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The Operational Testing Of The CPC ACF-50 On The US Navy's S-3B Viking Fleet

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Abstract:

Corrosion is the number one maintenance degrader of Aviation Weapon Systems in the Navy today. Because of the high cost of materials and the high number of maintenance man hours spent repairing and replacing corroded components and surfaces on the aircraft every year; any action that can be taken to reduce these expenditures should be aggressively pursued. The S3 Fleet Support Team [S3FST] has evaluated ACF-50, an ultrathin Corrosion Preventive Compound (CPC) that is used on aircraft in the Civilian Aviation Industry. ACF-50 provides a flexible but durable coating that displaces moisture on the aircraft structure and supplements the existing aircraft finish system.

During 1996, ACF-50 application and effectiveness were tested on an ES-3A aircraft assigned to VQ-5. Prior to the ACF-50 application, the aircraft received a Material Condition, Aircraft Service Period Adjustment [ASPA] Inspection to determine the overall condition of the Weapon System. All corrosion discrepancies were noted as to their Maintenance Level O, I or D [Organizational, Intermediate or Depot] and their severity [Minor, Major or Critical]. After the ASPA Inspection was completed, ACF-50 was applied to the entire interior surfaces of the airframe. The high pressure/low volume application of the CPC took approximately 4 hours and consumed approximately 20 Liters of ACF-50.

12 Months later [7 of which the aircraft was carrier deployed to the Persian Gulf] this same ES-3A again received a thorough Material Condition [ASPA] Inspection. To ensure consistency this second inspection was accomplished using the same ASPA inspection team and procedures used for the initial ASPA inspection. Again, all corrosion discrepancies were noted as to Maintenance Level and Severity. In comparison of these two ASPA Inspections; a **47%** reduction in corrosion discrepancies was noted. As a side note, all

maintenance accomplished on the ES-3A during the 12 month evaluation period was routine. No special corrosion preventative tasks were accomplished. Further research into this product determined that it has been commercially available World Wide since the mid 1980s. ACF-50 is currently approved for use by the United States Coast Guard, the Federal Aviation Administration and various Original Equipment Manufacturers [OEMs], including Beech Aircraft, British Aerospace, McDonnell Douglas, and Sikorsky.

Based on the proceeding research and prototyping; it is conservatively anticipated that a 20% reduction in overall organizational level maintenance man hours expended looking for and repairing corrosion discrepancies will be realized if the application of the CPC ACF-50 is accomplished at the 308 Day IMC interval. All of the required materials and application tools are readily available off-the-shelf from Pacific Corrosion Control Corporation. After initial ACF-50 application, maintenance of the film protection consists of inspection of treated areas at subsequent 308 day inspections and touch-up as necessary. It is also anticipated that a reduction in material cost expenditure will be realized both for O and D-Level Corrosion Discrepancies and D-Level Maintenance Man-Hours (MMHRS) expended addressing corrosion. However, at this point the S3FST is unable to quantify those cost savings.

During the first week in June 2000, 8 S-3B aircraft under the custody of Sea Control Wing Atlantic [WINGLANT] were fogged at Naval Air Station, Jacksonville, Florida. In addition to these 8 fogged aircraft the S-3 Fleet Support Team is also tracking corrosion on 5 additional control S-3B aircraft that were not fogged. During the first week in October 2000, 8 additional S-3B aircraft under the custody of Sea Control Wing Pacific [WINGPAC] were fogged at Naval Air Station, North Island, San Diego California. In addition to these 8 fogged aircraft the S-3 Fleet Support Team is also tracking corrosion on 7 additional control S-3B aircraft that were not fogged. As each aircraft reached its Special 308 Day Corrosion Inspection; reports are being generated and submitted to S-3 Reliability & Maintainability [R&M]. The last of these corrosion reports was expected be submitted to R&M in July 2001. The S-3 Fleet Support Team [North Island] was tasked by the S-3 Program Management Office [NAVAIRHQ] to submit a formal Engineering Paper, with S-3 Engineering's recommendation to either incorporate or not incorporate the routine application of the CPC ACF-50 across the S-3 Community. This final paper was submitted to NAVAIRHQ in August 2001.

