Joint Test Protocol for Validation of Citric Acid as an Alternative to Nitric Acid for Passivation of Stainless Steels

Final

June 1, 2012

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FINAL

Joint Test Protocol

For

Validation of Citric Acid as an Alternative to Nitric Acid for Passivation of Stainless Steels

June 1, 2012
PREFACE

This report was prepared by International Trade Bridge, Inc. (ITB) through the National Aeronautics and Space Administration (NASA) Technology Evaluation for Environmental Risk Mitigation Principal Center (TEERM). The structure, format, and depth of technical content of the report were determined by NASA TEERM, Government contractors, and other Government technical representatives in response to the specific needs of this project.

We wish to acknowledge the invaluable contributions provided by all the organizations involved in the creation of this document.
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LIST OF ACRONYMS

°F        Degrees Fahrenheit
AMS       Aerospace Material Specifications
APL       Approved Products List
ASTM      American Society for Testing and Materials
CCAD      Corpus Christi Army Depot
CARC      chemical agent resistant coating
DoD       Department of Defense
ft-lbs    foot-pounds
GMW       General Motors Worldwide Engineering Standards
ITB       International Trade Bridge, Inc.
J         Joules
JTP       Joint Test Protocol
JTR       Joint Test Report
KSC       John F. Kennedy Space Center
ksi       kilo-pound per square inch
LOX       liquid oxygen
MIL-HDBK-5 Metallic Materials and Elements for Aerospace Vehicle Structures Handbook
MMPDS     Metallic Materials Properties Development and Standardization Handbook
MPa       megapascals
MSFC      George C. Marshall Space Flight Center
NASA      National Aeronautics and Space Administration
NOx       Nitrogen oxide emissions
NSF       Notched Fracture Strength
SLT       Sustained Load Testing
T.O.      Technical Order
TEERM     Technology Evaluation for Environmental Risk Mitigation Principal Center
USA       United Space Alliance
1. INTRODUCTION

National Aeronautics and Space Administration (NASA) Headquarters chartered the Technology Evaluation for Environmental Risk Mitigation Principal Center (TEERM) to coordinate agency activities affecting pollution prevention issues identified during system and component acquisition and sustainment processes. The primary objectives of NASA TEERM are to:

- Reduce or eliminate the use of hazardous materials or hazardous processes at manufacturing, remanufacturing, and sustainment locations.
- Avoid duplication of effort in actions required to reduce or eliminate hazardous materials through joint center cooperation and technology sharing.

NASA and the Department of Defense (DoD) have similar equipment and processes which require the passivation of stainless steel. The standard practice for passivation uses nitric acid. While nitric acid exhibits excellent performance, there are a number of environmental, safety, and operational issues:

- Nitrogen oxide emissions (NOx) are considered greenhouse gases.
- NOx are volatile organic compounds that contribute to smog.
- NOx increase nitrogen loading (oxygen depletion) in bodies of water.
- Worker safety concerns.
- Nitric acid can remove beneficial heavy metals (nickel, chromium, etc) from treated surface.

The longtime military specification for passivation of stainless steel was QQ-P-35 (Passivation treatments for Corrosion-resistant Steel), but that has been cancelled in favor of American Society for Testing and Materials (ASTM) A 967 (Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts) and Aerospace Material Specifications (AMS) 2700 (Passivation Treatments for Corrosion-resistant Steel). The new specifications allow for the use of citric acid in place of nitric acid.

Another standard commonly used is ASTM A 380 (Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems). In addition, many Services/Agencies also have their own internal requirements listed below. Applicable excerpts can be found in the appendices.

- Army: Corpus Christi Army Depot (CCAD) Process Specification (Appendix A-1)
Validation of Citric Acid as an Alternative to Nitric Acid for Passivation of Stainless Steels

Joint Test Plan

- NASA:
  - Wiltech Corporation Procedures (Appendix B)

The primary objective of this effort is to demonstrate and validate citric acid as an alternative to nitric acid for the passivation of stainless steels. Citric acid offers a variety of benefits:

- It is naturally occurring and biodegradable.
- Upon disposal, it is rarely classified as a hazardous waste.
- It does not remove beneficial heavy metals from surface.
- There are no toxic fumes created during the passivation process.

This project is follow-on to United Space Alliance (USA) work at John F. Kennedy Space Center (KSC), FL, to optimize the parameters for the use of citric acid and verify effectiveness. USA evaluated the following parameters during their effort: concentration, temperature, and dwell time. This project will use the results from that testing to determine what process parameters will be used in the preparation of test coupons of corresponding alloys.

This Joint Test Protocol (JTP) contains the critical requirements and tests necessary to qualify citric acid as an alternative to nitric acid. These tests were derived from engineering, performance, and operational impact (supportability) requirements defined by a consensus of NASA and DoD participants.

A Joint Test Report (JTR) will document the results of the testing as well as any test modifications made during the execution of the testing. The JTR will be made available as a reference for future pollution prevention endeavors by other NASA centers, the DoD, and commercial users to minimize duplication of effort. Users of this JTP should check the project’s JTR for additional test details or minor modifications that may have been necessary in the execution of the testing. The technical stakeholders will have agreed upon test procedures modifications documented in the JTR.
2. ENGINEERING, PERFORMANCE, AND TESTING REQUIREMENTS

A joint group led by NASA TEERM and consisting of technical representatives from NASA centers and the DoD reached technical consensus on engineering, performance, and testing requirements for citric acid as an alternative to nitric acid for passivation of stainless steel substrates. The joint group defined critical tests with procedures, methodologies, and acceptance criteria to qualify alternatives against these technical requirements.

Once the JTP test criterion is approved, testing will be performed in a manner that will optimize the use of each test panel. For example, where practical, more than one type of test will be performed on the coated test panels. The number and types of tests performed on a given panel will be determined by the destructive nature of the tests in question.

Note: Tests specified in this JTP may involve the use of hazardous materials, operations, and equipment. This JTP does not address all safety issues associated with its implementation. It is the responsibility of each user of this JTP to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.

This project will compare the performance of citric acid to nitric acid for passivation of stainless steel alloys. The tests described in this JTP are summarized in Table 1 which includes acceptance criteria and the reference specifications, if any, used to conduct the tests.
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<td>Sample</td>
<td>Twenty samples must not react when impacted at 72 foot-pounds (ft-lbs) or 98 Joules (J). If one sample out of 20 reacts, 40 additional samples must be tested without any reactions.</td>
<td>NASA-STD-6001</td>
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3. **TEST PREPARATION**

The following substrate types have been agreed upon by the stakeholders:

- Super Austenitic: AL-6XN (UNS N08367)
- 200 Series Austenitic: A286 (UNS S66286)
- 300 Series Austenitic: 304 (UNS S30400)
- 300 Series Austenitic: 316 (UNS S31600)
- 300 Series Austenitic: 321 (UNS S32100)
- 400 Series Martensitic: 410 (UNS S41000)
- 400 Series Martensitic: 440C (UNS S44004)
- Precipitation-Hardened Martensitic: 15-5PH (UNS S15500)
- Precipitation-Hardened Martensitic: 17-4PH (UNS S17400)
- Precipitation-Hardened Martensitic: 17-7PH (UNS S17700)

The preparation of coupons will be documented by the technician preparing test coupons. For each test, a minimum of five (5) coupons shall be prepared for each substrate; those with the best coating as determined by the technician shall be used in accordance with the number of coupons required as specified in the **Test Methodology**. Unless otherwise required by a specific test, all coupons will be prepared as follows:

1. Initial degrease to remove machining contamination.
2. Test coupons not used for adhesion testing shall be grit blast with carbon steel to eliminate manufacturer’s passivation layer and introduce free iron.
3. Test coupons to be used for adhesion tests shall be prepared in such a way as to remove the manufacturer’s passivation layer without creating a surface profile. Possible procedures include “pickling” or milling or planing the surface. The actual procedure used shall be agreed upon by all stakeholders and documented in the JTR.
4. Prepare test coupons with nitric acid passivation per designated process in Appendix B.
5. Prepare test coupons with citric acid passivation per designated process in Appendix C.
6. Rinse coupons with deionized water to neutralize pH.
7. Blow dry with compressed air.
8. Store in clean, soft, low lint cloth in controlled environment until needed.
9. Apply coating if required for testing.

