Legacy Coating Stripping
Final Report (Milestone 2)

IMPROVED MAGNESIUM PROTECTION FOR DOD AVIATION AND WEAPON COMPONENT TECHNOLOGY

ESTCP Project WP-201319

Kyu Cho
Army Research Laboratory

Bill Gorman
Technology Applications Group

October 2019

OPSEC Review

Approved

The OPSEC Review serves as an approval record for ARL generated information to be presented or disseminated external to ARL.

Documents

Legacy Coating Stripping (ESTCP WP-201319 Milestone 2) Final Report

Type:	Other
Authors:	Kyu Cho
Contains Human Subjects study information?	No
File name:	CUserskyu.choDownloadstempTAGMilestone2FinalReportLegacyCoatingStrippingDISTA.docx

Package Details

Unclassified Title or Solicitation Number/Title:	Legacy Coating Stripping (ESTCP WP-201319 Milestone 2) Final Report
Distribution Statement:	Approved for public release; distribution is unlimited.
Reasons:	0. Public release
Security Classification:	Unclassified
Was the author extended a personal invitation by the sponsoring organization to give a presentation or submit a publication?	No
Is the manuscript subject to export control?	No
Will foreign nationals have access to this information?	Yes
Campaign areas:	Material Research
Collaborative mechanisms:	CA No W911NF-13-2-0019
Created on:	Dec 19, 2018, 12:36 PM
Approved on:	Dec 21, 2018, 10:30 AM

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*
10/01/2019

2. REPORT TYPE
ESTCP Interim Report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Legacy Coating Stripping (ESTCP WP-201319 Milestone 2) Final Report

IMPROVED MAGNESIUM PROTECTION FOR DOD AVIATION AND WEAPON COMPONENT TECHNOLOGY

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER
W911NF-13-2-0019

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)
Kyu Cho, Army Research Laboratory
Bill Gorman, Technology Applications Group

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Army Research Laboratory
Aberdeen Proving Ground, MD 21005

8. PERFORMING ORGANIZATION REPORT NUMBER
WP-201319

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Environmental Security Technology Certification Program
4800 Mark Center Drive, Suite 17D03
Alexandria, VA 22350-3605

10. SPONSOR/MONITOR'S ACRONYM(S)
ESTCP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
WP-201319

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution A: Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report details the testing, performance requirements and test results used to meet Objective 2 of the Joint Test Protocol. There are three (3) anodized coating applied to new build magnesium aerospace castings. Objective 2: Design and validate the stripping process needed to remove old coatings from legacy components. Feedback from engineers at CCAD and TAG has indicated that the successful application of an Immersion Tagnite coating on legacy components is primarily driven by the condition of the parts upon entering the Tagnite process. Experience has shown that all residual paints and coatings must be removed prior to introduction into the Tagnite process in order to apply a high quality Tagnite coating. In addition, several of the legacy parts were made from AZ91C or AZ91E. These alloys have a lot of porosity which can lead to fluid see page after Tagnite application, resulting in a compromised coating.

15. SUBJECT TERMS
Legacy Coating Stripping, Magnesium Protection, Aviation and Weapon Component Technology

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Kyu Cho
UNCLASS	UNCLASS	UNCLASS	UNCLASS	90	19b. TELEPHONE NUMBER *(Include area code)* 410-306-0820

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Table of Contents

List of Figures……..…….ii

List of Tables……iii

List of Appendices……..….iv

List of Acronyms and Symbols…….……..…v

Individuals responsible for JTP……..……...vi

1.0 Introduction…….1

2.0 Performance and Testing Requirements……..6

3.0 Test Panel Preparation for Legacy Coating Stripping Study……....16

3.1 Magnesium Test Panels……..……..16

3.2 Mil Spec Primer Source……16

3.3 Rockhard Sealant Source…….……..…….....16

3.4 Type Id Notch C ring Source……...…….....16

3.5 DOW 17 Anodize Source …….16

3.6 HAE Anodize Source…..……...……...16

4.0 Effect of Tagnite Chemical Stripping Process on Legacy Anodize Coatings……...17

4.1 Explanation of Tagnite Chemical Stripping Process……... 17

4.2 Effect of Tagnite Chemical Stripping Process on DOW 17 and HAE Legacy Anodize Coatings……19

5.0 Techniques to Eliminate Residual Fluid Leakage from Porous Aerospace Alloys…... 21

6.0 Dimensional and Weight Change Due to Stripping of Legacy Coatings…….23

6.1 Dimensional Loss Testing and Results…….23

6.2 Weight Loss Testing and Results……..32

7.0 Effectiveness of MIL-DTL-83936 Paint Stripper on Legacy Coatings……...…….…37

8.0 Effect of Tagnite Chemical Strip Process on Cad Plating and Hydrogen Embrittlement ……39

List of Figures

Figure 1: ZE41 Magnesium Panels after 9 hours of ASTM B117 Salt Fog……..…..1

Figure 2: Process Flow Diagram of Immersion Tagnite Line……..…6

Figure 3: AZ91D Magnesium Panel During Tagnite Anodic Spark……...7

Figure 4: Location of Micrometer Measuring Locations on Dimensional Loss Panels……10

Figure 5: Visual Summary of Tagnite Stripping Process……...18

Figure 6: Effect of Tagnite Chemical Stripping Process on Legacy Coatings……...20

Figure 7: Revised Location of Micrometer Measuring Locations on Dimensional Loss Panels……..……..24

Figure 8: Dimensional Change Summary for AZ91C…….……29

Figure 9: Dimensional Change Summary for EV31A…….……30

Figure 10: Dimensional Change Summary for ZE41A……31

Figure 11: Weight Change Summary for AZ91C……...……..34

Figure 12: Weight Change Summary for EV31A…….……35

Figure 13: Weight Change Summary for ZE41A…….…….…..36

Figure 14: Paint Chemical Stripping Results for Legacy Coatings……..….38

List of Tables

Table 1: Target HazMat Compounds…….4

Table 2: Dimensional Change Test Description for Chemical Stripping of Legacy Coatings ……..….11

Table 3: Paint Scheme to Test Effective of MIL-DTL-83936 Paint Stripper……..…...…..13

Table 4: Sampling Plan and Test Conditions for Hydrogen Embrittlement Study…….15

Table 5: Original Dimensional Change Test Description of Chemical Stripping of Legacy Coatings……25

Table 6: Modified Dimensional Change Test Description of Chemical Stripping of Legacy Coatings……..…….….26

Table 7: AMSAM-ENVI-TI Hydrogen Embrittlement Test Matrix……..……...39

Table 8: Normal Tagnite Stripping Parameters vs. Notched C Ring Stripping Parameters ……..….40

List of Appendices

Appendix A: Magnesium Blocks – Certificates of Compliance

Appendix B: AZ91C Statistical Dimensional and Weight Change Summary

Appendix C: EV31A Statistical Dimensional and Weight Change Summary

Appendix D: ZE41A Statistical Dimensional and Weight Change Summary

Appendix E: AMSAM-ENVI-TI Memo on Hydrogen Embrittlement Test Requirements

List of Acronyms and Symbols

AED:	**Aviation Engineering Directorate**
AFRL:	**Air Force Research Laboratory**
AMRDEC:	**Army Aviation and Missile Research Development and Engineering**
ANOVA:	**Analysis of Variance**
ARL:	**Army Research Laboratory**
BER:	**Beyond Economic Repair**
Cad:	**Cadmium**
CCAD:	**Corpus Christi Army Depot**
HVOF:	**High Velocity Oxy Fuel**
MED:	**Maintenance Engineering Directorate**
NAVAIR:	**U.S. Navy Naval Air Systems Command**
NDSU:	**North Dakota State University**
NECCI:	**New England Custom Coaters, Inc.**
NFS:	**Notch Fatigue Strength**
PATTI:	**Pull-Off Strength of Coatings Using Portable Adhesion Testers**
PEL:	**Permissible Exposure Limits**
QC:	**Quality Control**
TAG:	**Technology Applications Group**
TCP:	**Trivalent Chromate Conversion Coating**
TIG:	**Tungsten Inert Gas**
TLV:	**Threshold Limit Value**
TWA:	**Time Weighted Average**
UDRI:	**University of Dayton Research Institute**

Individuals responsible for JTP

Name	Organization	Phone	e-mail
Mr. Kyu Cho	U.S. Army Research Laboratory	(410) 306-0820	kyu.c.cho2.civ@mail.mil
Dr. Bill Gorman	Technology Applications Group	(701) 746-1818	bgorman@tagnite.com
Mr. Wesley Cass	U.S. Army AMRDEC	(361) 961-4544	wesley.cass@us.army.mil
Mr. Ricky McNalley	U.S. Army Aviation Engineering Directorate (AED)	256-955-6854	ricky.o.mcnalley.civ@mail.mil
Mr. Scott Howison	U.S. Army AMCOM G-4	(256) 876-6129	stephen.s.howison.civ@mail.mil
Mr. Don Duran	U.S. Army AMCOM/Camber Corp	(361) 961-1663	donald.r.duran.CTR@mail.mil
Dr. Elizabeth Berman	U.S. Air Force Research Laboratory	(937) 656-5700	elizabeth.berman@wpafb.af.mil
Mr. Jonathan Williams	Corpus Christi Army Depot – Chemical Process Branch, MPED	(361) 961-2301	jonathan.l.williams56.civ@mail.mil
Dr. Michael John Kane	Chief, Materials Division Aviation Engineering Directorate AMRDEC	(256) 313-8727	michael.john.kane@us.army.mil
Mr. Jeremy O. Smith	Chief Materials & Process Engineering Division Directorate of Production Engineering	(361) 961-0246	jeremy.smith4@us.army.mil

1.0 INTRODUCTION

All military aviation platforms have magnesium castings which are incorporated into various functions of the aircraft such as drive train components, auxiliary gearboxes and generator housings. Magnesium has the advantage of being a lightweight material which allows for greater payload or longer fuel ranges; however, magnesium is a very electrochemically "active" metal which leads to moisture induced corrosion and galvanic corrosion due to mating with dissimilar metals. As a consequence, magnesium components on aviation platforms must be inspected and replaced quite frequently. Several years ago, the inspection frequency was based on the number of flight hours. Typically, depot inspections were done every 500 hours. During the Iran/Iraq war, inspection frequencies were changed to conditional inspections and are now classified.

During the overhaul phase of the magnesium component, the anodic protective coatings (HAE, DOW 17 or Tagnite), primer and topcoat paint are stripped off to allow visual and penetrant inspection of the casting. After passing the inspection, the magnesium castings are dipped in a chemical conversion coating such as DOW 7 or DOW 19 before being placed back into service. The purpose of the DOW coatings is to act as a base for paint application. There are multiple problems with this approach:

1. These DOW chemical coatings leave a toxic hexavalent chromium film on the magnesium components. Exposure to hexavalent chromium during the application of the DOW chemical coatings is hazardous to operation personnel. For example, the magnesium component is placed in a vat of boiling hexavalent chromium DOW 7 solution for 30 minutes. Hexavalent chrome has been proven to cause lung cancer. The OSHA PEL for chromic acid is 0.005 mg (8-hour TWA) and the TLV is 0.05 mg/m^3. These PEL values are considered very low and the low PEL values require substantial ventilation engineering.
2. The cost of disposal of used chromate solution, contaminated containers, rinse water, contaminated auxiliary supply, etc. is expensive.
3. The DOW chemical overhauled magnesium components have dramatically short service life due to lack of corrosion protection seen with the chromate conversion coatings. Figure 1 shows ZE41 magnesium test coupons that have been treated with DOW 7 or DOW 19 and exposed to testing in a salt fog chamber for 9 hours along with a bare ZE41 panel. The picture clearly shows that the DOW coatings provide little, if any corrosion protection when compared to bare ZE41.
4. DOW 7 is not recommended for use on the following highly used magnesium alloys EK30A (UNS M12300), EK41A (UNS M12410), HK31A (UNS M13310), HM21A (UNS 13210), HM31A (UNS M13312), ZK60A (UNS 16600), LA141A (UNS M14141), and M1A (UNS M15100).
5. There are evidences that DOW 7 and DOW 19 do not produce adequate coatings on the newest aerospace magnesium alloy, EV31 (AMS 4429). An alloy is being heavily used in the Apache Block III Drivetrain Upgrade.

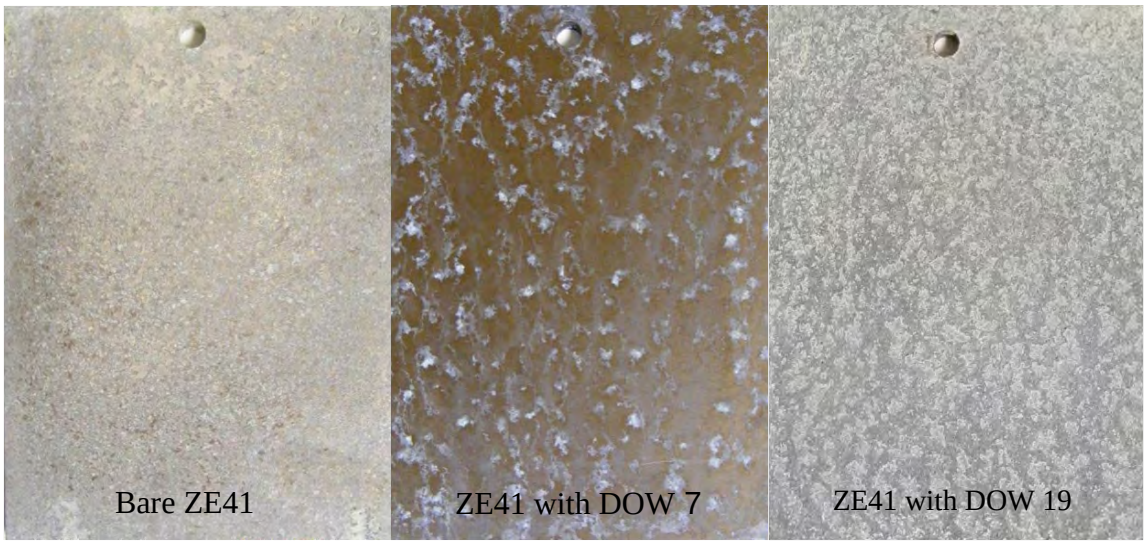


Figure 1: ZE41 Magnesium Panels after 9 hours of ASTM B 117 Salt Fog

Although Tagnite is approved for some new magnesium components (the list of approved parts continues to grow), refurbishment of legacy components with this coating system is problematic due to the presence of dissimilar metals (e.g. steel studs, liners, etc.) and compatibility with current and potential repair techniques such as corrosion pit fillers, weld repair and cold spray repair. Masking technology that has been developed by Technology Applications Group (TAG) requires demonstration at the depot before the use of chromated coatings on magnesium components can be eliminated. The DoD demonstration site will be the Corpus Christi Army Depot (CCAD) Plating Shop. One of the plating lines at CCAD will be converted into an Immersion Tagnite line and CCAD plating shop personnel trained in the operation of the Immersion Tagnite line and masking protocols.

The goal of this project is to eliminate the need for chromate conversion coatings during the overhaul phase of magnesium aerospace components through the use of Immersion Tagnite and Brush Tagnite Anodize coatings. The Tagnite coatings contain no chromates and provide much better corrosion protection than presently used DOW products. The Tagnite mixed metals finishing technology offers pollution prevention, improved performances, and reduced lifecycle sustainment cost. Specific objectives of this project are:

1. Establish and validate compatibility of the Immersion Tagnite and Brush Tagnite with the currently used or considered repair techniques;
2. Design, develop, and validate the stripping process needed to remove old coatings from legacy magnesium aerospace components in order to properly process the legacy parts through the Immersion Tagnite and Brush Tagnite systems;
3. Jointly develop and conduct Joint Test Protocol (JTP) of Brush Tagnite for other commonly used magnesium alloys, such as AZ91C/AZ91E, QE22 and EV31, with Army Aviation, NAVAIR, Air Force, and ESTCP. Currently, Brush Tagnite is only approved for use on the ZE41 magnesium alloy by Army Aviation;
4. Develop engineering design and retrofit an unused plating line at the Corpus Christi Army Depot (CCAD) plating shop for use as an Immersion Tagnite line;

5. Jointly develop the priority list of legacy magnesium components to be evaluated by the proposed system with Army Aviation, NAVAIR and Air Force;
6. Develop and validate masking protocols for high priority legacy magnesium components as determined by the three joint service branches;
7. Demonstrate and validate the complete integrated Tagnite process on Line D at CCAD plating shop using legacy magnesium housings and gearboxes using refurbished Beyond Economical Repair (BER) parts with mixed metal components; and
8. Quantitatively analyze and validate the pollution prevention resulted from the integrated Immersion and Brush Tagnite technology.

A Joint Test Protocol (JTP) is needed for Project Objectives 1 – 3 only. The objectives of the JTP are as follows:

Objective 1: Determine Tagnite compatibility with current and potential magnesium aerospace component repair techniques. The repair techniques are used to fill corrosion pits, porosity in the casting and/or restore dimensional loss. The repair techniques to be evaluated are:

- DEVCON Liquid Aluminum F2
- DEVCON Titanium Paste
- Tungsten Inert Gas (TIG) Weld Repair
- High Velocity Oxy Fuel (HVOF)
- Aluminum Cold Spray

Testing will include adhesion of fillers to magnesium, softening or lifting of repair area after Tagnite to determine if the repairs are degraded by the Tagnite pretreatment processes or the anodization step. Application of MIL-PRF-23377 primer over repaired area followed by pull-off testing and galvanic corrosion testing on test coupons with Tagnite only (no primer).

Objective 2: Design and validate the stripping process needed to remove old coatings from legacy components. Feedback from engineers at CCAD and TAG has indicated that the successful application of an Immersion Tagnite coating on legacy components is primarily driven by the condition of the parts upon entering the Tagnite process. Experience has shown that all residual paints and coatings must be removed prior to introduction into the Tagnite process in order to apply a high quality Tagnite coating. In addition, several of the legacy parts were made from AZ91C or AZ91E. These alloys have a lot of porosity which can lead to fluid seepage after Tagnite application, resulting in a compromised coating.

Magnesium coupons from porous magnesium alloys will be soaked in various fluids then tested using vapor degreasing and aqueous alkaline degreasers along with various heating cycles to determine the best way to remove any residual fluid prior to the Tagnite anodization stage.

Testing will done on the effectiveness of the MIL-DTL-83936 Paint Stripper to remove legacy organic coatings from legacy anodic coatings. The most commonly used anodic coatings for magnesium; HAE, DOW 17 and Tagnite, have some porosity which allows sealants and/or primers to seep into the pores and seal off the porosity. It is uncertain at this time whether the commonly used MIL-DTL-83936 Paint Stripper will be effectiveness at removing primers and

sealant embedded into the pores of the anodic coatings. Testing will be conducted to evaluate the effective of the paint removal process.