Background:

The S-3A was initially developed as an Anti-Submarine Warfare [ASW] Platform. Over the years this ASW capability has been enhanced and expanded. The current Type/Model/Series [T/M/S] designator is S-3B. The platform has also been modified for the Aerial Tanker Mission. In addition, the S-3B has also progress from a Sea Control platform into additional missions in surveillance and attack.

In the fall of 1995, R&M under the S3FST was tasked to evaluate the commercially available Corrosion Preventive Compound [CPC], ACF-50 and determine if it was a product that would be useful and/or beneficial to the US Navy.

Because the initial ACF-50 development work that was accomplished yielded only a single data point. And because other questions regarding the effectiveness of ACF-50; additional evaluations were pursued under the guidelines of the Aging Aircraft Program [AAP], the Affordable Readiness Initiatives [ARI] Program & the Aircraft Equipment Reliability and Maintainability Improvement Program [AERMIP]. The proceeding abstract paragraph gives a good synopsis of what has been accomplished by the S3FST to date.

Application Development, Tooling and Lessons Learned:

The proto-type application of ACF-50 was accomplished on an ES-3A [Signal Intelligence/Electronic Intelligence] T/M/S S-3 in the summer of 1996. The ES-3A T/M/S has since been retired from the Navy's inventory. Application of the CPC was accomplished by a licensed Airframe & Power Plant [A&P] Mechanic from Pacific Corrosion Control Corporation. The application was accomplished in a fleet hanger at North Island while the airframe had all of its panels removed and access doors open. Direct application to the airframe was accomplished via a High Pressure / Low Volume Pump System. This High Pressure / Low Volume technique yields a very fine atomization, a fog, that permeates the entire interior structure of the aircraft. The Nozzle Pressure during this application was 1200 PSI. This fogging type of application allows the CPC to wick its way into the entire airframe via capillary action. A Lesson Learned during this evolution was that first, the dispersion of the CPC is more effective if the airframe structure has fewer panel and doors open. And secondly, with fewer panel and doors open, dispersion of the CPC in the Hanger Spaces is less intrusive.

During the week of 5 Jun 2000, fogging was accomplished on 8 S-3Bs at WINGLANT. In addition, 5 non-fogged S-3Bs from WINGLANT were also identified as control aircraft. During the week of 2 Oct 2000, fogging was also accomplished on 8 S-3Bs at WINGPAC. In addition, 7 non-fogged S-3Bs from WINGPAC were also identified as control aircraft. All fogging was accomplished by O-Level maintenance personnel. In addition, technical representatives from Lear Chemical & Pacific Corrosion Control were on-site to train the O-Level Sailors and be available to resolve technical issues. Also on-site was an S3FST R&M Engineer to develop a maintenance program for ACF-50 and also resolve engineering issues.

Prior to the application of ACF-50, all S-3Bs that were to be fogged were inspected and photographed for corrosion and general material condition. Also the aircraft Log Books were review and Flight Data Information was recorded. The non-fogged aircraft were not photographed or inspected at that time. However, non-fogged aircraft Log Books were review and Flight Data Information was recorded. Some hard to access areas of the fogged airframes were inspected via Electronic Bore Scope Camera and Monitor.

In addition, Technical Documentation development was also accomplished during the fogging applications. Such things as Airframe Preparation, Specific Panel Removal Requirements, Sequence of Application of ACF-50 and which application tooling [fogging wands] best suited for each area of the aircraft were identified. The Team also identified specific precautions to be taken to prevent damage to systems. The following are the main precautions that were taken:

- The Parachutes and Seat Pans were removed from the Cockpit to prevent the possible intrusion of the CPC which could cause parachute fabric to stick together and/or also contaminate emergency rations located in the Seat Pan. The cockpit and also the internal avionics tunnel were not fogged. These areas are occupied by the crew during flight.