Based on the USA optimization testing, the following information should be used to determine passivation parameters for the identified substrates. For those substrates which are not indicated below, optimization testing of parameters (section 4.1) may be performed prior to testing.
Passivation parameters may also be determined based on an alloy’s similarity to one of the alloys identified below if all stakeholders agree.

- For UNS S30400 (304), temperatures of 100-140 degrees Fahrenheit (°F) and submersion times of 120 minutes provided the best corrosion protection.
- For UNS S41000 (410), temperatures of 140-180°F and submersion times of 30-75 minutes provided the best corrosion protection.
- For UNS S17400 (17-4PH), no increase in corrosion protection was observed for temperatures above 100°F and submersion times greater than 30 minutes.

For paint adhesion testing, test coupons shall be allowed 24 hours of unaided drying time prior to dry film thickness measurements. If liquid coatings are being tested for a destructive test, coupons shall be allowed to cure for an additional 14 days before they undergo any destructive testing to ensure full polymerization of the coating. Coating process parameters, including application method and cure schedule, shall be documented by the facility that prepares the test coupons.
4. TEST DESCRIPTIONS

Test requirements identified in Table 1 are further defined in this section to include the test description, rationale, and test methodology. The Test Methodology lists the major parameters, test coupon descriptions, number of test coupons, number of coupons per coating system, number of control coupons and acceptance (pass/fail) criteria. Any Unique Equipment or Instrumentation requirements and Data Analysis and Reporting Criteria are also included. The latest revision of each specification or standard shall be used unless otherwise stated.

4.1 Parameter Optimization Testing

Test Description

Previous testing by USA determined that the parameters for citric acid passivation that resulted in optimum performance varied by substrate. The data obtained during the original USA study shall be used for the testing of those identified substrates in this test plan. Parameter optimization testing, however; is necessary to determine the best parameters for the substrates included in this test plan that were not part of the USA study.

The USA study determined that a citric acid concentration of 4% provided optimum performance for all substrates and therefore a 4% concentration shall be used for the optimization testing in this test plan. The varying parameters shall be bath temperature and submersion time.

The USA study also found that treatments with elevated temperature and longer submersion times (temperature > 100 °F and time > 30 minutes) provide significantly better corrosion protection than treatments at ambient temperature or shorter submersion times (T ≈ 100°F and t ≈ 30 minutes).

Based on the available information, the following parameters shall be used:

- Time: 60 minutes, 90 minutes, and 120 minutes
- Temperature: 100 °F, 140 °F, and 180 °F

Tests shall be conducted on all coupons in accordance with ASTM B 117 [Standard Practice for Operating Salt Spray (Fog) Apparatus]. The test panels shall be evaluated every 168 hours.

The test panels shall be removed from testing once the panels have reached failure. Failure is defined as a Rust Grade rating of “8” as described by Table 1 of ASTM D 610 (Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces).

The parameters resulting in the best corrosion resistance shall be used for preparation of that substrate’s test panels for the remainder of the testing.
Rationale

The stakeholders agreed that optimization testing was required for those substrates not included in the original USA study.

Test Methodology

| Parameters                                | Per ASTM B 117 and ASTM D 610  
|                                          | Time: 60, 90, and 120 minutes  
|                                          | Temperature: 100, 140, and 180°F |
| Coupons Per Substrate/Coating System     | Three (3)                       |
| Trials Per Coupon                        | One (1)                         |
| Acceptance Criteria                      | Parameters resulting in the best corrosion resistance shall be used for preparation of that substrate’s test panels for the remainder of the testing |

Unique Equipment and Instrumentation

- Salt Fog test chamber

Data Analysis and Reporting

- Evaluation per ASTM D 610 every 168 hours.
- One (1) color photograph of a coupon for each substrate and coating shall be taken before the test. One (1) color photograph of each tested coupon shall be taken at each evaluation and the end of the test.

4.2 X-Cut Adhesion by Wet Tape

Test Description

This test method establishes the adequacy of intercoat and surface adhesion of an organic coating immersed in water by applying pressure sensitive tape over a scribed area of the coating. This test shall be performed in accordance with ASTM D 3359 (Standard Test Methods for Measuring Adhesion by Tape Test), Test Method A. Immersion time shall be 24 hours.

Inspect the X-cut and parallel lines-cut for removal of the coating from the substrate or previous coatings and rate the adhesion in accordance with the 0-5 scale outlined in ASTM D 3359,
Method A, Paragraph 7, Procedure, with the 0-A rating being *coating removal beyond the scribed area* and the 5-A rating being *no peeling or removal*.

The group decided to include NASA-STD-5008 Approved Products List (APL) coatings, chemical agent resistant coating (CARC) systems, cadmium plating, and chromium plating. The following specifications shall be used for preparation of coupons:

- CARC systems: specimens shall be prepared per
  - MIL-DTL-64159, *Camouflage Coating, Water Dispersible Aliphatic Polyurethane, Chemical Agent Resistant*, Type II
  - MIL-DTL-53072, *Chemical Agent Resistant Coating (CARC) System Application Procedures and Quality Control Inspection*, Types III, IV, and IX
  - For general use under CARC: Epoxy MIL-DTL-53022, *Primer, Epoxy Coating, Corrosion Inhibiting Lead and Chromate Free*
- Cadmium plating: specimens shall be prepared per QQ-P-416, *Plating, Cadmium (Electrodeposited)*, Type II
- Chromium plating: specimens shall be prepared per AMS 2460, *Plating, Chromium*

**Note:** Specific coatings used during testing will be identified in the test report.

Rationale

The X-cut with parallel lines scribe procedure increases the severity of this test over a dry tape adhesion test using a single "X" scribe and provides quantitative data for the adhesion of a coating system to the underlying metal substrate. All participants have agreed that adhesion testing is a performance requirement.

Test Methodology

<table>
<thead>
<tr>
<th>Parameters</th>
<th>ASTM D 3359 rating related to amount of coating removal</th>
</tr>
</thead>
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<tr>
<td><strong>Coupons Per Substrate/Coating System</strong></td>
<td>Three (3)</td>
</tr>
<tr>
<td><strong>Trials Per Coupon</strong></td>
<td>One (1)</td>
</tr>
</tbody>
</table>
Table 3 Test Methodology for X-Cut Adhesion by Tape Test

| Acceptance Criteria | Alternative performs as well or better than control process |

Unique Equipment or Instrumentation

- One (1)-inch wide semitransparent pressure-sensitive tape 3M Code 250 or equivalent
- Four and one half (4.5)-pound rubber-covered roller, approximately three and one-half (3.5)-inches diameter by one (1)-inch wide
- Cutting tool
- Cutting guide

Data Analysis and Reporting

- Report the results of the test using the classification guide in ASTM D 3359, Test Method A, paragraph 7.7.
- One (1) color photograph of a coupon for each substrate and coating shall be taken before the test. One (1) color photograph of each tested coupon shall be taken after the test.

4.3 Tensile (Pull-Off) Adhesion

Test Description

This test evaluates the pull-off strength (commonly referred to as adhesion) of a coating. The test determines either the greatest perpendicular force (in tension) that a surface area can bear before a plug of material is detached, or whether the surface of the material remains intact at a prescribed force. This test shall be performed in accordance with ASTM D 4541 (Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers).

This test method uses a class of apparatus known as portable pull-off adhesion testers. They are capable of applying a concentric load and counter load to a single surface so that coatings can be tested even though only one side is accessible. Measurements are limited by the strength of adhesion bonds between the loading fixture and the specimen surface or the cohesive strengths of the adhesive, coating layers, and substrate.

