marinAl

MARINE EXPERIENCES WITH ALUMINIUM

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SINTEF

Contents

- Good experiences
- Corrosion problems
- Recommendations to avoid galvanic corrosion

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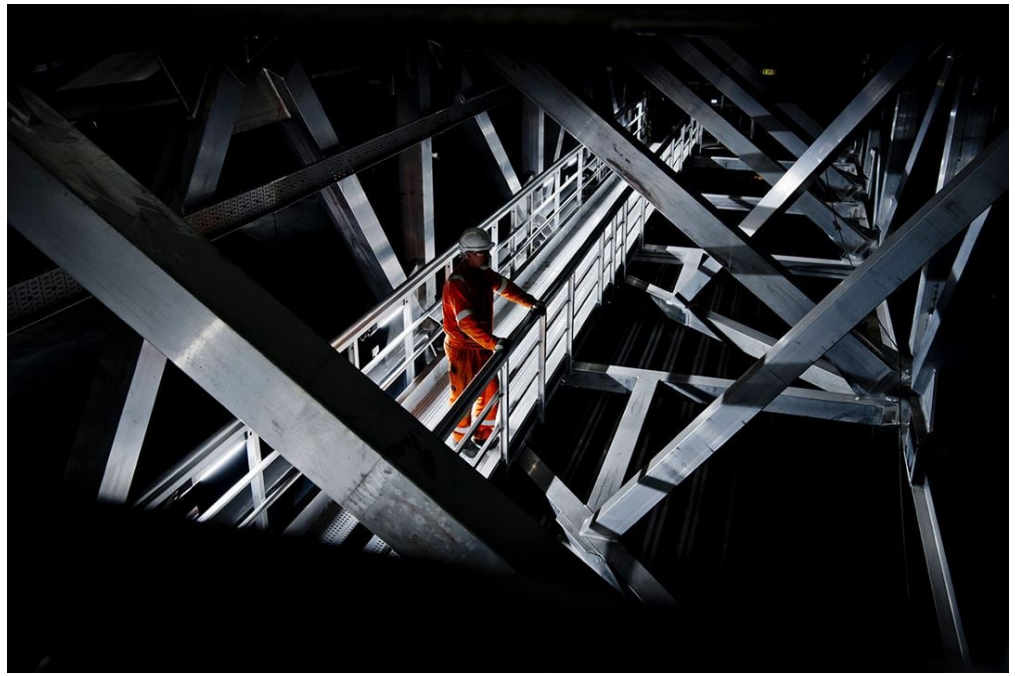


Photo: Marine Aluminium

North Sea Buoy II

- Investigation of samples at Hydro R&D

- Constructed from AA5083 sheet and AA6082 extrusions
- No surface treatment
- Sub-surface corrosion protection by sacrificial zinc anodes
- Zinc anode consumption approx. 1/5 of that required for cathodic protection of steel

Technical survey after 30 years of service in open sea:

- **No substantial wall thickness reduction**
- **No cracks** in base material or weld seams
- **Weldability** identical to new material
- **Joints with stainless steel screws fully intact** without galvanic isolation

