

Q Stainless steel and galvanized materials often are found together in industry with applications such as galvanized fasteners, stainless steel pressure vessels and roof and siding panels. Do I need to worry about these two metals corroding each other? What other concerns should I have pertaining to hot dip galvanized steel and stainless steel in contact?

Does galvanic corrosion occur when these metals are in contact?

The effect of having zinc and stainless steel in contact while being exposed to the same electrolyte causes the oxidation reaction to occur primarily at the zinc surface and the reduction reaction at the stainless steel surface. As a result, corrosion of the more noble metal (stainless steel) is decreased and that of the more active metal (zinc) increased.

However, when austenitic stainless steels (300 series) are in contact with zinc, neither material will suffer additional corrosion, or at the most, only slight corrosion. The slight corrosion is usually tolerable when in this bimetallic contact. There is one exception to this conclusion as follows.

Any time a bimetallic assembly contains metal systems that are subject to galvanic corrosion, as we have here, the ratio of the cathodic area (stainless steel) to that of the anode (zinc) must be carefully considered. The corrosion current that flows between the cathode and anode is independent of area, but the rate of penetration at the anode is dependent on the current per unit area, that is, current density. Therefore, it is undesirable to have a large cathode surface in contact with a small anode surface. The rate of penetration from corrosion increases as the ratio of the cathode to anode surface area increases; as it decreases, the rate of penetration decreases. This situation is portrayed using a riveted fastener as shown in Figures 1 and 2. When using a stainless steel plate with a zinc rivet (Fig. 1), the ratio of the cathode surface area to the anode surface area is large, and the rivet will fail rapidly because of accelerated corrosion. When combining a zinc plate with a stainless steel rivet (Fig. 2), the area ratio between the cathode and anode is reversed, and although more surface area is affected, the depth of penetration is small; the fastener should not fail because of corrosion. The size correlation to the corrosion rate is also shown in Table 1.

Figure 1

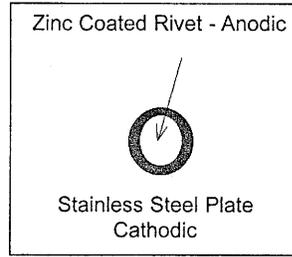


Figure 2

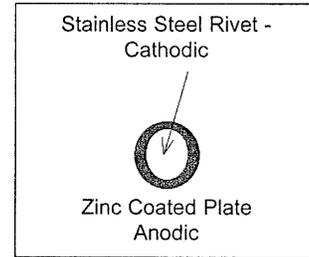


Table 1 - Contact Corrosion Between Dissimilar Metals

	*	Zinc	Stainless Steel
Zinc	Small Large	--- ---	S G
Stainless Steel	Small Large	G G	--- ---

* Refers to surface area of metal in left column relative to surface area of metals in top row.

S = Heavy corrosion of metal in row.

G = No or only slight corrosion of metal in row.

What are the dangers of liquid-metal embrittlement?

Solid-metals and liquid-metals can interact in several ways. (1) The solid and liquid metals may combine to form either a solid or liquid solution; or (2) the solid and liquid metals may form intermetallic compounds at the metal interfaces (i.e., the normal galvanizing reactions); or (3) no reaction may occur - some liquid metals do not react with certain solid metals. Temperature can also significantly effect the type and rate of reaction between the solid and liquid metals.

Now, in order to determine the reaction that will take place, we need to know about the steel involved. Stainless steels are iron-based alloys containing more than 12 percent but less than 30 percent chromium. These steels can be divided into two groups - those that contain nickel and those that do not. Those containing nickel are the 200 and 300 series stainless steels with an austenitic microstructure. Those containing little or no nickel are the 400 series stainless steels with ferritic or martensitic microstructures.

Contact between zinc and the *austenitic* stainless steel surface must occur for zinc attack to begin. This can be a solid-to-solid surface contact, which means zinc is solid, or a liquid-to-solid surface contact, this means the zinc is liquid. When zinc and the stainless steel contact, diffusion of the zinc into the stainless steel and dissolution of the stainless steel into the zinc occur.

Once zinc diffuses into the stainless steel, nickel within the steel reacts with the zinc to form nickel-zinc intermetallic compounds. This nickel-zinc compound development results in nickel exhaustion from part of the steel and changes the microstructure from austenite to ferrite. This change results in volume changes, which set up internal stresses. These stresses can then contribute to cracking of the steel.

Below its melting point of 786 F (419 C), zinc is solid and the reaction rate is slow. No embrittlement problems have been encountered because of the solid-solid reaction.

Zinc diffusion into the austenitic stainless steel can cause significant problems above 1380 F (750 C). The diff-used zinc reacts with nickel in the stainless steel matrix to form nickel-zinc intermetallic compounds, preferentially along the grain boundaries. The nickel depleted areas transform from austenite to ferrite causing increased internal stress. When liquid zinc comes in contact with hot externally tensile loaded austenitic stainless steel between 1380 F and 1660 F, intergranular cracking may occur.

Therefore, to initiate failure of austenitic stainless steels, zinc must be in contact with a hot tensile loaded stainless steel surface at temperatures between 1380 F and 1660 F. All of the conditions must be met to induce failure. Fig. 3 shows the correlation between the bimetallic contact of zinc and stainless steel with increasing temperature.

Can I just skip the technical stuff and galvanize the stainless steel?

Yes and No! Recall from above the two distinct statements concerning stainless steel and zinc.

Stainless steel can be divided into two groups - those that contain nickel and those that do not. Those containing nickel are the 200 and 300 series stainless steels with an *austenitic* microstructure. Those containing little or no nickel are the 400 series stainless steels with *ferritic* or *martensitic* microstructures.

For zinc attack to start, contact between zinc and the *austenitic* stainless steel surface must occur. The galvanizing process relies on solid and liquid-metals to form intermetallic compounds at the metal interfaces, which is what happens during the "zinc attack". Therefore, without the nickel elements in the 400 series stainless steel it is impossible to galvanize. The 300 series, however, *will* initiate the reaction necessary to achieve normal galvanizing.

In summary, when stainless steel and galvanized steel are in contact, although special attention should be given to the comparative surface areas no severe galvanic corrosion will take place. When these two metals are in contact and below the melting point of zinc, no effective embrittlement reaction

will take place. If the operating temperature rises past the melting point of zinc, beware of cracking and failure. Finally, if you feel the need to galvanize the family silverware, be sure that it is of the 300 series variety.

Figure 3 - Reactions Between Zinc and Austenitic Stainless Steels