- The LOX [Liquid Oxygen] Bottle was removed from its compartment. The LOX Lines were seal with double plastic bags. Initial fogging of ACF-50 was accomplished inside the LOX Compartment. However, R&M has determined that even though ACF-50 leaves no residue from fogging; safety precautions would dictate that petroleum products should not be in close proximity to Liquid Oxygen. All future fogging of the S-3B will be accomplished with the LOX Compartment Door Closed

- The FLIR [Forward Looking Infrared] was extended and the FLIR Optical Lens was masked to protect its special coating.

- The ES-3A contains a number of Avionic Boxes with very close tolerance Digital Membrane Pads. During the Proto-type fogging of this T/M/S, the Team masked these pads as a precaution in the event any of these membranes may have had pre-existing damage.

Another point R&M wishes to highlight; ACF-50 is authorized under MIL-C-81309 for both Class II and Class III applications. As a result, no other precautions were required with regard to electrical systems or equipment. One area that Lear Chemical identifies for General Aviation Aircraft is that if the aircraft contain an Auto Pilot that uses friction pads; these pads should be masked [protected from CPC intrusion].

During the fogging of all S-3Bs, R&M tracked the Elapsed Maintenance Time required to Fog each aircraft. In addition, the amount of ACF-50 consumed was also recorded. The Team also tried to determine the optimal number of Maintenance Personnel required to accomplish the most efficient application flow. Based on these engineering evaluations the following information applies:

- The optimal number of maintenance personnel needed to accomplish the efficient fogging of an S-3B is 4.

- The average number of hours required to fog an S-3B is 4 Hours

- The average amount of ACF-50 consumed during the fogging of an S-3B is 12 liters.

One other Technical Modification the Team made was to the S-3 Maintenance Requirement Cards [MRC] Deck, NA 01-S3IMC-6-3. With regard to lubrication requirements after the Special 14 Day Aircraft Washing/Cleaning requirements. R&M locally modified the pertinent Maintenance Requirement Cards to require the use of ACF-50 in aerosol cans in-lieu-of MIL-C-81309 and VV-L-800. These locally modified requirements primarily effect such items as piano hinges and electrical cannon plugs. Finally, as a Lessons Learned precaution from the ES-3A proto-type, WINGLANT and WINGPAC S-3B's were fogged outdoors at the Squadron's Wash Racks. This was done so the first, any dripping CPC from the airframe would be contain. And secondly, dispersion of the CPC in Hanger Spaces would not occur.

One of the major Lessons Learned during the fogging evolution is that although ACF-50 can be washed off with soap & water; it is still a viable product for use in aircraft Wheel Wells, Wing & Fin Fold Wells and Bomb Bays. The reason being is that although the CPC will be washed off of the surfaces of these areas during the aircraft's next 14 Day wash interval, the CPC has been applied via direct pressure spraying in these areas. What this application does is that the capillary action of the CPC wicks its way into all the cracks and crevices and under nuts, bolts, joints, rivets etc. and displaces any moisture that may be present. The capillary action has a direct impact on inhibiting corrosion at internal/external boundaries of the airframe structure. This phenomenon impacted corrosion percentage calculations and will be discussed further in the Inspection and Evaluation paragraphs of this paper. In addition, during the aircraft's next 14 Day wash interval, the CPC remains in place to continue to block the intrusion of moisture.

The following are a number of other Lessons Learned concerning application Equipment. R&M would like to point out that all tooling problems identified and recommendations made during the fogging evolution at WINGLANT in June 2000 were taken for action by Lear Chemical. By the time the WINGPAC aircraft were fogged in October 2000, all the identified modifications to tooling had been accomplished and these modified tools were supplied to both Wings at no additional cost to the government.

- The 25 foot hoses that run from the Pump to the Spray Gun were extended to 35 ft. On two of the WINGLANT aircraft, the Fins were unable to be folded and the Team was unable to Fog the Fin Tip without manually elevating the Pump System.

- The 5 wheel catty that the Pump System sits in was unstable in an operational ramp environment. The wheels were too small and they were spaced too close together. As a result, Lear Chemical replaced the 5 wheel catty with a Two Wheel Cart System.

- The Brass Quick Disconnects [QDs] that the Pump System initially used were too soft for a military environment. Lear Chemical replaced most of them with Steel QDs.