S. Jupp and T. Hentschel, Hydro (2010)

Successful insulation of aluminium from steel

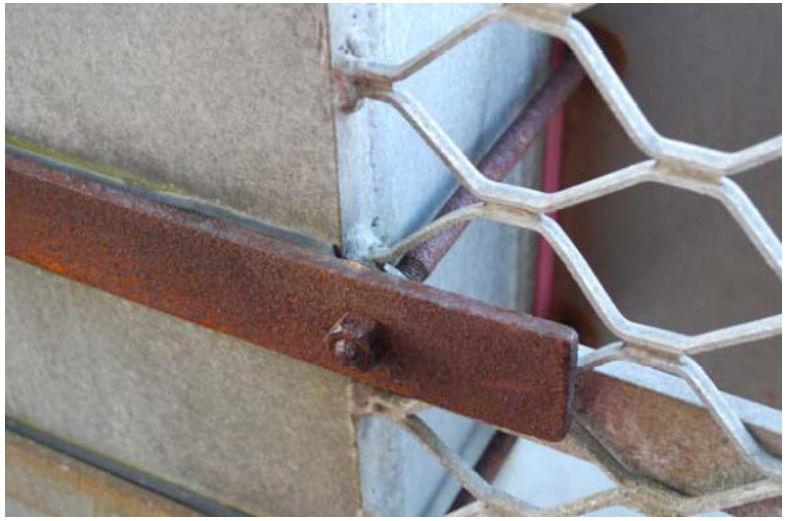


Photo:
Roald Lilletvedt
NTNU

Wrong alloy

- Severe corrosion on cast aluminium actuator
- The alloy contained about 1% Cu

- Standards for selection of Al alloys
  - NORSOK M-121
  - DIN 81249

Stagnant water

- Passive fire protection with absorbed salt water
- The water acidifies with time and becomes aggressive to aluminium

Galvanic corrosion

Under/around stainless bolts

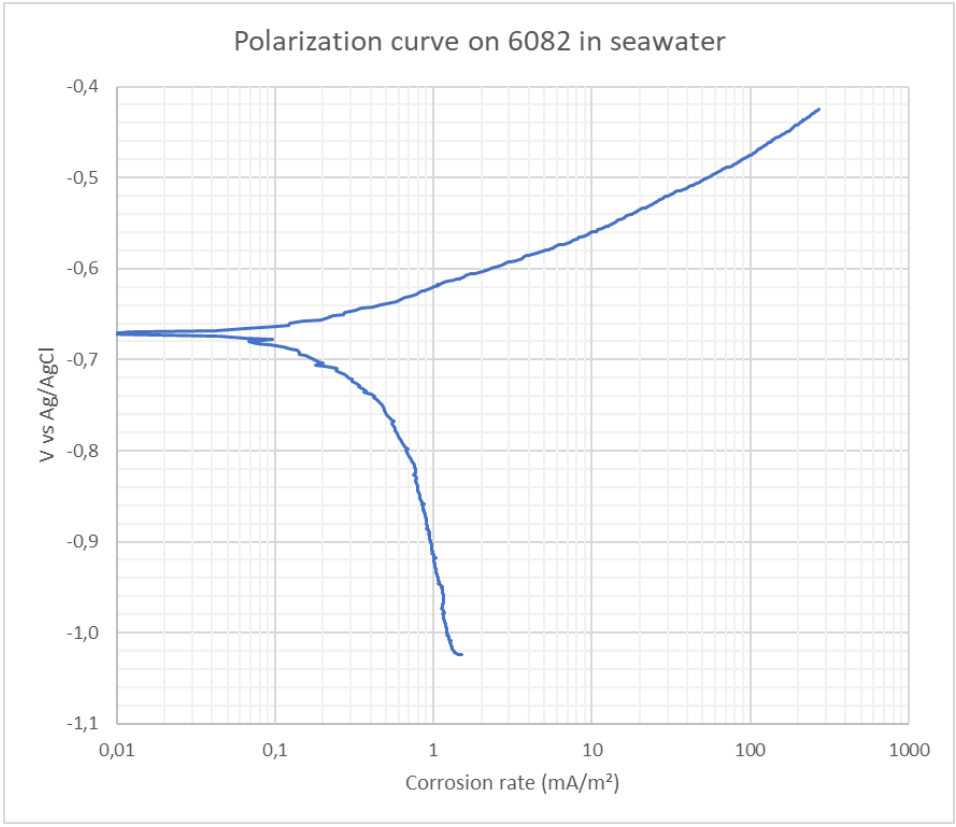
Low alloy bolts

Steel-aluminium weld

Galvanic corrosion

- Pitting potential for aluminium alloys is about – 0,7 V (Ag/AgCl reference)
- Corrosion potential of steel in seawater:
  - C-steel: about -0,6 V
  - Stainless steel: about 0 V
- Galvanic coupling to steel will polarize the aluminium above the pitting potential