Once the organic coatings has been stripped off, a chemical stripping for the inorganic anodic coatings will be developed and tested. After the chemical stripping process has been developed that will remove the old anodic coatings, testing must be conducted to determine the dimensional change that occurs during the stripping process and subsequent application of Tagnite. This information will allow engineers to determine if the stripping and Tagnite processes will result is dimensional changes that exceed the allowable limits. In addition, the stripping process will be tested on Cad plated bolts to see what impact, if any, the stripping process has on Cad plated fasteners. Lastly, hydrogen embrittlement testing will be performed after notched steel "C" rings have gone through the chemical stripping process.

Objective 3: Approval of Brush Tagnite for Use on Additional Magnesium Aerospace Alloys. Brush Tagnite is a handheld, selective anodization process for the touchup of small bare magnesium repair areas on magnesium aviation components. Brush Tagnite has been in use at CCAD since 2005 but its usage has been limited to application on ZE41 magnesium components that have the Immersion Tagnite anodize as the original coating. There are other magnesium aerospace alloys such as AZ91C/AZ91E, QE22 and EV31 which are in use on aviation platforms and Brush Tagnite performance data should be obtained for these alloys as well. Recommended testing will include:

a. Corrosion Resistance (Neutral Salt Fog and SO_2 Salt Fog)
b. Pull-off Adhesion
c. Outdoor exposure at an ocean front environment
d. Axial Fatigue Studies
e. Galvanic Corrosion Studies

The performance testing of the Brush Tagnite coatings will be compared to the currently used chromate conversion touchup coating, DOW 19 as well as trivalent chromium touchup process (TCP) used by NAVAIR. The acceptance criteria will be performance testing that is equal to or better than DOW 19 and/or TCP.

The targeted hazardous material is hexavalent chromium (Cr^{6+}) which is used at the military depots in various formulations. The most typically used formulations are called DOW 7 and DOW 19.

Table 1: Target HazMat Compounds

Target HazMat	**Current Process**	**Applications**	**Current Specifications**	**Affected Programs**
Hexavalent Chromium	DOW 7	Used as paint adhesion coating on magnesium aviation components	AMS-M-3171 Type III	UH-60 AH-64 CH-47 T-38/F-5

Hexavalent Chromium	DOW 19	Used as paint adhesion coating on magnesium aviation components	AMS-M-3171 Type VI	UH-60 AH-64 CH-47 T-38/F-5

Stakeholders:

1. Army Research Laboratory
    a. Mr. Kyu Cho – DoD PI for ESTCP project
2. Technology Applications Group– company that invented the Tagnite and Brush Tagnite anodized coatings for magnesium metal.
    a. Dr. Bill Gorman, Director of R & D
3. Corpus Christi Army Depot (CCAD), Materials & Process Engineering Division (MPED), Directorate of Production Engineering - oversight and management of Plating Shop which is the ESTCP demonstration site
    a. Mr. Jeremy Smith: Chief of the Materials & Process Engineering Division (MPED)
    b. Mr. Jonathan Williams: Chief – Chemical Process Branch, Materials & Process Engineering Division (MPED)
4. Army Aviation and Missile Research, Development and Engineering Center (AMRDEC) – responsible for approval of any design changes that affect airworthiness on Army Aviation assets.
    a. Dr. Michael Kane: Chief - Materials Division, Aviation Engineering Directorate (AED)
    b. Mr. Ricky McNalley: Engineer - Materials Division, Aviation Engineering Directorate (AED)
    c. Mr. Wesley Cass: Aerospace Engineer, Emerging Technology Manager for Aviation Engineering-Maintenance (AEM)
    d. Mr. Don Duran: Task Order Project Lead, Camber Corporation supporting Aviation Engineering-Maintenance (AEM)
5. Army Aviation and Missile Command (AMCOM) – responsible for repair and maintenance orders for Army Aviation assets
    a. Mr. Scott Howison: Scientist at AMCOM G-4, Environmental Division, Technology Integration Branch (TIB)
6. Air Force Research Laboratory – testing arm of Air Force for qualification of new coatings and technology
    a. Dr. Elizabeth Berman – Senior Research Engineer

2.0 PERFORMANCE AND TESTING REQUIREMENTS

This report details the testing, performance requirements and test results used to meet Objective 2 of the Joint Test Protocol. There are three (3) anodized coating applied to new build magnesium aerospace castings.

DOW 17 is a hexavalent chromate anodize process used to apply a coating to brand new magnesium surfaces prior to paint application. The DOW 17 application process is described in ASTM D1732, Class II, Type II. This process involves immersion of the magnesium component in a acidic solution containing sodium dichromate, and ammonium sulfate, The immersion time is typically 20 minutes at a temperature of 160 - 180°F. Depending on the coating thickness, the coating will vary from a light tan to a dark green, the color may not be uniform over the entire part.

HAE is a heavy metal containing magnesium anodizing process used to apply an anodized coating to brand new magnesium castings. The application process and performance characteristics are described in ASTM D1732-03, Class II, Type III. This process involves the immersion of the magnesium component in a tank containing the potassium permanganate, mixed hydroxides and fluorides dissolved in RO or DI water. The immersion time is typically 20 minutes at a temperature of 77 - 100°F. Depending on the coating thickness, the coating will vary from a light tan to a dark brown.

Immersion Tagnite: The need for a superior chromate-free surface finish on magnesium led Technology Applications Group, Inc. (TAG) to develop silica oxide-containing coatings which have markedly improved corrosion protection and abrasion characteristics relative to the more popular anodize and chromate chemical conversion coatings for magnesium. This silica oxide coating has been given the trademark TAGNITE^{TM}. Tagnite is typically applied to new magnesium casting prior to the installation of ferrous inserts, studs and liners.

The application of the TAGNITE coating as well as the performance characteristics are summarized in MIL-DTL-32459.

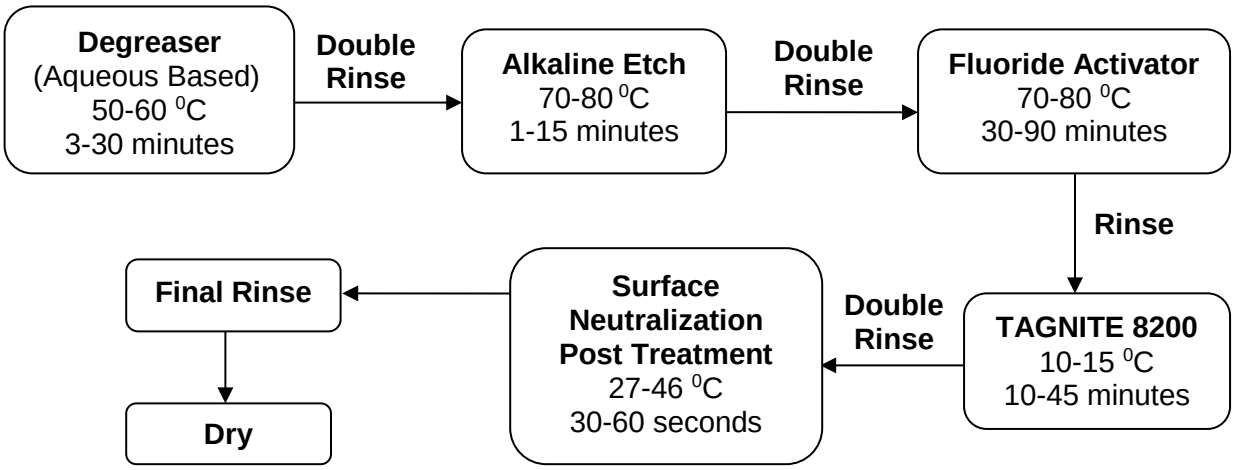


Figure 2: Process Flow Diagram of Immersion Tagnite Line

Typically, the degreaser and alkaline etch cleaning procedures shown in the process flow diagram (Figure 2) are sufficient to degrease and clean the surface. The coating process itself consists of two steps: (1) a chemical step which produces a barrier film coating which acts as an interface with the metal alloy and prepares the surface for the second step and (2) an electrodeposition step in which the magnesium alloy component is the anode in an electrolytic cell.

The first step (Fluoride Activator) is a simple chemical process in which the magnesium alloy is immersed into a heated solution containing the fluoride ion. This solution chemically reacts with the magnesium surface to leave a layer containing a mixture of magnesium fluoride/oxofluorides and magnesium oxide which serves as a base for the second step. An added benefit of this chemical step is the removal of minor corrosion products.

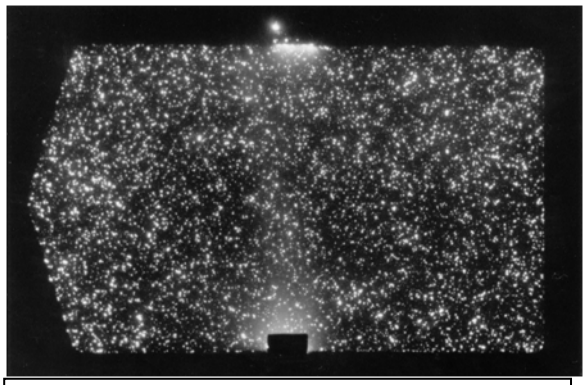


Figure 3: AZ91D magnesium panel during the Tagnite anodic spark

The second step (Tagnite 8200) is an electrochemical process in which the magnesium component is made the anode in an electrolytic cell. The electrolytic process is accomplished using a specially designed high voltage rectifier that supplies a combination AC/DC signal to the electrochemical cell. As in other anodization processes, the magnesium alloy is the anode while the stainless coating tank serves as the cathode. The electrolytic process involves the concurrent anodization or oxidation of the metal substrate and deposition of inorganic species from the silicate-containing electrolyte. As a result of the relatively high voltages, greater than 150V, a spark process develops during the deposition as seen in Figure 3.

2.1 Refine chemical stripping procedure used at TAG to remove legacy anodize coatings

Rationale of Testing: TAG has an internal procedure in place to remove the Tagnite coating from aerospace parts using our existing pretreatment baths, the mild alkaline etch and the fluoride activator. By varying the soak time in each tank and alternating between these pretreatment tanks, TAG has developed a means of chemical stripping the Tagnite coating. This procedure was used on the DOW 17 legacy anodize coating with some success, however, this procedure had little impact on the HAE legacy coating. The goal was to modify the current Tagnite chemical stripping process so that DOW 17 and HAE can be removed as well.

Testing: Magnesium test coupons made from the four major aerospace alloys, ZE41A-T5, EV31A-T6, AZ91E-T6 and QE22A-T6, were coated with the DOW 17 and HAE anodize coatings. These coated test coupons were put through the TAG chemical stripping process. Soak time in the mild alkaline etch and fluoride activator were varied. Progress was monitored based on visual observation of the integrity of the legacy coatings and the ability to remove the legacy coatings with minimal mechanical means such as pressure washing or Scotch Bright pads.

In the case of difficult residual coatings, a brief 1 – 3 minutes anodization in the Tagnite bath after the initial chemical strip was used in an attempt to undermine and loosen any residual legacy coatings. After this brief anodization step, the chemical stripping process was repeated until a satisfactory bare magnesium surface has been reached.

The success of the chemical stripping process was determined by the ability to apply an Immersion Tagnite coating to test coupons that have been stripped of legacy inorganic coatings. These Tagnite coated test coupons will undergo the standard Quality Control (QC) evaluation for Tagnite coatings, including visual inspection of coating, thickness, electrical continuity, salt fog corrosion and wear resistance to verify these Tagnite coatings meet all the QC specifications.

2.2 Techniques to eliminate residual fluid leakage from porous magnesium aerospace alloys

Rationale for Testing: Past experience at TAG has shown that new and legacy castings made from AZ91C or AZ91E can weep residual fluids after the Tagnite process when subjected to temperatures used to cure Rockhard. These residual fluids do not weep out during the Tagnite processing steps when Tagnite operators perform their water break free testing. The residual fluid will only weep out of the casting during the initial Rockhard part preheat phase (335 – 365°F for 15 -30 minutes) and as a result, stain the Tagnite coating. Removal of the staining requires time consuming wipe downs of the Tagnite coating with solvents.

Testing: Magnesium coupons from the porous AZ91 magnesium alloys will be soaked in various fluids such as transmission, hydraulic and lubricating oils. These test coupons will be subjected to vapor degreasing, pressure washing and/or alkaline degreasers along with various heating cycles to determine the best way to remove any residual fluid. Success will be based on the appearance of the Tagnite coated test panels after being subjected to a Rockhard preheat cycle.

Initial trials will start with aviation hydraulic fluid (MIL-PRF-83282) and lubricating oil (DOD-PRF-85734). During these trials, the test coupons will be put into containers and put through several days of cyclic heating and cooling. The test protocol for hydraulic fluid will be 8 hours of immersion at 150 ±10°F (66 ±5°C), followed by cool down for 16 hours. This cycle will be repeated for 4 days. After the 4th cycle, the panels will be removed and go through the normal Immersion Tagnite pretreatment. At the end of the Tagnite pretreatment, the coupons will be heated to 365±10°F (185±5°C) for 30 minutes which is the part preheat cycle for Rockhard. Upon removal from the oven, the panels will be wiped with paper towels or cotton gloves, looking for the presence of residual fluid on the towels. If fluid is observed, the heating cycle at 365±10°F (185±5°C) for 30 minutes will be repeated until no residual fluid is noted.

The same testing will take place with lubricating oil (DOD-PRF-85734) repeating the same four cycles of heating and cooling, except the lubricating oil heat cycle will be done at 250±10°F (121±5°C).

If there is noticeable residual fluid after the initial Tagnite pretreatment and Rockhard preheat cycle at 365±10°F (185±5°C) for 30 minutes, alternate cleaning methods such as vapor

degreasing or pressure washing will be explored. The objective is to find a cleaning protocol that removes all residual fluids prior to the Immersion Tagnite step.

2.3 Dimensional change to magnesium surfaces due to stripping of legacy coatings.
Rationale for Testing: TAG plans on using a mild alkaline etch to remove legacy coatings and it is a part of the normal Tagnite pretreatment process. This mild alkaline etch is known to remove metal at a rate of 0.0001" per 3 minutes of soak time. In addition, the application of a Tagnite coating will cause a dimensional change as about 50% of the Tagnite coating will penetrate into the base metal. Therefore, dimensional and weight loss information needs to be collected to quantify the effect the TAG stripping procedure and Tagnite reanodization on legacy parts.

Testing: A detailed test matrix is summarized in Table 2. Test coupons from each of the four aerospace alloys will be divided into groups and treated as stated below. This test matrix will collect data on the current stripping and coating processes of legacy parts and proposed methods going forward. Before and after each process step, each test coupon will be weighed on an analytical balance to $\pm$ 0.0001 grams and dimensions will be measured in at least 2 locations for each dimension using a micrometer. An example panel is shown in Figure 4.

Control Group: No treatment - used to determine variability in weight and dimensions over time due to changing environmental factors.

"Current" Group: This will simulate the current stripping and recoating process at CCAD. Test coupons will be HAE, DOW 17 and Tagnite anodized then:

1. Stripped via the current chromic acid procedure at the CCAD plating shop followed by
2. Submersion in the currently used DOW 7 conversion coating then
3. Stripped a second time using the chromic acid method.

"Future 1": This would be one potential stripping scenario seen at the depot level. Test coupons will be HAE, DOW 17 and Tagnite anodized then:

1. Stripped via the current chromic acid procedure at the CCAD plating shop followed by
2. Tagnite anodization and subsequently
3. Stripped by chromic acid again.

"Future 2": This would be preferred procedure going forward. Test coupons will be HAE, DOW 17 and Tagnite anodized then:

1. Stripped via the TAG chemical strip procedure developed in 2.1 followed by
2. Tagnite anodization and
3. Re-stripping by TAG chemical method.

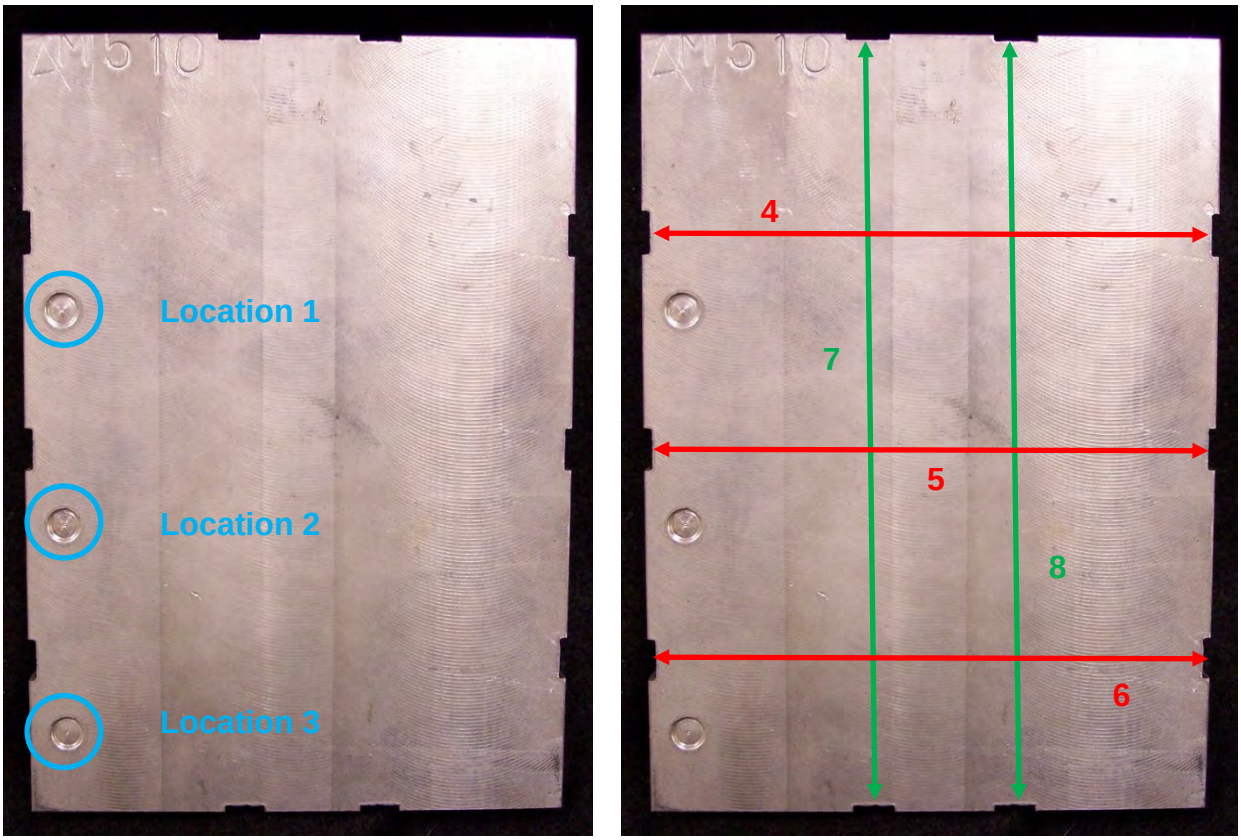


Figure 4: Location of Micrometer Measuring Locations on Dimensional Loss Panels

Table 2: Dimensional Change Test Description for Chemical Stripping of Legacy Coatings.

