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Passivation of stainless steel, and why it fails

Nordoxa — Materials & Corrosion Engineering, Rotterdam

Stainless steel is not corrosion resistant because chromium is a noble metal. It is not. Stainless steel is corrosion resistant because chromium reacts with oxygen faster than iron does, and the oxide it forms is dense, adherent and self-repairing.

Two conditions have to hold. The alloy must contain at least about 10.5 percent chromium in solid solution, and oxygen must be able to reach the surface. Both are routinely violated in service, and each violation has a characteristic failure signature.

Passivation is not pickling

	Pickling	Passivation
Purpose	Removes heat tint, scale and the chromium-depleted layer beneath	Removes free iron contamination, accelerates film formation
Medium	Nitric-hydrofluoric acid mixture	Nitric acid, or citric acid
Removes metal	Yes, a thin layer	Essentially no
Fixes heat tint	Yes	No

A specification that calls for passivation after welding, without pickling, does not address the heat tint. This single substitution accounts for a large share of the enquiries we receive about stainless steel that is rusting.

Four ways the film is defeated

Free iron contamination. Carbon steel particles embedded in a stainless surface will rust, and the rust staining is usually mistaken for failure of the stainless itself. The sources are predictable: carbon steel wire brushes, grinding discs previously used on carbon steel, shared fabrication tables, and carbon steel lifting equipment.

Weld heat tint. The coloured oxide beside a weld indicates a chromium-depleted zone beneath it. Darker colours mean more depletion. In chloride service it is where pitting starts. It must be removed mechanically or by pickling.

Oxygen starvation. Under a gasket, inside a crevice, beneath a deposit or under a fouling layer, dissolved oxygen is consumed and not replenished. The film cannot reform where it is damaged. This is the origin of crevice corrosion.

Reducing acids. Hydrochloric acid, and other reducing acids, dissolve the film faster than it can reform. Stainless steel has no useful resistance to hydrochloric acid at any concentration of practical interest.

A clean stainless surface will passivate naturally in air. Chemical passivation accelerates a process that would happen anyway; it does not create resistance that the alloy does not have.

Standards and further reading

1. ASTM A967 — Chemical passivation treatments for stainless steel parts.
2. ASTM A380 — Cleaning, descaling and passivation of stainless steel parts and systems.
3. ISO 16048 — Passivation of corrosion-resistant stainless steel fasteners.