➔ galvanic corrosion



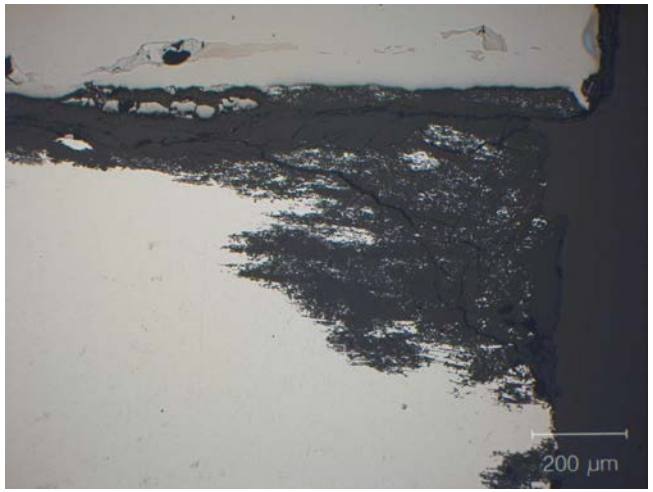
Galvanic corrosion in atmospheric conditions

- Designs where water may accumulate on the aluminium
  - Vertical lip on horizontal flange
  - Bolt holes that eventually fill with water
  - Non-draining surfaces
- Stagnant salt water on aluminium results in acidification (pH about 4) and corrosion

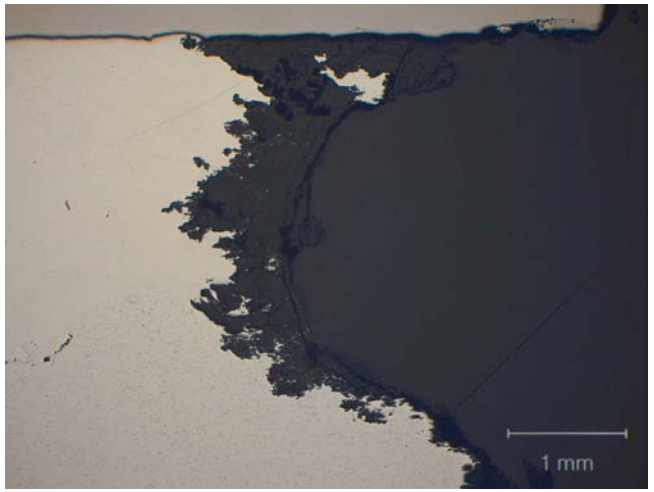
Galvanic corrosion in Al-steel explosion weld

