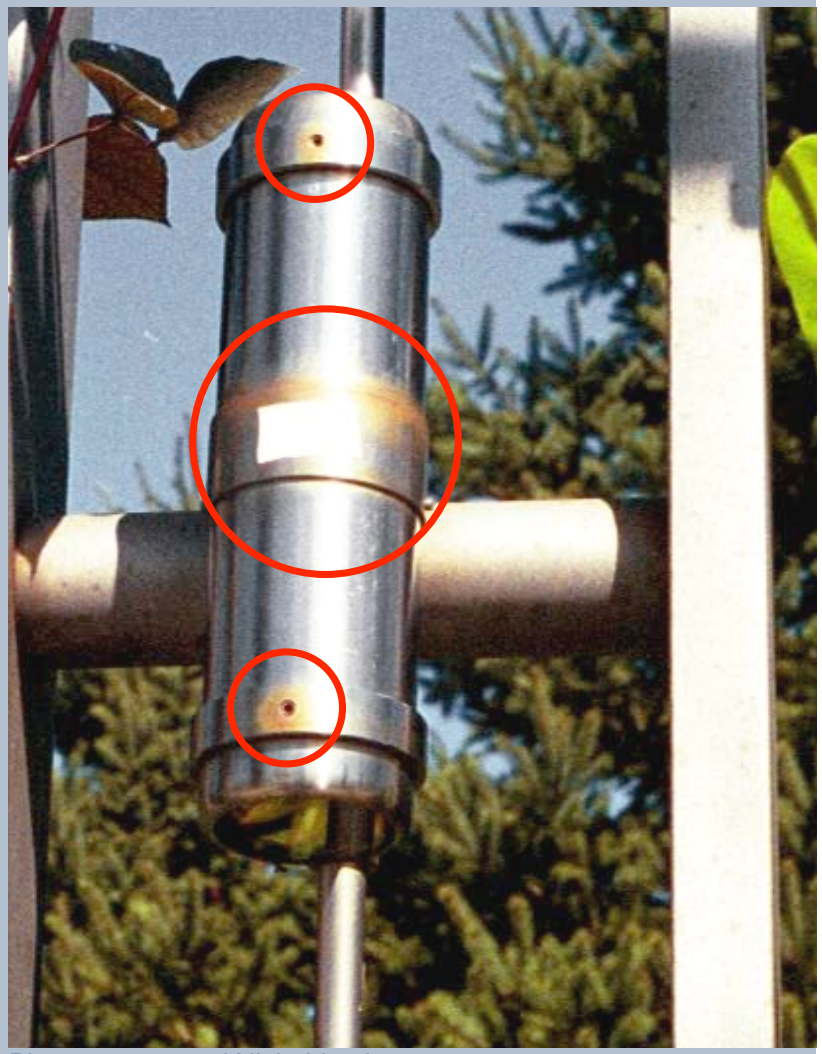

Photo courtesy of Nickel Institute

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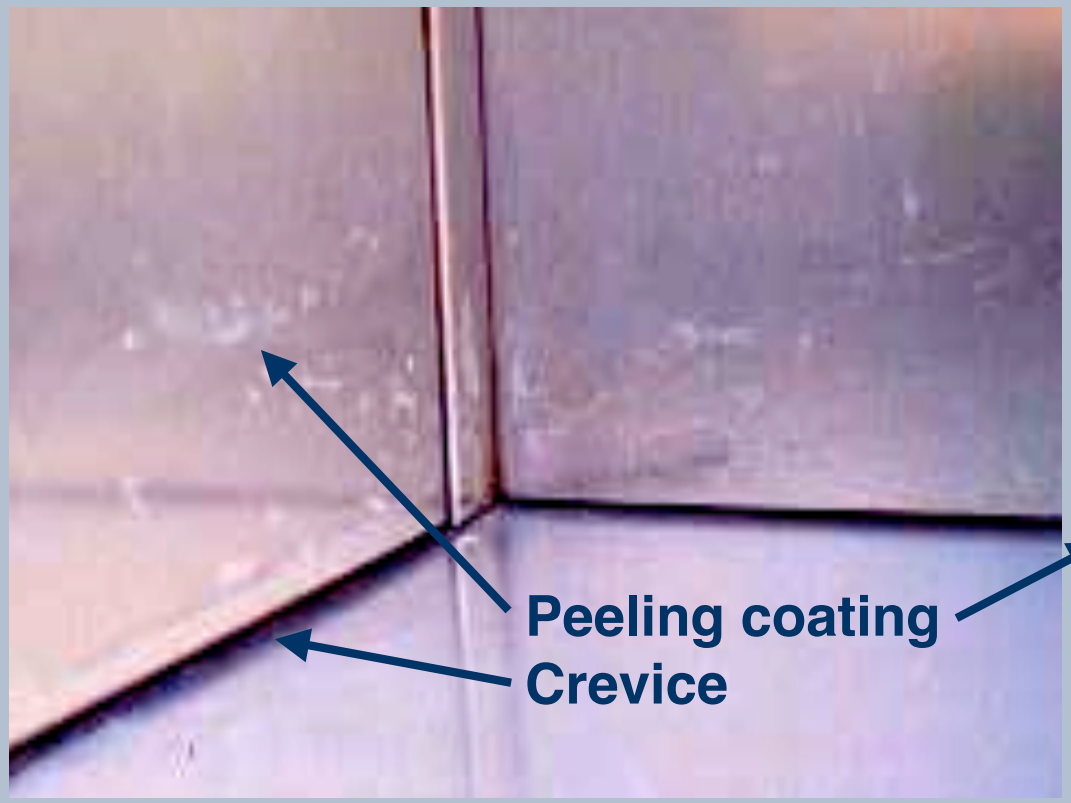
- Coatings are not necessary, require regular replacement, and can cause corrosion
- Using the right stainless steel is more cost effective