The group decided to include NASA-STD-5008 APL coatings, CARC systems, cadmium plating, and chromium plating. The following specifications shall be used for preparation of coupons:

- CARC systems: specimens shall be prepared per
Validation of Citric Acid as an Alternative to Nitric Acid for Passivation of Stainless Steels

Joint Test Plan

- MIL-DTL-64159, *Camouflage Coating, Water Dispersible Aliphatic Polyurethane, Chemical Agent Resistant, Type II*
- MIL-DTL-53072, *Chemical Agent Resistant Coating (CARC) System Application Procedures and Quality Control Inspection, Types III, IV, and IX*
- For general use under CARC: Epoxy MIL-DTL-53022, *Primer, Epoxy Coating, Corrosion Inhibiting Lead and Chromate Free*
- For aviation-specific applications: MIL-PRF-23377, *Primer Coatings: Epoxy, High Solids, Class N*
  - Cadmium plating: specimens shall be prepared per QQ-P-416, *Plating, Cadmium (Electrodeposited), Type II*
  - Chromium plating: specimens shall be prepared per AMS 2460, *Plating, Chromium*

**Note:** Specific coatings used during testing will be identified in the test report.

**Rationale**

Participants agreed that adhesion is a critical performance requirement and want to compare how citric acid may affect coating adhesion.

**Test Methodology**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Per ASTM D 4541</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coupons Per Substrate/Coating System</strong></td>
<td>Three (3)</td>
</tr>
<tr>
<td><strong>Trials Per Coupon</strong></td>
<td>Three (3)</td>
</tr>
<tr>
<td><strong>Acceptance Criteria</strong></td>
<td>Alternative performs as well or better than control process</td>
</tr>
</tbody>
</table>

**Unique Equipment and Instrumentation**

- Patti adhesion tester or equivalent

**Data Analysis and Reporting**

- Record the strength at which adhesion fails; there should be three (3) data points for each coupon.
- One (1) color photograph of a coupon for each substrate and coating shall be taken before the test. One (1) color photograph of each tested coupon and the dolly shall be taken after the test.
4.4 Cyclic Corrosion Resistance

Test Description

This test evaluates the ability of the passivation process to prevent corrosion when exposed to a simulated neutral pH corrosive environment. Tests shall be conducted on all coupons in accordance with General Motors Worldwide Engineering Standards (GMW) 14872 (Cyclic Corrosion Laboratory Test).

Coupons will be exposed for a total of 80 cycles and pictures will be taken every seven (7) cycles and at the end of the exposure period. The following information shall be recorded:

- Frequency of Salt Solution Changes
- Method of Salt Application
- pH of Solution
- Salinity or Conductivity of Solution
- Solution Constituents

Rationale

The GMW Cyclic Corrosion Laboratory Test provides an acceptable correlation between accelerated laboratory corrosion tests and actual corrosion experienced in the field.

Test Methodology

<table>
<thead>
<tr>
<th>Table 5 Test Methodology for Cyclic Corrosion Resistance Test</th>
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<tbody>
<tr>
<td><strong>Parameters</strong></td>
</tr>
<tr>
<td>Electrolyte solution:</td>
</tr>
<tr>
<td>• 0.9% sodium chloride</td>
</tr>
<tr>
<td>• 0.1% calcium chloride</td>
</tr>
<tr>
<td>• 0.075% sodium bicarbonate</td>
</tr>
<tr>
<td><strong>Note:</strong> One test cycle is equal to 24 hours</td>
</tr>
<tr>
<td><strong>Coupons Per Substrate</strong></td>
</tr>
<tr>
<td>Three (3)</td>
</tr>
<tr>
<td><strong>Trials Per Coupon</strong></td>
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<tr>
<td>One (1)</td>
</tr>
<tr>
<td><strong>Acceptance Criteria</strong></td>
</tr>
<tr>
<td>Alternative performs as well or better than control process</td>
</tr>
</tbody>
</table>

Unique Equipment or Instrumentation

- Programmable salt spray (fog) chamber

ITB, Inc.
Data Analysis and Reporting

- Report coating condition and corrosion data for each coupon.
- Photograph a selected test panel for each substrate prior to test initiation to use as a reference photo, group photographs in the test chamber at the end of each seven (7)-cycle period, and selected photographs at the terminus of the test to capture the results of the test.

4.5 Atmospheric Exposure Test

Test Description

This test evaluates the performance of the test and control process after exposure in a marine environment. All panels shall be passivated by either the control or the alternative. Some panels will also be prepared and coated with coatings identified for the adhesion tests (Sections 4.2 and 4.3).

Test panels will be installed at the KSC outdoor exposure rack approximately 150 feet from the ocean high tide line. Follow all KSC test rack procedures for fasteners and exposure angle as stated in NASA-STD-5008B (Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment).

Passivated only specimens shall be evaluated and photographed on a monthly basis until failure. Failure is defined as a Rust Grade rating of “8” as described by Table 1 of ASTM D 610 (Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces).

Coated test coupons shall be photographed every six (6) months for a total of 18 months. At the conclusion of 18 months, each coated test coupon condition shall be rated per ASTM D 610 (Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces). Use the numerical grade scale in ASTM D 610, Table 1, Scale and Description of Rust Grades, where 0 indicates 100% surface rusting and 10 indicating less than 0.01% surface rusting. Test coupon condition shall also be rated per ASTM D 714 (Standard Test Method for Evaluating Degree of Blistering of Paints); using the reference standards in section 3.

Rationale

This test documents the corrosion protection of the passivation alternative with actual exposure to UV radiation, as well as different cycles of salt spray exposure.

Test Methodology

<table>
<thead>
<tr>
<th>Table 6 Test Methodology for Atmospheric Exposure Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>Coupons Per System</td>
</tr>
</tbody>
</table>

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RELEASED - Printed documents may be obsolete; validate prior to use.
Table 6  Test Methodology for Atmospheric Exposure Test

<table>
<thead>
<tr>
<th>Trials Per Coupon</th>
<th>One (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance Criteria</td>
<td>Alternative performs as well or better than control process</td>
</tr>
</tbody>
</table>

Unique Equipment or Instrumentation

- KSC outdoor test rack located 150 feet from ocean high tide line

Data Analysis and Reporting

- For passivated only test panels, photograph and evaluate per ASTM D 610 until failure (Rust Grade rating of “8”).
- One (1) color photograph of each passivated only test panel shall be taken before the test. One (1) color photograph of each passivated only test panel shall be taken on a monthly basis until failure. One (1) color photograph shall be taken of the failed coupon.
- For coated test panels, report corrosion rating per ASTM D 610, Table 1, and blister rating per ASTM D 714, Section 3, after 18 months.
- One (1) color photograph of each coated test panel shall be taken before the test. One (1) color photograph of each coated test panel shall be taken at each six (6) month interval and at 18 months.

4.6 Stress Corrosion Cracking

Test Description

This test evaluates whether the passivation process will affect the material’s resistance to stress corrosion cracking. George C. Marshall Space Flight Center (MSFC)-STD-3029 (Guideline for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments) lists the following alloys as Table I materials. Table I materials experienced no failures of specimen stressed to 75% of the yield strength for 30 days of exposure per ASTM G 44 (Standard Practice for Preparation of Stress-Corrosion Test Specimens for Weldments) or ASTM B 117 [Standard Practice for Operating Salt Spray (Fog) Apparatus].

Test coupons shall be prepared in accordance with ASTM G 38 (Standard Practice for Making and Using C-Ring Stress-Corrosion Test Specimens) or ASTM G 39 (Standard Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens). Three specimens shall represent each alloy considered.

Three unexposed specimens shall be tested per ASTM E 8 (Standard Test Methods for Tension Testing of Metallic Materials) to determine the material properties of each alloy. Three specimens for each alloy are loaded in a test frame to 75% of the material’s yield strength per
ASTM G 38 or ASTM G 39. The stressed specimen shall be exposed, along with three more un-stressed specimens to 5% salt spray per ASTM B 117 for 30 days.

Rationale

Participants agreed that determining whether citric acid passivation lowers a material’s resistance to stress corrosion cracking is vital for approval of its use.