Fracture along the weld interface

Galvanic corrosion running along the interface, separating Al from steel



Galvanic corrosion on the aluminium, but not along the interface



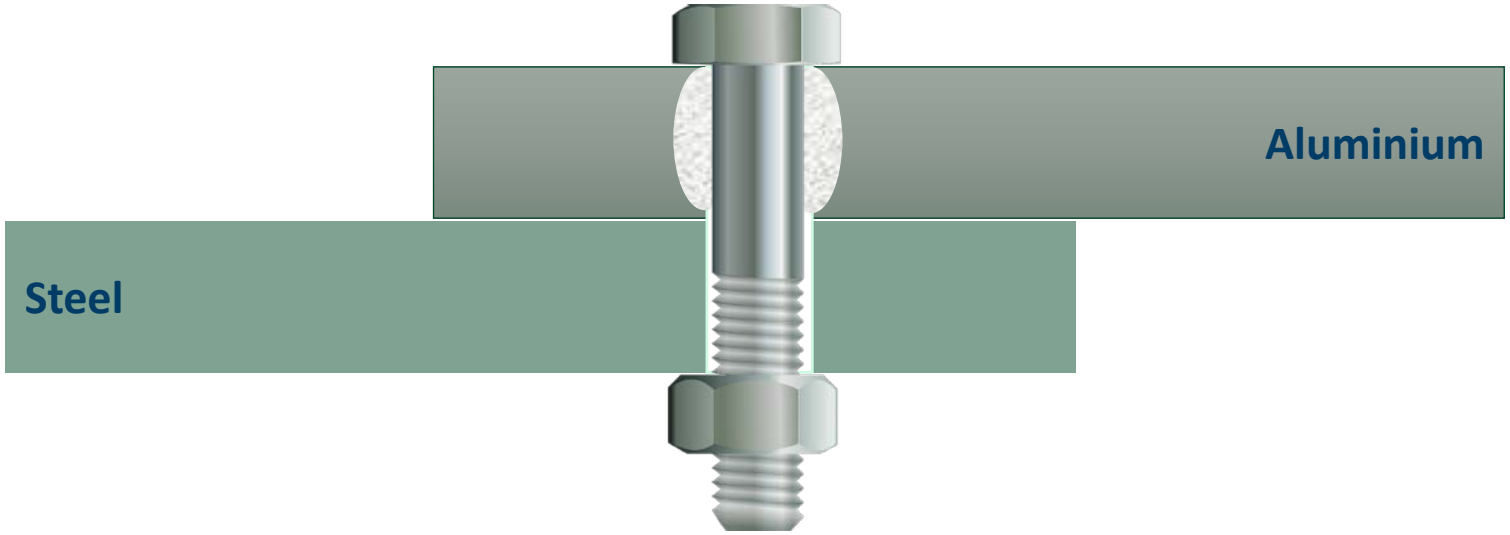
Galvanic corrosion in submerged conditions

- Aluminium parts on subsea ROV
- Stainless steel parts mounted on anodized aluminium (thick film anodized, 50 µm)
- Corrosion in the crevices
- CP probably not able to penetrate the crevice due to high resistance

Galvanic corrosion in submerged conditions

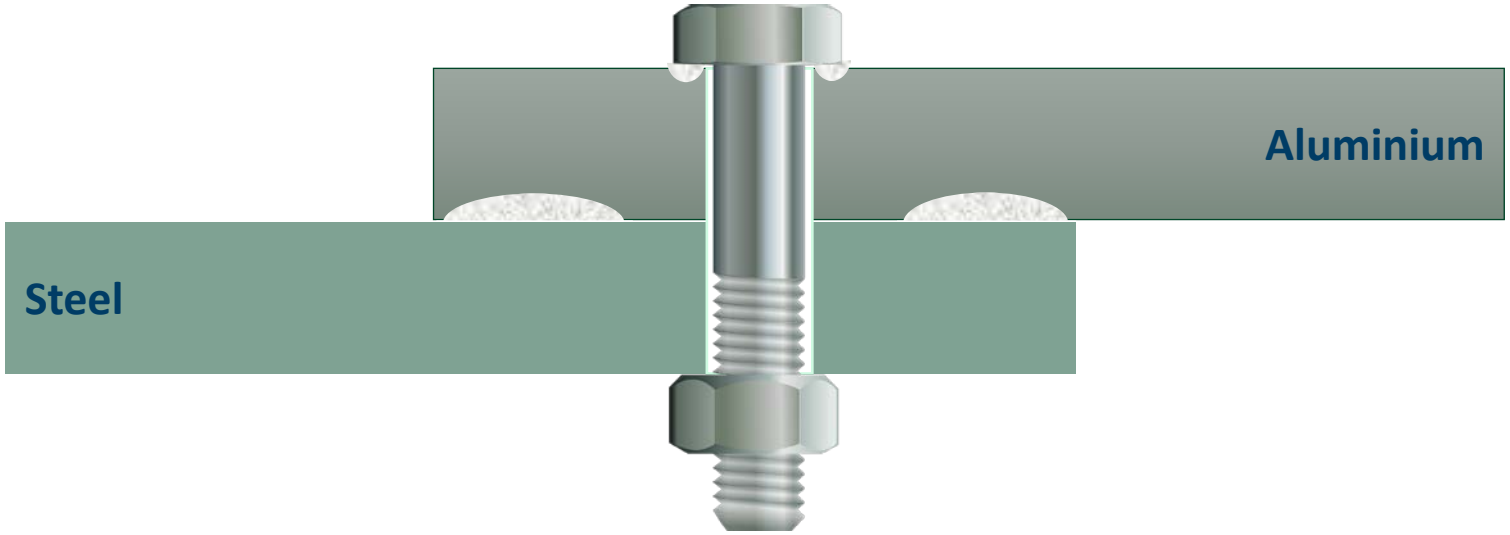
- Galvanic corrosion in damages/weaknesses in anodized layer
- No cathodic protection? Severe attacks locally