Photos courtesy of Nickel Institute

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Galvanic Corrosion Requires...

- Dissimilar metals
- Electrical connection between metals (i.e., metal-to-metal contact)
- Moisture is present and connects the metals

Solution

- Prevent direct metal to metal contact
  - Inert washers
  - Paint
  - Other non-conducting barriers

Galvanic Series
Metals and Alloys in Sea Water

Anodic
More Likely to corrode

Magnesium
Zinc
Aluminum Alloys
Mild Steel
Low Alloy Steel
Cast Iron
Muntz Metal
Yellow Brass
Red Brass
copper
Aluminum Bronze
Silver
Stainless Steel
Monel
Gold

More Noble
Cathodic

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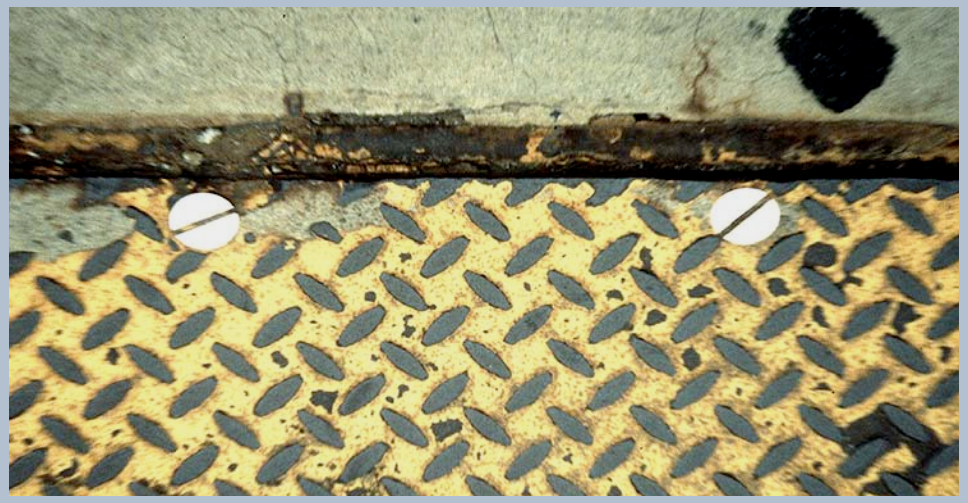
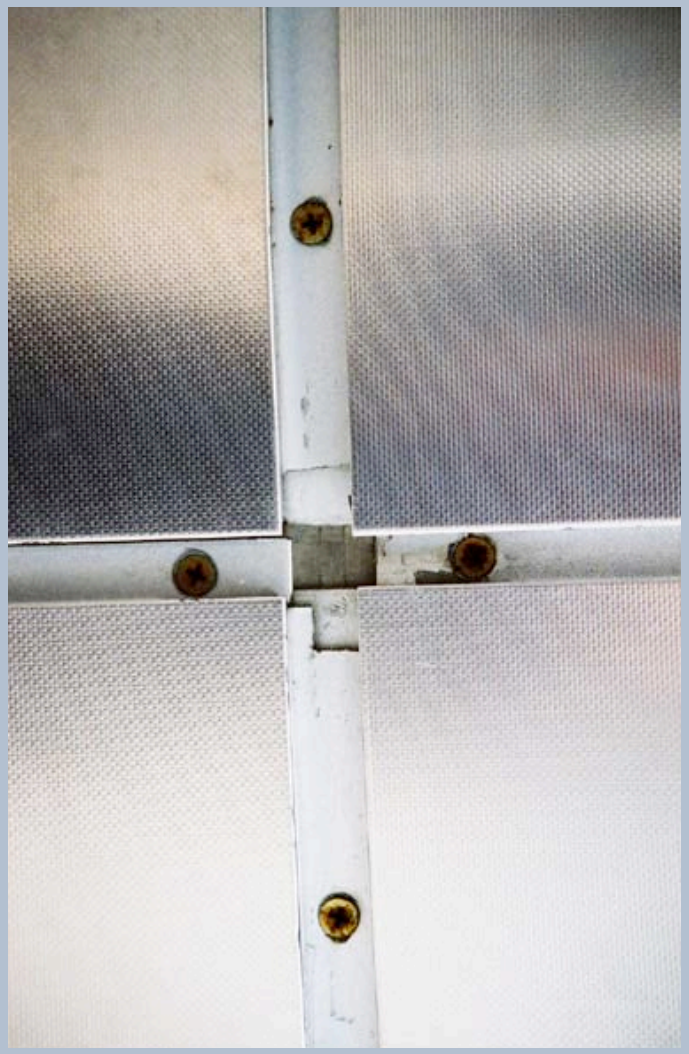