Test Methodology

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specimen shall be prepared per ASTM G 38 or ASTM G 39. The test shall be conducted in 5% salt spray per ASTM B 117 for 30 days.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupons Per Substrate</td>
<td>Three (3)</td>
</tr>
<tr>
<td>Trials Per Coupon</td>
<td>One (1)</td>
</tr>
<tr>
<td>Acceptance Criteria</td>
<td>All of the specimens survive 30 days without fracture.</td>
</tr>
</tbody>
</table>

Unique Equipment or Instrumentation

- Salt fog chamber per ASTM B 117
- Universal test machine per ASTM E 4 (*Standard Practices for Force Verification of Testing Machines*)

Data Analysis and Reporting

- Photograph all test specimens before and after exposure.
- Prepare stress vs. strain curves for all specimens at the completion of the test.

4.7 Fatigue

Test Description

This test evaluates the fatigue strength of metallic materials. This practice is limited to the fatigue testing of axial unnotched and notched specimens subjected to a constant amplitude, periodic forcing function in air at room temperature. Tests shall be conducted on all coupons in accordance with ASTM E 466 (*Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials*). Some peened samples [prepared per MIL-P-81985 (*Peening of Metals*)] shall also be included in the analysis.
There are several of these types of machines commercially available; coupons will be sized according to the requirements of the machine, but shall be similar to that of Figure 2 in ASTM E 466 (shown below).

![Figure 2: Specimens with Continuous Radius Between Ends](image)

This testing procedure will closely model the known S-N Curves shown in the *Metallic Materials Properties Development and Standardization Handbook* (MMPDS, which replaced MIL-HDBK-5, *Metallic Materials and Elements for Aerospace Vehicle Structures Handbook*); the results of the testing will be used as a comparative model to look for differences in the treated coupons.

Stress loads and cycles selected for each substrate were based on historical S-N Curve data in air at ambient temperature. Fatigue testing will only occur on the substrates identified below using the following stress loads and cycles:

- **A286**
  - Stress loads: 100 kilo-pound per square inch (ksi) to 60 ksi
  - Cycles: $10^4$ to $10^7$

- **304**
  - Stress loads: 45 ksi to 20 ksi
  - Cycles: $10^4$ to $10^7$

- **321**
  - Stress loads: 1450 ksi to 15 ksi
  - Cycles: $10^4$ to $10^7$

- **410**
  - Stress loads: 140 ksi to 85 ksi
  - Cycles: $10^4$ to $10^7$

- **440C**
  - Stress loads: 45 ksi to 30 ksi
  - Cycles: $10^4$ to $10^7
Validation of Citric Acid as an Alternative to Nitric Acid for Passivation of Stainless Steels

Joint Test Plan

- **17-4PH**
  - Stress loads: 150 ksi to 110 ksi
  - Cycles: $10^4$ to $10^7$

- **17-7PH**
  - Stress loads: 200 ksi to 70 ksi
  - Cycles: $10^4$ to $10^7$

**Rationale**

Participants agreed that determining whether citric acid accelerated or resulted in metal fatigue is a critical performance requirement.

**Test Methodology**

<table>
<thead>
<tr>
<th>Table 8 Test Methodology for Fatigue Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameters</strong></td>
</tr>
<tr>
<td><strong>Coupons Per Substrate</strong></td>
</tr>
<tr>
<td><strong>Trials Per Coupon</strong></td>
</tr>
<tr>
<td><strong>Acceptance Criteria</strong></td>
</tr>
</tbody>
</table>

**Unique Equipment or Instrumentation**

- Fatigue testing machine
- Scanning electron microscope

**Data Analysis and Reporting**

- Report procedures and results including a brief description of the fracture characteristics, identification of the fatigue mechanism, and the relative degree of transgranular and intergranular cracking.

- Fatigue Data will be used to create and compare S-N curves for nitric acid and citric acid passivated materials per ASTM E 739 [Practice for Statistical Analysis of Linear or Linearized Stress-Life (S-N) and Strain-Life (e-N)]. If there are negligible differences in the S-N curves, then the citric acid will be considered a suitable substitute.
• Photograph a selected test panel for each substrate (peened and unpeened) prior to test initiation to use as a reference photo and scanning electron microscope photos of specimens after testing.

### 4.8 Hydrogen Embrittlement

#### Test Description

This test evaluates whether exposure to chemicals encountered in service environments, such as the passivation process, can cause hydrogen embrittlement in steels.

Tests shall be conducted in accordance with ASTM F 519 *(Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments)*. This test method uses specimens made from Society of Automotive Engineers (SAE) 4340 steel (UNS G434006) and heat treated to 260-280 kilo-pound per square inch (ksi).

Prepare/obtain four (4) specimens with ASTM F 519 Type 1d, notched C-ring. This specimen type was selected because it was considered to be the most severe.

Test passivated specimens by the Sustained Load Testing (SLT) to 75% of the manufacturer-reported average Notched Fracture Strength (NSF) for 200 hours in air at room temperature. If all four (4) of the specimens sustain 200 hours SLT without fracture, the process is acceptable.

#### Rationale

Participants agreed that determining whether citric acid caused hydrogen re-embrittlement is a critical performance requirement.

#### Test Methodology

<table>
<thead>
<tr>
<th>Table 9 Test Methodology for Hydrogen Embrittlement Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameters</strong></td>
</tr>
<tr>
<td>Specimen shall be Type 1d, notched C-ring per ASTM F 519. The test shall be conducted in air at room temperature.</td>
</tr>
<tr>
<td><strong>Coupons Per Substrate</strong></td>
</tr>
<tr>
<td>Four (4) SAE 4340 steel (UNS G434006) heat treated to 260-280 ksi.</td>
</tr>
<tr>
<td><strong>Trials Per Coupon</strong></td>
</tr>
<tr>
<td>One (1)</td>
</tr>
<tr>
<td><strong>Acceptance Criteria</strong></td>
</tr>
<tr>
<td>All of the specimens sustain 200 hours SLT without fracture</td>
</tr>
</tbody>
</table>
Unique Equipment or Instrumentation

- Hydrogen embrittlement testing machine

Data Analysis and Reporting

- Record the time under load and sustained or threshold load, or percent of notched fracture strength or notch bend strength of unplated specimens, or displacement as appropriate for the type of specimen tested.
- Photograph a selected test panel for each substrate prior to test initiation to use as a reference photo and photos of post test specimens.

4.9 LOX Compatibility

NOTE: After LOX Compatibility Testing was identified by stakeholders, it was found that NASA’s MSFC had previously conducted LOX Compatibility testing on citric acid solution. All samples passed showing no reaction. The stakeholders agreed that no additional testing is required.

Test Description

The purpose of this test is to determine if materials in liquid oxygen (LOX) environments react when mechanically impacted. A reaction from mechanical impact can be determined by an audible report, an electronically or visually detected flash, or obvious charring of the sample, sample cup, or striker pin.


Rationale

This test is specified in NASA-STD-6001 and was identified as a testing requirement. Materials intended for use in space vehicles, specified test facilities, and specified ground support equipment must meet the requirements of this document.
## Test Methodology

### Table 10 Test Methodology for LOX Compatibility Test

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Per NASA-STD-6001; The thickness of the sample must be the worst-case thickness. Test conditions (pressure and temperature) are the ambient pressure of the test facility and the boiling point of LOX at that pressure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samples</td>
<td>Twenty (20)*</td>
</tr>
<tr>
<td>Trials Per Sample</td>
<td>One (1)</td>
</tr>
<tr>
<td>Control Samples Required For Testing</td>
<td>None</td>
</tr>
<tr>
<td>Acceptance Criteria</td>
<td>Twenty samples must not react when impacted at 72 ft-lbs (98 J). If one sample out of 20 reacts, 40 additional samples must be tested without any reactions.</td>
</tr>
</tbody>
</table>

*Minimum required

### Unique Equipment and Instrumentation

- ABMA-Type Impact Tester

### Data Analysis and Reporting

- The test report must include sample identification, configuration, test conditions, number of reactions, and observations from the test. Proper reporting of the test observations, especially of unusual behavior, is critical.
5. REFERENCE DOCUMENTS

The documents in Table 11 were referenced in the development of this JTP.