Treatment Group	**Experimental Control**				**Current Depot Process**				**Future Process #1**				**Future Process #2**			
Magnesium Alloy	AZ91E-T6	EV31A-T6	QE22A-T5	ZE41-T5	AZ91E-T6	EV31A-T6	QE22A-T5	ZE41-T5	AZ91E-T6	EV31A-T6	QE22A-T5	ZE41-T5	AZ91E-T6	EV31A-T6	QE22A-T5	ZE41-T5
# of Coupons	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Initial Anodize Coating	None				DOW 17 HAE Tagnite				DOW 17 HAE Tagnite				DOW 17 HAE Tagnite			
Initial Stripping Process	None				Chromic Acid				Chromic Acid				TAG Chemical Strip			
Second Coating Process	None				DOW 7				Tagnite				Tagnite			
Second Stripping Process	None				Chromic Acid				Chromic Acid				TAG Chemical Strip			
Acceptance Requirement	Dimensional Loss cannot exceed airworthiness requirements															

2.4 Effectiveness of MIL-DTL-83936 Paint Stripper on Legacy Coatings

Rationale for Testing: : During a previous trip to the CCAD facility, TAG personnel presented the engine cleaning shop with some test coupons coated with Tagnite + 3 coats of Rockhard sealant and additional test coupons with Tagnite + MIL-PRF-23377 primer. The test coupons were used to test the effectiveness of the paint stripper (Aerostrip 5182) in use at that time in the CCAD engine shop. The test coupons were run through the stripping process and returned to TAG. Visual inspection of the panels at TAG revealed that the top layers of Rockhard and MIL-PRF-23377 primer were gone, however, there appeared to be Rockhard and Primer embedded in the Tagnite pores. TAG personnel used their current Tagnite chemical strip method and attempted to strip the Tagnite off. Initial attempts were unsuccessful at removing the paint embedded Tagnite coating. With extreme efforts, TAG was able to remove the Tagnite embedded with Rockhard. This raises the questions:

1) Do the HAE and DOW 17 legacy anodize coatings absorb paint into their pores similar to Tagnite?

2) How easily can the embedded paint and anodized coatings can be stripped?

Since this site visit, a new paint stripping chemical is being used at CCAD and this product's effectiveness needs to be evaluated for this project.

Testing: Magnesium test coupons will be coated with the currently used anodized coatings, HAE, DOW 17 and Tagnite. The test coupons will then receive the sealant, primer and top coat combinations currently being used on the AH-64 and UH-60 platforms. The organic coatings are as follows:

Sealant: High Temperature Rockhard Stoving Enamel, P/N 576-450-002

Primer for AH-64: MIL-PRF-23377

Primer for UH-60: MIL-PRF-85582

Top Coat for AH-64: MIL-DTL-53039

Top Coat for UH-60: MIL-C-46168

Table 3 summarizes the anodize coating and paint combinations to be tested. The painted coupons will be stripped in the MIL-DTL-83936 stripper currently being used at CCAD. After paint stripping, the anodized coatings will be stripped in the chemical stripping process developed in 3.2.1.

Table 3: Paint Scheme to Test Effectiveness of MIL-DTL-83936 Paint Stripper on Legacy Coatings

Magnesium Alloy	ZE41A-T6	ZE41A-T6	ZE41A-T6
Panel Pretreatment	HAE	DOW 17	Tagnite
# of Coupons per Pretreatment	15	15	15
Paint Scheme #1	3 Coats of HT Rockhard	3 Coats of HT Rockhard	3 Coats of HT Rockhard
Paint Scheme #2	1 Coat of MIL-PRF-23377	1 Coat of MIL-PRF-23377	1 Coat of MIL-PRF-23377
Paint Scheme #3	3 Coats of HT Rockhard + MIL-PRF-85582	3 Coats of HT Rockhard + MIL-PRF-85582	3 Coats of HT Rockhard + MIL-PRF-85582
Paint Scheme #4	3 Coats of HT Rockhard + MIL-PRF-85582+ MIL-C-46168	3 Coats of HT Rockhard + MIL-PRF-85582+ Sikorsky Top Coat	3 Coats of HT Rockhard + MIL-PRF-85582+ Sikorsky Top Coat
Paint Scheme #5	3 Coats of HT Rockhard + MIL-PRF-23377 + MIL-DTL-53039 Apache Top Coat	3 Coats of HT Rockhard + MIL-PRF-23377 + MIL-DTL-53039 Apache Top Coat	3 Coats of HT Rockhard + MIL-PRF-23377 + MIL-DTL-53039 Apache Top Coat
# of Coupons per Paint Scheme	3	3	3
Acceptance Criteria	MIL-DTL-83936 will remove organic coatings in a manner that allows TAG chemical stripper to remove legacy anodize coatings. If this process is unacceptable, alternate methods will be investigated.		

2.5 Effect of TAG Chemical Stripping Process on Cad Plated Fasteners
Rationale for Testing: The proposed TAG chemical strip process needs to be properly evaluated on Cad plated studs. There were some casual observations during previous research that the TAG chemical strip process may have an effect on Cad plated materials. A more methodical approach is needed to gather the appropriate data to make a definite decision on the impact of the TAG chemical strip process on Cad plated materials.

Testing: Cad plated studs will be subjected to the TAG stripping process at maximum temperatures and chemical concentrations. Soak times will be twice the time necessary to strip anodic coatings. After immersion in the stripping solution, visual comparison of plating color will be made between a new fastener and a fastener after the stripping process. Any changes in fastener color will be an indication of loss of Cad plating. Samples of the stripping bath will be analyzed after use for cadmium content and quantity.

Acceptance Criteria: If the TAG stripping process is found to remove Cad plating, Tagnite processing instructions for legacy magnesium aviation components must state that Cad plated fasteners will be masked off prior to the stripping process and Tagnite anodization.

2.6 Effect of TAG Chemical Stripping Process on Hydrogen Embrittlement of Steel
Rationale for Testing: The proposed TAG chemical strip process needs to be properly evaluated for any potential impact from hydrogen embrittlement of Cad plated studs and other types of steel inserts. The TAG chemical stripping process will need to be a new process for implementation at CCAD and hydrogen embrittlement testing is routine for all processes that could potential affect the steel inserts on a magnesium aerospace component.

The Hydrogen Embrittlement Test (ASTM F 519) is designed to test the degree to which steel becomes brittle and fractured following exposure to hydrogen. Specifically, this test will examine the effect TAG production chemicals and processing will have on steel samples.

The test specimens are steel c-rings with notches for load testing. Each trial will consist of four bare steel rings and four cadmium plated steel rings. The first trial will expose the test specimens to the chemical stripping process at maximum temperature and maximum concentration for twice the production time. The samples are then stress tested for embrittlement. The load placed on the samples is 75% of the notch fracture strength (NFS). The samples are stressed by the load for 200 hours. After 200 hours, the specimens are examined for fractures. If two or more specimens have fractured in each of the 4-ring groups, hydrogen embrittlement is indicated. If only one specimen or no specimens have fractured, hydrogen embrittlement is ruled out.

The second trial repeats the above process with pre-stressed rings. The rings are first pre-stressed at 75% of the NFS. The rings are exposed to the same simulated stripping process as stated above and stress tested with the same 75% load. The criteria for failure and success are the same as indicated above.

Testing: The TAG chemical stripping process shall be evaluated using Type 1d notched C rings per ASTM F519-13, Reference 1c. As stated in Reference 1c paragraph 11.2, a minimum of 4

rings each shall be tested for both the bare and cadmium plated treatments. These rings shall be subjected to the stripping process solutions at maximum temperatures and concentrations allowed by the TAG chemical stripping process specification. Additionally, times in each solution evaluated shall be 2x that allowed by the TAG stripping process specification. Prior to testing the C ring lot will be validated by taking 10 bare specimens and 10 cad plating specimens that are stressed @ 75% of the notch fracture strength (NFS) and observing for 200 hours at ambient conditions. If the batch testing has are no failures after 200 hours, these specimens are to be discarded and the testing in the stripping solution can proceed as described in Table 4.

Table 4: Sampling Plan and Test Conditions for Hydrogen Embrittlement Testing of the TAG Chemical Stripping Process

Specimen Condition	Bare	Bare	Cad Plated	Cad Plated
# of Specimens under No Preload Conditions	4		4	
# of Specimens under Preload to 75% NFS Conditions		4		4
# of Specimens for TAG Chemical Strip @ Max Temp - Max Concentration and 2X Soak Time	All	All	All	All
# of Specimens for Post Exposure Stress 200 hrs @ 75% NFS	All	All	All	All
Pass/Fail Criteria	See Section 11 of ASTM F519			

Acceptance Criteria: If the TAG stripping process is found to cause hydrogen embrittlement, Tagnite processing instructions for legacy magnesium aviation components must state dissimilar metals must be masked off prior to stripping process and Tagnite anodization.

3.0 TEST PANEL PREPARATION FOR LEGACY COATING STUDY

3.1 Magnesium Test Panels

a. AZ91C, EV31A, QE22A and ZE41A Test Blocks were purchased from Magnesium Alloy Products, Compton, CA. All test blocks for each alloy were from the same melt number. (Certificate of Conformance: Appendix A).
b. All Magnesium Test Blocks were machined into 4" x 6" x 0.2" test coupons by Northern Valley Machine, East Grand Forks, MN.
c. Panel IDs stamped into test coupons by Technology Application Group

3.2 Mil Spec Primer Source: All test panels were sprayed with the same lot number of MIL-PRF-23377K, Ty 1, CL N non-chromated primer at New England Custom Coaters, Inc. (NECCI), Agawam, MA

3.3 Rockhard Sealant Source: Test panels needing Rockhard Sealant were sprayed at Technology Applications Group, Grand Forks, ND using Rockhard Clear Stoving Enamel 576-450-002. If needed the Rockhard Stoving Enamel was diluted using Rockhard Resin Thinner 665-550-025.

3.4 Notched "C" rings Source: For hydrogen embrittlement testing were purchased from Green Specialty Services, Ft. Worth, TX and made per ASTM F519 as 1D C Rings.

3.5 DOW 17 Anodize Coating Source: The DOW 17 coating was applied to magnesium test coupons by PTI, Enfield, CT per MIL-M-45202, Type I, Class C.

3.6 HAE Anodize Coating Source: The HAE coating was applied to magnesium test coupons by Barry Avenue Plating, Los Angeles, CA per MIL-M-45202, Type I, Class A.

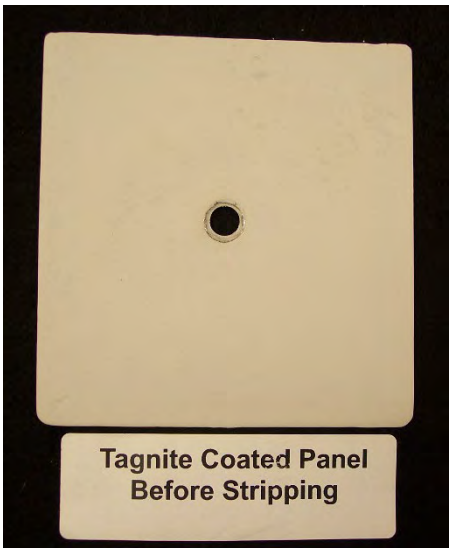
4.0 EFFECT OF TAGNITE CHEMICAL STRIPPING PROCESS ON LEGACY ANODIZE COATINGS

4.1 Explanation of Tagnite Chemical Stripping Process

Through the years, scientists at Technology Applications Group have developed a procedure for removing the Tagnite coating using the Tagnite pretreatment process to loosen and/or dissolve the Tagnite coating. This process also allows TAG operators to remove Tagnite that was damaged or improperly applied without any adverse effect on the surface finish or dimensional tolerances of the original casting. Once this process has been completed, the parts can be placed in the Tagnite anodize bath and a new Tagnite coating applied.

The Tagnite chemical stripping process involves two steps:

1. The component that needs to have the Tagnite removed is first placed in the mild alkaline etch solution. The mild alkaline etch is a mixture of sodium borate and sodium pyrophosphate operated at 160 – 180°F. The process allows for a slow, easily controlled etch process. The component to be stripped is placed in the etch tank for 5 – 15 minutes. The amount of time is dependent on the alloy and the Tagnite thickness. During a typical strip cycle, the Tagnite operator will check on the component every few minutes while in the etch tank. The component will be removed when there is evidence of darkening of the Tagnite along the edges of the component as seen in Figure 5 (Upper Right). At this point, the component is given a quick (< 1 minute) water rinse then transferred to the Fluoride Activator tank.
2. The fluoride activator solution is a fluoride based solution operated at 160 – 180°F. The purpose of the solution during the stripping process is to dissolve the magnesium oxide layer next to the base metal which softens the coating making it easier to remove. This process can take 1 – 2 hours with the operator checking at frequent intervals for lifting of the coating or a clumpy appearance. If the operator can remove the coating with a gentle wipe from a Scotch Brite non-abrasive pad, then the stripping process is complete (Figure 5 – Lower Right). At this point in time, the component can now be recoated with Tagnite.



Above Left: Test Coupon with Tagnite 8200
Above Right: Test Coupon after 8 minutes in Alkaline Etch. Note darken areas around the edges where Tagnite has been removed.

Below Left: Test Coupon after 1 hour soak in Fluoride Activator. Tagnite appearance is spotty with bare metal present

Below Right: Test Coupon after soak in Fluoride Activator and light scrubbing with Scotch Brite pad on right side. Bare metal is now present.

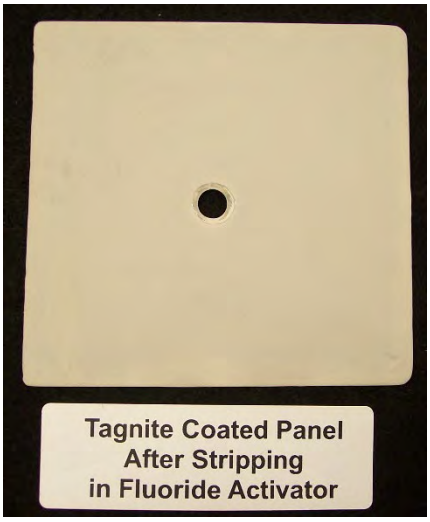


Figure 5: Visual Summary of Tagnite Stripping Process

4.2 Effect of Tagnite Chemical Stripping Process on the DOW 17 and HAE Legacy Anodize Coatings

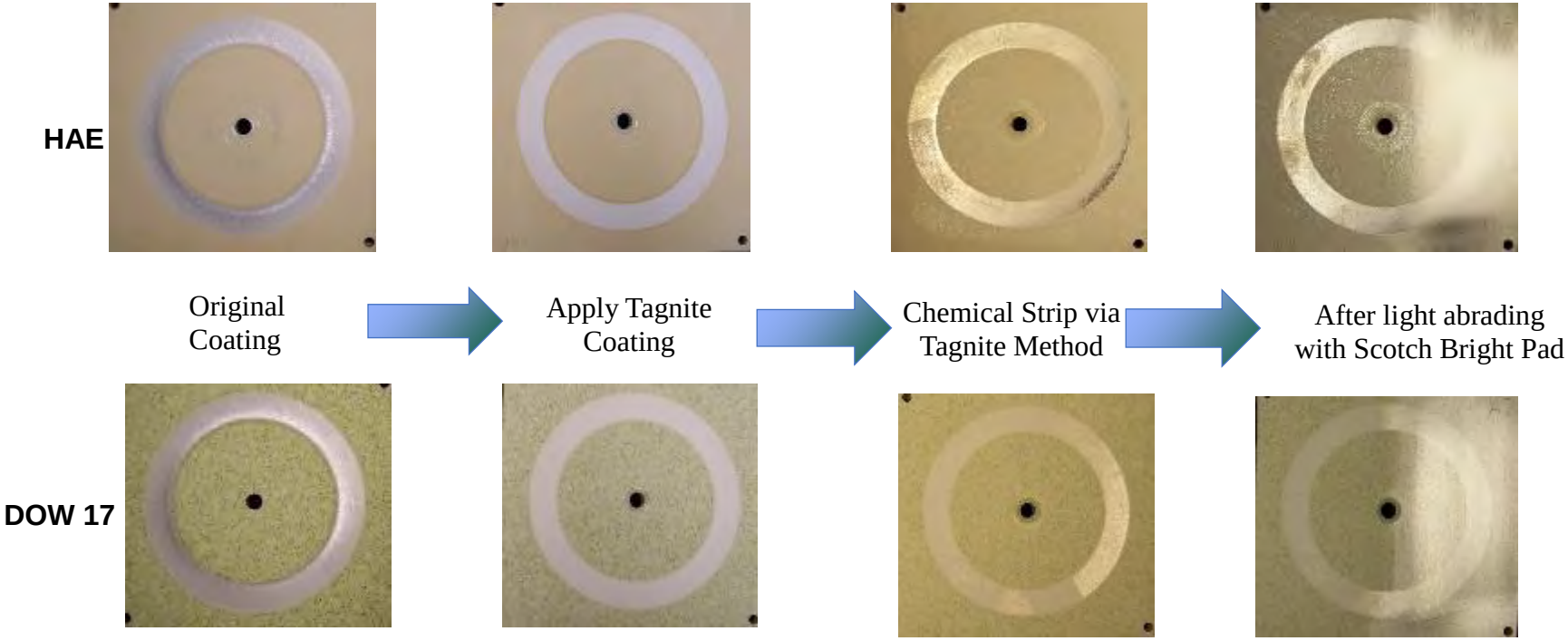
Magnesium test panels that were coated with the DOW 17 and HAE anodize coatings were put through the Tagnite stripping process described in Section 4.1. Visual examination and scratch testing of the panels showed that neither of the legacy anodize coatings was affected by the Tagnite chemical stripping process. There was no evidence of softening or lifting of the coating. Attempts to remove the legacy coatings with Scotch Brite pads or aluminum oxide sandpaper were unsuccessful.

