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NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND

TECHNICAL INFORMATION MEMORANDUM

REPORT NO: NAWCADPAX/TR-2018/169

EVALUATION OF AIRCRAFT PROTECTION EQUIPMENT

by

Dane Hanson

09 October 2019

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DEPARTMENT OF THE NAVY
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND

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This report documents the previous and recent evaluations of aircraft protection equipment, also known as sunshades. A logistics and technical assessment of the equipment is included.

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SUMMARY

Aircraft protection equipment (APE) structures are used sporadically within the Navy-Marine Corps enterprise at shore-based locations. APE provide numerous benefits including protecting aircraft from the damaging environmental elements (e.g. rain, Ultra-violet light, heat) and providing improved conditions for maintainers who work on the aircraft despite those extreme environmental conditions. Obviously, the benefits from site-to-site vary based on the prevailing environmental conditions when the aircraft is stationed there. Based on surveying, stakeholders at the sites are keenly aware of their local environmental conditions and the impact that those conditions have on their assets.

Although many studies have been performed on APE within the enterprise, they have primarily been focused on quantifying corrosion rates for witness coupons and monitoring environmental variables (e.g. heat, humidity, conductivity) that contribute to corrosion, by placing the specimens under test protected by the APE and boldly exposed to the environment. By and large, the early efforts under OSD project WNA05 were based on the potential to reduce the effects of the corrosive environment; however, the benefits of APE extend beyond corrosion into the anecdotally recognized benefits discussed above.

To be able to appropriately communicate the benefits of APE at each site and justify procurement of equipment to decision-makers, more quantifiable metrics need to be established tailored around the effects of the extreme elements and improved time-on-aircraft for maintenance. This report summarizes previous work performed under the OSD project and raises points to consider for assessment and justification of APE in the future. Moving forward, based on our interest and continued efforts, any activities considering or working through approvals to install APE are recommended to contact the office of the author.

Contents

Page No.

Introduction..........1
    Background..........1
    Purpose..........1

Methods..........5

Discussion..........6

Conclusions..........9

Recommendations..........12

Appendices
    A. SITE DRAWINGS AND INSTALLATION SPECIFICS..........15
    B. SITE CORROSIVITY MONITORING CHARTS..........19

Distribution..........28

ACKNOWLEDGEMENTS

NAVAIR initiated project WNA05 Aircraft Shelters under the Office of the Secretary of Defense (OSD) Demonstration Project Program in 2007. The total OSD project included participants from multiple services and initiated studies to quantify the benefits of shelters. Under the direction of Messrs. Craig Matzdorf and Bill Nickerson, the NAVAIR program was focused on quantifying the corrosion benefits of aircraft sunshades procured and placed at NAS Whidbey Island and NAS Oceana in conjunction with other corrosivity studies being conducted by Mr. Bill Abbott of Battelle. Secondarily, the project drove the undertaking of novel processes to establish procurement, construction, and maintenance procedures at sites and to nationally clarify the definitions for “shelters”, “sunshades”, and “aircraft protection equipment (APE).” Because there had been no disambiguation of terms prior to this project, we refer to each interchangeably within the text that follows. In the meantime, since the project was conceived and initiated in 2007, however, better clarity has come towards the definitions of each of the aforementioned terms. In serialized letter N4/10U54553 issued on 01 July 2010, CNIC clarifies to CNAF that “APE does not support hangar functions while Aircraft Shelters do.” Based on the Enclosure to the serialized letter, APE colloquially known as “sunshades” are open-sided covers only; likewise, shelters have enclosed sides, can be dehumidified, and may possess electrical or pneumatic power to enable “hangar functions.”

When additional work to support the OSD project was conceived in 2016 by Messrs. Dane Hanson and Andy Magkasi, the goal was to document the progress under the previous project and renew interest in quantifying benefits and justifying procurement. Since that time, not only has there been tremendous support from the NAE CPT and the NATEC C-MRT site reps, there is interest from the 4.6 Human Factors Engineering Department in recognizing the value of APE for maintainer quality of life and performance. From the standpoint of the current authors, we have identified segmented work throughout the command that could benefit from a standardized justification and approach to procurement. With that, we have initiated new studies using Infrared imaging, surveying site representatives, and incorporating the value of the Designing for Maintainers (DFM) Branch. Thus, while we hope that this report provides value in and of itself, there will be a lot more valuable work to come.

The author wishes to thank the following for their previous and ongoing support for studies related to optimizing storage and preservation of Navy aircraft: Mr. Rich Hays, Mr. Craig Matzdorf, Mr. Randy Boatwright, Mr. Bill Nickerson, Mr. Ray Rose, Mr. Steve Spadafora, Mr. Bill Abbott, and Mr. Andrei Magkasi.

INTRODUCTION

Aircraft in the Navy and Marine Corps have not historically been protected from the environment during normal operations. Studies have shown significant reductions in corrosion and corrosion maintenance when these assets are stored in controlled and/or dehumidified storage areas; however, a comprehensive evaluation, demonstration, and validation of sheltering and dehumidification technologies had previously not been completed for Naval Aviation. The value of this evaluation is to provide sound technical and cost bases to support implementation of these technologies across the aviation community.

BACKGROUND

Corrosion is one of the largest cost drivers for aircraft repair and persistently acts to reduce aircraft and equipment availability and service life. Impact damage, composite delamination, adhesive bonding separation, and fluid ingress are examples of problems, which reduce mission life of composite components. Water intrusion can cause severe damage to honeycomb structures and internal structures, which are difficult to inspect and treat. Severe cold at high altitudes can cause the water to freeze and expand, rupturing the cells of the honeycomb, which severely weakens the strength of the component. Additionally, while parked on the open-air ramps, even while closed, cockpit canopies can leak, exposing sensitive avionics and electronics to water and moisture. Other environmental threats such as wind-blown sand and hail can obstruct critical avionics sensors and control surfaces as well as potentially damage the aircraft exterior. As a potential mitigation for these effects, open-air aircraft shelters, the focus of previous studies conducted by the Air Force Corrosion Prevention and Control Office (AF CPCO), were credited with reduction in corrosion rates of 4-10 times compared to the same open-air environment.

Previous studies were funded by the Office of Secretary of Defense (OSD) Corrosion Policy and Oversight Office (CPO) and executed and reported on by Mr. Bill Abbott. The results demonstrated that silver chloride deposition rates and 6061-T6 Aluminum mass corrosion rates could be reduced by 2-6 times by altering location on the USS Stennis and USS Nimitz carriers between above deck and below deck, in hangar bay 3. Although hangar bay 3 was noted as not a standard aircraft storage location aboard carrier, the benefit of sheltering started to become evident, whereby interest in monitoring corrosion rates in boldly exposed and sheltered regions of operational sites grew. Additionally, the author of the OSD CPO report speculated that sheltering may reduce rates of corrosion by limiting air flow and contaminant, including chlorides, deposition rates, but that it may also increase rates if other practices, such as washes, are altered after storage under shelters, or if diurnal cycling contributes to high humidity conditions. At the recommendation of that author, shelter studies should not rely on theoretical data but instead should look to demonstrate and validate the storage means in the real world environment to which the asset is or will be exposed. Ideally, data from enough sites should allow the program and airfield managers to understand the role of the shelter as it related to the local environmental conditions.

In addition to the OSD CPO funded report, studies conducted by NAVAIR and funded by the Strategic Environmental Research and Development Program (SERDP) as project WP-1133 demonstrated how polymeric coatings are susceptible to Ultraviolet exposure from the sun, contributing to color and gloss loss and other effects contributing to premature polymer degradation because of susceptibility to the environment. Potential benefits of reduced UV-exposure of aircraft include reduced degradation of coatings and sealants, which, in the case of sheltering, may allow for the increase in the time between inspections and re-applications of new materials. Shelter studies should consider not only the measurable effects on the corrosion rates of aircraft alloys, but also on the rates of degradation of the polymeric materials on the aircraft.

Other services have also demonstrated and realized benefits from sheltering aircraft at sites. Taking an example from the Air Force, the most critical section of the F-15 weapons system platform is the cockpit area. The cockpit includes the Aces II ejection seat, engine throttles, life support equipment, communication equipment, weapons display, and a host of avionics displays and sensors. Corrosion has been documented on the Aces II seat and its ejection egress rails to include bulkhead supports. The Air Force documented that hundreds of man-hours have been spent correcting/repairing the effects of corrosion on the ejection seats and railings. Rust and galvanic corrosion of fasteners is exacerbated by continual environmental exposure. The corrosion on fasteners causes the hardware to become brittle and break off, which could result in potential foreign object damage (FOD) in the cockpit.

