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CORROSION · GALVANIC SERIES · DISSIMILAR METALS · REFERENCE DOCUMENT · PUBLIC

Galvanic & corrosion compatibility

Which metals can touch — the galvanic series and anodic-index rules — plus the other corrosion forms and how to design them out of an assembly.

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ABSTRACT

When two dissimilar metals touch in the presence of an electrolyte (even humidity), the more active one corrodes preferentially — galvanic corrosion. It's one of the most common and most avoidable field failures in mixed-material assemblies. The galvanic series and a few rules tell you which couples are safe.

Section 1 explains galvanic corrosion. Section 2 is the galvanic series / anodic index. Section 3 is the compatibility rules. Section 4 covers the other corrosion forms. Section 5 is mitigation. Section 6 is a checklist.

COUPLE TWO METALS IN AN ELECTROLYTE AND THE MORE ACTIVE (ANODIC) ONE CORRODES TO PROTECT THE NOBLE ONE. KEEP THE ANODIC-INDEX GAP SMALL — AND REMEMBER A SMALL ANODE AGAINST A LARGE CATHODE CORRODES FAST.

CONTENTS

1. Galvanic corrosion

Galvanic corrosion needs **three things at once** — remove any one and it stops:

1. **Two dissimilar metals** (different nobility), 2. an **electrolyte** bridging them (seawater, condensation, even humid air), and 3. **electrical contact** between them.

The more active (anodic) metal becomes the anode and corrodes faster than it would alone; the nobler (cathodic) metal is protected. The bigger the nobility gap and the more conductive the electrolyte, the faster it goes.

`Anode`	The more active metal — it corrodes (loses material)
`Cathode`	The nobler metal — it's protected
`Anodic index`	A metal's nobility on a 0 (noble) → 1.75 (active) scale; the *difference* predicts risk
`Area ratio`	Cathode area / anode area — a large cathode driving a small anode is the dangerous case

2. Galvanic series (anodic index)

Ranked from **noble (cathodic, protected)** to **active (anodic, corrodes)** — the index difference between two coupled metals predicts the risk (MIL-STD-889 style):

METAL	ANODIC INDEX (V)
Gold, platinum, graphite	0.00
Silver	0.15
Stainless (passive), titanium, nickel	0.30
Copper, brass, bronze	0.40
Tin, lead, solder	0.65
Stainless (active)	0.50–0.85
Carbon steel, cast iron	0.85
Aluminium alloys	0.90–0.95
Cadmium	0.80
Zinc (and galvanising)	1.25
Magnesium	1.75

Zinc and aluminium are deliberately **sacrificial** — galvanising and zinc-rich primers protect steel by corroding first. Stainless is noble *when passive* but drops toward active in stagnant, oxygen-starved crevices.

3. Compatibility rules

Keep the **anodic-index difference** below the threshold for the environment:

ENVIRONMENT	MAX INDEX DIFFERENCE
Harsh / marine / outdoor	≤ 0.15 V
Normal indoor	≤ 0.25 V
Dry / temperature- & humidity-controlled	≤ 0.50 V

And mind the **area ratio**: a *small anode* feeding a *large cathode* corrodes fast (e.g. a steel fastener in a big copper plate — bad; a copper fastener in a big steel plate — far less so). Fasteners should be at least as noble as the parts they join.

4. Other corrosion forms

FORM	CAUSE	GUARD AGAINST IT
Uniform	general oxidation	coatings, paint, nobler alloy, thickness allowance
Pitting	chloride attack on passive films (stainless)	316/higher-Mo grades, avoid stagnation
Crevice	oxygen-starved gaps (under seals, laps)	seal/eliminate crevices, drainage
Stress-corrosion cracking	tensile stress + specific environment	lower stress, resistant alloy, shot-peen
Intergranular	sensitised stainless welds (Cr carbides)	low-carbon (304L/316L) or stabilised grades

5. Mitigation

- **Select compatible couples**
  the cheapest fix is choosing metals within the allowed index gap.
- **Isolate when you must mix: non-conductive gaskets, shoulder washers/sleeves on fasteners, coatings on one or both faces (break the electrical path).**
- **Favourable area ratio**
  make the anode large or the cathode small; never a tiny anodic fastener in a large cathodic part.
- **Coat the cathode (counter-intuitive but right: a coating defect on the anode concentrates attack).**
- **Sacrificial anodes (zinc/magnesium) for large structures; inhibitors / sealants to exclude the electrolyte.**
- **Drainage**
  design out water traps and crevices.

6. Checklist

- **List every metal in contact (including fasteners, coatings, springs).**
- **Electrolyte? indoor dry, humid, splash, or immersed/marine.**
- **Index gap**
  look up each metal; check the difference against the environment limit.
- **Area ratio**
  is the anode small relative to the cathode? Fasteners at least as noble as the joint.
- **If incompatible: isolate (gasket/sleeve/coating), reselect, or add a sacrificial element**
  and design out crevices and water traps. Pairs with the
  Heat & surface treatment
  and
  Materials
  references.