At this point in time, TAG scientists decided to use a different approach. It is a proven fact that the DOW 17 and HAE coatings are extremely porous compared to the Tagnite coating. The pores in these legacy coatings are much larger than the pores seen in the Tagnite coating. In addition, these pores channel down and have direct contact with the base metal. The porosity of the Tagnite coating does not allow direct access to the base metal. TAG personnel theorized that we could take advantage of the large pores of the legacy coatings by applying the Tagnite coating while the legacy coatings were in place. The working theory was the high deposition voltages/currents of the Tagnite process would drive the Tagnite solution through the pores down to the base metal and allow a Tagnite coating to build up from the magnesium and lift up the legacy coatings. After this step, the Tagnite chemical stripping process could be used to soften and lift the Tagnite coating next to the magnesium surface and undermine the legacy coatings.

This theory was tested with a series of experiments on some test coupons coated with the DOW 17 or HAE legacy anodize coatings. Prior to applying the initial Tagnite coating, the DOW 17 and HAE panels were placed on a Taber Abraser machine and a track was wore into the coating until only bare magnesium was present in the track. This track would allow us to see the Tagnite deposition and stripping progress. Examples of this process on the HAE and DOW 17 coatings are seen in Figure 6. This approach was somewhat successful in removing the legacy coatings. There was only limited success because of the need to use non-abrasive pads to finish the legacy coating removal process.

Conclusions:

1. The Tagnite chemical stripping process was not successful in removing the legacy HAE and DOW 17 coatings.
2. Incorporating a Tagnite deposition step prior to the chemical stripping process met with more success, however, extra steps were needed to remove the residual legacy coatings.
3. After talking with CCAD engineers and production personnel, the consensus was that the Tagnite deposition/chemical stripping process/non-abrasive pad process was too labor intensive and involved too many processing steps. The decision was made to investigate other means of removing the legacy coatings.



Process Steps for Alternate Chemical Stripping Approach:

Use Taber Abraser machine to remove legacy coatings and expose a track of bare magnesium.
Process HAE/DOW 17 coated panels through Tagnite pretreatment process
Apply thin coating (0.16 - 0.20 mils) of Tagnite. Note gray Tagnite in taber track and slightly gray appearance on DOW 17 and HAE coated areas where Tagnite filled in the pores
Strip using Tagnite chemical stripping process. Stripping of Tagnite in the taber track is clearly visible.
Light sanding with Scotch Bright pad removed most of legacy coating.

Figure 6: Effect of Tagnite Chemical Stripping Process on Legacy Coatings

5.0 TECHNIQUES TO ELMINIATE RESIDUAL FLUID LEAKAGE FROM POROUS AEROSPACE ALLOYS

Original Testing Protocol: This JTP task called out the use of AZ91 magnesium test coupons that were soaked in various rotary wing fluids such as transmission, hydraulic and lubricating oils. TAG scientists soaked the AZ91 coupons in these fluids as called out in Section 2.2, however, when processed through the Tagnite pretreatment tanks, no residual fluids were observed after the high temperature Rockhard preheat phase. There are several reasons for the lack of weeping residual fluid from the magnesium test coupons.

1. The panels were not soaked long enough in the fluid.
2. The fluid must be at operating temperature for significantly longer periods then used on the test panel before any significant adsorption into the porosity of the magnesium occurs.

This approach was discontinued due to a lack of time for prolonged soak periods and the fact that TAG was not equipped to process these coupons at the operating temperatures of the fluids. Therefore, the focus of the study shifted from test coupons to scrap parts.

Revised Test Protocol: A variety of helicopter scrap parts made from the AZ91 magnesium alloy family were obtained from AMRDEC SAFR facility. These parts were run through several typical degreasing procedures and studied for residual fluid weeping. The degreasing procedures used were vapor degreasing, pressure washing and alkaline degreasers. TAG's experience has shown that baking the parts at the Rockhard preheat temperature range of 335 – 365°F for 15 – 30 minutes was the best way to force any residual fluids trapped in the porosity of the magnesium component to the surface.

The test protocol was to treat these scrap housings using the magnesium degreasing protocols listed above, then place the components in a curing oven at 365°F for 30 minutes. Once the component has cooled to room temperature, cotton gloves were wiped over the surface and inspected for residual fluids.

Vapor Degreasing Results: The vapor degreasing was done at the CCAD plating shop using their standard vapor degreaser for 15 minute cycles. In a limited number of tests, after one vapor degreasing cycle there was no residual fluid seen after the high temperature drying.

Pressure Washing Results: Parts were pressure washed at 1000 psi using a commercially available pressure washer with a 25° high pressure nozzle for 3 – 5 minutes while adding some Oakite NST degreasing concentrate to the soap container. This process was the least effective as residual fluid was observed even after 3 pressure washer/365°F drying cycles.

Alkaline Degreasing Results: For this test, the TAG degreaser used as the first step in the Tagnite pretreatment process was tested. The TAG degreaser consists of a 10 – 12 % solution of Oakite NST Aluminum Cleaner with the pH adjusted to 10.3 – 12.0 using 50 % sodium hydroxide. Each scrap part was soaked in the TAG degreaser for 20 minutes at 50 – 60°C, rinsed

for 5 minutes in RO water and placed in the curing oven. About 50 % of the time, there was no residual fluid on the surface of the part after the first 365°F drying cycle. The other half of the time the parts needed at least one additional 20 minute soak in the TAG degreaser to completely remove the residual fluid.

Residual Fluid Conclusions: These conclusions are based on a limited amount of scrap parts and additional testing is recommended.

1. Vapor degreasing appeared to remove the greatest amount of residual fluid based on the lack of weeping residual fluid at the end of the initial vapor degreasing/high temperature drying protocol.
2. Alkaline Immersion Degreasing was the second best option at removing residual fluids, however, a significant number of parts needed a second degreasing cycle before all the residual fluid was removed.
3. Pressure washing had no effect on residual fluid removal and is only recommended for the removal of heavy oil or grease on the surface of the part.

Recommended Method for Removal of Weeping Residual Fluid after Tagnite: There will be times regardless of how aggressively the part has been degreased when weeping residual fluid will be found in the Tagnite coating after the initial Rockhard preheating step (typically this step is 335 - 365°F for 15 – 30 minutes after part reaches temperature). The weeping fluid will darken or discolor the Tagnite coating – it will look like an oil stain. TAG has developed a procedure to remove the residual fluid from the Tagnite without having to strip the Tagnite coating. The procedure is:

1. If fluid stain is noticed immediately after being taken out of the oven, allow the part to cool down to $\leq$ 120°C. Continue to Step 3.
2. If the fluid stain is not noticed until the part is at room temperature, preheat part to 335 – 365°F for 15 – 30 minutes then allow part to cool down to $\leq$120°F. Proceed to Step 3.
3. Saturate a lint-free cloth with acetone and wipe the stained area. Only wipe the area once than fold the cloth to expose clean cloth for the next wipe. It is very important that you continually fold the cloth and do not use any cloth that has absorbed the oil as it will be easily transferred to a new area.
4. After the stained area has been cleaned to the point where the stained Tagnite looks like the “normal” Tagnite, place the part back in the oven for another 335 – 365°F preheat cycle of 15 – 30 minutes.
5. Allow to cool down, inspect the part and, if necessary, repeat the acetone wipe and the preheat cycle until no more residual fluid is seen on the Tagnite surface.
6. Part is now ready for Rockhard application per the appropriate specification.

6.0 DIMENSIONAL AND WEIGHT CHANGE DUE TO STRIPPING OF LEGACY COATINGS

6.1 Dimensional Change

Original Testing Protocol: A detailed test matrix is summarized in Table 5. Test coupons from each of the four aerospace alloys were to be treated as below. This test matrix would collect data on the current stripping and coating processes of legacy parts and proposed methods going forward. Before and after each process step, each test coupon would be weighed on an analytical balance to $\pm$ 0.0001 grams and dimensions would be measured in at least 2 locations for each dimension using a micrometer. An example panel is shown in Figure 7.

Control Group: No treatment - used to determine variability in weight and dimensions over time and changing environmental factors.

"Current" Group: This will stimulate the current stripping and recoating process at CCAD. Test coupons will be HAE, DOW 17 and Tagnite anodize coatings which are coatings put on the original, new build casting, then:

1. Stripped via the current chromic acid procedure at the CCAD plating shop followed by
2. Submersion in the currently used DOW 7 conversion coating then
3. Stripped a second time using the chromic acid method.

"Future 1": This would be one potential stripping scenario seen at the depot level. Test coupons will be HAE, DOW 17 and Tagnite anodize coatings on the magnesium coupons then:

1. Stripped via the current chromic acid procedure at the CCAD plating shop followed by
2. Tagnite anodization and subsequently
3. Stripped by chromic acid again.

"Future 2": This would be preferred procedure going forward. Test coupons will be HAE, DOW 17 and Tagnite anodize coatings on the magnesium coupons, then:

1. Stripped via the TAG chemical strip procedure developed in 4.1 followed by
2. Tagnite anodization and
3. Re-stripping by TAG chemical method.

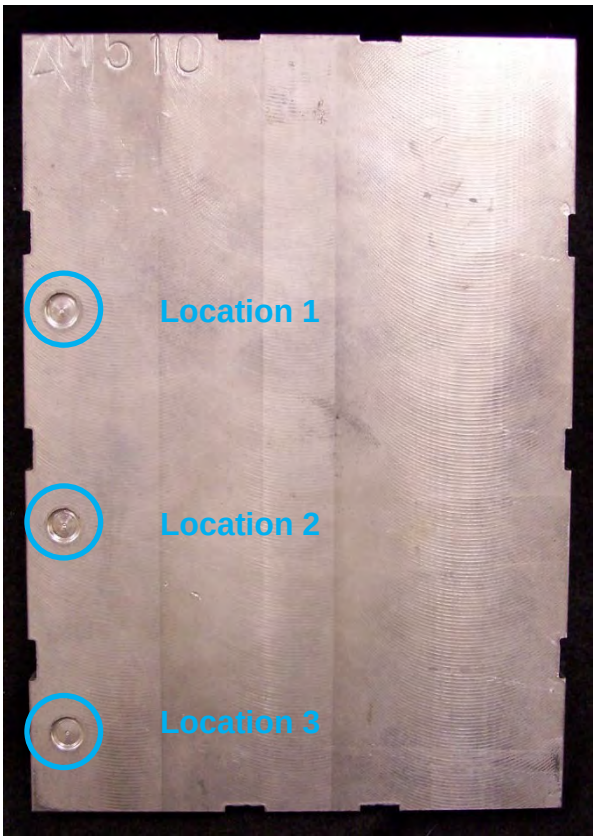


Figure 7: Location of Micrometer Measuring Locations on Dimensional Loss Panels

Table 5: Original Dimensional Change Test Description for Chemical Stripping of Legacy Coatings.

Treatment Group	**Experimental Control**				**Current Depot Process**				**Future Process #1**				**Future Process #2**			
Magnesium Alloy	AZ91E-T6	EV31A-T6	QE22A-T5	ZE41-T5	AZ91E-T6	EV31A-T6	QE22A-T5	ZE41-T5	AZ91E-T6	EV31A-T6	QE22A-T5	ZE41-T5	AZ91E-T6	EV31A-T6	QE22A-T5	ZE41-T5
# of Coupons	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Initial Anodize Coating	None				DOW 17 HAE Tagnite				DOW 17 HAE Tagnite				DOW 17 HAE Tagnite			
Initial Stripping Process	None				Chromic Acid				Chromic Acid				TAG Chemical Strip			
Second Coating Process	None				DOW 7				Tagnite				Tagnite			
Second Stripping Process	None				Chromic Acid				Chromic Acid				TAG Chemical Strip			
Acceptance Requirement	Dimensional Loss cannot exceed airworthiness requirements															

Revised Test Protocol: As this project progressed, the rational behind the dimensional change protocol changed. The "Current" Group testing process was eliminated because the DOW 7 conversion coating tank is being phased out. The "Future 2" testing process was eliminated due to the failure of Tagnite stripper to remove the HAE and DOW 17 anodize coatings. As a consequence, the project group was left with a modified version of the "Future 1" testing process. The modified version is shown in Table 6.

Table 6: Modified Dimensional Change Test Matrix for Chemical Stripping of Legacy Coatings.

Treatment Group	**Experimental Control**			**Future Process #1**		
Magnesium Alloy	AZ91E-T6	EV31A-T6	ZE41-T5	AZ91E-T6	EV31A-T6	ZE41-T5
# of Coupons	3	3	3	6	6	6
Initial Anodize Coating	None			DOW 17 HAE Tagnite		
Initial Stripping Process	None			Chromic Acid		
Second Coating Process	None			Tagnite		
Acceptance Requirement	Dimensional Loss cannot exceed airworthiness requirements					

There were two items left off this modified test matrix.

1. QE22-T5 was left off the matrix because of this alloy is not present on H-60 platform.
2. The second chromic acid stripping step was eliminated due to time constraints.

Waypoints for Dimensional Change and Panel Weight Measurements: Dimensional change and panel weight measurements were collected at four different waypoints during this experiment.

1. Bare panel – no pretreatments of coating applied. Due to a technician oversight, the test coupon dimensions for the bare panels prior to the HAE anodize were not done.
2. After original anodize was applied. The anodize coatings were either HAE, DOW 17 or Tagnite.
3. After the chromic acid stripping at the CCAD plating shop.

4. After the application of Tagnite to all of the stripped panels, equivalent to re-anodization of the panel.

Dimensional Change Measuring Protocols:

1. Prior to measuring the control/test panels for dimensional change, the panels were placed in drying oven at 60°C for 20 minutes, then allowed to cool at room temperature for another 20 minutes prior to measurement.
2. The dimensional change was always measured at the location points #1, 2 and 3 (Figure 7) on every control and test coupon. Each location point was measured six (6) times.
3. The values were entered into a spreadsheet and the average dimensional change at each location was calculated.
4. If there was a dimensional change in the location average of the control panels, this change was applied to the test panel average.
5. The average dimensional and weight change was calculated for:
    a. Change between the bare panel and original anodize coating.
    b. Change between the original anodize coating and after chromic acid strip.
    c. Change between bare panel and after chromic acid strip.
    d. Change between after chromic acid strip and Tagnite re-anodization.
    e. Change between bare panel and Tagnite re-anodization.

Dimensional Change Results:

The statistical summary of the dimensional change data is seen in Appendices B – D. Figures 8 – 10 summarize the results.

1. The DOW 17 panels had a negative (loss) dimensional change after the DOW 17 coating was applied (difference between bare and anodize). This is unusual and implies that the DOW 17 pretreatment process led to some dimensional loss and that the DOW 17 coating was thinner than the Tagnite coating. Eddy current readings of the thickness showed the DOW 17 coating was < 0.2 mils (0.0002”) thick while the Tagnite coating was 0.34 mils (0.00034”) thick.
2. TAG has completed studies that show the Tagnite coating thickness consists of 50 % penetration into the magnesium and 50 % buildup. The measured Tagnite thickness was 0.34 mils (0.00034”), therefore the buildup (dimensional change) was 0.17 mils per surface or 0.34 mils overall. The dimensional change in the Tagnite thickness was in the expected range during the Bare to Original anodize Step. There is some variation in buildup which is due to the amount of time spent in the mild alkaline etch pretreatment bath. AZ91C and ZE41A test coupons went through the Tagnite process at the same time and had the same dimensional change in the Bare to Original Anodize step. The EV31A had a larger dimensional change due to less time in etch.
3. The largest dimensional change occurred after each original anodize coating was stripped off using chromic acid. This is unusual because chromic acid is not supposed to attack magnesium. However, if there is a significant contaminate level in the chromic acid, it will attack magnesium. If a second chromic acid step was done as originally proposed, the dimensional loss would have been much greater, potentially leading to failure of the dimensional tolerance limits.

4. When the panels were re-anodized with Tagnite, there was still an overall dimensional loss (Chromic Acid to After Tagnite bars) for all three original anodize groups. There was a small dimensional loss between the Chromic Acid Strip to After Tagnite step for EV31A and ZE41A which is probably due to a greater time spent in the mild alkaline etch. The AZ91C panels had a slight dimensional decrease.
5. For panels originally coated with DOW 17 and Tagnite, the overall dimensional loss for all three (3) alloy groups (Bare to After Tagnite bars) showed that the maximum dimensional loss never exceeded 1.0 mils (0.001”). For panels originally coated with DOW 17 and Tagnite, the Bare to After Tagnite readings showed an overall dimensional loss, primarily driven by the large dimensional loss after the chromic acid strip step. The overall dimensional loss was very consistent for all three alloys.

Figure 8: Graph of Dimensional Change for AZ91C over the course of Applying Fresh Anodize Coating, Stripping and Re-anodizing with Tagnite.

Figure 9: Graph of Dimensional Change for EV31A over the course of Applying Fresh Anodize Coating, Stripping and Re-anodizing with Tagnite.

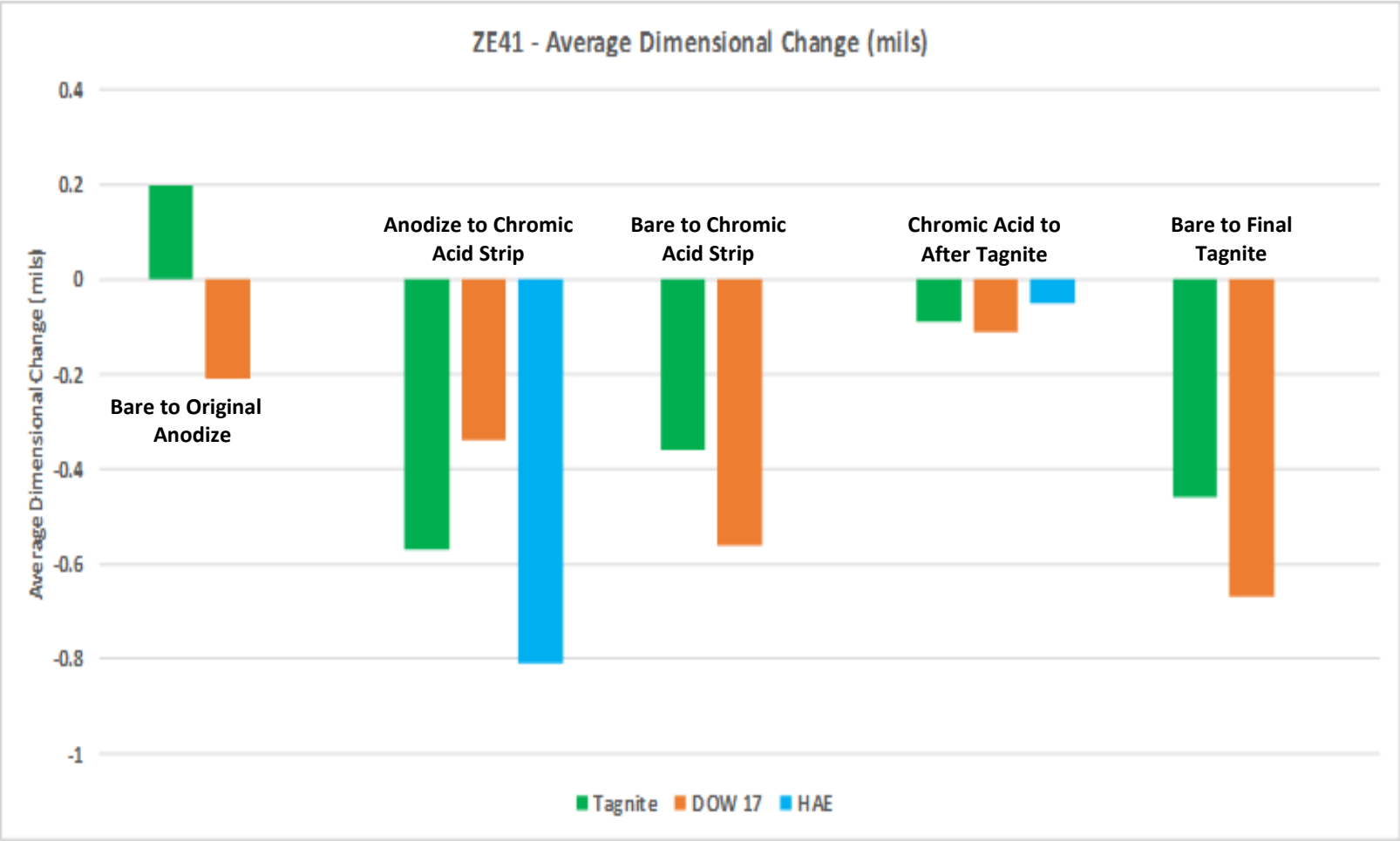


Figure 10: Graph of Dimensional Change for ZE41A over the course of Applying Fresh Anodize Coating, Stripping and Re-anodizing with Tagnite.