The F-15 canopy is another component which unfortunately permits water intrusion, especially while aircraft are on the ground, sitting unprotected in the rain. While the aircraft is sitting on the ground, the canopy seal that provides watertight reliability is not fully functioning. The canopy seal is an inflatable seal that fully inflates only when the aircraft engines are running. An F-15 canopy that is exposed to rain while sitting on the open-air ramp is not fully protected from water penetration and intrusion due to the canopy seal not being fully inflated. This is an inherent problem that has been unsuccessfully fought with tape and canopy covers. As a result, moisture and corrosion are frequently found on cockpit instrumentation, various access doors, panels, and throughout the underlying deck areas. The leading cause of water intrusion and resulting corrosion is changing climatic conditions which changes the relative humidity and causes condensation. Sheltering that reduces these extreme temperature variables would help eliminate or reduce the conditions under which condensation is produced.

While these examples are taken from the Air Force, the problems are not unique to one service; each of the services could benefit from sheltering their assets, and modern anecdotes abound from Navy experience. The common denominator related to all aircraft corrosion and faulty electrical system/electronic performance is that the equipment is stored outside, unprotected from the environmental elements.

PURPOSE

Sheltering may yield numerous benefits ranging from reducing corrosion rates of metallic structure to delaying degradation of non-metallic aircraft materials to other peripheral benefits. The goal of this study was to validate the technical and cost benefit of using shelters alone. Specifically, the goal of this study was to validate the beneficial effect of open-air shelters on corrosion maintenance and control at two locations, NAS Oceana, VA and NAS Whidbey Island, WA. This is critical for the widespread authorization and implementation of these technologies for the fleet of aircraft in the Navy and Marine Corps. Some examples of APE used within the enterprise are shown in Figures 1, 2, and 3. Note that Figures 1 and 2 are of sites and aircraft studied under the program, while Figure 3 is included to demonstrate the minor variability in the appearance of the sunshades.

Figure 1: An EA-6B "Prowler" under a sunshade at NAS Whidbey Island, WA

Figure 2: Four side-by-side FA-18 “Super Hornets” under sunshades at NAS Oceana, VA.

Figure 3: Multiple T-45 “Goshawks” at NAS Meridian, MS. Note. The T-45 was not studied under the program; images are presented here to show the variation in APE construction.

METHODS

Two locations for initial shelter deployment were targeted based on the Air Force Environmental Severity Index and historical corrosion documentation from aircraft based at these sites: NAS Whidbey Island, Washington; and NAS Oceana, Virginia. Targeted platforms at the site included the EA-6B Prowler at NAS Whidbey Island and FA-18 Hornet at NAS Oceana. The plan was for the shelters to be set up so that one aircraft per test squadron could be kept under the shelter during normal storage conditions, while other aircraft were exposed to the elements. Against the study design, this condition was not met, as the squadrons used the shelters as maintenance facilities during periods of inclement weather, such that many aircraft were cycled through the shelters space. While this demonstrated a peripheral benefit of the shelter, it disabled feedback gathering for the original technical study. Shelter design was planned to incorporate lighting to allow for nighttime maintenance on the aircraft. One supplier, Big Top Manufacturing, had provided a number of similar shelters at the targeted sites. Turn-key installations by Big Top at these sites were well received by Navy facilities personnel. As a result, bids for the turn-key shelters were requested from Big Top as well as a second supplier to ensure competition. Finally, concurrent with the establishment of facilities processes for procuring sunshades and identification of intangible benefits, a technical assessment of the sunshades was conducted by assessing the mass loss of Aluminum under the sunshades and boldly exposed to the local environment.

DISCUSSION

The study helped clarify the path for procurement and installation of aircraft protection equipment at shore-based CONUS operational sites. Assessing the corrosivity data alone using mass loss coupons, the benefits of the APE are mixed.

Task 1. Coordinate with Civil Engineering for Shelter Installation at Sites

The installation of a semi-permanent structure aboard an air station and specifically aboard a flight-line could be met with resistance, since the hypotheses are valid but remain unproven. The first task focused on identifying the requirements of any and all of the stakeholders including NAVFAC, the airfield manager, and the air station public works office. Fortunately, the Commanding Officer of the Air Station was an advocate for the shelters and the study and endorsed the full proposal as prepared by the cross-functional team of NAVAIR, NAVFAC, and local site representatives. The full text of the authorization request for placement of shelters at NAS Whidbey Island is below. Similar language and approval processes were used for placement of the shelters at NAS Oceana. Related documentation is included in Appendix A.

> "*NAVAIR requests two shelters be constructed at NAS Whidbey Island to be used to measure their effectiveness to reduce aircraft corrosion. Two identical shelters are proposed, with each having dimensions of 70' X 68' and 32' high.*
> *One shelter would be located at an existing wash-rack site (CCN 116-10). This shelter would be 87' from the edge of the aircraft parking apron. The minimum distance a structure is to be located from the edge of a parking apron is 100' per the P-80 for CCN 113-20. This structure does not penetrate the transitional surface of runway 07/25, since it is 1,023 feet from the extended centerline of the runway which thus allows a structure of 35.7.' The calculations are as follows: 1,023' - 750' lateral primary surface zone = 273' divided by 7' = 39' maximum height before penetration of the transitional surface. The extended centerline of Runway 07/25, at a point perpendicular to the washrack site, has an elevation of 18.4' and the wash rack site has an elevation of 14.7'. which technically allows a structure of 42.7' [39' + 3.7' = 42.7' (18.4' - 14.7' = 3.7')].*
> *The second shelter would be located on a parking apron (CCN 113-20), and would be approximately 5 feet from the closest parked aircraft, and would be approximately 1,126 from the centerline of the closest runway (RNWY 07/25). The elevation of runway 07/25 at a point perpendicular to the Apron site is 17.5'. The elevation of the Apron site is 12.9'. Therefore the maximum structure height is 53.7' [1,126' - 750' = 376' divided by 7 = 53.7' (technically a structure could be an additional 4.6' high which is the difference in elevation between the runway elevation of 17.5' and the shelter site elevation of 12.9')].*
> *Note that NAVAIR will fund this project."*

Task 2. Purchase and Install Demonstration Shelters

Two shelters were purchased and installed at NAS Whidbey Island, WA per the drawings and plans described in Task 1. A second set of two shelters were purchased and installed at NAS Oceana, VA. Partially through the demonstration period, site re-organization required that the shelters at NAS Oceana be re-located to a new site. Due to the nature of this study as a NAVAIR-led project and the unexpected nature of this development in the project, neither project funds nor facilities funds from the site (e.g. NAVFAC, NAS Whidbey Island) were available to contract the effort to de-construct, re-locate, and re-construct the 2 shelters; thus, the shelters were de-constructed, and this portion of the task was terminated.

Task 3. Track Corrosion Prevention and Control Maintenance of Aircraft Stored under the Shelter
The plan for the study was to have 1 aircraft identified and isolated to protect under the shelter for the duration of the study normal storage times. This request was made to be able to study the long-term effects of sheltering on corrosion and polymeric degradation. Unfortunately, once the shelter was turned over to the custody of the squadron and site, because of the presence of the operating lights inside the shelter, it was used as an alternate maintenance facility. Thus, the long-term effects of sheltering on 1 aircraft could not be demonstrated, and the isolated benefits of the shelter could not be validated. Nonetheless, other benefits including increased time availability to perform maintenance were documented, and other shelter benefits have been realized, even after the study period ended.

Task 4. Evaluation of Aluminum Mass Loss under Shelters Compared to Unprotected Sites near Shelter
Mass loss data for 2024-T3 Aluminum were gathered at both NAS Oceana and NAS Whidbey Island for coupons placed in boldly exposed areas, 11 feet off of the ground under the shelter, and 22 feet off the ground under the shelter. Data were gathered at intervals throughout the exposure period to be able to show trending over time and to help identify seasonal effects. Raw data for NAS Oceana and NAS Whidbey Island are shown in Tables 1 and 2, respectively. Line graphs plotting these data and line graphs for other sites monitored under the program are shown in Appendix B.