- Stainless steel fasteners in carbon steel cover
  - Good ratio = no impact on corrosion rate
- Galvanized fasteners in stainless steel
  - Bad ratio = rapid corrosion



Photos courtesy of Nickel Institute

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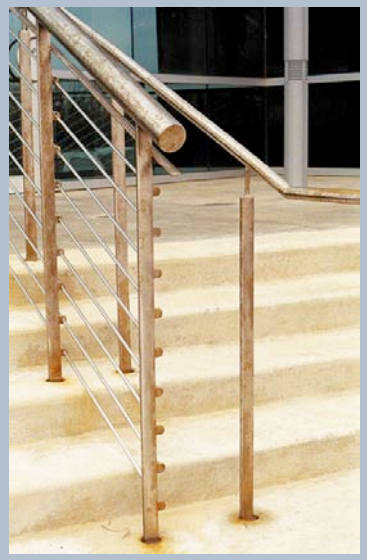
Evaluation Scores Case Study 01

Section	Chicago	Pittsburgh
Environment	2	2
Deicing salt	3 or 4	2
Weather	-1	-1
Design	-1 to -2	2



Pittsburgh, Type 304

Chicago, Type 316

Photos courtesy of TMR Consulting

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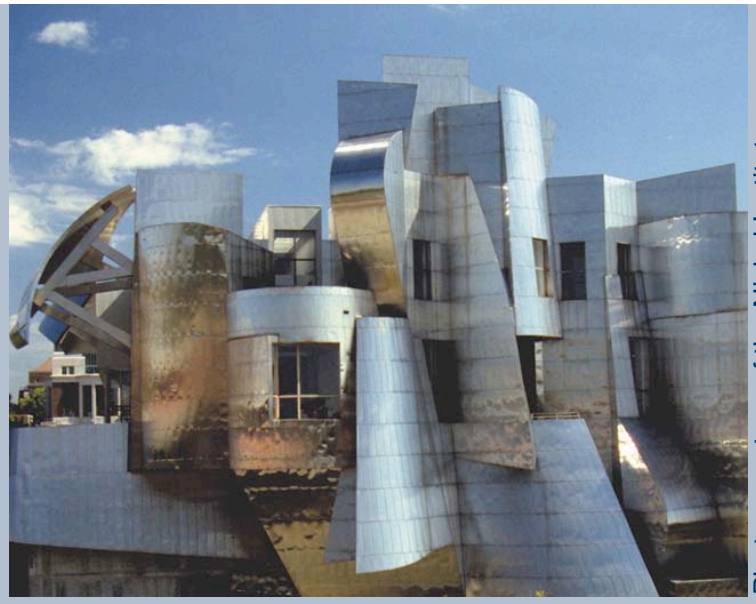
Evaluation Scores
Case Study 02