6.2 Weight Change Results

Weight Change Measuring Protocols:

1. Prior to weighing the control/test panels for weight change, the panels were placed in drying oven at 60°C for 20 minutes, then allowed to cool at room temperature for another 20 minutes prior to measurement.
2. If there was a weight change of the control panels, this change was used to adjust for the test panel average.
3. Due to the varying test panel weights, the weight change was normalized to the test panel weight and the weight change is expressed as "Average % Weight Change". For example, if you are looking at the Average % Weight Change for **Bare to Anodize** values on the graph, the values were calculated by:

   $$\text{Average \% Weight Change} = \frac{(\text{Anodize} - \text{Bare Panel Weight in gms}) \times 100\%}{\text{Bare Panel Weight}}$$

4. The weight values were entered into a spreadsheet and average % weight change was calculated for waypoint measurements.
   a. Change between the bare panel and original anodize coating.
   b. Change between the original anodize coating and after chromic acid strip.
   c. Change between bare panel and after chromic acid strip.
   d. Change between after chromic acid strip and Tagnite re-anodization.
   e. Change between bare panel and Tagnite re-anodization.

Weight Change Results:

The statistical summary of the weight change data is seen in Appendices B – D while Figures 11 – 13 summarize the results.

1. The greatest weight change of the original anodize coatings applied was Tagnite as seen in the Bare to Original Anodize weight change measurements. This verifies that the DOW 17 and HAE coatings were significantly thinner than the Tagnite.
2. There was little to no weight change after the HAE coating was applied which again shows that the HAE coating was thinner than the Tagnite coating.
3. The largest weight change occurred after each original anodize coating (HAE, DOW 17 and Tagnite) was stripped off using chromic acid. In theory, chromic acid should only remove the anodize coatings, leaving the magnesium alone and the panel weight should be close to the original bare panel weight. However, the Anodize to Chromic Acid Strip weight changes show a significant loss of weight. These results are significant because it shows that the chromic acid is not only removing the anodize coating but also etching the magnesium. Magnesium etching only occurs in the chromic acid when there is a significant contaminate level in the chromic acid.
4. When the panels were re-anodized with Tagnite, weight gain was very constant (Chromic Acid to After Tagnite bars) for all three original anodize groups and all alloys showing that Tagnite is a very controllable process.
5. The overall weight loss (Bare to After Tagnite bars) was highest for the panels originally coated with HAE. The panels that started with Tagnite, stripped and

recoated with Tagnite had very consistent weight losses and the EV31A and AZ91C alloys had the lowest weight gain loss.

Overall Dimensional and Weight Loss Conclusions:

1. The test panels that were originally coated with Tagnite, stripped and recoated with Tagnite behaved a very consistent manner in terms of dimensional loss and weight loss.
2. The dimensional loss for the panels that were originally coated with Tagnite, stripped and recoated with Tagnite was the least of the test group. This implies that stripping and recoating with Tagnite can be done in a consistent and predictable manner.
3. Dimensional loss for all the test panel groups did not exceed 1.0 mils (0.0001”) from start (bare) to finish (After Final Tagnite).
4. The chromic acid strip had a big impact on the dimensional and weight loss data. The data shows that the chromic acid attacked the magnesium surface and this only occurs when there is significant contamination of the chromic acid bath.
5. The use of the chromic acid bath will not be justified in the future as the DoD moves forward to eliminate all sources of hexavalent chromium. This dimensional and weight loss study will have to be repeated using a more environmentally friendly method of removing the legacy anodize coatings.

Figure 11: Graph of Panel Weight Change for AZ91C over the course of Applying Fresh Anodize Coating, Stripping and Re-anodizing with Tagnite.

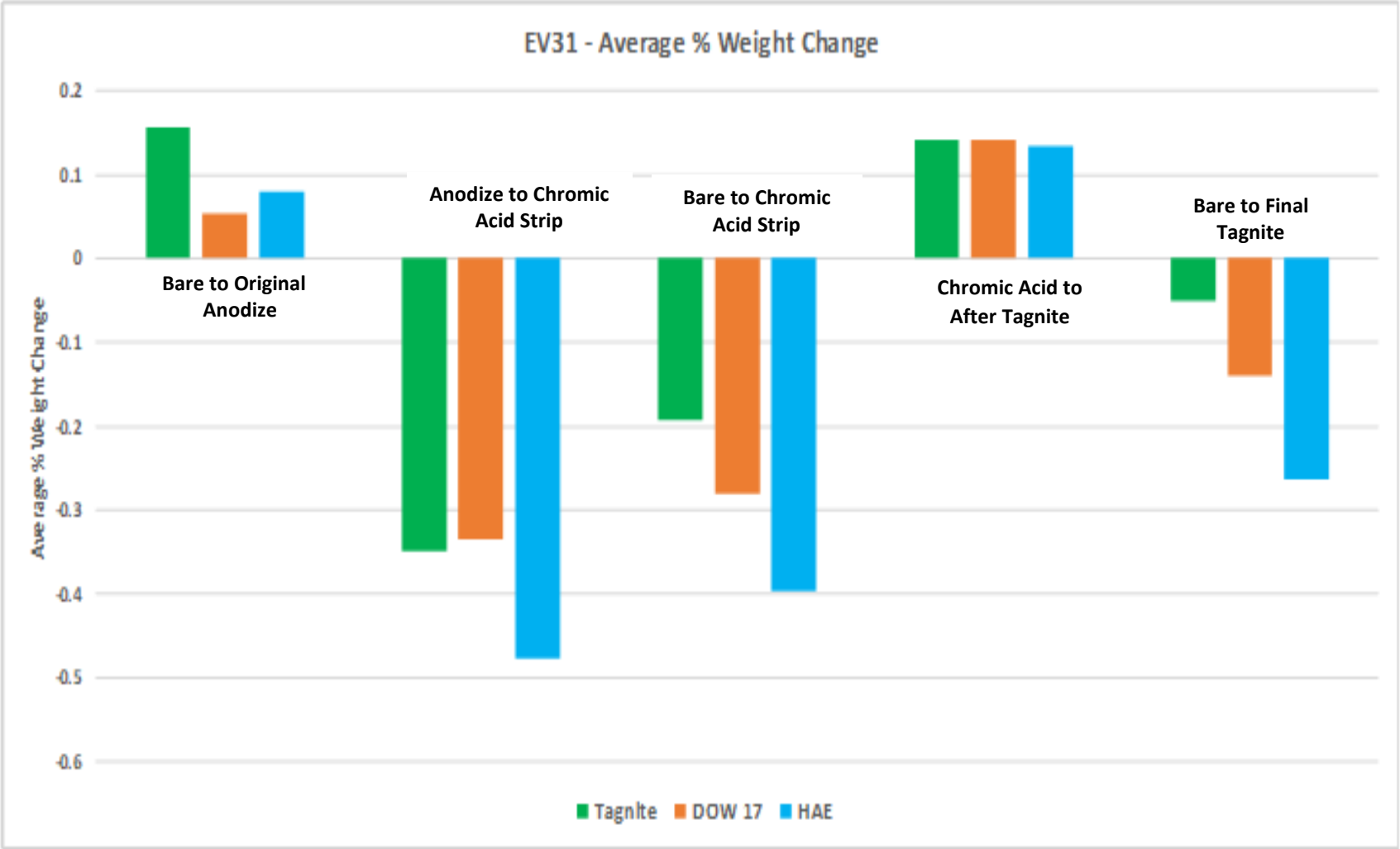


Figure 12: Graph of Panel Weight Change for EV31A over the course of Applying Fresh Anodize Coating, Stripping and Re-anodizing with Tagnite.

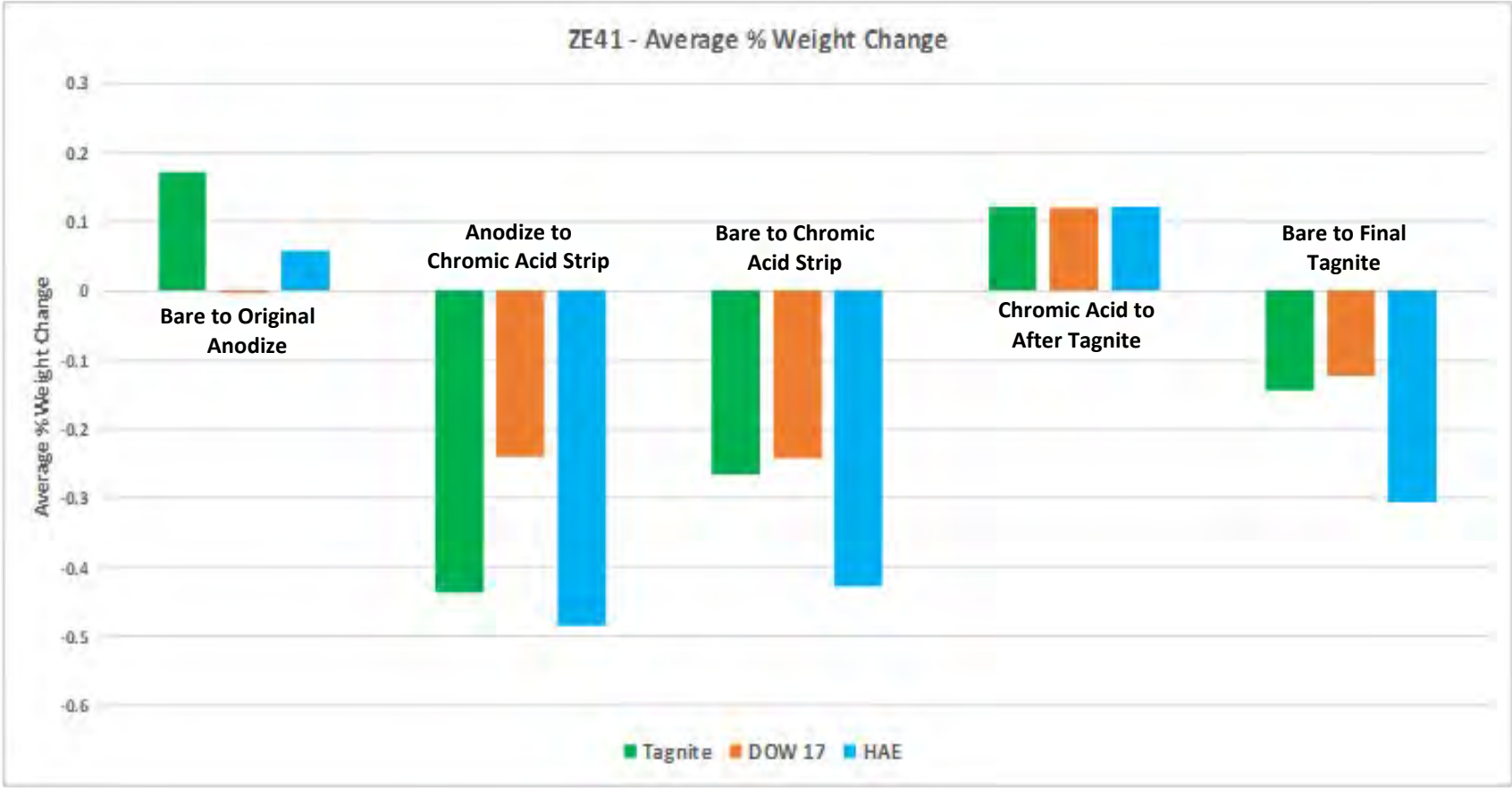


Figure 13: Graph of Panel Weight Change for ZE41A over the course of Applying Fresh Anodize Coating, Stripping and Re-anodizing with Tagnite.

7.0 EFFECTIVENESS OF MIL-DTL-83936 PAINT STRIPPER ON LEGACY ANODIZE COATINGS

Results of Legacy Coatings Painted with Rockhard or Primer: During some early testing, Tagnite coated test panels painted with Rockhard Sealant or MilSpec Primer where placed in a MIL-DTL-83936 chemical stripper at the CCAD plating shop. Inspection of the test panels after the stripping process showed that the top layers of the Rockhard or Primer had been removed. However, based on the color of the Tagnite after the chemical stripping process, Rockhard and/or Primer was still embedded in the Tagnite pores as seen in Figure 14. Attempts to remove the Tagnite using the Tagnite chemical stripper were unsuccessful which verified that residual paint was embedded in the Tagnite pores. TAG also attempted to apply more Tagnite to these panels after Tagnite chemical stripping but this approach was also unsuccessful which again verified that residual paint was embedded in the Tagnite pores.

This same experiment was done to the legacy anodize coatings, DOW 17 and HAE. Magnesium test panels coated with DOW 17 and HAE were painted in the same manner as the Tagnite panels than placed in the same paint stripper. Once the top layers of paint were removed, it was obvious that there was still paint embedded in the pores of the legacy coatings similar to the Tagnite coating after paint stripping.

TAG tested a variety of paint strippers, solvents and acids to see what impact these chemicals had on the paint embedded into the porosity of the legacy coatings. None the chemicals tested had any impact on the embedded paint. TAG also attempted the Tagnite re-anodization process described in Section 4 in an attempt to undermine the legacy coatings with Tagnite. This attempt failed as well because the embedded paint blocked any access to the bare magnesium which preventing the initiation of the Tagnite anodization process.

Conclusions:

1. The MIL-DTL-83936 chemical paint stripping process was successful in removing the Rockhard and MIL-PRF-23377 primer from the anodized magnesium test coupons. However, it was unable to remove the residual paint from the porosity of the Tagnite, HAE and DOW 17 coatings.
2. A brief investigation of other paint strippers and solvents was unsuccessful in removing the paint embedded in the pores of the legacy coatings.
3. After talking with CCAD engineers and production personnel, it became apparent the chemical paint stripping process needed a thorough investigation which was above the scope of this project. The decision was made to utilize baking soda media blast to remove all the legacy coatings on the demonstration parts due the following reasons:
    - Environmentally friendly
    - Ability to remove organic coatings (primers and paints)
    - Ability to minimize dimensional loss on the bare magnesium surfaces.

Observations:

1. Paint chemical stripping at CCAD was good at removing surface paint.
2. All anodize coatings showed evidence of residual paint or primer embedded in the porosity.
3. Tagnite chemical stripper was not effective in removing Tagnite coatings embedded with residual paint.

Figure 14: Paint Chemical Stripping Results for Legacy Coatings

8.0 EFFECT OF TAGNITE CHEMICAL STRIP PROCESS ON CAD PLATING AND HYDROGEN EMBRITTLEMENT

Original Testing Protocol: In the original JTP, TAG stated that the effect of the Tagnite chemical strip process on Cad plated hardware would be evaluated by running Cad plated hardware through the stripping process and note any visual changes in the Cad plate color. If the characteristic color were to change during the process, it would be assumed that there was an adverse effect.

After review of the original JTP, AMSAM-ENVI-TI disapproved of this task in a memo (Appendix E) and submitted their own hydrogen embrittlement testing requirement.

Revised Test Protocol (from paragraph 3 of AMSAM-ENVI-TI memo): "*The stripping process shall be evaluated using type 1d notched C rings per ASTM F519-13, reference 1c. Per reference 1c paragraph 11.2, a minimum of 4 rings each shall be tested in both the bare and cadmium plated condition. These rings shall be subjected to the stripping process solutions at maximum temperatures and concentrations allowed by the TAG process specification. Additionally, times in each solution evaluated shall be 2x that allowed by the TAG stripping process specification. To validate the specimen batch, prior to testing 4 bare specimen and 4 cad plating specimen shall be stressed @ 75% of the notch fracture strength (NFS) for 200 hours. Provided that there are no failures, these specimens are to be discarded and the testing in the stripping solution can proceed (see chart).*"

Table 7: AMSAM-ENVI-TI Hydrogen Embrittlement Test Matrix

Specimen Condition	No Preload	Preload to 75% NFS	Strip @ Max Temp - Max Concentration and 2X Time	Post Exposure Stress 200 hrs @ 75% NFS
Bare	4		All	All
Bare		4	All	All
Cad Plated	4		All	All
Cad Plated		4	All	All

C Ring Testing Breakdown: The Type 1D C rings were obtained from Green Specialty Services, Ft. Worth, TX. The order consisted of 18 bare C rings and 18 Cad plated C rings. The testing breakdown was:

1. Two (2) Bare and two (2) Cad plated C rings were used to determine the NFS (Notch Fracture Strength).
2. Four (4) Bare and four (4) Cad plated C rings were used to validate the specimen batch (lot) by stressing the C rings @ 75 % NFS for 200 hours.

3. Four (4) Bare and four (4) Cad plated C rings with no preload were tested in the stripping process at max temp/ max concentration and 2X the maximum allowable soak time for parts.
4. Four (4) Bare and four (4) Cad plated C rings preloaded to 75 % NFS were tested in the stripping process at max temp/ max concentration and 2X the maximum allowable soak time for parts.