- The Cone Head QD Nozzle [about _ inch in thickness and the diameter of a quarter] that was used to Fog the Wheel Wells, Wing & Fin Butts and Bomb Bays was inadvertently shot into the interior bilges of the Bomb Bay Door on one of the Fogged Birds. This Nickel Plated Brass Fitting, FOD [Foreign Object Damage], took a Boring Tool and a number hours to retrieve and then patch the door. As a result, Lear Chemical has installed a lanyard on this one fitting to prevent future FODing.

- Lear Chemical also provided us with an experimental fogging wand for testing. The team found this experimental wand to be one of the most useful tools used during fogging. The tool was excellent for fogging into drain holes. The Team identified that if another foot was added to the wand hose; it would be perfect. Lear Chemical has accomplished the modification and supplied one to each Wing.

- During the WINGLANT Fogging, one of the Plastic Hose Flex Wands crimped [folding crease] at its QD. Lear Chemical Improved the design by installing a 6 inch length of spring at the QD to prevent this crimping. Lear Chemical has also supplied these to each WING.

During the third day of fogging aircraft at WINGLANT, the Team fogged an S-3B that was undergoing an Integrated Maintenance Concept [IMC], Planned Maintenance Interval [PMI]. The Horizontal Stabilizer was off this aircraft for an In Service Repair for major corrosion of the Stab's Rear Spar. The Stab was on a stand and there was no rear spar installed. As a result, the entire interior structure of the Stab was open for visibility. This Stab was fogged as we had accomplished on the 6 previous aircraft. We were able to identify that we were not getting adequate atomization for complete distribution of the CPC through out the internal structure. By experimenting with the shop air pressure into the pump and the atomization pressure at the spray nozzle; we were able to determine the optimum settings for best atomization pressure was 80 psi shop air in and 400 psi out, at the nozzle. Because of this Lesson Learned, the Team has used these pressure setting on all of the additional S-3Bs that have been fogged to date.

Corrosion Inspection & Evaluation:

The S-3B has the following Routine Maintenance Cycles: Daily, Turnaround, 7, 14 & 28 Day Inspections. In addition the Viking has an additional Maintenance Cycle of 308 Days, 616 Days and IMC PMIs. The PMIs are broken into 3 "Phases". Each Phase addresses different specific areas of the aircraft. A PMI is accomplished every 616 Day. The Daily through 616 Day Maintenance Cycles are accomplished by Organizational and/or Intermediate Level Maintenance Personnel only. The IMC PMIs are accomplished by all three Personnel Maintenance Levels; O, I and D. During the 308 Day Maintenance Cycle, the MRC Deck identifies a thorough Corrosion Inspection of the entire Weapon System. These Corrosion Inspection requirements are identified in Card 65 Series of NA 01-S3IMC-6-3.

Each S-3B that was part of the ACF-50 Operational Evaluation was at a different point in its 308 Day Maintenance Cycle. None of the fogged nor non-fogged aircraft were purposely based lined. Some of the S-3Bs were at the beginning of their 308 Day Maintenance Cycle. Some of the S-3Bs were in the middle and some were at the end of their 308 Day Maintenance Cycle. As each S-3B reached its 308 Day Inspection interval; R&M requested that specific Operational Data and all corrosion inspections results be reported to them by each VS Squadron via the squadrons appropriate WING. R&M has received all of these reports for the 8 Fogged and 5 Non-Fogged S-3Bs assigned to WINGLANT. With regard to the 8 Fogged and 7 Non-Fogged S-3Bs at WINGPAC, R&M has only received 50% of the reports to date. However, R&M was able to retrieve NALCOMIS, Equipment Condition Analysis [ECA], Malfunction [MAL] Code 170 [MAL Code 170 is Corrosion] Data, for the 10 month period from October 2000 to July 2001. As a point of information; within the Naval Aviation Maintenance Program, anytime maintenance is accomplished on aircraft, that maintenance must be documented using what the Navy calls a Maintenance Action Form [MAF]. Contained on these MAFs are specific data areas the require entries. One of these data areas requires the type of Malfunction that is being addressed. Corrosion is one example. Cracked, Broken, Out of Adjustment, etc. are other types of malfunction examples. As a result, engineering is able to query the MAF Reporting Data Base that is located in NALCOMIS and retrieve the number of specific MAL Code hits an aircraft may receive during an identified period of time.