Section	Museum	Window
Environment	2	2
Deicing salt	3	3
Weather	-1	-1
Design	-1	0



Photos courtesy of the Nickel Institute

Frederick R. Weisman Art Museum, Type 316

Window frame, Type 304

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Evaluation Scores
Case Study 03

Section	Miami Beach	Jones Beach
Environment	2	2
Coastal salt	3	3
Weather	1	-1
Design	3	-1

Photo courtesy of TMR Consulting

Miami Beach
light pole, Type 304

Photo courtesy of AISI

Jones Beach
light poles, Type 316

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Evaluation Score Case Study 04

Section	Singapore
Environment	2
Coastal salt	3
Weather	-1
Design	-1

Photos courtesy of Ewing Cole, Photographer: Erhard Pfeiffer

Singapore Turf Club,
Type 316 roof

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Evaluation Scores
Case Study 05

Section	Cheung Kong	Railings
Environment	3	3
Coastal salt	3	5
Weather	0	0
Design	-1 or -2	2

Photo courtesy of Nickel Institute

Hong Kong Convention Center railings, Type 316

Photo courtesy of Outokumpu

Cheung Kong Center, Type 316

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Evaluation Score Case Study 06

Section	Canary Islands
Environment	0
Coastal salt	3 to 5
Weather	1
Design	-1 or -2

Canary Island light pole, Type 316

Canary Island railing, 2205 stainless steel

Photos courtesy of Outokumpu

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Evaluation Score Case Study 07

Section	Mapfre Tower
Environment	2
Coastal salt	3
Weather	1
Design	0

Photo courtesy of ACERINOX

Mapfre Office Tower,
Barcelona, Type 316

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Evaluation Score
Case Study 08

Section	Bank Boston
Environment	4
Coastal salt	0
Weather	1
Design	-1

Bank Boston, São Paulo,
Brazil, Type 316

Photo courtesy of Núcleo Inox

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Evaluation Scores
Case Study 09

Section	Post	Gate
Environment	0	0
Coastal salt	4	4
Weather	0	0
Design	2	-1

Australian Coastal fence,
Type 316 gate and Type 304 post

Photo courtesy of the Australian Stainless Steel Development Association

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Evaluation Score Case Study 10

Section	Splashed	Non Splashed
Environment	0	0
Coastal salt	7	3
Weather	-1	-1
Design	1	1

Gantry Plaza Park

Railings and Seating

New York City

Type 316

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Evaluation Score Case Study 11

Section	Thames River Barrier
Environment	0
Coastal salt	5
Weather	0
Design	-2

Thames River Barrier, London, England, Type 316

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Maintenance Schedule

Points	Section 5: Maintenance Schedule (Select only one)
0	Not washed
-1	Washed at least annually
-2	Washed four or more times per year
-3	Washed at least monthly

Standard Cleaning

- Rain
- Hot water power wash
- Mild chloride-free detergent
- Degreaser
  - 5% ammonia and water (window cleaners)
  - Alcohol
  - Vinegar and water
  - Citrus cleaner
- 200 mesh or finer calcium carbonate abrasive (except on colored or mirror-like finishes)

Photo courtesy of Allegheny Ludlum

150 East 42nd Street, New York City
Cleaned for the first time after 30 years of service

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Reusing Stainless Steel

525 William Penn Place
Pittsburgh, Pennsylvania
Completed in 1952

- Stainless entrance/lobby
- Lobby renovation in 2002
- Most of the stainless steel was refinished and reused
- Architect IKM

Before

After

Photos courtesy of IKM and Nickel Institute

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Remedial Cleaning

- Adhesives
  - Alcohol, citric cleaner or other solvent recommended by adhesive supplier
- Paint and marker pens
  - Solvents or chemical paint remover and soft brush
- Cement or mortar
  - Rinse off with water while still wet
  - If it has dried, use power washing and if necessary abrasives

Embedded Iron Corrosion

- Remove by
  - Mechanical cleaning
  - Chemical cleaning ("Passivation")
- Confirm cleaning by test to
  - ASTM A 967, Chemical Passivation Treatments for Stainless Steel Parts

Photo courtesy of Nickel Institute

Muriatic Acid Corrosion

- Tile, stone, masonry or concrete are sometimes cleaned with Muriatic (hydrochloric) acid
- Muriatic acid is very corrosive to stainless steel!
- Avoid Muriatic acid containing cleaners
- Use citric acid or other non-corrosive cleaners