Galvanic corrosion in boltholes



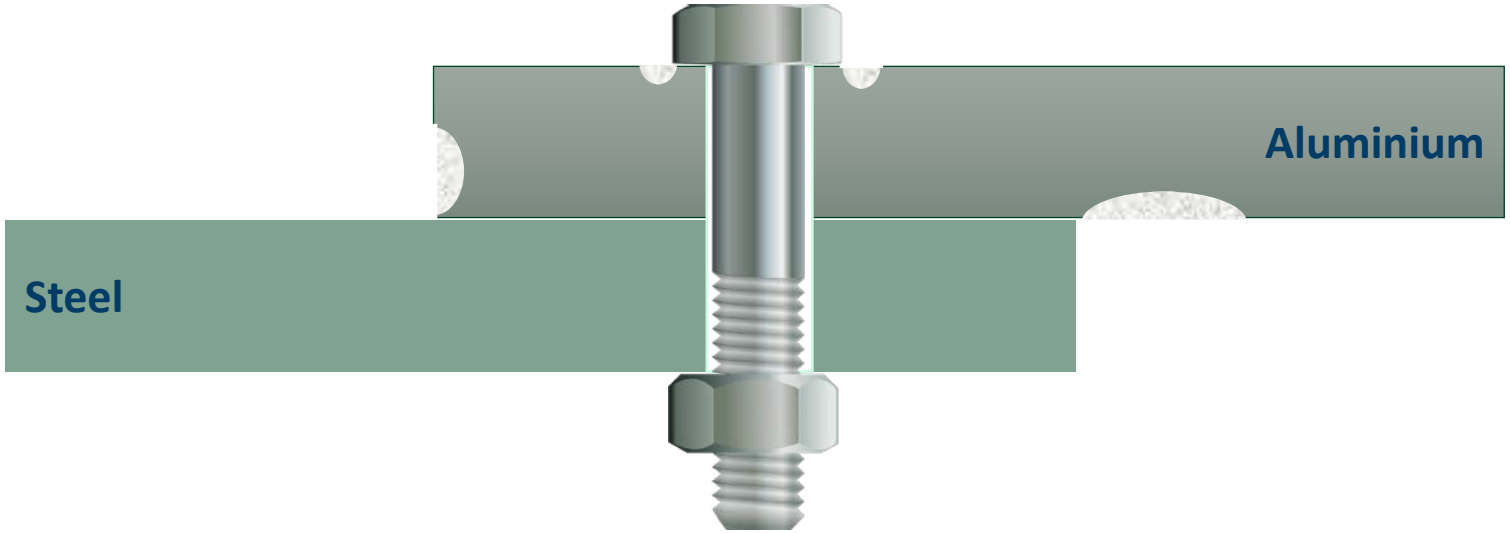
If the bolt hole gets filled with salt water ➔ galvanic corrosion

Galvanic crevice corrosion



If the crevice is filled with salt water ➔ galvanic corrosion
CP will not work inside the crevice – too high resistance in the electrolyte