<table>
<thead>
<tr>
<th>Reference Document</th>
<th>Title</th>
<th>JTP Test</th>
<th>JTP Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMS 2460</td>
<td>Plating, Chromium</td>
<td>X-Cut Adhesion by Wet Tape, Tensile (Pull-Off) Adhesion</td>
<td>4.2, 4.3</td>
</tr>
<tr>
<td>AMS 2700</td>
<td>Passivation Treatments for Corrosion-resistant Steel</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>AMS QQ-P-416</td>
<td>Plating, Cadmium (Electrodeposited)</td>
<td>X-Cut Adhesion by Wet Tape, Tensile (Pull-Off) Adhesion</td>
<td>4.2, 4.3</td>
</tr>
<tr>
<td>ASTM A 380</td>
<td>Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>ASTM A 967</td>
<td>Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>ASTM D 610</td>
<td>Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces</td>
<td>18-Month Marine Exposure</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Reference Document</strong></td>
<td><strong>Title</strong></td>
<td><strong>JTP Test</strong></td>
<td><strong>JTP Section</strong></td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------</td>
<td>--------------</td>
<td>----------------</td>
</tr>
<tr>
<td>ASTM D 2512</td>
<td>Compatibility of Materials with Liquid Oxygen (Impact Sensitivity Threshold and Pass-Fail Techniques)</td>
<td>LOX Compatibility</td>
<td>4.9</td>
</tr>
<tr>
<td>ASTM D 3359</td>
<td>Standard Test Methods for Measuring Adhesion by Tape Test</td>
<td>X-Cut Adhesion</td>
<td>4.2</td>
</tr>
<tr>
<td>ASTM E 4</td>
<td>Standard Practices for Force Verification of Testing Machines</td>
<td>Stress Corrosion Cracking, Hydrogen Embrittlement</td>
<td>4.6, 4.8</td>
</tr>
<tr>
<td>ASTM E 8</td>
<td>Standard Test Methods for Tension Testing of Metallic Materials</td>
<td>Stress Corrosion Cracking</td>
<td>4.6</td>
</tr>
<tr>
<td>ASTM E 466</td>
<td>Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials</td>
<td>Fatigue</td>
<td>4.7</td>
</tr>
<tr>
<td>ASTM E 739</td>
<td>Practice for Statistical Analysis of Linear or Linearized Stress-Life (S-N) and Strain-Life (e-N)</td>
<td>Fatigue</td>
<td>4.7</td>
</tr>
<tr>
<td>ASTM G 38</td>
<td>Standard Practice for Making and Using C-Ring Stress-Corrosion Test Specimens</td>
<td>Stress Corrosion Cracking</td>
<td>4.6</td>
</tr>
</tbody>
</table>
## Table 11 Summarized Test and Evaluation Reference Listing

<table>
<thead>
<tr>
<th>Reference Document</th>
<th>Title</th>
<th>JTP Test</th>
<th>JTP Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM G 39</td>
<td>Standard Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens</td>
<td>Stress Corrosion Cracking</td>
<td>4.6</td>
</tr>
<tr>
<td>ASTM G 44</td>
<td>Standard Practice for Preparation of Stress-Corrosion Test Specimens for Weldments</td>
<td>Stress Corrosion Cracking</td>
<td>4.6</td>
</tr>
<tr>
<td>General Motors Worldwide Engineering Standards (GMW) 14872</td>
<td>Cyclic Corrosion Laboratory Test</td>
<td>Cyclic Corrosion Resistance</td>
<td>4.4</td>
</tr>
<tr>
<td>MIL-DTL-53022</td>
<td>Primer, Epoxy coating, Corrosion Inhibiting Lead and Chromate Free</td>
<td>X-Cut Adhesion by Wet Tape, Tensile (Pull-Off) Adhesion</td>
<td>4.2, 4.3</td>
</tr>
<tr>
<td>MIL-DTL-53039</td>
<td>Coating, Aliphatic Polyurethane, Single Component, Chemical Agent Resistant</td>
<td>X-Cut Adhesion by Wet Tape, Tensile (Pull-Off) Adhesion</td>
<td>4.2, 4.3</td>
</tr>
<tr>
<td>MIL-DTL-53072</td>
<td>Chemical Agent Resistant Coating (CARC) System Application Procedures and Quality Control Inspection</td>
<td>X-Cut Adhesion by Wet Tape, Tensile (Pull-Off) Adhesion</td>
<td>4.2, 4.3</td>
</tr>
<tr>
<td>MIL-DTL-64159</td>
<td>Camouflage Coating, Water Dispersible Aliphatic Polyurethane, Chemical Agent Resistant</td>
<td>X-Cut Adhesion by Wet Tape, Tensile (Pull-Off) Adhesion</td>
<td>4.2, 4.3</td>
</tr>
<tr>
<td>MIL-HDBK-5</td>
<td>Metallic Materials and Elements for Aerospace Vehicle Structures Handbook</td>
<td>Fatigue</td>
<td>4.7</td>
</tr>
<tr>
<td>MIL-P-81985</td>
<td>Peening of Metals</td>
<td>Fatigue</td>
<td>4.7</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Reference Document</th>
<th>Title</th>
<th>JTP Test</th>
<th>JTP Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-PRF-23377</td>
<td>Primer Coatings: Epoxy, High-Solids</td>
<td>X-Cut Adhesion by Wet Tape, Tensile (Pull-Off) Adhesion</td>
<td>4.2, 4.3</td>
</tr>
<tr>
<td>MMPDS</td>
<td>Metallic Materials Properties Development and Standardization</td>
<td>Fatigue</td>
<td>4.7</td>
</tr>
<tr>
<td>MSFC-STD-3029</td>
<td>Guideline for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments</td>
<td>Stress Corrosion Cracking</td>
<td>4.6</td>
</tr>
<tr>
<td>NASA-STD-5005C</td>
<td>Standard For The Design And Fabrication Of Ground Support Equipment</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>T.O 42C2-1-7</td>
<td>Metal Treatments: Electrodeposition of Metals and Metal Surface Treatments to Meet Air Force Maintenance Requirements</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>QQ-P-35</td>
<td>Passivation Treatments for Corrosion-resistant Steel</td>
<td>N/A</td>
<td>1</td>
</tr>
</tbody>
</table>
APPENDIX A

Currently Used Passivation Specifications
Appendix A-1

Excerpt from Army Specification

CCAD Process Specification
1.0 GENERAL INFORMATION

1.1 Purpose. This method covers the passivation of austenitic, ferritic, martensitic and precipitation hardened corrosion resistant steels. The resulting treatments shall meet or exceed the latest requirements of Federal Specification QQ-P-35, Passivation Treatments for Corrosion Resistant Steel.

1.2 Passivation. During processing operations such as grinding and machining, particulate material may become embedded in the surface of the corrosion resistant steel part. These particles then form galvanic corrosion cells and appear as rust. Passivation treatments remove metallic particles and form a corrosion resistant film over the surface of the part.

1.3 Treatments. Passivation treatments will be used on the following types of corrosion resistant steels (see QQ-P-35 for a specific listing of alloys).

   a. Type II: Used on parts with the following series 440, 400 (martensitic), 303, 347Se, 416, and precipitation hardenable steels.

   b. Type VI: Parts made from austenitic 200 and 300 series chromium nickel and chromium grades with 17% chromium or greater, except for 440 series.

   c. Type VII: Parts made from the same alloys as those listed in b, (the operating conditions are different).

   d. Type VIII: Parts made from high carbon and high chromium grade alloy (400 series) and precipitation hardened stainless steels.

1.4 Chromate Treatment. When specified and within one hour of passivation, all ferritic and martensitic steels shall undergo the dichromate treatment process. Temperature of the solution will be 140-160°F, and part dwell time will be 30 minutes.

1.5 High Strength Alloys. Alloys with a Rockwell hardness of C40 or greater, and 440C series are subject to hydrogen embrittlement, or intergranular attack when exposed to acids. Cleaning by a mechanical method such as glass bead blasting is recommended.

1.6 Special Cases. Carburized surfaces will not be passivated. Nitrided stainless steels will not be passivated. Passivation must be done before nitriding.