C Ring Testing Conditions:

1. The NFS was determined by placing an index point on tightening nut, then while slowly tightening the nut, count the number of turns it took to fracture the specimen. All specimens took between 3.75 and 4 turns to fracture.
2. After determining the NFS, four (4) bare and four (4) Cad plated specimens were preloaded to 75 % NFS, set aside for 200 hours.
3. The remaining specimens were put through the strip process under the following conditions.

Table 8: Normal Tagnite Stripping Parameters vs. C Ring Hydrogen Embrittlement Parameters

Normal Stripping Process Parameters			
	Working Concentration	Operating Temperature	Allowable time in tank
Step 1: Mild Alkaline Etch	30 – 36 g/L Pyrophosphate	70 – 80ºC	5 – 15 minutes
Step 2: Fluoride Activator	42.5 – 55.0 g/L Fluoride	70 – 80ºC	30 min – 1.5 hours
C Ring Stripping Process Parameters			
	Actual Concentration	Operating Temperature	Allowable time in tank
Step 1: Mild Alkaline Etch	35.5 g/L Pyrophosphate	79ºC	30 minutes
Step 2: Fluoride Activator	54.2 g/L Fluoride	80ºC	3 hours

C Ring Testing Results:

1. There were no notch fractures seen on any of the specimens after 200 hours @ 75 % NFS during the specimen batch (lot) validation testing. Therefore, the specimen batch (lot) was validated.
2. After 30 minutes in the mild alkaline etch under the conditions listed above, there were no notch fractures noted.
3. After 3 hours in the fluoride activator under the conditions listed above, there were no notch fractures noted. However, both the bare and Cad plated C rings has softened significantly and were rotating back and forth on the notch. The notch was acting like a hinge for the two C rings sections to flop up and down. This is considered an adverse event and therefore a failure.

Conclusions:

1. The fluoride activator step of the stripping process had an adverse effect on the Type 1d notched C rings. Therefore, any steel on a magnesium housing should be properly masked off before using the Tagnite chemical stripping process.

2. The fluoride activator is also used during as the final pretreatment step prior to Tagnite anodize. Therefore, all steel on a magnesium housing should be properly masked off before pretreating/anodizing using the Tagnite process. If there is a masking failure during exposure to the fluoride activator bath, the steel liner should be examined for evidence of pitting, rusting or softening of the steel. If the steel liner has been or is suspected of having prolonged exposure to the fluoride activator, the part should be scrapped.

Appendix A: C of C for AZ91C Magnesium Blocks

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

PACKING SLIP

Packing Slip#	Date	Page
018191-01	**01/15/14**	1

Sold To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Ship To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Gust P.O.#: **3318**
Terms: **NET 30 DAYS**
Reference#: **SO# 018191**
Salesperson: **HOUSE**
Government Contract#:
D.O.0. Priority Rating:

Attn: **Bill Elmquist**
Phone:
Ship Via: **TO BE DETERMINED**

ITEMS SHIPPED

ITEM	DESCRPTION	QTY ORDR	PREY SHIP	THIS SHIP	BACK ORDER
	12 .75 X1 2.75 X1.4-#1	8		8	
	UNIT NET WEIGHT: 15.00 LB TOTAL NET WEIGHT: 120.00 LB				

NOTES

Revision: Alloy: AZ91E Condition: T6
ORDER CONSIDERED COMPLETE

Appendix A: C of C for AZ91C Magnesium Blocks

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

IDENTIFICATION FOR TRACEABILITY FORM

Packing Slip#	Date	Page
018191-01	01/15/14	1

Customer: **TECHNOLOGY APPLICATIONS GROUP**

Part Number: **12.75X12.75X1.4-#1**

Gust P.O.#: **3318**

Quantity: **8**

SERIAL NUMBERS

WELDS	SERIAL	HEAT#	HT#	X-RAY	PENETRANT	PHYSICALS	MISCELLANEOUS
	[3]	H13329	167	NIA	NIA	NIA	
	[3]	H13330	167	NIA	NIA	*NIA*	
	[2]	H13331	167	*NIA*	NIA	N/A	

NOTES

MAGNESIUM ALLOY PRODUCTS

Tony Garcia
QUALITY ASSURANCE MANAGER

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CUSTOMER SHIPMENT INFORMATION

Customer: **TECHNOLOGY APPLICATIONS GROUP**
Packing Slip: **018191-01**
Date: **01/15/14**
Part Number: **12.75Xi2.75X1.4-#1**
Drawing Revision:

Purchase Order: **3318**
Quantity: **8**
Alloy: **AZ91E** Cond: **T6**
Government Contract#:
D.0.O Priority Rating:

STATEMENT OF CONFORMANCE

The parts finished under the purchase order and packing slip noted above were produced from materials for which it has available for examination chemical and/or physical test reports or other evidence of conformance to applicable specifications. And, that all processes required in the production of these parts were performed by a facility specifically approved by the supplier's cognizant government agency and/or Customer Engineering Department when such approval is required by an applicable specification as indicated.

PART SPECIFICATIONS

Material or Process	Specification	Revision	Class	Processing Facility
MATERIAL SPECIFICATION - MG	AMS4437	E		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
SOLUTION HEAT TREATMENT	AMS 2768 AMS-M-6857	C A		MAGNESIUM ALLOY PRODUCTS COMPTON.CA
PRECIPITATION HEAT TREATMENT	AMS2768 AMS-M-6857	C A		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
CLASSIFICATION AND INSPECTION	AMS2175	A	1	AIRCRAFT XRAY LABORATORIES HUNTINGTON PARK, CA

HARDNESS TESTING

Heat#	Heat Treat#	Rockwell E Scale - HREW	Heat#	Heat Treat#	Rockwell E Scale - HREW
H13329	167	N/A			
H13330	167	**N/A**			
H13331	167	**N/A**			

Paae 1 of 2

Appendix A: C of C for AZ91C Magnesium Blocks

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CHEMICAL ANALYSIS

Heat#	AL	ZN	MN	SI	CU	NI	FE	OE	TO
H13329	8.80	0.74	0.22	0.03	0.002	0.001	0.003	< 0.00	< 0.00
H13330	8.80	0.77	0.23	0.03	0.002	0.001	0.004	< 0.01	< 0.30
H1333i	8.80	0.74	0.22	0.03	0.002	0.001 1	0.00	< 0.0i	< 0.30

HEAT TREATMENT: SOLUTION

Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp OF	Castings	Test Specimens	
H13329	12/10/13	155	3	23.50	775 °F	3	4	
H13330	12/10/13	155	3	23.50	775 °F	3	4	
H13331	12/10/13	155	3	23.50	775 °F	2	4	

HEAT TREATMENT: PRECIPITATION

Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp OF	Castings	Test Specimens	
H13329	12/13/13	167	i	4.00	426 °F	3	4	
H13330	12/13/13	167	1	4.00	426 °F	3	4	
H1333i	12/13/13	167	1	4.00	426 °F	2	4	
'								

..------7 ,,

1/jz/tt./

Tony Gare!

Date

-

Paae 2 of 2

Appendix A: C of C for EV31A Magnesium Blocks

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

PACKING SLIP

Packing Slip#	Date	Page
018193-01	01/16/14	1

Sold To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Ship To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Gust P.O.#: **3316**
Terms: **NET 30 DAYS**
Reference#: **SO# 018193**
Salesperson: **HOUSE**
Government Contract#:
D.O.D. Priority Rating:

Attn: **Bill Elmquist**
Phone:
Ship Via: **TO BE DETERMINED**

AS SHIPPED

ITEM	DESCRIPTION	QTY ORDR	PREV SHIP	THIS SHIP	BACK ORDER
	12.75X12.75X1 .4-#2	7		7	
	UNIT NET WEIGHT: 15.00 LB TOTAL NET WEIGHT: i05.00 LB				

NOTES

Revision: Alloy: EV31A Condition: TS
ORDER CONSIDERED COMPLETE

Appendix A: C of C for EV31A Magnesium Blocks

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

IDENTIFICATION FOR TRACEABILITY FORM

Packing Slip#	Date	Page
018193-01	01/16/14	1

Customer: **TECHNOLOGY APPLICATIONS GROUP**

Part Number: **12.75X12.75X1.4-#2**

Gust P.O.#: **3316**

Quantity: **7**

SERIAL NUMBERS

WELDS	SERIAL	HEAT#	HT#	X-RAY	PENETRANT	PHYSICALS	MISCELLANEOUS
	[3]	H13317	130	*NIA*	*NIA*	*NIA*	
	[3]	H13319	130	*NIA*	NIA	NIA	
	[1]	H13322	130	N/A	NIA	NIA	

NOTES

MAGNESIUM ALLOY PRODUCTS

Tony Garcia
QUALITY ASSURANCE MANAGER

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CUSTOMER SHIPMENT INFORMATION

Customer: **TECHNOLOGY APPLICATIONS GROUP**
Packing Slip: **918193-01**
Date: **01/16/14**
Part Number: **12.75X12.75X1.4-#2**
Drawing Revision:

Purchase Order: **3316**
Quantity: 7
Alloy: **EV31A** Cond: **TG**
Government Contract#:
D.O.D Priority Rating:

STATEMENT OF CONFORMANCE

The parts finished under the purchase order and packing slip noted above were produced from materials for which it has available for examination chemical and/or physical test reports or other evidence of conformance to applicable specifications. And, that all processes required in the production of these parts were performed by a facility specifically approved by the supplier's cognizant government agency and/or Customer Engineering Department when such approval is required by an applicable specification as indicated.

PART SPECIFICATIONS

Material or Process	Soecification	Revision	Class	Processino Facilitv
MATERIAL SPECIFICATION -AL	AMS4429	A		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
SOLUTION HEAT TREATMENT	AMS4429	A		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
PRECIPITATION HEAT TREATMENT	AMS 4429	A		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
CLASSIFICATION AND INSPECTION	AMS2175	A	1	AIRCRAFT XRAY LABORATORIES HUNTINGTON PARK, CA

HARDNESS TESTING

Heat#	Heat Treat#	Rockwell E Scale - HREW	Heat#	Heat Treat#	Rockwell E Scale - HREW
H13317	130	N/A			
H13319	130	N/A			
H13322	130	NIA			

i

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CHEMICAL ANALYSIS

Heat#	ND	GD	CE	ZN	ZR	AG	CU	FE	NI
H13317	2.90	1.40	0.12	0.31	0.57	0.02	0.002	0.003	0.002
H13319	2.90	1.40	0.12	0.31	0.54	0.01	0.002	0.003	0.002
H13322	3.10	1.40	0.12	0.29	0.50	0.02	0.002	0.003	0.002

HEAT TREATMENT: SOLUTION

Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp •F	Castings	Test Soecimens	
H13317	11/21/13	121	2	8.00	970 Of	3	4	
H13319	11/21/13	121	2	8.00	970 °F	3	4	
H13322	11/21/13	121	2	8.00	970 Of	1	4	

HEAT TREATMENT: PRECIPITATION

Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp OF	Castings	Test Specimens	
H13317	11/27/13	130	1	14.00	402 °F	3	4	
H13319	11/27/13	130	1	14.00	402 °F	3	4	
H13322	11/27/13	130	1	14.00	402 °F	1	4	

Tony Garcia, duality As

Date U'fl(f

Paae 2 of 2

Appendix A: C of C for QE22A Magnesium Blocks

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

PACI<ING SLIP

Packing Slip#	Date	Page
018194-01	**01/16/14**	1

Sold To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Ship To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Gust P.O.#: **3317**
Terms: **NET 30 DAYS**
Reference#: **SO# 018194**
Salesperson: **HOUSE**
Government Contract#:
D.O.D. Priority Rating:

Attn: **Bill Elmquist**
Phone:
Ship Via: **TO BE DETERMINED**

ITEMS SHIPPED

ITEM	DESCRIPTION	QTY ORDR	PREV SHIP	THIS SHIP	BACK ORDER
	12.75X12.75X1.4-#5	7		7	
	UNIT NET WEIGHT: 14.00 LB TOTAL NET WEIGHT: 98.00 LB				

NOTES

Revision: Alloy: QE22 Condition: T6
ORDER CONSIDERED COMPLETE

Appendix A: C of C for QE22A Magnesium Blocks

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

IDENTIFICATION FOR TRACEABILITY FORM

Packing Slip#	Date	Page
018194-01	01/16/14	1

Customer: **TECHNOLOGY APPLICATIONS GROUP**

Part Number: **12.75X12.75X1.4-#5**

Cust P.O.#: **3317**

Quantity: **7**

SERIAL NUMBERS

WELDS	SERIAL	HEAT#	HT#	X-RAY	PENETRANT	PHYSICALS	MISCELLANEOUS
	[3]	H13336	199	N/A	NIA	N/A	
	[3]	H13338	199	N/A	N/A	N/A	
	[1]	H13339	199	N/A	N/A	N/A	

NOTES

MAGNESIUM ALLOY PRODUCTS

Tony Garcia
QUALITY ASSURANCE MANAGER

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CUSTOMER SHIPMENT INFORMATION

Customer: **TECHNOLOGY APPLICATIONS GROUP**
Packing Slip: **018194-01**
Date: **01/16/14**
Part Number: **12. 75X12.75X1.4-#5**
Drawing Revision:

Purchase Order: **3317**
Quantity: 7
Alloy: **QE22** Cond: **T6**
Government Contract#:
D.0.D Priority Rating:

STATEMENT OF CONFORMANCE

The parts finished under the purchase order and packing slip noted above were produced from materials for which it has available for examination chemical and/or physical test reports or other evidence of conformance to applicable specifications. And, that all processes required in the production of these parts were performed by a facility specifically approved by the supplier's cognizant government agency and/or Customer Engineering Department when such approval is required by an applicable specification as indicated.

PART SPECIFICATIONS

Material or Process	Specification	Revision	Class	Processing Facility
MATERIAL SPECIFICATION - MG	AMS 4418	H		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
SOLUTION HEAT TREATMENT	AMS2768	C		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
PRECIPITATION HEAT TREATMENT	AMS 2768	C		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
CLASSIFICATION AND INSPECTION	AMS2175	A	1	AIRCRAFT XRAY LABORATORIES HUNTINGTON PARK, CA

HARDNESS TESTING

Heat#	Heat Treat#	Rockwell E Scale - HREW	Heat#	Heat Treat#	Rockwell E Scale - HREW
H13336	199	N/A			
H13338	199	N/A			
H13339	199	N/A			

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CHEMICAL ANALYSIS

Heat#	ZR	CE	AG	cu	NI	OE
H13336	0.68	2.20	2.40	0.002	0.01	< 0.30
H13338	0.67	2.10	2.10	0.002	0.01	< 0.30
H13339	0.77	2.20	2.10	0.002	,0.01	< 0.30

HEAT TREATMENT: SOLUTION

Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp OF	Castings	Test Specimens	
H13336	12/18/13	177	2	8.00	971 °F	3	4	
H13338	12/18/13	177	2	8.00	971 °F	3	4	
H13339	12/18/13	177	2	8.00	971 °F	1	4	

HEAT TREATMENT: PRECIPITATION

Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp OF	Castings	Test Specimens	
H13336	01/07/14	199	1	8.00	402 °F	3	4	
H13338	01/07/14	199	1	8.00	402 °F	3	4	
H13339	01/07/14	199	1	8.00	402 °F	1	4	

J

Tony Garcia, Quality Assur • nager

t lr1fC/

Date

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

PACI<ING SLIP

Packing Slip#	Date	Page
018192-01	**01/16/14**	1

Sold To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Ship To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Gust P.O.#: **3315**
Terms: **NET 30 DAYS**
Reference#: **SO# 018192**
Salesperson: **HOUSE**
Government Contract#:
D.O.D. Priority Rating:

Attn: **Bill Elmquist**
Phone:
Ship Via: **TO BE DETERMINED**

ITEM	DESCRIPTION	QTY ORDR	PREV SHIP	THIS SHIP	BACK ORDER
	12.75X12.75X1.4-#3	16		16	
	UNIT NET WEIGHT: 15.00 LB TOTAL NET WEIGHT: 240.00 LB				

NOTES

Revision: Alloy: ZE41A Condition: T5
ORDER CONSIDERED COMPLETE

Appendix A: C of C for ZE41A Magnesium Blocks

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

IDENTIFICATION FOR TRACEABILITY FORM

Packing Slip#	Date	Page
018192-01	**01/16/14**	1

Customer: **TECHNOLOGY APPLICATIONS GROUP**

Part Number: **12.75X12.75X1.4-#3**

Gust P.O.#: **3315**

Quantity: 16

SERIAL NUMBERS

WELDS	SERIAL	HEAT#	HT#	X•RAY	PENETRANT	PHYSICALS	MISCELLANEOUS
	[3]	H13312	114	N/A	NIA	NIA	
	[3]	H13316	114	NIA	NIA	NIA	
	[2]	H13318	114	NIA	NIA	NIA	
	[3]	H13323	129	NIA	NIA	NIA	
	[3]	H13324	129	*NIA*	N/A	*NIA*	
	[2]	H13325	129	N/A	N/A	*NIA*	

NOTES

MAGNESIUM ALLOY PRODUCTS

Tony Garcia
QUALITY ASSURANCE MANAGER

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: {310) 608-1637

Certificate of Conformance

CUSTOMER SHIPMENT INFORMATION

Customer: **TECHNOLOGY APPLICATIONS GROUP**
Packing Slip: **018192-01**
Date: **01/16/14**
Part Number: **12.75X12.75X1 .4-#3**
Drawing Revision:

Purchase Order: **3315**
Quantity: **16**
Alloy: **ZE41A** Cond: **TS**
Government Contract#:
D.O.D Priority Rating:

STATEMENT OF CONFORMANCE

The parts finished under the purchase order and packing slip noted above were produced from materials for which it has available for examination chemical and/or physical test reports or other evidence of conformance to applicable specifications. And, that all processes required in the production of these parts were performed by a facility specifically approved by the supplier's cognizant government agency and/or Customer Engineering Department when such approval is required by an applicable specification as indicated.

