On Galvanic Corrosion

Between Stainless Steel and Aluminum in Marine Environments

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PREVENTING GALVANIC CORROSION IS ALWAYS A CONCERN

when installing aluminum structures in or near water. Aluminum alloy 6061 is highly resistant to destructive oxidation in air, water, seawater, or acid due to the toughness and adhesion of its natural oxide layer. When aluminum is in electrical contact with other metals, however, galvanic corrosion can become a concern. Instead of being attacked by chemicals in the air or water, the surface of a more noble metal attacks the surface of the aluminum.

In order for there to be a galvanic attack, two conditions must be in place. 1) There must be a dry, direct electrical contact between the aluminum piece and the second metal. 2) The aluminum and second metal must both be in contact, at a different location, with the same electrolyte media. The media can be a puddle of water, a patch of salt from evaporated seawater, or concrete. By these two rules, there are many locations on marine structures that may undergo galvanic attack by stainless steel, which is a more noble metal than aluminum.

However, these two rules just help us understand if there will be galvanic action, and not the severity of the attack. One rule of thumb to predict the severity of a galvanic attack is the area ratio. If the surface area of the noble, attacking metal is large compared to the surface area of the victimized metal, the attack will be fast. If the opposite is true, the attack will be slow. Consider the case of small stainless fasteners through large aluminum columns and beams, above ground. These connections are vertical, so water will not collect around them. Instead, the expected electrolyte media is a thin layer of evaporated salt which is roughly over the entire structure. For this reason, the area ratio of stainless surface over aluminum surface is so small that the galvanic attack is almost undetectably slow.

Therefore, a long life is expected from above-ground aluminum structures where the only dissimilar metal present is a stainless fastener, even in a salt spray environment. This is diagrammed in Figure 1, the situation is referred to as 'Above puddle'.

The advantages offered by the area ratio and the absence of puddles are not present at the ground level and below the waterline. Here, only the area in contact with a puddle or with the concrete will be attacked. Consider the design of a stainless anchor bolt into the concrete with an aluminum clip angle.

Here the surface area of aluminum is still greater than the surface area of the stainless; however, the advantage is not so great that concern can be eliminated. The next question is, given that the attack is probable at a fast enough rate to be a concern, is the affected area structurally valuable? The affected area is the underside of the foot. It is possible that this foot would lose thickness from the bottom up all while being in contact with the water (corro-

sion working upwards, gravity keeping the whole thing in contact with the puddle). This reaction could continue until the clip angle is basically a vertical plate and the connection of the whole structure to the anchor bolt is lost, so it is not an acceptable risk.

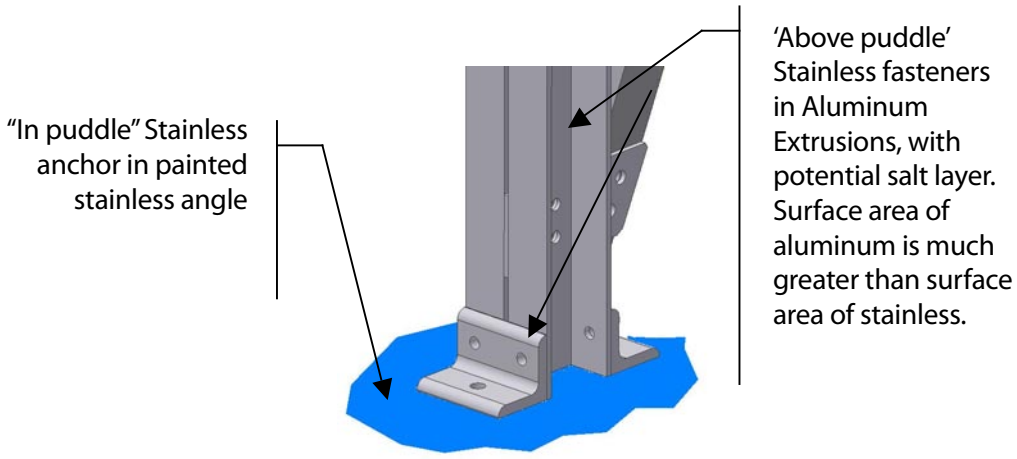

FIGURE 1 – SHOWING TYPICAL FOOTING OF ENTECH STRUCTURES 'IN PUDDLE'

So instead, we typically attach such structures to the ground with stainless anchor bolts and mating to this bolt a painted stainless, rather than aluminum, angle. Since stainless is more noble than aluminum, the clip angle will never be attacked by galvanic action. The only aluminum in the 'puddle' instead is the two pieces of channel, which could be attacked if an imperfection in the paint job allowed dry electrical contact between the stainless angle and the aluminum extrusion

Unlike the attack described in the previous paragraph, however, the vulnerable piece of aluminum is not as valuable in a structural sense and the attack ends where the puddle ends. The channels will continue to be held up by the stainless anlge they are mated to, and the puddle will never be tall enough to go near the lowest connection point, which can easily be detailed to be 1.5 inches above ground or water level. Further, the paint reduces the area on contact with water to almost nothing and adds resistance to the electrical connection. This assures a favorable area ratio and makes the rate of galvanic attack negligible.

CONCLUSION

All structures that aren't made out of precious metals are vulnerable to corrosion and will completely corrode in the course of thousands of years. Aluminum, steel, and even stainless steel are no exceptions. The key is to understand the corrosive environment and take steps to slow this process down. In structures of predominately aluminum proper detailing this assures that the 'attack' of corrosion, above ground, will be divided across a large surface and therefore proceed very slowly. At the waterline, using painted stainless steel to eliminate the possibility of puddles of water or the concrete itself from setting up an accelerated reaction assures that the pace will be slow enough to for a long service life.