Table 1: Mass loss data for 2024-T3 Aluminum at NAS Oceana

ug/cm2	Oceana, Outdoors		Oceana, 11 feet		Oceana, 22 feet	
	Absolute Loss	Incremental Loss	Absolute Loss	Incremental Loss	Absolute Loss	Incremental Loss
106 days	176	176	142	142	137	137
199 days	386	210	316	174	354	217
289 days	531	145	441	125	497	143

Table 2: Mass loss data for 2024-T3 Aluminum at NAS Whidbey Island

ug/cm2	Whidbey, Outdoors		Whidbey, 11 feet		Whidbey, 22 feet	
	Absolute Loss	Incremental Loss	Absolute Loss	Incremental Loss	Absolute Loss	Incremental Loss
90 days	143	143	176	176	448	448
180 days	274	131	469	293	741	293
270 days	376	102	898	429	1001	260
365 days	552	176	1268	370	1425	424

Comparing the Absolute mass loss data from NAS Oceana for different storage conditions, there appears to be a minor reduction in corrosion rate due to storage under the sunshade. Some seasonal effects were noted when analyzing the incremental mass loss data. During the 93-day period between data collection points 1 and 2, conditions actually contributed to slightly higher corrosion rates at the 22-foot height under the shelter relative to the exposed condition, and the specimens at the 11-foot height condition exhibited the least corrosion.

For data from NAS Whidbey Island, the specimens exposed to the elements outside of the sunshade actually exhibited less corrosion than the specimens under the sunshade both when analyzed absolutely and incrementally. Mass loss during the initial 90 day period for specimens exposed and 11-feet under the sunshade were relatively similar (143 ug/cm2 versus 176 ug/cms); however, for the 90 days between the 180-day and 270-day sampling points, the difference was more pronounced (102 ug/cm2 compared to 429 ug/cm2). This demonstrates the effect that seasonal variation may have on corrosion rates and the role of the shelters.

Knowledge of weather patterns at NAS Oceana is useful in predicting how the sunshade is affecting the corrosion rate. NAS Oceana is located within a “humid subtropical” weather zone, characterized by mild winters and hot, humid summers. Thus, we speculate that there are intermittent periods of rain and thunderstorms in the summer, followed by extensive sunny periods. Further, the condition of wetting caused by thunderstorms and salt spray followed by drying due to sun and wind exposure contributes to higher corrosion rates for exposed coupons. This is due to a combination of the increase of the salt concentration as the surface dries and the localization of the wet film as the surface area decreases due to drying. Thus, one should expect high rates of corrosion during seasons that are rainy, followed by conditions amenable to drying. A specimen that is under a sunshade, and, thus, never exposed to the rain may not experience a high wetness condition, and, thus, the rapid rate of corrosion is not witnessed.

Likewise, the climate at NAS Whidbey Island is classified as “oceanic” or “temperate marine”, which is exhibited through weather patterns of cool, wet winters and mild, relatively dry summers. In this case, our speculation is that high rates of rainfall keeps the surface of an exposed specimen “wet”, but that it also reduces the concentration of the electrolyte, which reduces the rate of corrosion. In a protected condition, such as under a sunshade, there is no precipitation of diluting salt deposits, and, instead, the most important factor is the humidity of the air. Thus, if the humidity in the air stabilizes around the humidity at which a salt converts from non-hygroscopic to hygroscopic, the surface is constantly in a wetting and drying phase. When the surface is in the drying phase as the electrolyte film is concentrating and localizing, as discussed earlier, it is expected that the corrosion rate will increase. For these reasons, the conditions under the sunshade may be more corrosive at NAS Whidbey Island.

CONCLUSIONS

Navy aircraft operate and are stored in a variety of adverse environments. Exposure to heat, Ultraviolet light, and inclement weather contributes to material degradation and adverse working conditions. APE can help alleviate these effects, but the benefits must be studied further to isolate the true benefits. While a lot of the evidence is anecdotal, future studies are planned to quantify the measurable benefits of these protective systems. The initial APE procurement at NAS Oceana and NAS Whidbey Island and the associated corrosivity analysis initiated the efforts to formally quantify these benefits and justify procurement to sponsoring authorities.

In consideration of only the corrosion rate data analyzed for NAS Oceana and NAS Whidbey Island and that contained within Appendix B for other monitored sites, the results are generally inconclusive regarding the benefits of the shelters on corrosion rate. For specific sites and conditions, sunshades have demonstrated considerable benefits to corrosion rate reduction. In general, however, that was not the result of this study. Our recommendation is that a determination to use sunshades as a means to protect against corrosion should be made on a site-by-site basis; at some sites, sunshades may provide the greatest return on investment, while at others, the preferred choice should be dehumidified storage. Dehumidified storage provides all of the benefits of sunshades and reduces the likelihood and kinetic rate of corrosion. In addition, for future efforts, studies which can isolate aircraft under sunshades and which track assets cycled under sunshades and exposed to the elements should be considered to optimize their usage for corrosion control only.

Beyond potential corrosion rate reduction benefits at sites, we have gathered anecdotal data from programs that participated in this study that confirmed the suspected benefits of sunshades beyond reduction in corrosivity. As discussed prior, the sunshades built at NAS Oceana and NAS Whidbey Island for this study were not dedicated to any one particular aircraft assigned to the site. Instead, multiple aircraft were cycled through the sunshade, such that the benefits of the sunshade – namely lighting, protection from rain, and reduction of surface temperatures – could be realized across the squadron to which these aircraft were assigned. Further, operational squadrons communicated that, since their assets were not exposed to rain under the sunshades, that they could leave their canopies open to “air out”, which potentially reduces rates of corrosion in the cockpit. Follow-on studies could be focused on quantifying the extended degree to which maintenance can be performed under the sunshade and the corrosivity of the cockpit when closed versus open to validate some of these anecdotal claims.

Our follow-on surveys of programs within NAVAIR that are using sunshades also resulted in positive feedback. Benefits of extending the useful lives of non-metallic, polymeric material (e.g. coatings, seals, canopies) were communicated and may be a result of the reduction in Ultraviolet radiation to which a surface is exposed when protected by a sunshade. Additionally, sunshades reduce the temperature of the asset, which potentially reduces degradation rates of non-metallic materials beyond rate reductions attributed to UV reduction. Sunshades definitely contribute to improved working conditions for maintainers. In high sun conditions, the temperature of the asset is lower under a sunshade, which both enables maintenance to be performed where it otherwise might not have been able and, where maintenance would have been permitted in hot conditions, the reduced temperature under the sunshade may contribute to a lower error rate. To be able to fully classify this benefit, our recommendation is to study breakdown of polymeric materials further in conjunction with protection and exposure to the elements using sunshades.

Beyond NAVAIR, we are aware that other uniformed services specify protective coverings, sunshades, and shelters for short-term and long-term storage of aircraft. One of the original intents of this project was to collect and document what the Air Force, Army aviation, and Coast Guard aviation communities specify for aircraft storage. Unfortunately, because of the timing of this report, participants from the original OSD program are no longer involved in these specifications. Our suggestion is that the OSD CPO S&T WIPT, Shelters and Monitoring Sub-WIPT conduct surveys of the services to determine the current status of storage and the technical justification for each. Leveraging that, we would suggest a longer term study focused on quantifying the effects of UV and heat on aircraft materials and human performance to be able to fully recognize the benefits of sunshades and justify usage by additional programs.

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RECOMMENDATIONS

As discussed, a number of NAVAIR programs have adopted sunshades either at local sites or across their fleets to realize numerous benefits. Sheltering and use of sunshades provide numerous benefits, and implementation should be an over-arching design concept that should be factored into a program's corrosion control approach during concept development. Since aircraft are complex systems and not simply bare substrates, the ability to extend the life of protective coatings, sealing materials, and other functional non-metallic materials is more valuable than the reductions in rates of corrosion that these structures enable.

While APE has its benefits, one of the best long-term and economical solutions is to have a dehumidified space/structure to prevent corrosion. Moving forward, our plan is to continue to quantify the benefits of various types of environmental protection for aircraft to include sunshades and dehumidified storage to justify their usage and to incorporate recommendations for procurement into acquisition planning documents. During future studies, the considerations below should be made to fully realize the benefits of the APE system.

A. CNIC Classification

APE or Aircraft Protection Equipment is defined as semi-permanent or deployable structures that can be removed single or multi-aircraft shelters that protect aircraft from exposure of harmful ultraviolet radiation and weather condition. It also provides personnel safety and preserve avionics equipment by blocking radiant energy from heated surfaces. The CNIC Memo Ser N4/10U54553 and OPNAVINST 11010.33C disambiguates the definitions for shelters and APE and clarifies procurement of APE.