PART SPECIFICATIONS

Material or Process	Specification	Revision	Class	Processino Facilitv
MATERIAL SPECIFICATION·MG	AMS4439	G		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
PRECIPITATION HEAT TREATMENT	AMS2768	C		MAGNESIUM ALLOY PRODUCTS COMPTON.CA
CLASSIFICATION AND INSPECTION	AMS2175	A	1	AIRCRAFT XRAY LABORATORIES HUNTINGTON PARK, CA

HARDNESS TESTING

Heat#	Heat Treat#	Rockwell E Scale· HREW	Heat#	Heat Treat#	Rockwell E Scale - HREW
H13312	114	N/A			
H13316	114	N/A			
H13318	114	N/A			
H13323	129	N/A			
H13324	129	NIA			
H13325	129	N/A			

Paae 1 of 2

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CHEMICAL ANALYSIS

Heat#	ZN	ZR	CE	CU	NI	MN	OE	TO
H13312	4.40	0.73	1.30	0.01	< 0.005	0.01	< 0.10	< 0.30
H13316	4.30	0.80	1.30	0.00	< 0.005	0.02	< 0.10	< 0.30
H13318	4.30	0.73	1.30	0.00	<0,005	0.02	< 0.10	< 0.30
H13323	4.20	0.71	1.20	0.00	<0,005	0.02	< 0.10	< 0.30
H13324	4.30	0.72	1.30	0.00	<0.005	0.02	< 0.10	< 0.30
H13325	4.30	0.73	1.30	0.00	< 0.005	0.02	< 0.10	< 0.30

HEAT TREATMENT: PRECIPITATION

Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp •F	Castings	Test Specimens	
H13312	11/21/13	114	2	2.00	626 °F	3	4	
H13316	11/21/13	114	2	2.00	626 °F	3	4	
H13318	11/21/13	114	2	2.00	626 °F	2	4	
H13323	11/26/13	129	1	2.00	626 °F	3	4	
H13324	11/26/13	129	1	2.00	626 °F	3	4	
H13325	11/26/13	129	1	2.00	626 °F	2	4	

Tony Gartia, Qua er

Date

Appendix A: C of C for AZ91C Round Bar

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

PACKING SLIP

Packing Slip#	Date	Page
018231-01	02/05/14	1

Sold To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Ship To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Gust P.O.#: **3375**
Terms: **NET 30 DAYS**
Reference#: **SO# 018231**
Salesperson: **HOUSE**
Government Contract#:
D.O.D. Priority Rating:

Attn: **Bill Elmquist**
Phone:
Ship Via: **TO BE DETERMINED**

ITEMS SHIPPED

ITEM	DESCRIPTION	QTY ORDR	PREV SHIP	THIS SHIP	BACK ORDER
	1.125X8 #1	25		25	

NOTES

Revision: Alloy: AZ91E Condition: T5
ORDER CONSIDERED COMPLETE

Appendix A: C of C for AZ91C Round Bar

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

IDENTIFICATION FOR TRACEABILITY FORM

Packing Slip#	Date	Page
018231-01	**02/05/14**	1

Customer: **TECHNOLOGY APPLICATIONS GROUP** PartNurnber: **1.125X8#1**

Cust P.O.#: **3375** Quantity: **25**

SERIAL NUMBERS

WELDS	SERIAL	HEAT#	HT#	X-RAY	PENETRANT	PHYSICALS	MISCELLANEOUS
	[25]	H13345	278	N/A	N/A	N/A	

NOTES

AGNESIUM ALLOY PRODUCTS

Tony Garcia
QUALITY ASSUR NCE MANAGER

Appendix A: C of C for AZ91C Round Bar

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CUSTOMER SHIPMENT INFORMATION

Customer: **TECHNOLOGY APPLICATIONS GROUP**
Packing Slip: **018231-01**
Date: **02/05/14**
Part Number: **1.125X8 #1**
Drawing Revision:

Purchase Order: **3375**
Quantity: **25**
Alloy: **AZ91E** Cond: **TS**
Government Contract#:
D.O.D Priority Rating:

STATEMENT OF CONFORMANCE

The parts finished under the purchase order and packing slip noted above were produced from materials for which it has available for examination chemical and/or physical test reports or other evidence of conformance to applicable specifications. And, that all prqcesses required in the production of these parts were performed by a facility specifically approved by the supplier's cognizant government agency and/or Customer Engineering Department when such approval is required by an applicable specification as indicated.

PART SPECIFICATIONS

:erial or Process	Specification	Revision	Class	Processing Facility
MATERIAL SPECIFICATION - MG	AMS4437	E		MAGNESIUM ALLOY PRODUCTS COMPTON, CA
SOLUTION HEAT TREATMENT	AMS2768 AMS-H-6088	C C		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
PRECIPITATION HEAT TREATMENT	AMS2768 AMS-H-6088	C C		MAGNESIUM ALLOY PRODUCTS COMPTON,CA

HARDNESS TESTING

Heat#	Heat Treat#	Rockwell E Scale - HREW	Heat#	Heat Treat#	Rockwell E Scale - HREW
H13345	278	N/A			

CHEMICAL ANALYSIS

Heat#	AL	ZN	MN	SI	CU	NI	FE	OE	TO
H13345	8.90	0.75	0.23	0.04	0.003	0.001	0.004	< 0.01	< 0.30

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

HEAT TREATMENT: PRECIPITATION								
Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp OF	Castings	Test Specimens	
H13345	02/03/14	278	3	4.00	426 °F	25	4	

Tony Garcio/,Quality As ger

2 (u /9
Date

Appendix A: C of C for EV31A Round Bar

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

PACKING SLIP

Packing Slip#	Date	Page
018230-01	**02/05/14**	1

Sold To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Ship To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Gust P.0.#: **3376**
Terms: **NET 30 DAVS**
Reference#: **SO# 018230**
Salesperson: **HOUSE**
Government Contract#:
D.O.D. Priority Rating:

Attn: **Bill Elmquist**
Phone:
Ship Via: **TO BE DETERMINED**

ITEM	DESCRIPTION	QTY ORDR	PREV SHIP	THIS SHIP	BACK ORDER
	1.125X8 #2	25		25	

NOTES

Revision: Alloy: EV31A Condition: TS
ORDER CONSIDERED COMPLETE

Appendix A: C of C for EV31A Round Bar

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

IDENTIFICATION FOR TRACEABILITY FORM

Packing Slip#	Date	Page
018230-01	02/05/14	1

Customer: **TECHNOLOGY APPLICATIONS GROUP**

Part Number: **1.125X8 #2**

Gust P.O.#: **3376**

Quantity: **25**

SERIAL NUMBERS

WELDS	SERIAL	HEAT#	HT#	X-RAY	PENETRANT	PHYSICALS	MISCELLANEOUS
	[25]	H13345	273	NIA	NIA	NIA	

NOTES

MAGNESIUM ALLOY PRODUCTS

QUALITY ASSURANCE MANAGER

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CUSTOMER SHIPMENT INFORMATION

Customer: **TECHNOLOGY APPLICATIONS GROUP**
Packing Slip: **018230-01**
Date: **02/05/14**
Part Number: **1.125X8#2**
Drawing Revision:

Purchase Order: **3376**
Quantity: **25**
Alloy: **EV31A** Cond: **T6**
Government Contract#:
D.O.D Priority Rating:

STATEMENT OF CONFORMANCE

The parts finished under the purchase order and packing slip noted above were produced from materials for which it has available for examination chemical and/or physical test reports or other evidence of conformance to applicable specifications. And, that all processes required in the production of these parts were performed by a facility specifically approved by the supplier's cognizant government agency and/or Customer Engineering Department when such approval is required by an applicable specification as indicated.

PART SPECIFICATIONS

Material or Process	Specification	Revision	Class	Processinq Facility
MATERIAL SPECIFICATION -AL	AMS4429	A		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
SOLUTION HEAT TREATMENT	AMS4429	A	--	MAGNESIUM ALLOY PRODUCTS COMPTON,CA
PRECIPITATION HEAT TREATMENT	AMS 4429	A		MAGNESIUM ALLOY PRODUCTS COMPTON,CA

HARDNESS TESTING

Heat#	Heat Treat#	Rockwell E Scale - HREW	Heat#	Heat Treat#	Rockwell E Scale - HREW
H13345	273	*NIA*			

CHEMICAL ANALYSIS

Heat#	ND	GD	CE	ZN	ZR	AG	CU	FE	NI
H13345	2.90	1.30	0.13	0.29	0.63	0.02	0.00	0.00	< 0.00

Paae 1 of 2

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

HEAT TREATMENT: SOLUTION								
Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp •F	Castings	Test Soecimens	
H13345	01/29/14	269	2	8.00	971 °F	25	4	
AGITATION TIME : 3 MINS			QUENCH DELAY TIME: 25 SEC					
QUENCH TEMPERATURE								
BEFORE QUENCH: 72 • F			DURING QUENCH: 129 • F					
AFTER QUENCH: 115 ° F			QUENCH TIME 20 MINS					

HEAT TREATMENT: PRECIPITATION								
Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp • f	Castings	Test Specimens	
H13345	01/30/14	273	2	16.02	401 °F	25	4	

Tony Garcia:Quali ance Manager

e /4/;'-t_
Date

Appendix A: C of C for QE22A Round Bar

MAGNESIUM ALLOY PRODUCTS.
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

PACKING SLIP

Packing Slip#	Date	Page
018233-01	**03/05/14**	1

Sold To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Ship To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Gust P.O.#: **3378**
Terms: **NET 30 DAYS**
Reference#: **SO# 018233**
Salesperson: **HOUSE**
Government Contract#:
D.O.D. Priority Rating:

Attn: **BILL ELMQUIST**
Phone:
Ship Via: **TO BE DETERMINED**

ITEMS SHIPPED

ITEM	DESCRIPTION	QTY ORDR	PREV SHIP	THIS SHIP	BACK ORDER
	1.125X8 #4	25		25	

NOTES

Revision: Alloy: QE22 Condition: T6
ORDER CONSIDERED COMPLETE

Appendix A: C of C for QE22A Round Bar

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

IDENTIFICATION FOR TRACEABILITY FORM

Packing Slip#	Date	Page
018233-01	03/05/14	1

Customer: **TECHNOLOGY APPLICATIONS GROUP**

Part Number: **1.125X8 #4**

Gust P.0.#: **3378**

Quantity: **25**

SERIAL NUMBERS

WELDS	SERIAL	HEAT#	HT#	X-RAY	PENETRANT	PHYSICALS	MISCELLANEOUS
	[25]	H13347	345	N/A	N/A	N/A	

NOTES

MAGNESIUM ALLOY PRODUCTS

Tony Garcia
QUALITY ASSURANCE MANAGER

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CUSTOMER SHIPMENT INFORMATION

Customer: **TECHNOLOGY APPLICATIONS GROUP**
Packing Slip: **018233-01**
Date: **03/05/14**
Part Number: **1.125X8 #4**
Drawing Revision:

Purchase Order: **3378**
Quantity: **25**
Alloy: **QE22** Cond: **T6**
Government Contract#:
D.O.D Priority Rating:

STATEMENT OF CONFORMANCE

The parts finished under the purchase order and packing slip noted above were produced from materials for which it has available for examination chemical and/or physical test reports or other evidence of conformance to applicable specifications. And, that all processes required in the production of these parts were performed by a facility specifically approved by the supplier's cognizant government agency and/or Customer Engineering Department when such approval is required by an applicable specification as indicated.

PART SPECIFICATIONS

Material or Process	Specification	Revision	Class	Processino Facilitv
MATERIAL SPECIFICATION - MG	AMS 4418	H		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
SOLUTION HEAT TREATMENT	AMS2768	C		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
PRECIPITATION HEAT TREATMENT	AMS2768	C		MAGNESIUM ALLOY PRODUCTS COMPTON,CA

HARDNESS TESTING

Heat#	Heat Treat#	Rockwell E Scale - HREW	Heat#	Heat Treat#	Rockwell E Scale - HREW
H13347	345	N/A			

CHEMICAL ANALYSIS

Heat#	ZR	CE	AG	CU	NI	OE
H13347	0.69	2.10	2.10	0.00	< 0.01	< 0.30

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

. HEAT TREATMENT: SOLUTION								
Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp •F	Castings	Test Specimens	
H13347	02/25/14	335	2	6.00	986 ° F	25	4	
AGIATION TIME: 2 MIN		QUENCH DELAY TIME : 27 SEC						
QUENCH TEMP: BEFORE QUENCH: 72 ° DURING QUENCH: 110 ° QUENCH TIME: 15 MINS								

HEAT TREATMENT: PRECIPITATION								
Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp •F	Castings	Test Specimens	
H13347	02/28/14	345		8.00	402 ° F	25	4	

Tony Ga{cia, Quality Assurance Manager

Date 3/7/14

Appendix A: C of C for ZE41A Round Bar

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

PACKING SLIP

Packing Slip#	Date	Page
018232-01	02/05/14	1

Sold To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Ship To:
TECHNOLOGY APPLICATIONS GROUP
810 SOUTH 48TH STREET

GRAND FORKS ND 58201

Gust P.O.#: **3377**
Terms: **NET 30 DAYS**
Reference#: **SO# 018232**
Salesperson: **HOUSE**
Government Contract#:
D.O.D. Priority Rating:

Attn: **BILL ELMQUIST**
Phone:
Ship Via: **TO BE DETERMINED**

ITEMS SHIPPED

ITEM	DESCRIPTION	QTY ORDR	PREV SHIP	THIS SHIP	BACK ORDER
	1.125X8 #3	25		25	

NOTES

Revision: Alloy: ZE41A Condition: T5
ORDER CONSIDERED COMPLETE

Appendix A: C of C for ZE41A Round Bar

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

IDENTIFICATION FOR TRACEABILITY FORM

Packing Slip#	Date	Page
018232-01	02/05/14	1

Customer: **TECHNOLOGY APPLICATIONS GROUP**

Part Number: **1.125X8 #3**

Gust P.O.#: **3377**

Quantity: **25**

SERIAL NUMBERS

WELDS	SERIAL	HEAT#	HT#	X-RAY	PENETRANT	PHYSICALS	MISCELLANEOUS
	[25]	H13346	222	N/A	N/A	N/A	

NOTES

MAGNESIUM ALLOY PRODUCTS

Tony Garcia
QUALITY ASSURANCE MANAGER

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

CUSTOMER SHIPMENT INFORMATION

Customer: **TECHNOLOGY APPLICATIONS GROUP**
Packing Slip: **018232-01**
Date: **02/05/14**
Part Number: **1.125X8 #3**
Drawing Revision:

Purchase Order: **3377**
Quantity: **25**
Alloy: **ZE41A** Cond: **T5**
Government Contract#:
D.O.D Priority Rating:

STATEMENT OF CONFORMANCE

The parts finished under the purchase order and packing slip noted above were produced from materials for which it has available for examination chemical and/or physical test reports or other evidence of conformance to applicable specifications. And, that all processes required in the production of these parts were performed by a facility specifically approved by the supplier's cognizant government agency and/or Customer Engineering Department when such approval is required by an applicable specification as indicated.

PART SPECIFICATIONS

Material or Process	Specification	Revision	Class	Processing Facility
MATERIAL SPECIFICATION - MG	AMS4439	G		MAGNESIUM ALLOY PRODUCTS COMPTON,CA
SOLUTiON HEAT TREATMENT	AMS 2768	C		MAGNESIUM ALLOY PRODUCTS COMPTON, CA
PRECIPITATION HEAT TREATMENT	AMS 2768	C		MAGNESIUM ALLOY PRODUCTS COMPTON, CA

HARDNESS TESTING

Heat#	Heat Treat#	Rockwell E Scale - HREW	Heat#	Heat Treat#	Rockwell E Scale - HREW
H13346	222	*NIA*			

CHEMICAL ANALYSIS

Heat#	ZN	ZR	CE	CU	NI	MN	OE	TO
H13346	4.30	0.76	1.20	0.00	<0.005	0.01	< 0.10	< 0.30

MAGNESIUM ALLOY PRODUCTS
P. 0. BOX 4668
COMPTON, CA 90224
Tel: (310) 605-1440 Fax: (310) 608-1637

Certificate of Conformance

HEAT TREATMENT: PRECIPITATION								
Heat#	Date	Heat Treat#	Furnace#	Time Hrs.	Temp OF	Castings	Test Specimens	
H13346	01/14/14	222	1	2.00	626 °F	25	4	

Tony Garcia(Quality er

Date

Appendix B: AZ91C Statistical Dimensional and Weight Change Summary

AZ91C Dimensional and Weight Change Summary

Bare to Tagnite Summary

Average Weight Change (gms)	0.2956
Average % Weight Change	0.1789
% Wt. Change Std. Dev.	0.00305
Minimum % Weight Change	0.1760
Maximum % Weight Change	0.1848
Average Dimensional Change (in)	0.00024
Standard Deviation	0.000049
Minimum Dimensional Change (in)	0.00016
Maximum Dimensional Change (in)	0.00032

Tagnite to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.6022
Average % Weight Change	-0.3637
% Wt. Change Std. Dev.	0.01121
Minimum % Weight Change	-0.3851
Maximum % Weight Change	-0.3558
Average Dimensional Change (in)	-0.00078
Standard Deviation	0.000082
Minimum Dimensional Change (in)	-0.00096
Maximum Dimensional Change (in)	-0.00058

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.3066
Average % Weight Change	-0.1855
% Wt. Change Std. Dev.	0.01103
Minimum % Weight Change	-0.2077
Maximum % Weight Change	-0.1787
Average Dimensional Change (in)	-0.00054
Standard Deviation	0.000069
Minimum Dimensional Change (in)	-0.00068
Maximum Dimensional Change (in)	-0.00038

Bare to DOW 17 Summary

Average Weight Change (gms)	0.11045
Average % Weight Change	0.0666
% Wt. Change Std. Dev.	0.01751
Minimum % Weight Change	0.0410
Maximum % Weight Change	0.0858
Average Dimensional Change (in)	-0.00004
Standard Deviation	0.000070
Minimum Dimensional Change (in)	-0.00014
Maximum Dimensional Change (in)	0.00012

DOW 17 to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.52995
Average % Weight Change	-0.3195
% Wt. Change Std. Dev.	0.00177
Minimum % Weight Change	-0.3211
Maximum % Weight Change	-0.3165
Average Dimensional Change (in)	-0.00048
Standard Deviation	0.000053
Minimum Dimensional Change (in)	-0.00056
Maximum Dimensional Change (in)	-0.00034

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.41950
Average % Weight Change	-0.2532
% Wt. Change Std. Dev.	0.01833
Minimum % Weight Change	-0.2799
Maximum % Weight Change	-0.2353
Average Dimensional Change (in)	-0.00052
Standard Deviation	0.000054
Minimum Dimensional Change (in)	-0.00062
Maximum Dimensional Change (in)	-0.00044

Bare to HAE Summary

Average Weight Change (gms)	0.09368
Average % Weight Change	0.0564
% Wt. Change Std. Dev.	0.00520
Minimum % Weight Change	0.0494
Maximum % Weight Change	0.0633
Average Dimensional Change (in)	No Dimensional Measurements on HAE Bare Panels
Standard Deviation	
Minimum Dimensional Change (in)	
Maximum Dimensional Change (in)	

HAE to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.69967
Average % Weight Change	-0.4208
% Wt. Change Std. Dev.	0.01256
Minimum % Weight Change	-0.4373
Maximum % Weight Change	-0.4037
Average Dimensional Change (in)	-0.00078
Standard Deviation	0.000047
Minimum Dimensional Change (in)	-0.00086
Maximum Dimensional Change (in)	-0.00068