Photos courtesy of Nickel Institute

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Removing Welding Heat Tint

- Mechanical methods
  - Grinding
  - Abrasive blasting
- Chemical methods
  - Pickle paste
  - Pickling

Photo courtesy of ASSDA

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Evaluation Scores
Case Study 01

Section	Chicago	Pittsburgh
Environment	2	2
Deicing salt	3 or 4	2
Weather	-1	-1
Design	-1 to -2	2
Maintenance	-1	0
Total	**3**	**5**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice
≥ 5	A more corrosion resistant stainless steel such as 2205, 904L, 317LMN, super duplex, super ferritic or a 6% molybdenum super austenitic stainless steel may be needed

Evaluation Scores
Case Study 02

Section	Museum	Window
Environment	2	2
Deicing salt	3	3
Weather	-1	-1
Design	-1	0
Maintenance	0	0
Total	**3**	**4**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice
4	Type 317L or a more corrosion resistant stainless steel is suggested

Evaluation Scores
Case Study 03

Section	Miami Beach	Jones Beach
Environment	2	2
Coastal salt	3	3
Weather	1	-1
Design	3	-1
Maintenance	0	0
Total	**9**	**3**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice
≥ 5	A more corrosion resistant stainless steel such as 2205, 904L, 317LMN, super duplex, super ferritic or a 6% molybdenum super austenitic stainless steel may be needed

Evaluation Score
Case Study 04

Section	Singapore
Environment	2
Coastal salt	3
Weather	-1
Design	-1
Maintenance	0
Total	**3**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice

Evaluation Scores
Case Study 05

Section	Cheung Kong	Railings
Environment	3	3
Coastal salt	3	5
Weather	0	0
Design	-1 or -2	2
Maintenance	-2	-3
Total	**2 or 3**	**7**

Total Score	Stainless Steel Selection
2	Type 304/304L is generally the most cost-effective choice
3	Type 316/316L or 444 is generally the most economical choice
≥ 5	A more corrosion resistant stainless steel such as 2205, 904L, 317LMN, super duplex, super ferritic or a 6% molybdenum super austenitic stainless steel may be needed

Evaluation Score Case Study 06

Section	Canary Islands
Environment	0
Coastal salt	3 to 5
Weather	1
Design	-1 or -2
Maintenance	0
Total	**3 to 5**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice
≥ 5	A more corrosion resistant stainless steel such as 2205, 904L, 317LMN, super duplex, super ferritic or a 6% molybdenum super austenitic stainless steel may be needed

Evaluation Score
Case Study 07

Section	Mapfre Tower
Environment	2
Coastal salt	3
Weather	1
Design	0
Maintenance	-3
Total	**3**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice

Evaluation Score
Case Study 08

Section	Bank Boston
Environment	4
Coastal salt	0
Weather	1
Design	-1
Maintenance	-2
Total	**2**

Total Score	Stainless Steel Selection
2	Type 304/304L is generally the most cost-effective choice

Evaluation Scores Case Study 09

Section	Post	Gate
Environment	0	0
Coastal salt	4	4
Weather	0	0
Design	2	-1
Maintenance	0	0
Total	**6**	**3**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice
≥ 5	A more corrosion resistant stainless steel such as 2205, 904L, 317LMN, super duplex, super ferritic or a 6% molybdenum super austenitic stainless steel may be needed

Evaluation Score
Case Study 10

Section	Splashed	Non Splashed
Environment	0	0
Coastal salt	7	3
Weather	-1	-1
Design	1	1
Maintenance	0	0
Total	**7**	**3**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice
≥ 5	A more corrosion resistant stainless steel such as 2205, 904L, 317LMN, super duplex, super ferritic or a 6% molybdenum super austenitic stainless steel may be needed

Evaluation Score
Case Study 11

Section	Thames River Barrier
Environment	0
Coastal salt	5
Weather	0
Design	-2
Maintenance	0
Total	**3**

Total Score	Stainless Steel Selection
3	Type 316/316L or 444 is generally the most economical choice

How Can I Reduce the Score?

- Design for rain washing
- Select smooth surface finishes
- Use vertical finish grain orientation
- Eliminate sheltered areas and horizontal surfaces
- Eliminate or seal crevices
- Design to facilitate manual washing
- Use natural or artificial barriers to reduce deicing salt road mist exposure

Conclusions

- Carefully evaluate each site and application
- If technical questions arise, contact (*insert appropriate organization name*)
- In more corrosive environments, have a metallurgical engineer with architecture experience evaluate the site and applications