B. Human Factors Benefits

NAVMED Directive P-5010-3 provides guidance in prevention and treatment of heat related injuries. (i.e., heat stroke, hyperthermia, heat rash, heat cramps, heat syncope, heat exhaustion). It also describes the measurements necessary to assess physical and physiological effects of hot environments at sea and ashore. Leaders who pushed their subordinates in the presence of hot or heat stress exposure risk performance degradation and potentially inflict harm. The old mentality of "dehydration tolerance" and 'being tough and motivated' can be replaced by leadership decisions based on effective heat stress training and proactive adherence of the above instruction. APE may improve conditions which contribute to heat stress and enable a safer work environment for aircraft maintainers.

Beyond the reduction in heat-related injuries, error and re-work rates may be reduced by enabling a more comfortable working environment for the Sailor or Marine. In inclement weather where maintenance is to be performed on the flight-line, APE may provide a benefit in sheltering personnel from the adverse environment. Where maintenance currently has to be delayed because of inclement weather, schedule may be accelerated where the protective environment exists. No such effort has been taken to quantify delayed maintenance because of foul weather.

C. Isolating Effectiveness of APE

Some factors that should be considered when gauging the benefits provided by APE are as follows. At any one site, environmental conditions vary between days and times of year, and these should be considered during studies. Even immediate exposure determinations and measurements are affected by wind-speed, relative humidity, cloud cover, inclement weather variables, so all variables should be assessed when measuring APE performance. During on-going studies sponsored by the NAE CPT, a FLIR camera, a wind and air temperature monitor, and UV indexer were used to gather data for normalization; analysis is on-going. A FLIR Infrared Thermal Imaging Camera model C3 was used to measure aircraft heat on specific areas. A Kestrel 3000 hygrometer / thermometer was used to measure ambient heat and humidity. A Spectraline DSE 100x radiometer was used to measure ultra-violet radiation. Results were collected and are being normalized for analysis. As study points, desert environment vice Pacific northwest CONUS environment were chosen to differentiate temperature and humidity effects.

D. Preliminary Conclusions from Recent Studies

-Aircraft exposure

Initial results indicate a temperature variation of between 15-45 °F from aircraft under the shelter compared with exposed aircraft on the flight line. For example, AV-8 temperature inside a closed canopy was measured at 120 °F exposed on the flight line vice 90 °F covered by the APE. By design, the majority of the UV radiation is filtered by the canopy enclosure and has a reduced impact effect inside of the cockpit. Radiant heat is a factor, but all cockpit non-metallic components (fabric, elastomeric materials, etc.) meet or exceed the applicable military design standards for environmental exposure.

-Human factors

Fleet technicians were informally surveyed, and the overall responses were that heat stress and dehydration are big concerns. An enclosure saves time and provides some level of comfort when maintaining aircraft. For example, if the actual temperature (with 50% humidity) is 100 °F, it ‘feels’ like 120 °F if working outside. Working inside the shelter lowers the temperature by at least 15 °F which can be the difference between a dangerous and a safe working temperature.

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APPENDIX A
SITE DRAWINGS AND INSTALLATION SPECIFICS

Figure A1: NAS Whidbey Island Site Drawing

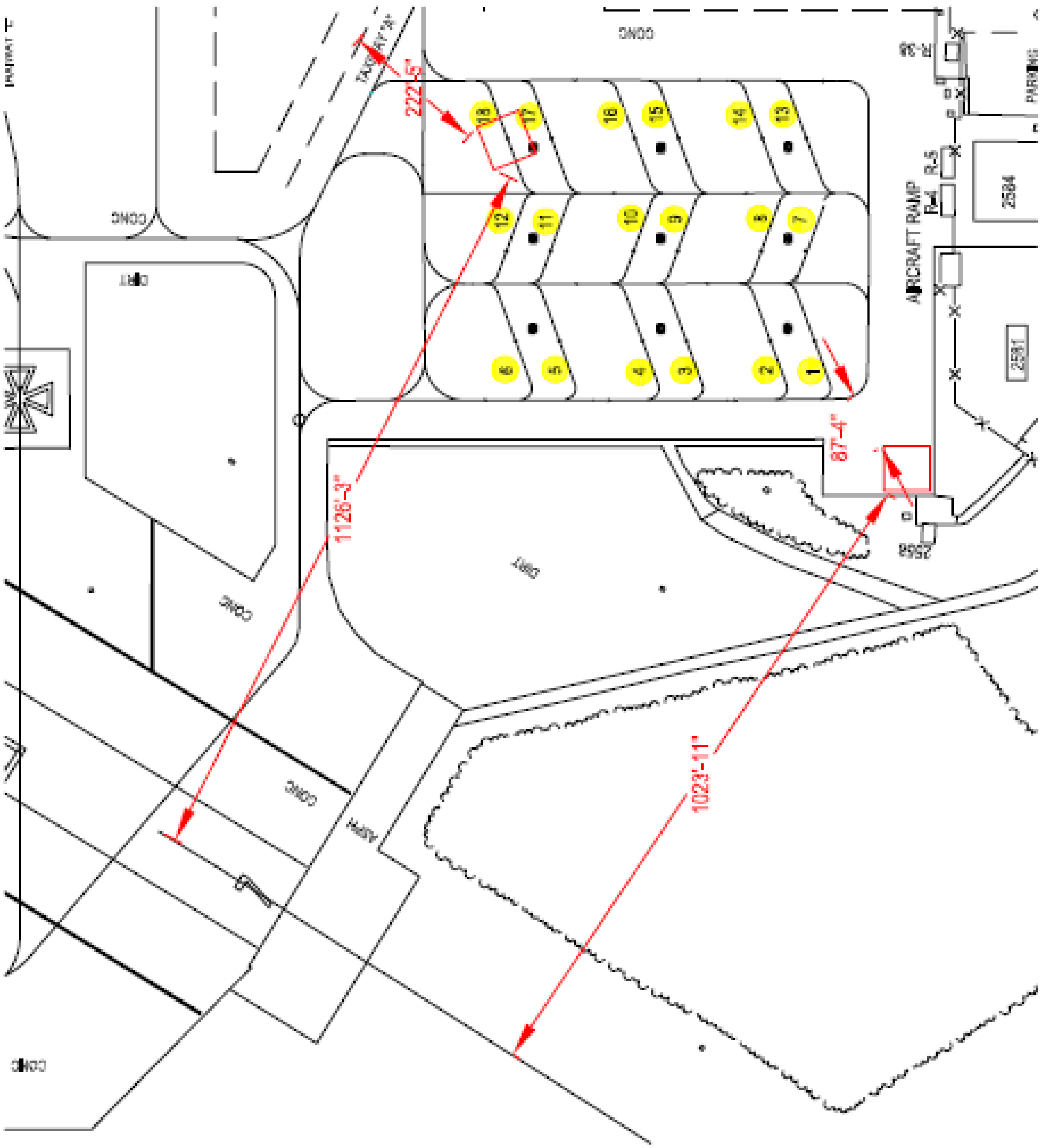
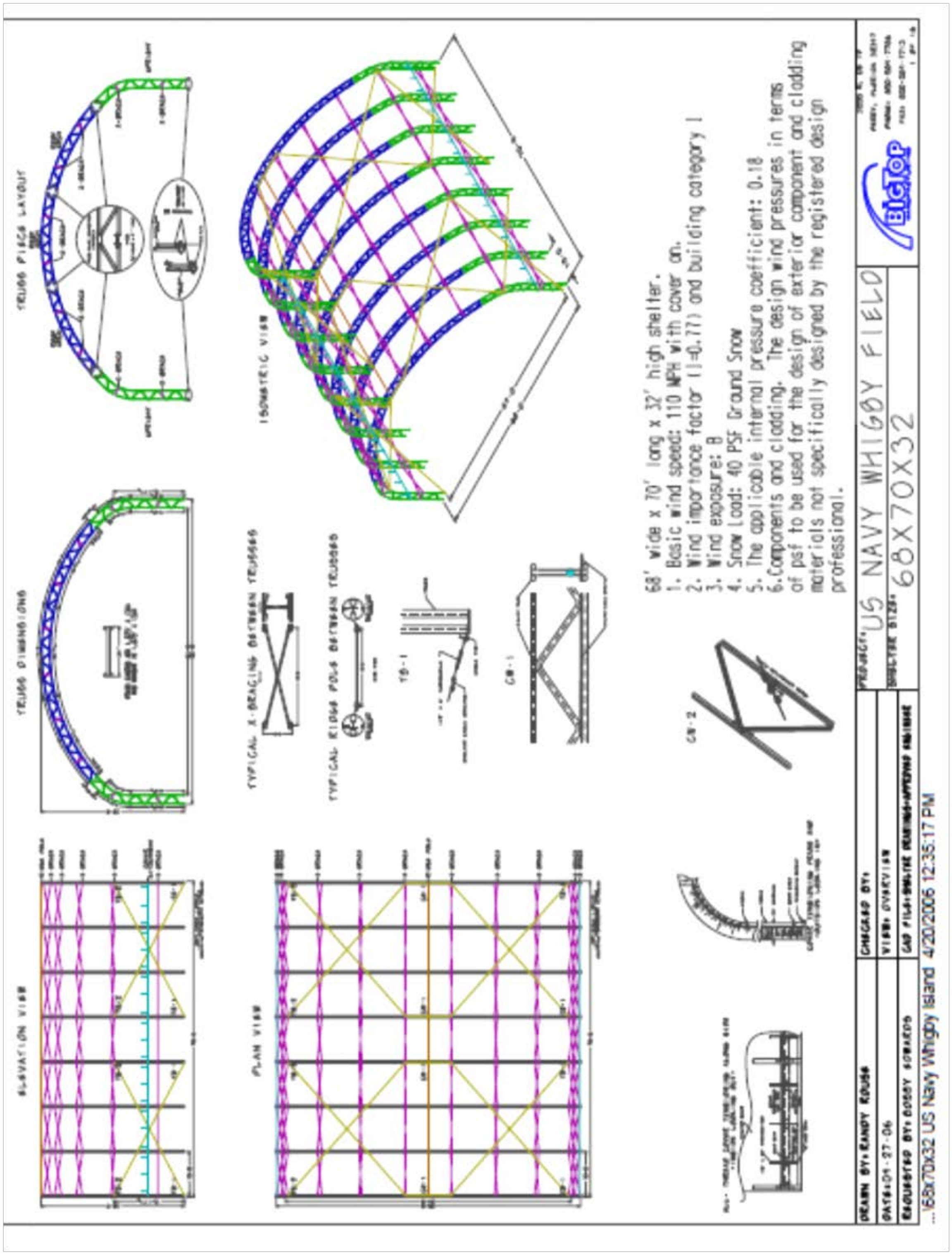