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.60599
Average % Weight Change	-0.3647
% Wt. Change Std. Dev.	0.01080
Minimum % Weight Change	-0.3785
Maximum % Weight Change	-0.3545
Average Dimensional Change (in)	No Dimensional Measurements on HAE Bare Panels
Standard Deviation	
Minimum Dimensional Change (in)	
Maximum Dimensional Change (in)	

Appendix B: AZ91C Statistical Dimensional and Weight Change Summary

AZ91C Dimensional and Weight Change Summary

Chromic Acid to After 2nd Tagnite Summary		From Bare to 2nd Tagnite Summary	
Average Weight Change (gms)	0.22098	Average Weight Change (gms)	-0.08558
Average % Weight Change	0.1339	Average % Weight Change	-0.0518
% Wt. Change Std. Dev.	0.00784	% Wt. Change Std. Dev.	0.01490
Minimum % Weight Change	0.1244	Minimum % Weight Change	-0.0799
Maximum % Weight Change	0.1429	Maximum % Weight Change	-0.0397
Average Dimensional Change (in)	0.00022	Average Dimensional Change (in)	-0.00032
Standard Deviation	0.000246	Standard Deviation	0.000243
Minimum Dimensional Change (in)	0.0000	Minimum Dimensional Change (in)	-0.0005
Maximum Dimensional Change (in)	0.0012	Maximum Dimensional Change (in)	0.00066

Chromic Acid to After Tagnite Summary		From Bare to DOW 17 to Tagnite Summary	
Average Weight Change (gms)	0.22912	Average Weight Change (gms)	-0.19038
Average % Weight Change	0.1386	Average % Weight Change	-0.1149
% Wt. Change Std. Dev.	0.00392	% Wt. Change Std. Dev.	0.01717
Minimum % Weight Change	0.1324	Minimum % Weight Change	-0.1380
Maximum % Weight Change	0.1423	Maximum % Weight Change	-0.0963
Average Dimensional Change (in)	-0.00001	Average Dimensional Change (in)	-0.00054
Standard Deviation	0.000049	Standard Deviation	0.000055
Minimum Dimensional Change (in)	-0.0001	Minimum Dimensional Change (in)	-0.0006
Maximum Dimensional Change (in)	0.0001	Maximum Dimensional Change (in)	-0.0005

Chromic Acid to After Tagnite Summary		From Bare to HAE to Tagnite Summary	
Average Weight Change (gms)	0.24063	Average Weight Change (gms)	-0.36535
Average % Weight Change	0.1453	Average % Weight Change	-0.2199
% Wt. Change Std. Dev.	0.00450	% Wt. Change Std. Dev.	0.01488
Minimum % Weight Change	0.1386	Minimum % Weight Change	-0.2404
Maximum % Weight Change	0.1510	Maximum % Weight Change	-0.2040
Average Dimensional Change (in)	0.00002	Average Dimensional Change (in)	No Dimensional Measurements on HAE Bare Panels
Standard Deviation	0.000035	Standard Deviation	
Minimum Dimensional Change (in)	0.0000	Minimum Dimensional Change (in)	
Maximum Dimensional Change (in)	0.0001	Maximum Dimensional Change (in)	

Appendix C: EV31A Statistical Dimensional and Weight Change Summary

EV31 Dimensional and Weight Change Summary

Bare to Tagnite Summary

Average Weight Change (gms)	0.2986
Average % Weight Change	0.1568
% Wt. Change Std. Dev.	-0.0034
Minimum % Weight Change	0.1526
Maximum % Weight Change	0.1618
Average Dimensional Change (in)	0.00044
Standard Deviation	0.00094
Minimum Dimensional Change (in)	0.00012
Maximum Dimensional Change (in)	0.0043

Tagnite to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.66472
Average % Weight Change	-0.3486
% Wt. Change Std. Dev.	-0.01340
Minimum % Weight Change	-0.3708
Maximum % Weight Change	-0.3354
Average Dimensional Change (in)	-0.00058
Standard Deviation	0.000062
Minimum Dimensional Change (in)	-0.0007
Maximum Dimensional Change (in)	-0.00044

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.36610
Average % Weight Change	-0.1923
% Wt. Change Std. Dev.	-0.0101
Minimum % Weight Change	-0.2096
Maximum % Weight Change	-0.1819
Average Dimensional Change (in)	-0.0001
Standard Deviation	0.0009
Minimum Dimensional Change (in)	-0.0005
Maximum Dimensional Change (in)	0.0037

Bare to Dow 17 Summary

Average Weight Change (gms)	0.10545
Average % Weight Change	0.0545
% Wt. Change Std. Dev.	-0.0069
Minimum % Weight Change	0.0464
Maximum % Weight Change	0.0649
Average Dimensional Change (in)	-0.00002
Standard Deviation	0.00004
Minimum Dimensional Change (in)	-0.00010
Maximum Dimensional Change (in)	0.00006

DOW 17 to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.6490
Average % Weight Change	-0.3349
% Wt. Change Std. Dev.	-0.0351
Minimum % Weight Change	-0.4051
Maximum % Weight Change	-0.3114
Average Dimensional Change (in)	-0.0007
Standard Deviation	0.0001
Minimum Dimensional Change (in)	-0.0008
Maximum Dimensional Change (in)	-0.0005

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.5435
Average % Weight Change	-0.2805
% Wt. Change Std. Dev.	-0.03028
Minimum % Weight Change	-0.3405
Maximum % Weight Change	-0.2575
Average Dimensional Change (in)	-0.0007
Standard Deviation	0.0001
Minimum Dimensional Change (in)	-0.0008
Maximum Dimensional Change (in)	-0.0005

Bare to HAE Summary

Average Weight Change (gms)	0.1549
Average % Weight Change	0.0802
% Wt. Change Std. Dev.	-0.00431
Minimum % Weight Change	0.0745
Maximum % Weight Change	0.0860
Average Dimensional Change (in)	No Dimensional Measurements on HAE Bare Panels
Standard Deviation	
Minimum Dimensional Change (in)	
Maximum Dimensional Change (in)	

HAE to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.92287
Average % Weight Change	-0.4773
% Wt. Change Std. Dev.	-0.02267
Minimum % Weight Change	-0.5166
Maximum % Weight Change	-0.4546
Average Dimensional Change (in)	-0.00093
Standard Deviation	0.00007
Minimum Dimensional Change (in)	-0.00108
Maximum Dimensional Change (in)	-0.00080

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.76799
Average % Weight Change	-0.3975
% Wt. Change Std. Dev.	-0.02297
Minimum % Weight Change	-0.4334
Maximum % Weight Change	-0.3734
Average Dimensional Change (in)	No Dimensional Measurements on HAE Bare Panels
Standard Deviation	
Minimum Dimensional Change (in)	
Maximum Dimensional Change (in)	

Appendix C: EV31A Statistical Dimensional and Weight Change Summary

EV31 Dimensional and Weight Change Summary

Chromic Acid to After 2nd Tagnite Summary		From Bare to 2nd Tagnite Summary	
Average Weight Change (gms)	0.26933	Average Weight Change (gms)	-0.09677
Average % Weight Change	0.1417	Average % Weight Change	-0.0509
% Wt. Change Std. Dev.	-0.0055311	% Wt. Change Std. Dev.	-0.00623
Minimum % Weight Change	0.1344	Minimum % Weight Change	-0.0588
Maximum % Weight Change	0.1511	Maximum % Weight Change	-0.0436
Average Dimensional Change (in)	0.00231	Average Dimensional Change (in)	-0.00038
Standard Deviation	0.00961	Standard Deviation	0.00005
Minimum Dimensional Change (in)	-0.0002	Minimum Dimensional Change (in)	-0.0005
Maximum Dimensional Change (in)	0.04194	Maximum Dimensional Change (in)	-0.00028

Chromic Acid to After Tagnite Summary		From Bare to DOW 17 to Tagnite Summary	
Average Weight Change (gms)	0.27400	Average Weight Change (gms)	-0.26953
Average % Weight Change	0.1419	Average % Weight Change	-0.1391
% Wt. Change Std. Dev.	-0.0054904	% Wt. Change Std. Dev.	-0.02953
Minimum % Weight Change	0.1326	Minimum % Weight Change	-0.1973
Maximum % Weight Change	0.1490	Maximum % Weight Change	-0.1187
Average Dimensional Change (in)	-0.00002	Average Dimensional Change (in)	-0.00068
Standard Deviation	0.00006	Standard Deviation	0.00011
Minimum Dimensional Change (in)	-0.0002	Minimum Dimensional Change (in)	-0.0009
Maximum Dimensional Change (in)	0.0001	Maximum Dimensional Change (in)	-0.0005

Chromic Acid to After Tagnite Summary		From Bare to HAE to Tagnite Summary	
Average Weight Change (gms)	0.25770	Average Weight Change (gms)	-0.51029
Average % Weight Change	0.1340	Average % Weight Change	-0.2640
% Wt. Change Std. Dev.	-0.00326	% Wt. Change Std. Dev.	-0.02098
Minimum % Weight Change	0.1291	Minimum % Weight Change	-0.2974
Maximum % Weight Change	0.1376	Maximum % Weight Change	-0.2412
Average Dimensional Change (in)	-0.00090	Average Dimensional Change (in)	No Dimensional Measurements on HAE Bare Panels
Standard Deviation	0.00248	Standard Deviation	
Minimum Dimensional Change (in)	-0.0100	Minimum Dimensional Change (in)	
Maximum Dimensional Change (in)	0.0002	Maximum Dimensional Change (in)	

Appendix D: ZE41A Statistical Dimensional and Weight Change Summary

ZE41 Dimensional and Weight Change Summary

Bare to Tagnite Summary

Average Weight Change (gms)	0.28918
Average % Weight Change	0.1731
% Wt. Change Std. Dev.	0.00407
Minimum % Weight Change	0.1684
Maximum % Weight Change	0.1792
Average Dimensional Change (in)	0.00020
Standard Deviation	0.000053
Minimum Dimensional Change (in)	0.00014
Maximum Dimensional Change (in)	0.00034

Bare to Dow 17 Summary

Average Weight Change (gms)	-0.00383
Average % Weight Change	-0.0023
% Wt. Change Std. Dev.	0.01074
Minimum % Weight Change	-0.0133
Maximum % Weight Change	0.0093
Average Dimensional Change (in)	-0.00021
Standard Deviation	0.000033
Minimum Dimensional Change (in)	-0.00026
Maximum Dimensional Change (in)	-0.00016

Bare to HAE Summary

Average Weight Change (gms)	0.09782
Average % Weight Change	0.0583
% Wt. Change Std. Dev.	0.00404
Minimum % Weight Change	0.0529
Maximum % Weight Change	0.0637
Average Dimensional Change (in)	No Dimensional Measurements on HAE Bare Panels
Standard Deviation	
Minimum Dimensional Change (in)	
Maximum Dimensional Change (in)	

ZE41 Dimensional and Weight Change Summary

Tagnite to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.73237
Average % Weight Change	-0.4375
% Wt. Change Std. Dev.	0.00724
Minimum % Weight Change	-0.4448
Maximum % Weight Change	-0.4249
Average Dimensional Change (in)	-0.00057
Standard Deviation	0.001282
Minimum Dimensional Change (in)	-0.00328
Maximum Dimensional Change (in)	0.00396

DOW 17 to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.40253
Average % Weight Change	-0.2404
% Wt. Change Std. Dev.	0.00629
Minimum % Weight Change	-0.2490
Maximum % Weight Change	-0.2338
Average Dimensional Change (in)	-0.00034
Standard Deviation	0.000063
Minimum Dimensional Change (in)	-0.00048
Maximum Dimensional Change (in)	-0.0002

HAE to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.81370
Average % Weight Change	-0.4848
% Wt. Change Std. Dev.	0.00795
Minimum % Weight Change	-0.4958
Maximum % Weight Change	-0.4728
Average Dimensional Change (in)	-0.00081
Standard Deviation	0.000228
Minimum Dimensional Change (in)	-0.00094
Maximum Dimensional Change (in)	0.00012

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.44318
Average % Weight Change	-0.2648
% Wt. Change Std. Dev.	0.00467
Minimum % Weight Change	-0.2706
Maximum % Weight Change	-0.2565
Average Dimensional Change (in)	-0.00036
Standard Deviation	0.001266
Minimum Dimensional Change (in)	-0.00306
Maximum Dimensional Change (in)	0.0041

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.40637
Average % Weight Change	-0.2426
% Wt. Change Std. Dev.	0.01666
Minimum % Weight Change	-0.2623
Maximum % Weight Change	-0.2255
Average Dimensional Change (in)	-0.00056
Standard Deviation	0.000073
Minimum Dimensional Change (in)	-0.00066
Maximum Dimensional Change (in)	-0.0004

Bare to After Chromic Acid Strip Summary

Average Weight Change (gms)	-0.71588
Average % Weight Change	-0.4265
% Wt. Change Std. Dev.	0.01177
Minimum % Weight Change	-0.4429
Maximum % Weight Change	-0.4091
Average Dimensional Change (in)	0.19347
Standard Deviation	0.002319
Minimum Dimensional Change (in)	0.18986
Maximum Dimensional Change (in)	0.1979

No Dimensional Measurements on HAE Bare Panels

Appendix D: ZE41A Statistical Dimensional and Weight Change Summary

ZE41 Dimensional and Weight Change Summary

Chromic Acid to After Tagnite Summary		From Bare to 2nd Tagnite Summary	
Average Weight Change (gms)	0.20233	Average Weight Change (gms)	-0.24085
Average % Weight Change	0.1214	Average % Weight Change	-0.1442
% Wt. Change Std. Dev.	0.00380	% Wt. Change Std. Dev.	0.00450
Minimum % Weight Change	0.1152	Minimum % Weight Change	-0.1494
Maximum % Weight Change	0.1267	Maximum % Weight Change	-0.1366
Average Dimensional Change (in)	-0.00009	Average Dimensional Change (in)	-0.00046
Standard Deviation	0.000066	Standard Deviation	0.001233
Minimum Dimensional Change (in)	-0.0002	Minimum Dimensional Change (in)	-0.0031
Maximum Dimensional Change (in)	0	Maximum Dimensional Change (in)	0.0039

Chromic Acid to After Tagnite Summary		From Bare to DOW 17 to Tagnite Summary	
Average Weight Change (gms)	0.19957	Average Weight Change (gms)	-0.20680
Average % Weight Change	0.1194	Average % Weight Change	-0.1235
% Wt. Change Std. Dev.	0.00318	% Wt. Change Std. Dev.	0.01773
Minimum % Weight Change	0.1144	Minimum % Weight Change	-0.1425
Maximum % Weight Change	0.1206	Maximum % Weight Change	-0.1028
Average Dimensional Change (in)	-0.00011	Average Dimensional Change (in)	-0.00067
Standard Deviation	0.000066	Standard Deviation	0.000077
Minimum Dimensional Change (in)	-0.0003	Minimum Dimensional Change (in)	-0.0008
Maximum Dimensional Change (in)	0.0000	Maximum Dimensional Change (in)	-0.0005

Chromic Acid to After Tagnite Summary		From Bare to HAE to Tagnite Summary	
Average Weight Change (gms)	0.20358	Average Weight Change (gms)	-0.51230
Average % Weight Change	0.1219	Average % Weight Change	-0.3054
% Wt. Change Std. Dev.	0.00140	% Wt. Change Std. Dev.	0.01138
Minimum % Weight Change	0.1206	Minimum % Weight Change	-0.3227
Maximum % Weight Change	0.1227	Maximum % Weight Change	-0.2890
Average Dimensional Change (in)	-0.00005	Average Dimensional Change (in)	No Dimensional Measurements on HAE Bare Panels
Standard Deviation	0.000323	Standard Deviation	
Minimum Dimensional Change (in)	-0.0010	Minimum Dimensional Change (in)	
Maximum Dimensional Change (in)	0.0009	Maximum Dimensional Change (in)	

Appendix E: AMSAN-ENVI-TI Memo on Hydrogen Embrittlement Test Requirements

RDMR-AEF

17 FEB 2014

MEMORANDUM FOR AMSAM-ENVI-TI (Mr. Glenn Williams)

SUBJECT: Review Draft ESTCP Task 2 (Stripping) Test Requirements, TN 131353

1. References:

a. TN 131353, subject as above, dated 2/10/2014

b. ESTCP Task 2 draft test procedure, "Removal of Legacy Coatings Prior to Tagnite Anodization."

c. ASTM F519-13, "Standard Method for mechanical Hydrogen Embrittlement Evaluation of Plating/ Coating Processes and Service Environments."

2. We have reviewed and disapprove the subject task, reference 1a, from a materials engineering point of view. This is a review of reference 1b, ESTCP 13 E-WP4-034, "Improved Magnesium Protection for DoD Aviation and Weapon Component Technology Program." Reference 1b paragraph 2.5 "Effect of Tagnite Chemical Strip Process on Cadmium Plating and Hydrogen Embrittlement (HE)" states that, "Cad plated bolts will exposed to the TAG stripping process and the visual appearance of the bolts will be documented after processing." This method of HE evaluation is inadequate to properly determine if cad plated fasteners will be embrittled by the TAG stripping process. A hydrogen embrittlement test procedure meeting the requirements of paragraph 3 below shall be submitted to this office for approval.

3. The stripping process shall be evaluated using type 1d notched C rings per ASTM F519-13, reference 1c. Per reference 1c paragraph 11.2, a minimum of 4 rings each shall be tested in both the bare and cadmium plated condition. These rings shall be subjected to the stripping process solutions at maximum temperatures and concentrations allowed by the TAG process specification. Additionally, times in each solution evaluated shall be 2x that allowed by the TAG stripping process specification. To validate the specimen batch, prior to testing 4 bare specimen and 4 cad plating specimen shall be stressed @ 75% of the notch fracture strength (NFS) for 200 hours. Provided that there are no failures, these specimen are to be discarded and the testing in the stripping solution can proceed (see chart).

Specimen Condition	No Preload	Preload to 75% NFS	Strip @ Max Temp - Max Concentration and 2X Time	Post Exposure Stress 200 hrs @ 75% NFS
Bare	4		All	All
Bare		4	All	All
Cad Plated	4		All	All
Cad Plated		4	All	All

Appendix E: AMSAN-ENVI-TI Memo on Hydrogen Embrittlement Test Requirements

RDMR-AEF-M 17 FEB 2014

SUBJECT: TN 128425, Develop Requirements for Qualification of Alternatives to Chromic Acid Anodizing.

4. The point of contact for this memo is Ricky McNalley, 256-955-6854, ricky.mcnalley.civ@mil.mail

MICHAEL J. KANE Ph.D.
Chief, Materials Branch
Structures and Materials Division

Originator 2-18-14
Team Leader KRH 18FEB14