

SEVERE MARINE ATMOSPHERE (CHLORIDE PITTING)

Photos A, B, C, D and E (front cover), courtesy of Technical Marketing Resources, were taken a few years ago at the LaQue Laboratories test site at Kure Beach, NC in the United States. The metal coupons were installed 820 feet from mean high tide for the duration noted. The results of these field tests serve to support the specification of Type 316 stainless steel in a similar marine environment. The rapid pitting that occurred in the painted aluminum sample suggests a shortened life span with this material.

While the sample photographs above suggest T316 stainless steel is appropriate, environments like the Persian Gulf or the Red Sea are more severe than Kure beach. Therefore, a more corrosion resistant alloy is suggested. We offer the Kure Beach information to show the superiority of stainless steel to aluminum in coastal environments, even though T316 stainless is usually insufficient for severe marine locations. By all measures ATI 2003™ provides superior corrosion resistance as compared to T316. This alloy has been used in such applications as desalinization equipment and offshore drilling rigs.

Middle Eastern environments will be a challenge to T316L stainless as well as painted aluminum, as suggested in the accompanying table outlining conditions in Doha and Jeddah, where corrosion of T316 stainless steel has occurred. These environments are similar to elevated temperature, salt fog chambers with little or no rinsing. We have three informal reports on red rust pitting corrosion of T316L after short exposure in that region. First, in Saudi Arabia on the Red Sea (see Photo F), exterior panels made of Type 316L #4 Stainless Steel began corroding shortly after installation. In addition, a Doha, Qatar window trim installation experienced a similar result (the structure is not directly on the Persian Gulf coast.) The third example is an arch in downtown Doha, comprised of crossing swords that span a city street. The arch, which exhibits visible rust, is reportedly made of Type 316 stainless steel (see Photos G & H).

Based on these examples, we can predict T316 stainless steel will corrode, as it lacks sufficient chloride pitting resistance to perform in the project's environment. What essentially will happen is that chloride molecules will rest on the surface of the stainless steel between periods of rain or washing. With the addition of atmospheric moisture, an electric cell will be created, that will act like a battery, thereby depleting the chromium oxide layer, creating a conduit to the iron molecules beneath the surface. These iron molecules, once exposed, will oxidize and produce red rust. Once iron oxidation starts, the material will gradually erode away until a hole is burned through the surface of the material. While it may take a considerable amount of time for perforation to occur, the unsightly appearance will be an issue for the building owner.

Table I: Environmental Conditions		
Location	Doha, Qatar - Persian Gulf	Jeddah, Red Sea
Average Summertime High Temperature	106° F	99° F
Typical Summertime Humidity	80%	55%
Surface Salinity (Persian Gulf/Red Sea)	40%	37%
Annual Rainfall	3.2"	2.4"



Photo F: Red Sea, Saudi Arabia

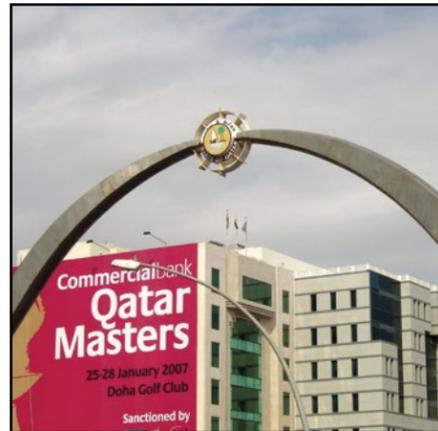


Photo G: Downtown Doha Arch, Qatar



Photo H: Close-up of Doha Arch, Qatar

ATI 2003™ has been tested for chloride pitting resistance, in accordance with ASTM G150. The pitting resistance was determined to be substantially better than T316 and even marginally better than T317. While absolute test data are not readily translated to atmospheric conditions in the field, the test is nonetheless useful in ranking alloys in terms of their relative pitting resistance. It is clear that ATI 2003™ offers a considerable improvement over T316 with regard to pitting resistance. Supporting the technical basis for our suggestion is the fact that as of the September 2008 publication of this paper, the ATI 2003™ InvariMatte® roof panels on the mock up for the Doha Airport terminal building have shown no signs of corrosion after a year of exposure to the elements.