Figure A2: NAS Whidbey Island Site View (Aerial View of Shelter Locations, Enclosed in Red)

Figure A3: Drawings showing Dimensions for Big Top Shelters Constructed at NAS Whidbey Island



APPENDIX B
SITE CORROSIVITY MONITORING CHARTS

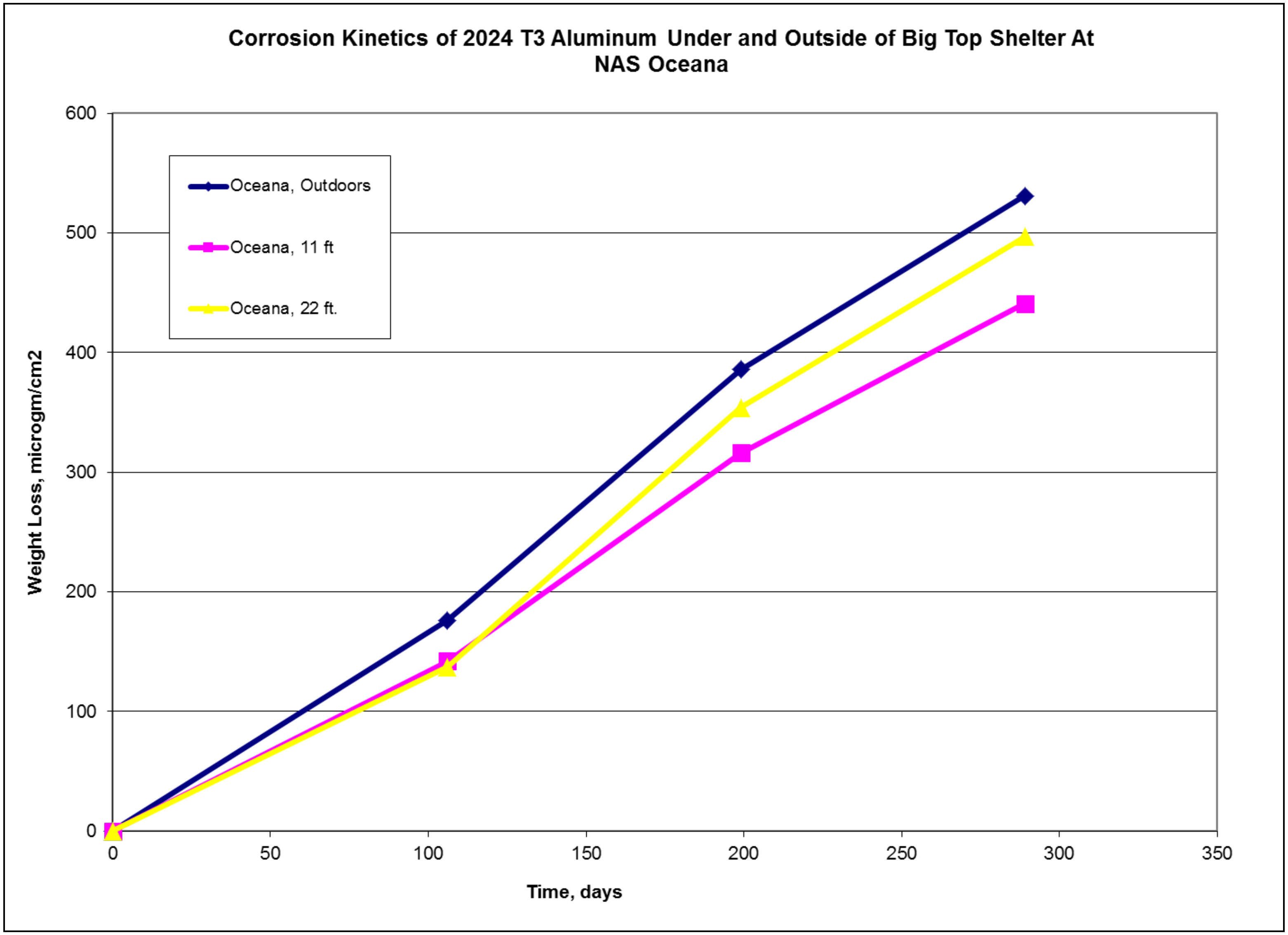


Figure B1: NAS Oceana Corrosion of 2024 T3 Aluminum.