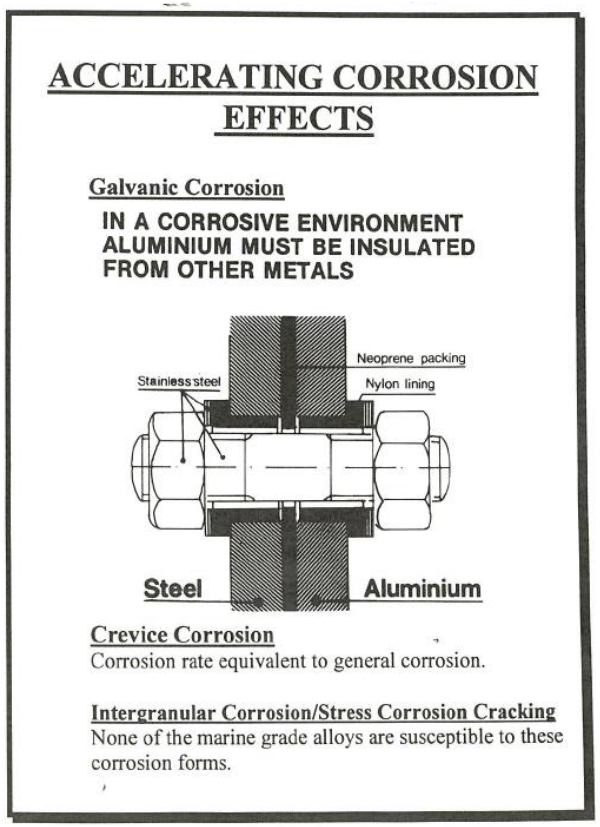
Atmospheric galvanic corrosion



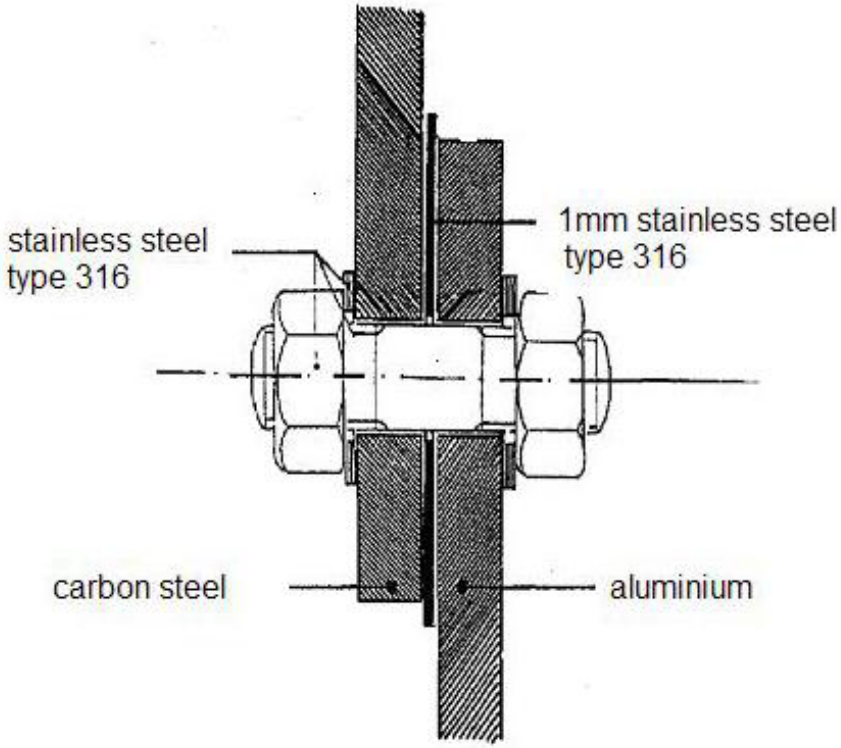
When the surface is covered with salt deposits ➔ galvanic corrosion