1.7 Workmanship. Passivated parts will exhibit clean surfaces with no etching, pitting, or frosting. The part shall have a waterbreak free surface during rinsing, slight discolorations on dried surfaces are permissible.

1.8 Final Authority. The latest version of QQ-P-35, Passivation Treatments for Corrosion Resistant Steel, will be used to answer any specific questions relating to passivation treatments.
Solution Codes

C461 Stainless Steel Passivation, Type II
Nitric acid (O-N-350) 20-50% (V/V)
Sodium Dichromate (O-S-595) 2-4 oz/gal
Operating Temperature 130°F
Time 20 minutes max

C466 Passivation Sealer, Chromate Treatment
Sodium Dichromate (O-S-595) 5-8 oz/gal
Operating Temperature 140-160°F
Time 20 minutes max

D112 Acid Corrosion Remover, MIL-C-10578, Type III
MIL-C-10578, Type III 50% (V/V)
Phosphoric Acid
Diethyl Thiourea
Nacconol 90f
Operating Temperature Ambient

D115 Stainless Steel Passivation, Type VII
Nitric acid (O-N-350) 20-50% (V/V)
Operating Temperature 130°F
Time 20 minutes max

D133 Corrosion Inhibitor
Cee-Bee MX-15U (McGean-Rohco) 0.25-1.0 oz/gal
Operating Temperature Ambient
Appendix A-2

Excerpt from Air Force Specification

*Air Force T.O 42C2-1-7*
CHAPTER 25
PASSIVATION OF STAINLESS STEEL

25.1 PURPOSE.
This chapter provides instruction of the passivation of austenitic, ferritic, martensitic, and precipitation-hardened, corrosion-resistant steels. Passivation shall meet the requirements of Specification SAE AMS-QQ-P-35.

25.2 GENERAL.
During the processing operations such as forming, grinding, lapping, machining, tumbling, etc., iron particles or other foreign metallic particles may become embedded in or smeared on the surface of corrosion-resistant steel parts. These particles, if not removed, may appear as rust spots or establish a galvanic cell that could prove detrimental to the part. Passivation is a process by which metallic particles are removed and an impervious oxide film formed to improve the corrosion resistance of parts made from austenitic, ferritic, martensitic, and precipitation-hardened corrosion-resistant steel.

25.3 CLASSIFICATION OF TREATMENTS.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type II</td>
<td>Medium temperature nitric acid solution with sodium dichromate additive</td>
</tr>
<tr>
<td>Type VI</td>
<td>Low temperature nitric acid solution</td>
</tr>
<tr>
<td>Type VII</td>
<td>Medium temperature nitric acid solution</td>
</tr>
<tr>
<td>Type VIII</td>
<td>Medium temperature, high concentration nitric acid solution</td>
</tr>
</tbody>
</table>

25.4 TREATMENT APPLICATION.

25.4.1 Type II shall be used on parts made of high carbon/high chromium grades (440 series), straight chromium grades with 12 – 14% chromium (martensitic 400 series), or for corrosion-resistant steels containing relatively large amounts (0.15%) of sulfur or selenium (304, 304Se, 347Se, 316, 416Se, 430F, 430Se, and precipitation-hardenable steels).

25.4.2 Type VI and VII shall be used on austenitic 200 and 300 series chromium nickel and chromium grades with 17% chromium or greater (with the exception of the 440 series) corrosion-resistant steels.

25.4.3 Type VIII can be used for parts made from high carbon and high chromium grades (400 series) and precipitation-hardening stainless steels.

25.5 FINISH.
The passivated parts shall exhibit a clean surface and show no etching, pitting, or frosting. A slight discoloration will be allowed.

25.6 EQUIPMENT.

25.6.1 Tank Construction. Passivation tanks should be constructed of stainless steel.

25.6.2 Ventilation. The passivation tank shall be equipped with a positive ventilation system capable of meeting or exceeding the ventilation requirements of AFOSH STD 48-2.
Table 25-1. Passivation of Corrosion-Resistant Steels

<table>
<thead>
<tr>
<th>Step</th>
<th>Operation</th>
<th>Time</th>
<th>Solutions, Materials, and Current</th>
<th>Temp °C</th>
<th>Temp °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vapor degrease.</td>
<td>As Req'd</td>
<td>ASTM D4081 and ASTM D4376 (Tetrachloroethylene) Alternates:</td>
<td>120 – 124</td>
<td>248 – 256</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ASTM D4080 (Trichloroethylene)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>WARNING</strong></td>
<td></td>
<td><strong>NOTE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solvent vapors are toxic.</td>
<td></td>
<td>Not to be used where prohibited by state regulations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Avoid inhalation of vapors or contact with skin or clothing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Alkaline clean.</td>
<td>5 – 15 min</td>
<td>C-206 Immersion Only</td>
<td>65 – 99</td>
<td>150 – 210</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alternates:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C-209 Immersion Only</td>
<td></td>
<td></td>
<td>65 – 99</td>
<td>150 – 210</td>
</tr>
<tr>
<td>3</td>
<td>Rinse.</td>
<td>As Req'd</td>
<td>Water</td>
<td>Rm – 82</td>
<td>Rm – 180</td>
</tr>
<tr>
<td>4</td>
<td>Passivate.</td>
<td>20 min</td>
<td>C-461 Immersion Only</td>
<td>49 – 54</td>
<td>120 – 130</td>
</tr>
<tr>
<td></td>
<td>Type II treatment.</td>
<td></td>
<td>C-462 Immersion Only</td>
<td>21 – 32</td>
<td>70 – 90</td>
</tr>
<tr>
<td></td>
<td>Type VI treatment.</td>
<td>30 min</td>
<td>C-322 Immersion Only</td>
<td>49 – 60</td>
<td>120 – 140</td>
</tr>
<tr>
<td></td>
<td>Type VII treatment.</td>
<td>20 min</td>
<td>C-311 Immersion Only</td>
<td>49 – 54</td>
<td>120 – 130</td>
</tr>
<tr>
<td></td>
<td>Type VIII treatment.</td>
<td>30 min</td>
<td>C-466</td>
<td>60 – 71</td>
<td>140 – 160</td>
</tr>
<tr>
<td>5</td>
<td>Rinse.</td>
<td>As Req'd</td>
<td>Water</td>
<td>21 – 93</td>
<td>70 – 200</td>
</tr>
<tr>
<td>6</td>
<td>Chromate treat all ferritic and martensitic parts.</td>
<td>30 min</td>
<td>C-466</td>
<td>60 – 71</td>
<td>140 – 160</td>
</tr>
<tr>
<td>7</td>
<td>Rinse.</td>
<td>As Req'd</td>
<td>Water</td>
<td>Rm – 82</td>
<td>Rm – 180</td>
</tr>
</tbody>
</table>
### Table 25-1. Passivation of Corrosion-Resistant Steels - Continued

<table>
<thead>
<tr>
<th>Step</th>
<th>Operation</th>
<th>Time</th>
<th>Solutions, Materials, and Current</th>
<th>Temp °C</th>
<th>Temp °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Dry.</td>
<td>As Req’d</td>
<td>Shop Air</td>
<td>Room</td>
<td>Room</td>
</tr>
</tbody>
</table>

25-3/(25-4 blank)
Appendix A-3

Excerpt from NASA Specification

NASA-STD-5005C

*Standard for the Design and Fabrication of Ground Support Equipment*
Caution should be exercised in using 400 series stainless steels to minimize hydrogen embrittlement, corrosion, and stress corrosion. Austenitic stainless steels are susceptible to pitting corrosion and crevice corrosion in a chloride-rich (marine) environment; some austenitic stainless steels are susceptible to SCC in a chloride-rich (marine) environment.

c. Service-related corrosion issues are common for free-machining alloys such as UNS S30300 and UNS S30323; and they shall not be used in applications where they can get wet, such as natural or launch-induced environments.

d. UNS N08367 or UNS S31254 shall be used in pressure piping and tubing in lieu of 300-series stainless steel when the piping on tubing is directly exposed to the marine and launch-induced environment.

e. Cleaning, descaling, and passivating of stainless steel parts, assemblies, equipment, and installed systems shall be in accordance with ASTM A380, Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.

f. When acid cleaning baths are used for steel parts, the parts shall be baked in accordance with SAE AMS 2759/9, Hydrogen Embrittlement Relief (Baking) of Steel Parts, to alleviate potential hydrogen embrittlement problems.