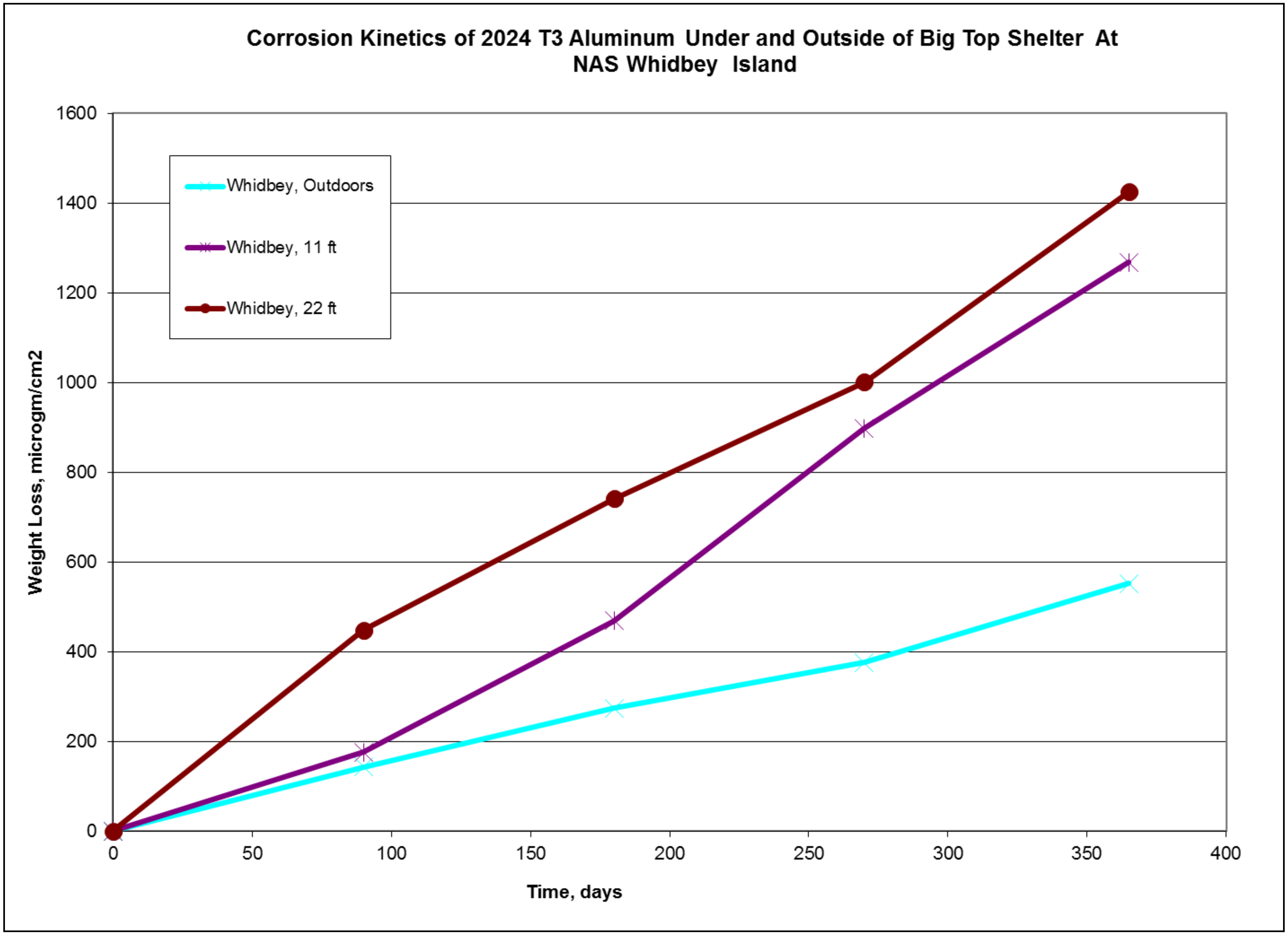


Figure B2: NAS Whidbey Island Corrosion of 2024 T3 Aluminum.

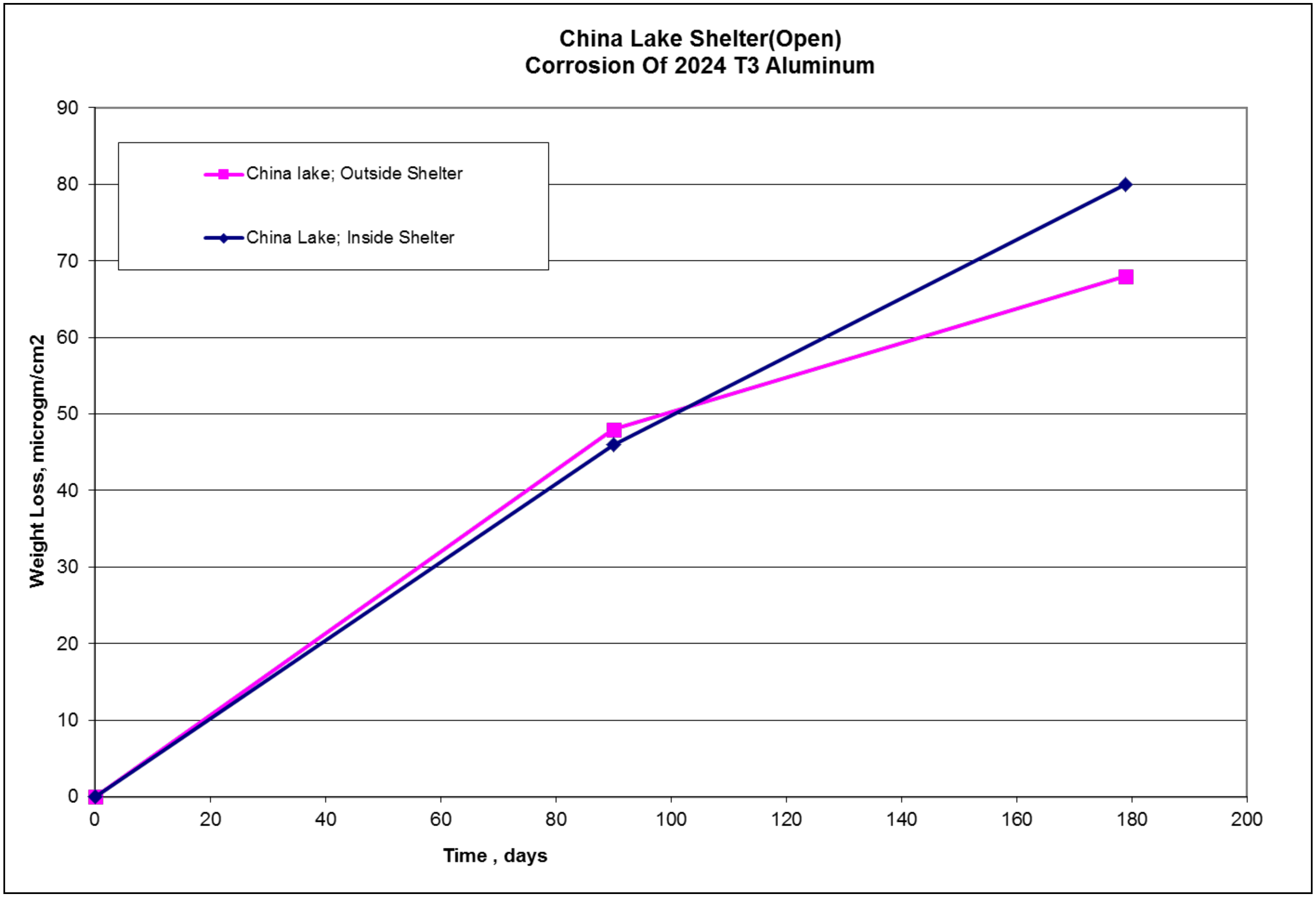


Figure B3: NAS China Lake Corrosion of 2024 T3 Aluminum.

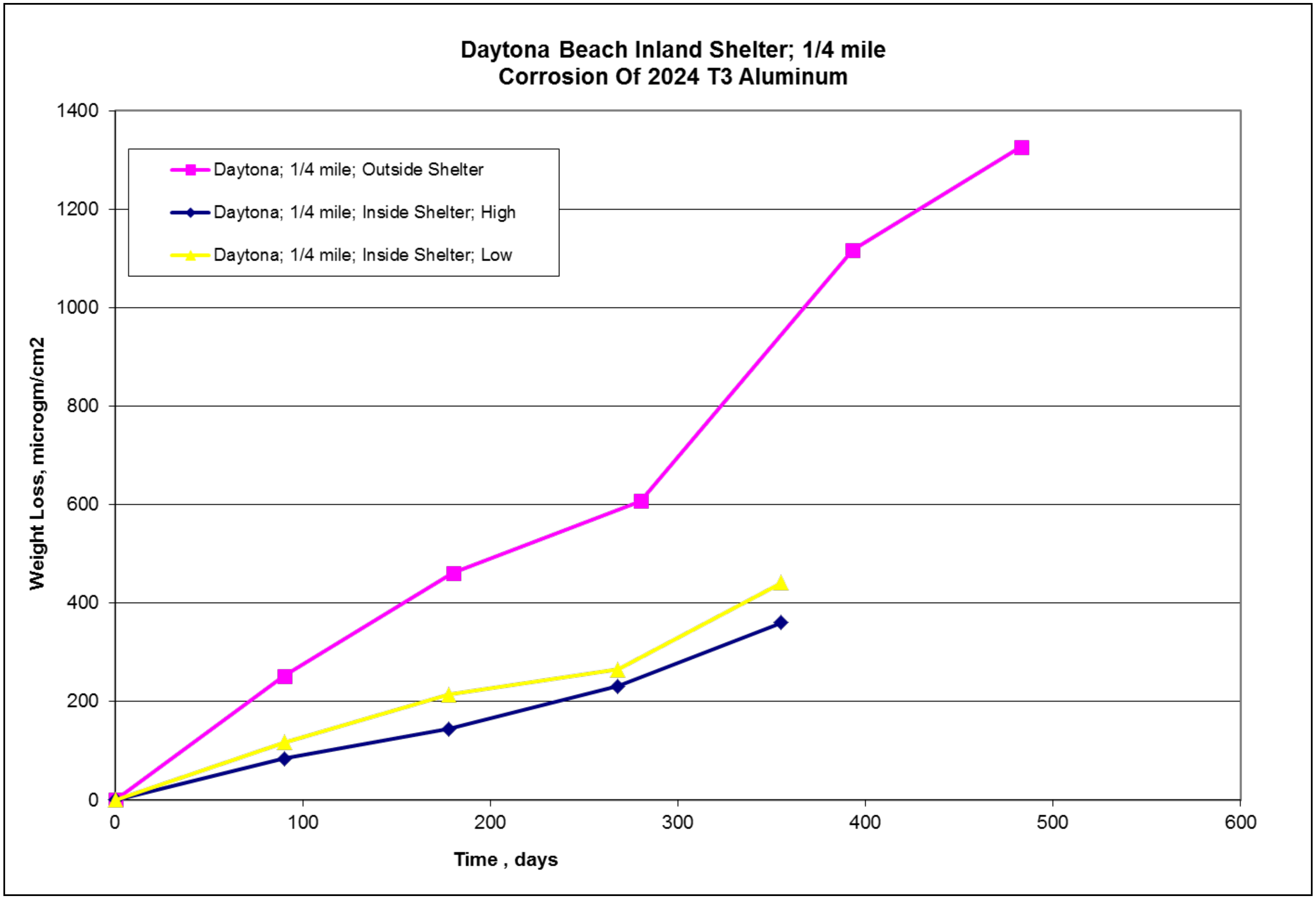


Figure B4: Daytona Beach Corrosion of 2024 T3 Aluminum.