Previously recommended joint designs

Electric insulation – difficult and weak

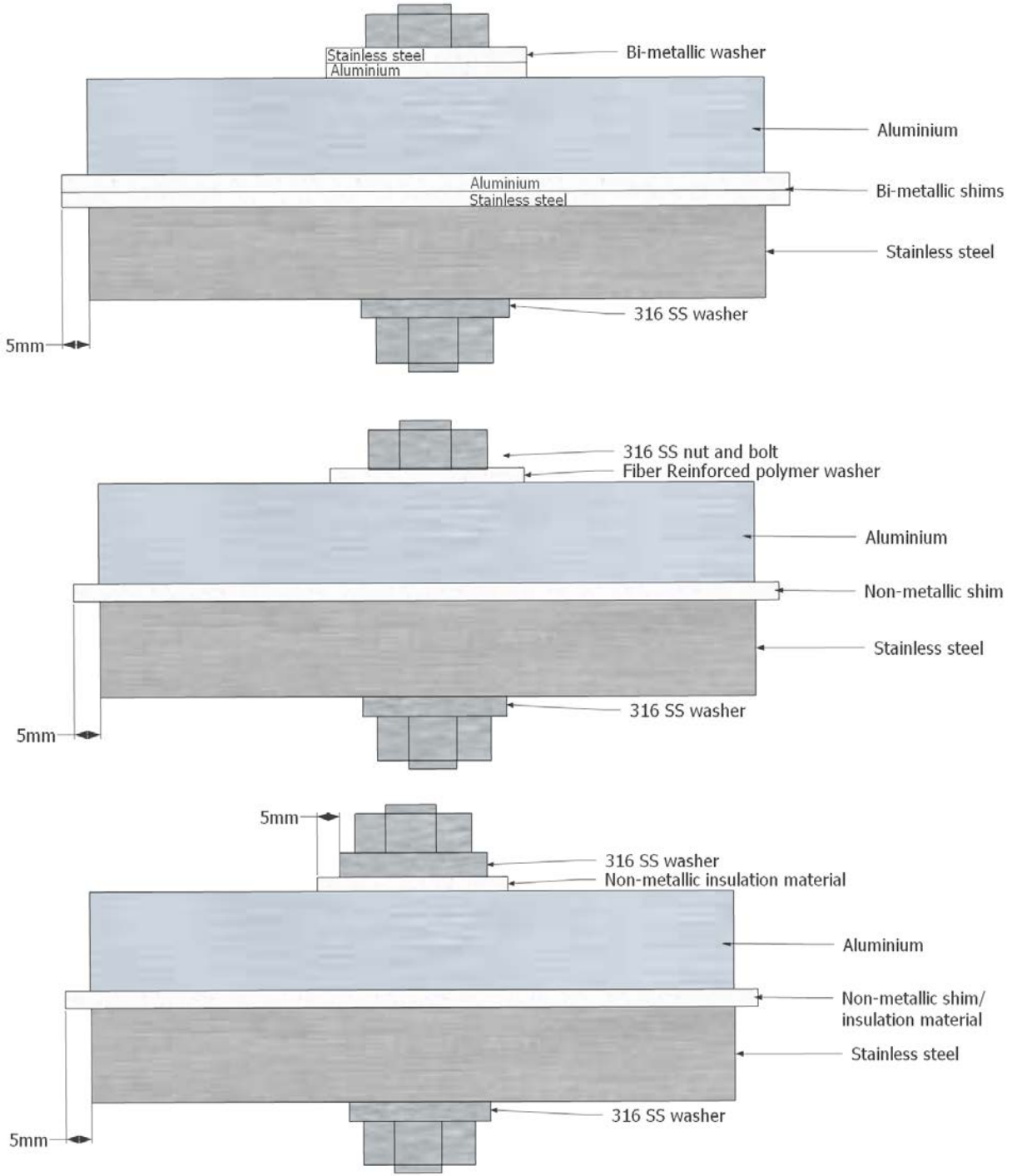


Stainless steel shims – only partly effective



NORSOK M-001:2014 Annex B

- Nonmetallic shim or bimetallic shim
- Nonmetallic, FRP or bimetallic washer
- Shims are to extend 5 mm beyond the aluminium



Summary

- Successful use of aluminium in marine constructions
  - When aluminium is used alone, no connection to other materials
  - When aluminium is galvanically insulated from other materials
- Reported corrosion issues with aluminium in marine constructions
  - Mainly galvanic corrosion in aluminium-steel joints
  - Submerged: Cathodic protection will not help, the protection will not enter the crevice
- Protection against galvanic corrosion
  - Electrical insulation works, but must be done correctly and may degrade with time
  - Bimetallic shims/washers may work but is not commercially available or well documented