CREVICE CORROSION

An architectural panel system is prone to crevice corrosion in the seam areas. A crevice is anywhere contaminants, such as chloride molecules can become trapped at the surface of the material. Given severe marine environments with high humidity levels, there is cause for concern. Trapped chloride molecules, with the benefit of atmospheric moisture can create an electric cell, thereby depleting the chromium oxide layer in the case of T316 stainless steel, creating a conduit to the iron molecules beneath the surface, which will oxidize and produce red rust. Once iron oxidation starts, the material will gradually erode away, compromising the integrity of the seam. While the process in this example is akin to chloride pitting, the occurrence of this phenomenon in a crevice condition will lead to more rapid corrosion and a potentially more serious consequence.

The same is true for aluminum corrosion relating in a crevice condition. We predict limited performance of a painted aluminum system in severe marine environments. While a layer of paint is effective for extending the life of an aluminum panel, it can actually have a detrimental effect on corrosion resistance if that layer is breached and moisture is trapped at the metal interface. Incidental damage to a roof panels can easily occur from maintenance workers, sandstorms and birds dropping shellfish on the roof to break the shells open. Paint deterioration from UV exposure and sand storms is also an issue in many environments. If moisture and chlorides are trapped at the metal surface, rapid deterioration, known as crevice corrosion, will occur.

Table II: Stress Corrosion Cracking Performance*	
ALLOY	BOILING 26% NaCl
Austenitic Type 304L (8% Ni)	Failed (850 hours)
Austenitic Type 316 (12% Ni, 2.5% Mo)	Failed (530 - 940 hours)
Austenitic Type 317L (13% Ni, 3.5% Mo)	Failed (1000 hours)
Duplex ATI 2003™ (3% Ni, 1.7% Mo)	Passed (1000 hours)

* "Failed" indicates failure by chloride stress corrosion cracking.

A real world example of a painted aluminum failure appears in Photo I (below). These painted aluminum panels were installed in 1982 when this Tampa, FL building was constructed. This photograph, taken 20 years later, shows complete perforation. We theorize that crazing of the paint layer at the bend radius of the panel (which normally occurs during fabrication) provided enough opportunity for chlorides (from the marine environment) to find crevices in which to reside, propagating rapid corrosion.



Photo I: 20 Yr. Old Painted Aluminum Panels - Tampa, FL

STRESS CORROSION CRACKING

The dual phase microstructure in duplex stainless steels provides better resistance to stress corrosion cracking than conventional austenitic and ferritic stainless steels, a potential problem at the crimped panel seams. As wind loads subject the panel system to stresses, stress corrosion cracking can occur where corrosion has compromised the integrity of the material that is being subjected to stress. Once a crack occurs, it can migrate until a catastrophic panel failure occurs. In addition, aluminum is not immune to stress corrosion cracking. Given the strong potential for corrosion of aluminum in the Doha environment, we predict stress cracking will occur if this option is pursued.

Ferritic stainless steels are generally considered to resist stress corrosion cracking in chloride-containing environments. However, resistance to cracking is reduced by deformation. Austenitic stainless steels, like the T316 material commonly used in coastal environments, are more prone to this problem, provided chloride corrosion is experienced in the first place. Since we can expect corrosion issues with T316 in this environment, there is considerable risk of stress corrosion

failure. Duplex alloys, like ATI 2003™ provide the best of both worlds by virtue of their combined austenite-ferrite structure. ATI 2003™ has been tested in accordance with NACE TMO177-90, which tests materials in an acid-bearing chloride solution at 90% of tensile strength.

No cracking was observed with ATI 2003™ (see Table II, courtesy of Allegheny Ludlum Corporation).

In order to prevent stress corrosion failure, there are two elements within our control; use a more corrosion resistant alloy in the first place and use an alloy that is also more resistant to stress corrosion cracking. ATI 2003™ addresses both requirements.

INTERGRANULAR CORROSION

ATI 2003™ has excellent resistance to intergranular corrosion, a problem that can occur in weld areas. This alloy's ability to reform austenite, combined with its low carbon content inhibits grain boundary precipitation.

PAINT DETERIORATION

Painted surfaces do not last forever. Even the best paint systems will fade and look tired in 30 years in rather mild environments. With the added challenges of salt and sulfur dioxide in the air, high UV exposure and sand storms, paint deterioration will occur more rapidly in the Middle East. InvariMatte® does not depend upon a coating to create visual uniformity. It is textured stainless steel. In addition, ATI 2003™ lean duplex InvariMatte® stainless steel has adequate resistance to the contaminants (chlorides and pollutants) that are present in the severe coastal atmospheres.