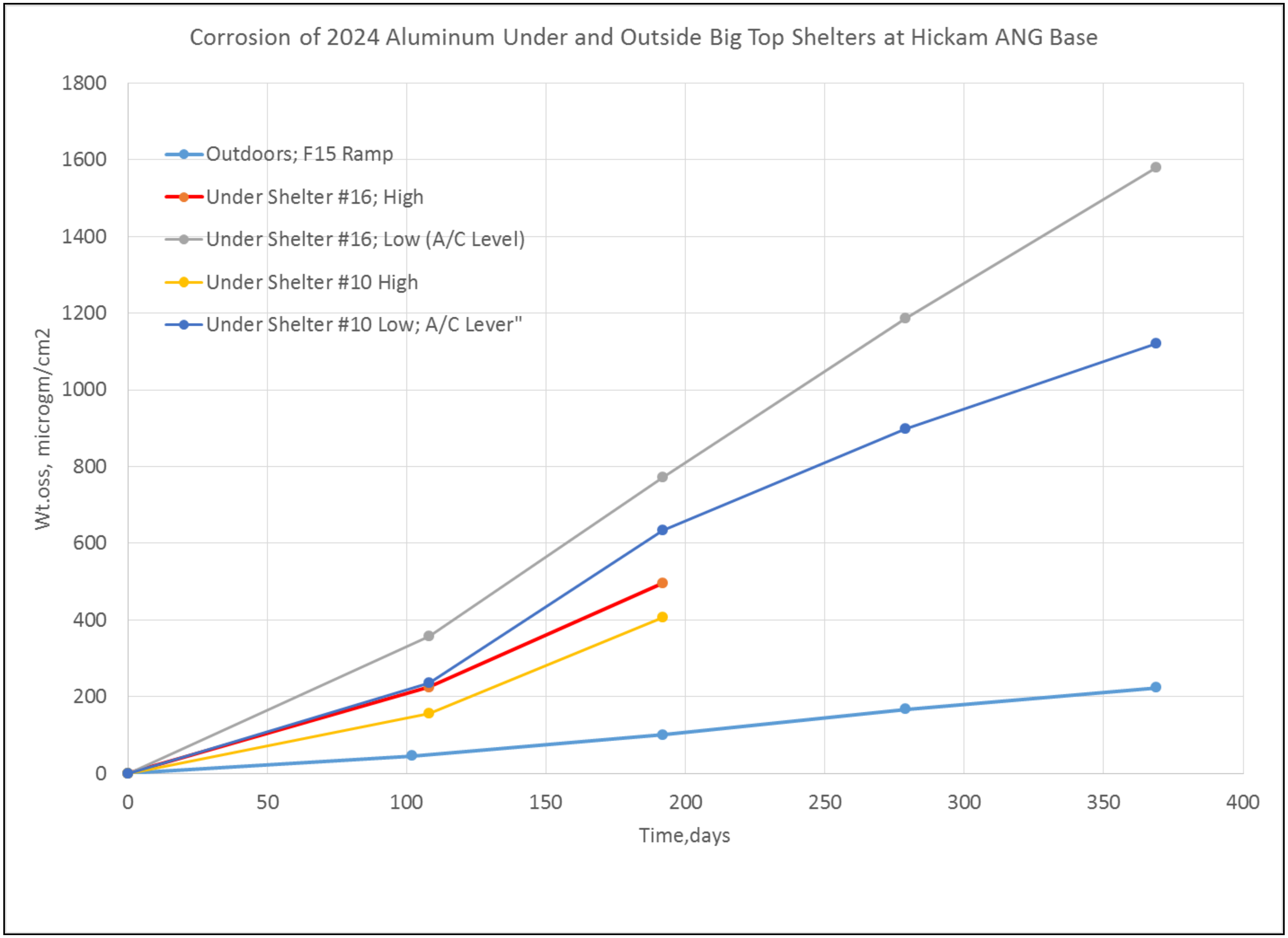


Figure B5: Hickam ANG Base Corrosion of 2024 T3 Aluminum

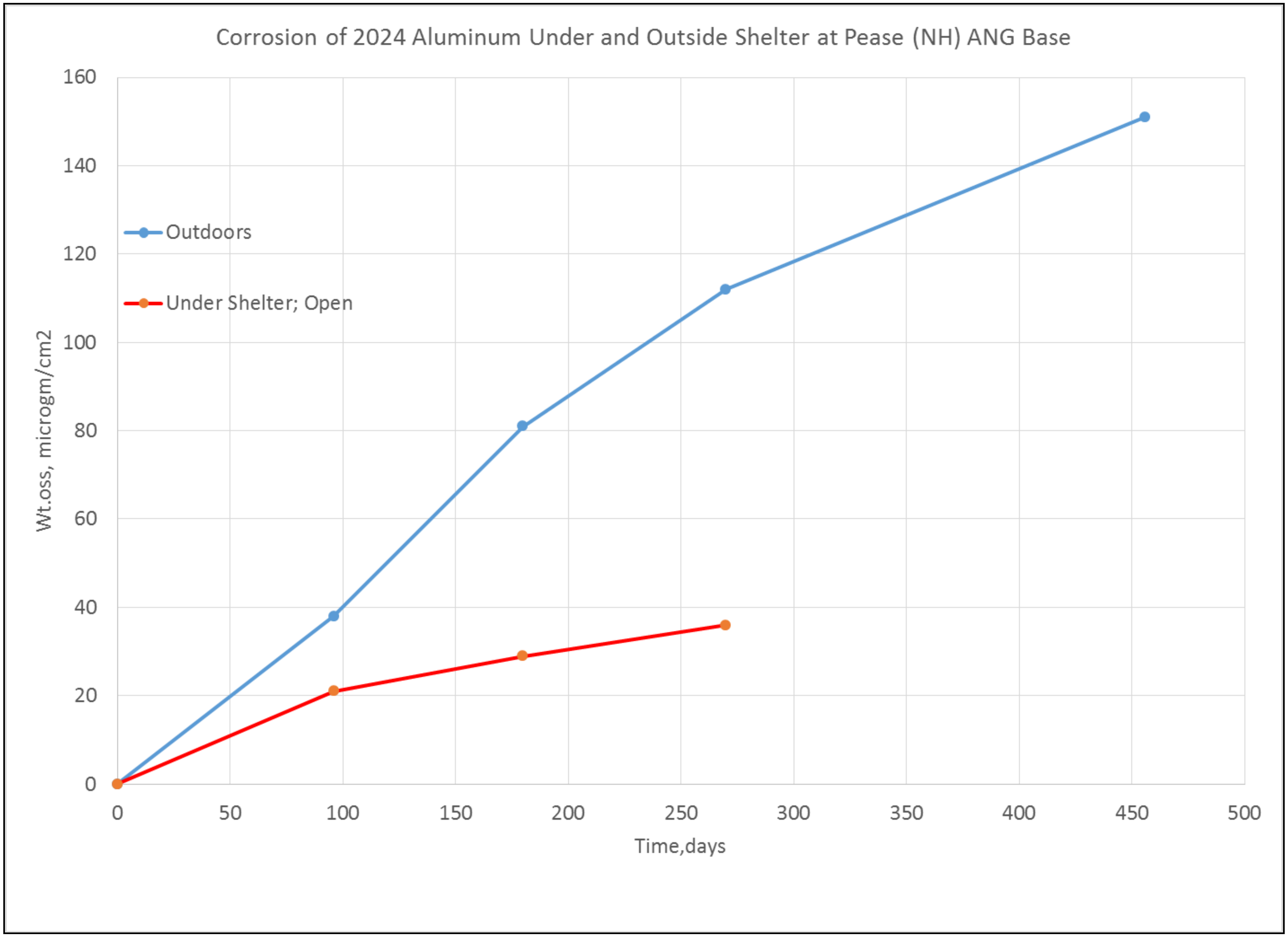


Figure B6: Pease ANG Base Corrosion of 2024 T3 Aluminum

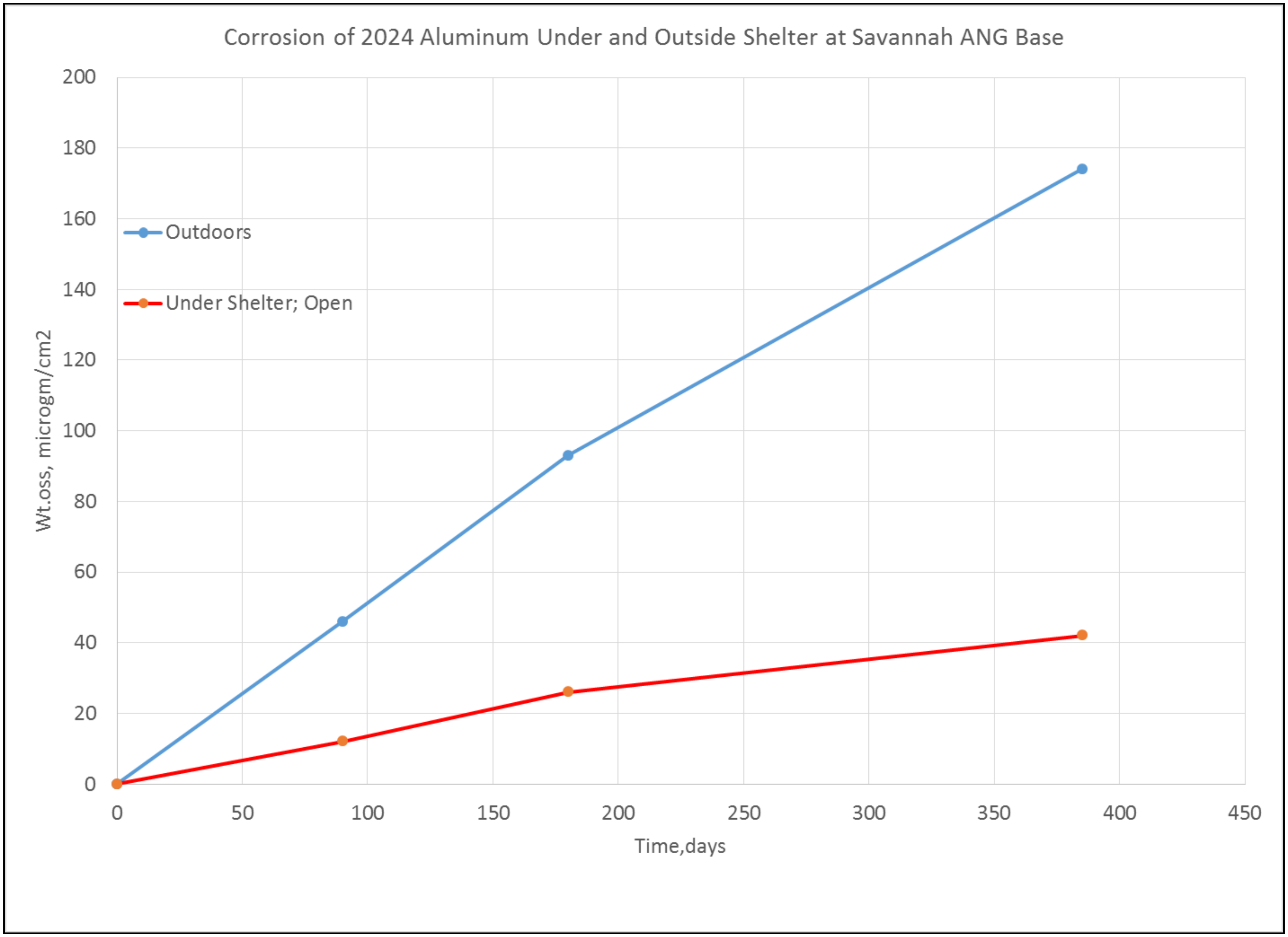