The type of Operational Data that R&M was requesting were such thing as total number of flight hours flown during the evaluation period. Other Operational Data that was collected were the number of catapult launches accomplished and also the number of arrestments completed during the evaluation period. This Operational Data allowed R&M to better understand each S-3B's, by BUNO, usage and environment experienced during the evaluation period. From WINGLANT, 4 of the Fogged and 4 of the Non-Fogged aircraft belonging to VS-30 deployed to sea for 6 months starting in July 2000. The 4 Fogged and 1 Non-Fogged aircraft belonging to VS-24 remained at Jacksonville during the entire evaluation period. From WINGPAC, 4 of the Fogged and 4 of the Non-Fogged aircraft belonging to VS-29 deployed to sea for 6 months starting in November 2000. The 4 Fogged and 3 Non-Fogged aircraft belonging to VS-33 remained at North Island for 6 months after fogging and are now operationally deployed. Because of these current Operational Commitments, R&M has only received 50% of the reports on the WINGPAC aircraft. R&M intends to incorporate additional VS-33 data into R&M's ACF-50 evaluation as it becomes available.

Other factors that have had an impact on the data that is being complied is that some S-3Bs have been transferred to other squadrons. Some of the evaluation S-3Bs underwent an IMC PMI during the evaluation period. Also, some of the squadron personnel that were involved in the initial ACF-50 developmental work have now rotated to other activities. And, new squadron personnel have had to pick up the reporting requirements with very little or no background information on what is attempting to be accomplished. All of these items have had some degree of impact on the overall program. However, R&M is making every attempt to ensure that all collected data properly reflect what has actually occurred and is as accurate as possible.

Another point that R&M wishes to make is that through our total evaluations, we have determined that ACF-50 has impacted what we have identified as Airframe Structural Boundaries. What is meant by this is that because of the active capillary action of the CPC wicking its way throughout the entire aircraft structure, those area of the structure that did not receive a direct application of the CPC, are still experiencing benefits from this active CPC. Over the operational life of naval aircraft, NAVAIR Engineering has determined that the majority of corrosion initiates at structural interfaces. A structural interface is where two pieces of an aircraft structure come together. These interfaces primarily see corrosion because of moisture. Moisture can be trapped in these area which creates an active conduit for a corrosion cell.

During the review of the corrosion data collected, a question arose as to whether R&M should only count the Corrosion hits against those areas that received an application of ACF-50. Or, whether all corrosion hits, external as well as internal, should be considered in the final percentage calculation. Because the corrosion percentage calculations that were accomplished during the ES-3A proto-type used total corrosion numbers; R&M wishes to remain consistent with the current aircraft being evaluated. However, R&M also wishes to emphasize that if only the corrosion hits applicable to the those areas of the airframe that were Fogged were counted; the percentage of corrosion between Fogged and Non-Fogged S-3Bs would be substantially higher in favor of the Fogged airframes.

After review of all the data that was available to R&M, final calculations indicate that the Fogged WINGLANT S-3Bs had **31.6%** less corrosion then Non-Fogged S-3Bs. In addition, R&M calculations have reflected that the Fogged WINGPAC S-3Bs had **37.5%** less corrosion then Non-Fogged S-3Bs.

One other final point that R&M wishes to emphasize is that during this entire operational evaluation of ACF-50; not one negative feedback was received by the S-3FST. The CPC, ACF-50 had no negative impact with regard to paint adhesion, seal deterioration, loosening of faying surfaces or any other type of material degradation to date.