LOW GLARE

In addition to being visually uniform, InvariMatte® has low reflectivity compared to typical stainless steel finishes. Low glare is often a good idea on a large surface area, like a roof that is prominently visible. In fact, InvariMatte® has lower gloss (<20@85°) than many paint finishes. InvariMatte® has been selected for a number of major projects including the Boston Convention Center, Seattle

Art Museum, Detroit Airport, Raleigh-Durham Airport, Jamaica Air-Train Terminal (see PROJECT REFERENCES for images) and the new Doha International Airport in Qatar (the same ATI 2003™ version we are suggesting here).

LIFE CYCLE COST

While titanium will also perform beautifully from a sustainability standpoint, the added cost compared to stainless steel does not yield a benefit in most cases. At the other end of the spectrum, an aluminum system, whether or not it is painted, will require maintenance or replacement at some point in the future. While it may be a little cheaper up front, it is sure to



Photo J: Chrysler Building - New York

be more costly on a life cycle basis. In contrast, ATI 2003™ InvariMatte® stainless steel can be expected to last the useful life of a building in a severe marine environment with little maintenance (clear gutters and wash panels for cosmetic reasons). Stainless steel's longevity is exemplified by the domed roof of the Chrysler Building in New York (Photo J), which has stood the test of time. Made of stainless steel, it is still in service after 77 years, having been cleaned only twice.

VISUAL CONGRUITY

InvariMatte® can be made in thicknesses ranging from .012" (.4mm) to .187" (4.7mm). This allows for maximum design flexibility. For example, it may be desirable to have heavy gauge wall elements that match lighter gauge roof panels. The use of InvariMatte® will make this possible.

We hope that the aforementioned issues will be taken into consideration when reaching a decision regarding the material to be used for building envelope applications in severe marine environments. Despite our concerns about the sustainability of lesser materials like painted aluminum or even Type 316 stainless, we are confident that ATI 2003™ InvariMatte® stainless steel will outperform these other materials in severe coastal locations.

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STAINLESS STEEL FOR SEVERE MARINE ENVIRONMENTS



Photo A:
Painted Cast Aluminum
12 Yrs.



Photo B:
Painted Carbon Steel
12 Yrs.

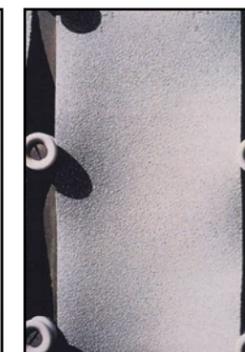


Photo C:
Zinc
40 Yrs.

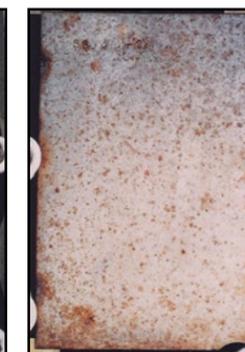


Photo D:
Type 304 Stainless Steel
59 Yrs.



Photo E:
Type 316 Stainless Steel
59 Yrs.

Severe marine environments like the Persian Gulf suggest that duplex stainless steel or titanium would be appropriate material choices for exterior building panel applications. These metals can be expected to last the life of the building with little or no maintenance. In most market conditions, stainless steel has an economic advantage compared to titanium. Additionally, titanium's corrosion resistance in severe environments is unquestionable. In light of these facts, we offer our suggestion of ATI 2003™ Lean Duplex Stainless Steel with InvariMatte® finish as a suitable stainless steel grade and finish combination for exterior building envelope applications in severe marine environments. ATI 2003™ is a corrosion resistant grade of stainless steel developed by Allegheny Ludlum Corporation. InvariMatte® is a specially-rolled, low glare stainless steel finish developed by Contrarian Metal Resources that is available in a variety of grades, including ATI 2003™.

More common metals like galvanized steel and aluminum are not recommended for severe marine environments for the simple reason that they are not sustainable. At some point in the future even painted versions of these metals will need to be replaced. While solid zinc alloy is sometimes installed in marine environments, it is not recommended in proximity to severe marine environments like the Persian Gulf. Zinc that is installed in this area will oxidize, producing an unsightly white residue that indicates accelerated corrosion. The presence of sulfur dioxide in the air will further increase the opportunity for zinc to corrode prematurely.

While we are certain that stainless steel involves a cost premium over painted aluminum or possibly other metals that might be considered in severe marine environments, there is little doubt that it is the low cost choice in the long term when maintenance and replacement costs are considered. For the reasons to follow, we suggest ATI 2003™ Lean Duplex Stainless Steel with InvariMatte® finish be considered for building envelope applications, like roofing and wall panels in severe marine environments.



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