Figure B7. Savannah ANG Base Corrosion of 2024 T3 Aluminum

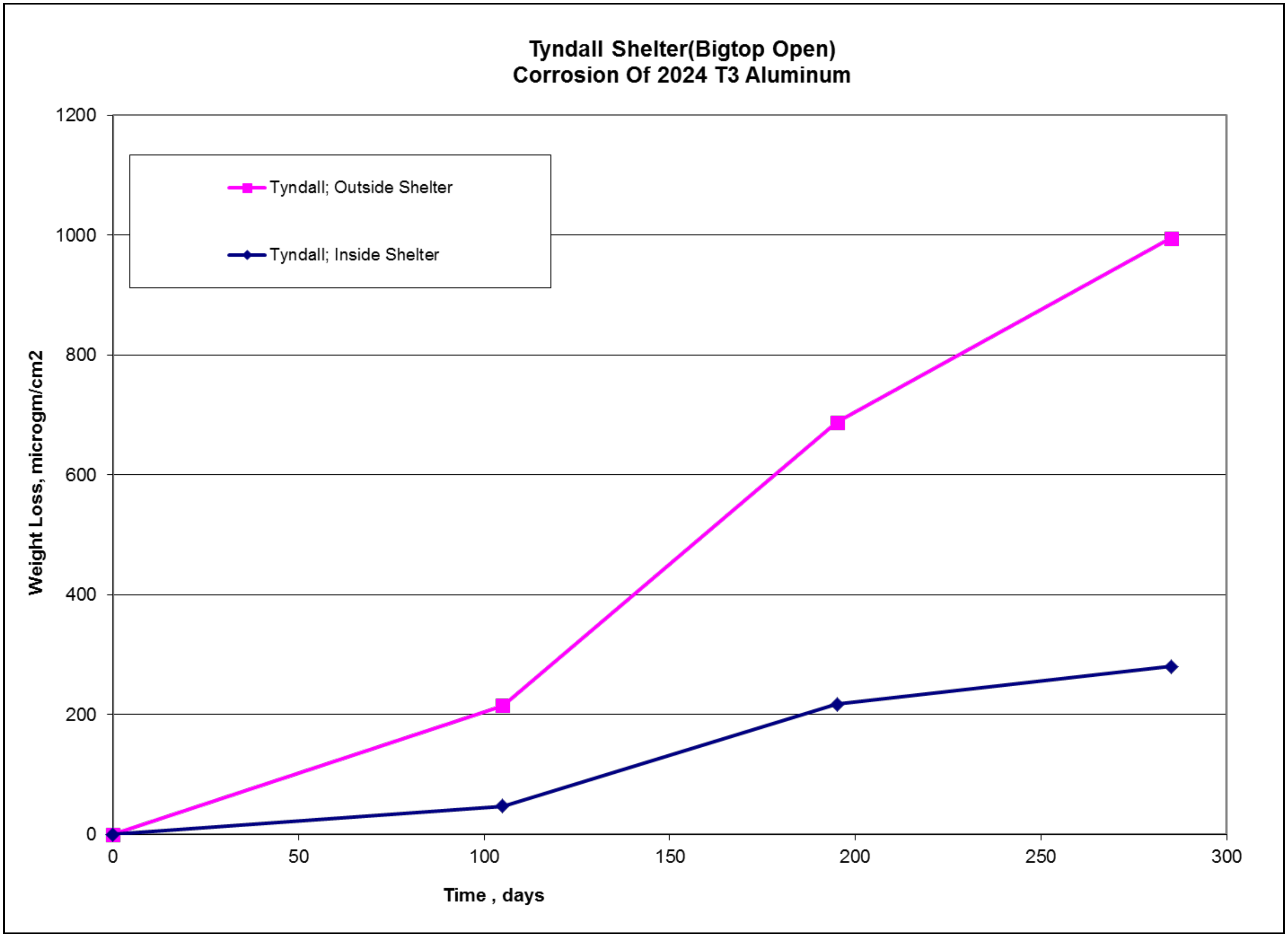


Figure B8: Tyndall AFB Corrosion of 2024 T3 Aluminum

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