Hardware should be designed to avoid fretting and/or wear of stainless steel alloys. Lubricants and lubricated coatings should be considered for use with stainless steel materials in applications where they come into contact with each other through a sliding movement, and galling-resistant alloys such as Nitronic® should be considered as alternatives.

5.11.3.1.4.3 Aluminum

a. Aluminum alloys used in structural applications shall be resistant to general corrosion, pitting, intergranular corrosion, and SCC.

b. 5000-series alloys containing more than 3 percent magnesium shall not be used in applications where the temperature exceeds 66 °C (150 °F), because grain boundary precipitation above this temperature can create stress-corrosion sensitivity.

Hardware made with aluminum alloys should not be loaded through the short transverse grain direction, as resistance to SCC is at a minimum in that direction.

5.11.3.1.4.4 Nickel-Based Alloys

Alloys with a high nickel content are susceptible to sulfur embrittlement; therefore, any foreign material that could contain sulfur, such as oils, grease, and cutting lubricants, shall be removed prior to heat treatment, welding, or high temperature service.
APPENDIX B

Excerpt from Wiltech Procedures for Nitric Acid Passivation Process
PASSIVATION AND PROCESSING OF
SMALL/LARGE PARTS, FITTINGS, AND PIPING
PER FED. SPEC. QQ-P-35

NOTICE: NEITHER WILTECH CORPORATION NOR ANY PERSON ACTING ON BEHALF OF WILTECH ASSUMES ANY LIABILITY RESULTING FROM THE USE OF INFORMATION CONTAINED IN THIS DOCUMENT.
PASSIVATION AND PROCESSING OF SMALL/LARGE PARTS, FITTINGS, AND PIPING PER FED. SPEC. QQ-P-35

Signature on File

PREPARED BY

08/05/05

DATE

Signature on File

VALIDATED BY

08/09/05

DATE

Signature on File

QA/SAFETY

08/10/05

DATE

Signature on File

APPROVAL

08/10/05

DATE

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## COMPONENT PROCESSING OUTLINE FOR:

**PASSIVATION AND PROCESSING OF SMALL/LARGE PARTS, FITTINGS, AND PIPING**  
PER FED. SPEC. QQ-P-35

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TASK</th>
<th>DOCUMENT</th>
<th>SECT/APPENDIX</th>
<th>PARAGRAPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DECONTAMINATION (If Applicable)</td>
<td>4-0-385/OP-52</td>
<td>8.1</td>
<td>PER CDR</td>
</tr>
<tr>
<td>2</td>
<td>PROOF TESTING (If Applicable)</td>
<td>4-0-385</td>
<td>8.13</td>
<td>8.13.3</td>
</tr>
<tr>
<td>3</td>
<td>DISASSEMBLY</td>
<td></td>
<td>NOT APPLICABLE OR PER CDR’S SPECIAL INSTRUCTIONS</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>PAINT REMOVAL (If Applicable)</td>
<td>4-0-385/OP-52</td>
<td>6.3</td>
<td>6.3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.2</td>
<td>8.2.3</td>
</tr>
<tr>
<td>5</td>
<td>PRECLEANING</td>
<td>4-0-385/OP-52</td>
<td>8.3</td>
<td>8.3.11</td>
</tr>
<tr>
<td>6</td>
<td>FINAL CLEANING (If Applicable)</td>
<td>4-0-385/OP-52</td>
<td>8.11</td>
<td>8.11.12</td>
</tr>
<tr>
<td></td>
<td>Small Parts</td>
<td></td>
<td>8.11</td>
<td>8.11.3.7</td>
</tr>
<tr>
<td></td>
<td>Large Parts</td>
<td></td>
<td>8.11</td>
<td>8.11.5.1.2</td>
</tr>
<tr>
<td></td>
<td>Tubing</td>
<td></td>
<td>8.11</td>
<td>8.11.5.1.4</td>
</tr>
<tr>
<td></td>
<td>Back-To-Back</td>
<td></td>
<td>8.11</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>LUBRICATION AND ASSEMBLY</td>
<td></td>
<td>NOT APPLICABLE OR PER CDR’S SPECIAL INSTRUCTIONS</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>FUNCTIONAL TEST (If Applicable)</td>
<td>4-0-385/OP-52</td>
<td>8.18</td>
<td>8.18.3</td>
</tr>
<tr>
<td></td>
<td>Media: GN₂ (or GHe Per CDR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>SAFETY WIRING (If Applicable)</td>
<td>4-0-385</td>
<td>8.14</td>
<td>8.14.7</td>
</tr>
<tr>
<td>10</td>
<td>PACKAGING</td>
<td>4-0-385/OP-52</td>
<td>8.12</td>
<td>8.12.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.12.4.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.12.4.2</td>
<td></td>
</tr>
</tbody>
</table>

Material:
- Poly (Cleaning NOT Required)
- Aclar For Oxidizer, LO₂, GO₂, and B. Air
- Nylon For All Others Media

**Released** - Printed documents may be obsolete; validate prior to use.
ROCKWELL SMALL PARTS PASSIVATION  
(INCLUDING TUBING AND BACK-TO-BACKS  
NOT REQUIRING ELECTROPOLISHING)  
STAINLESS STEEL (300 / 400 SERIES)  
CLEANING AND PASSIVATION

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ROCKWELL SMALL PARTS PASSIVATION
(INCLUDING TUBING AND BACK-TO-BACKS
NOT REQUIRING ELECTROPOLISHING)
STAINLESS STEEL (300 / 400 SERIES)
CLEANING AND PASSIVATION #

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DATE
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07/13/05
VALIDATED BY
DATE
Signature on File
07/15/05
QA/SAFETY
DATE
Signature on File
07/15/05
APPROVAL
DATE

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APPENDIX C

Citric Acid Passivation Process
1.0 Citric Acid Passivation

FIGURE 1-1 PROCESS OVERVIEW FLOW CHART

CAUTION
Items with exposed critical surfaces are susceptible to damage during processing. When processing such items, an increased level of care and awareness is mandatory. Do not stack items.

WARNING
Wear face shield, body protection and impermeable rubber gloves when performing hazardous steps.

1.1. Degrease items per paragraph 2.0 of this procedure.

1.2. Metal stamp each coupon in accordance with run table. Number each coupon sequentially, ensuring that the numbers correspond with the coupon materials listed as in Tables 1-1 and 1-2. Center the number on one side only of the 6 inch side approximately ¼ inch from the edge.

NOTE
The following step will be performed at Kennedy Space Center’s Corrosion Control Facility by EG&G.
1.3. Grit blast coupons with plain carbon steel shot, both sides, using cross-hatch technique, covering each surface once with horizontal passes and once with vertical passes. Use blast tape to preserve coupon number.

1.4. Degrease items per paragraph 2.0 of this procedure a second time.

1.5. Rack or position parts in a processing basket so that full contact with process solutions and accessibility with rinse waters will be achieved.

1.6. Completely immerse work in Solution E (see Table 3-2) for 15 to 30 minutes.

**CAUTION**
Ensure a catch basin or drip pan is in place when mechanically applying process solutions to work and that all waste is disposed of properly.

1.7. Flush with demineralized (DM) water for at least 30 seconds. Continue rinsing until wet surface pH is between 6.0 and 8.0.

1.8. Check the wet surfaces for water-breaks. Surfaces shall exhibit continuity of water film when wet with DM water. Formation of droplets or discontinuity of the water film indicates the presence of oily or greasy residue. If a water-break free surface has not been achieved, reclean per paragraphs 1.6 and 1.7 until surface is acceptable. Continue to the next step once an acceptable surface has been achieved.