Summary and Recommendations:

R&M has accomplished a Reliability Centered Maintenance [RCM] Analysis on all of the data that has been complied on the ACF-50 Operational Evaluation. Some of the questions that R&M asked during this evaluation are:

- **Is there a return on our investment?** Or more clearly stated, is there a return to the Navy if the routine application of the CPC, ACF-50, is incorporated into the S-3B's Maintenance Plan? Cost analysis shows that there is an initial cost investment for the Heavy Duty Application System #90032 of $2450.00 Ea. This cost is derived from the 2001-2002 GSA Contract Consumables amount to approximate 12 liters of CPC from a 20 liter pale, NSN: 8030 01 438 4086-ACF-50, at a cost of $307.45 per 20 liter pale. These costs also come from the 2001-2002 GSA Contract And finally the cost of a case aerosol cans, NSN: 8030 01 438 4079-ACF-50, used at the Special 14 Days interval for spot application at a cost of $119.73 per case. In addition, there is the Maintenance Man-Hours [MMHRS] cost of the application of ACF-50 on one S-3B. This amounts to the organization labor cost of 4 fleet sailors times approximately 4 MMHRS per S-3B. Or, the cost to fog one S-3B of approximately $200 in ACF-50 bulk material cost. Plus, approximately $300 in ACF-50 Aerosol material cost to maintain the aircraft every 308 Days. The Organizational Labor cost amounts to approximately $1000. **These totals amount to approximately $1500 in Labor and Material Costs per S-3B fogged every 308 Days.** The initial investment of $2450 for the Heavy Duty Application System can be pro-rated over a period of time. For the purpose of this ACF-50 Evaluations, the AERMIP Program Office purchased one application system for each WING. In addition the AERMIP Program Office purchased enough bulk and aerosol ACF-50 to fog and maintain the 16 Fogged S-3Bs for the evaluation period. It is the recommendation of R&M that there be a minimum of 2 Heavy Duty Application Systems at each Naval Air Station. This allows for aircraft to still be fogged if one system should be down for parts. Maintenance requirements for the application system are negligible.

- **Will the incorporation of the routine application of the CPC, ACF-50, increased or decreased the Organizational Level Maintenance Workload [Corrosion Control MMHRS]?** Additional impact on O-Level Maintenance requires the new need to apply the CPC, ACF-50, after each Special 308 Day Inspection and also at the completion of each IMC Planned Maintenance Interval. However, base on the percentage seen during the R&M ACF-50 evaluation; the trade off is a substantial reduction in total Corrosion Control MMHRS.

- **Have or will other levels of Maintenance [Intermediate and/or Depot] be impacted by the routine application of ACF-50 on the S-3B Weapons System?** Again, base on the percentage seen during the R&M ACF-50 evaluation; the trade off is a substantial reduction in total Corrosion Control MMHRS at all levels of maintenance.

- **What impacts will be made on O/I/D Material requirements and cost by the routine application of ACF-50 on the S-3B Weapons System?** Again, base on the percentage seen during the R&M ACF-50 evaluation; it becomes quite apparent that the potential material cost saving should be substantial at all levels of maintenance. If there is a reduced requirement to replace aircraft structure, aircraft material or system components, due to corrosion; logic dictates that material cost should be less.

Based on our Fleet Supports Teams analysis; R&M's recommendation is that the use of the CPC ACF-50 be incorporated into the S-3B's regular Maintenance Plan at the earliest possible date. In closing, the R&M Team would like to reiterate a quote from one of the VS Squadrons Maintenance Control Chief's that was made during the ACF-50 evaluation. The quote reads:

"ACF-50 Is Not a Silver Bullet. However, It Is a Very Useful and Productive Tool That Enhances the Ability of Our White Hats to Maintain Our Fleet Assets at an Acceptable Operational Level!"

About the author:

Mr. Mullin was formally a member of the Reliability and Maintainability Team under S-3 Engineering at the Naval Air Depot North Island, San Diego, California. Mr. Mullin was reassigned to the F/A-18 Structures Fleet Support Team, also located at NAVAIR Depot North Island, in October 2001. Mr. Mullin holds a BS in Aeronautical Flight Operational Engineering from San Jose State University. Mr. Mullin is also a Civilian Graduate of the United States Naval War College at Newport, Rhode Island with a Master in National Security and Strategic Studies. Mr. Mullin is a FAA Licensed Airframe & Power Plant Mechanic. He is also a Retired Aviation Structural Mechanic and US Navy Aircrewman. He has been actively involved in Naval Aviation continuously for the past 36 Plus Years.