1.9. Ensure that two bath thermocouples are in place in the Lindberg/Blue M, Model number WB1110A. Reference Figure 1-2 for thermocouple placement. Start temperature data-logger.

1.10. Passivate parts according to the run table. For Citric acid passivation, use the “Constant Temperature Bath” manufactured by Lindberg/Blue M, Model number WB1110A. Position coupons in the bath in accordance with Figures 1-2 and 1-3.
FIGURE 1-2 LINDBERG/BLUE M WATERBATH
MODEL # WB110A
SECTION VIEW
FIGURE 1-3 LINDBERG/BLUE M, MODEL # WB1110A SOLUTION BATH
NOTE
After processing, handle parts in a manner to prevent recontamination by dirt, grease, fingerprints, moisture, and any other soil. Personnel handling parts shall wear clean, low-lint gloves. Prepared parts that will require short term storage shall be protected by wrapping with polyethylene material or placing parts in polyethylene bags.

NOTE
When interim packaging is used during processing, it shall be adequate to protect details from contamination, corrosion or damage during handling and storage.

1.11. After passivation, remove coupons from bath and flush with DM water for at least 30 seconds. Continue rinsing until wet surface pH shows no noticeable color change on litmus paper.

1.12. Blow dry the work with filtered GN₂ until visibly dry.

1.13. End temperature data logging session.

1.14. Visually examine parts for evidence of contamination. Reprocess contaminated parts per paragraphs 1.5 through 1.6.

1.15. Package in a single poly zip-top bag. No certification is required.
2.0 Aqueous Degreasing

2.1. The aqueous degreasing processing flow is illustrated above.

WARNING
Wear face shield, body protection and impermeable rubber gloves when performing hazardous steps.

CAUTION
Items with exposed critical surfaces are susceptible to damage during processing. When processing such items, an increased level of care and awareness is mandatory.

2.2. Solvent wipe, as required, per paragraph 3.0 to remove labels, tape residues, grease pencil markings, ink, and layout dye.

NOTE
The Hydro P4000 is a suitable substitute for the “Gross Parts Washer” in the removal of gross contamination in subsequent steps. If gross contamination is not evident then the subsequent “Gross Parts Washer” steps may be skipped.
CAUTION
Do not stack parts on top of one another in the rotating basket. Parts with critical surfaces must be positioned so that contact with one another is avoided.

2.3. Rack or position parts in the rotating basket of the “Gross Parts Washer” so that full contact with [Solution OO (see Table 3-2)] spray patterns will be achieved. Use properly sized restraining fixtures, as required, to test coupons if necessary.

2.4. Set the operational controls of the “Gross Parts Washer” per Table 2-1 for this system (“Gross Parts Washer”).

2.5. Close the lid and start the unit. Allow the full cycle to terminate before opening the lid.

2.6. After the process cycle is complete, allow the excess fluids to drain/return to sump before opening the lid.

2.7. Visually examine the parts for evidence of gross contamination. Remove the contaminant with the unit’s spray wand or reprocess the contaminated parts per paragraphs 2.3 through 2.6.

CAUTION
Do not stack parts on top of one another in the processing basket. Parts with critical surfaces must be positioned so that contact with one another is avoided.

2.8. Remove the parts from the rotating basket of the gross parts washer and carefully place them into proper sized metal processing basket, ensuring they do not touch each other.

2.9. Set the operational controls of System “A” per Table 2-1 for this system.

2.10. Position the work in System “A” so that full contact with the processing solution [Solution MM (see Table 3-2)] is achieved.
CAUTION
Do not touch degreased parts with bare human hands after processing in System “A”. Natural human oils will transfer to clean surfaces of parts.

2.11. When parts are positioned properly within the tank of the Primary Degreaser (System “A”), actuate the start switch and wait for completion of process cycle.

NOTE
To prevent surfactant solutions from drying on hot metal substrates, immediate rinsing of fresh hot DM water (120-150°F) to remove solution residues is required.

CAUTION
Parts removed from System “A” must be moved to System “B” for immediate rinsing.

2.12. Set the operational controls of System “B” per Table 2-1 for this system.

2.13. Turn on the water deluge spray in System “B” and quickly remove degreased parts from System “A” and suspend the parts and basket within the hot demineralized water (DM) water spray, working them in an upward and downward motion for approximately 15 +5 seconds.

2.14. Remove parts and basket from water deluge spray bath and place them into main DM water rinse tank of System “B”.

2.15. When parts are positioned properly within the tank of the Primary Rinser (System “B”), actuate the start switch and wait for completion of process cycle.
2.16. After completion of the rinsing cycle check wet surfaces for water-breaks. Surfaces shall exhibit continuity of water film when wet with DM water. Formation of droplets or discontinuity of water film indicates the presence of oily or greasy residue.

2.17. If a water-break free surface has not been achieved contact engineering for further instructions.

**NOTE**
Evidence shows that minor contamination is deposited on parts when leaving the chemical processing baths. To assist the cleanliness validation phase of precision cleaning, a secondary degreasing process is required.

**CAUTION**
Ensure the component parts are placed on a single plane of work, on bottom of basket and not touching one another.

2.18. Rack or position parts in the proper sized metal processing basket, ensuring they do not touch each other.

**CAUTION**
Verify the surfaces of the component parts are of a neutral pH, 6.0 to 8.0, to prevent acid or alkaline contamination of Solution QQ (see Table 3-2).

2.19. Set the operational controls of System “C” per Table 2-1 for this system.

2.20. Position the work in Tank “A” of System “C” so that full contact with the processing solution [Solution QQ (see Table 3-2)] is achieved.
2.21. When the parts are positioned properly within Tank “A” of the Secondary Degreaser (System “C”), actuate the start switch and wait for completion of process cycle.

**NOTE**
To prevent surfactant drag-out, pre-rinse the parts back into surfactant bath with the hand wand before placing in main rinse tank “B”.

2.22. Lift parts from Tank “A” and pre-rinse them with the spray wand back into Tank “A”. This will help reduce the effects of surfactant drag-out.

2.23. Position the work in Tank “B” of System “C” so that full contact with the processing solution [Solution JJ (see Table 3-2)] is achieved.

2.24. When the parts are positioned properly within Tank “B” of the Secondary Degreaser (System “C”), press the start switch and wait for completion of the rinsing process.

**NOTE**
Handle parts, after processing, in a manner to prevent recontamination by dirt, grease, fingerprints, moisture, and any other soil. Personnel handling parts shall wear clean, low-lint gloves. Prepared parts that will require short-term storage shall be protected by wrapping with polyethylene material or placing parts in polyethylene bags.

**CAUTION**
Icing may occur during vacuum drying - Verify there are no cold spots on parts after drying.
2.25. Dry the work using either the Thermal Vacuum Dryer, Forced Air Over HEPA Dryer or Blow dry the work with filtered GN₂ until visibly dry. Temperature settings for the dryers shall be 150-160°F.

2.26. Visually examine parts for evidence of contamination. Notify engineering for further instructions if contamination is noted.

**NOTE**
When interim packaging is used during processing, it shall be adequate to protect details from contamination, corrosion or damage during handling and storage.

2.27. Return to passivation processing per paragraph 1.0. If this was the first degreasing, return at paragraph 1.2. If this was the second degreasing, return at paragraph 1.5.

<table>
<thead>
<tr>
<th>GROSS PARTS WASHER</th>
<th>SYSTEM A (27KHz)</th>
<th>SYSTEM B (40KHz)</th>
<th>SYSTEM C (40KHz)</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash (Minutes)</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Process (Minutes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rinse (Minutes)</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agitation (Secs. On/Off)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasonics Zones 1-4</td>
<td>OFF</td>
<td>AUTO</td>
<td>AUTO</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Shaded areas represent equipment not used for that Material Class.

1 Set ultrasonics OFF for Flight & Type I GSE hardware; Set to AUTO for other hardware.

**TABLE 2-1 EQUIPMENT/LOAD SETTINGS**
3.0 Solvent Wipe

**CAUTION**

Items with exposed critical surfaces are susceptible to damage during processing. When processing such items, an increased level of care and awareness is mandatory.

**CAUTION**

Do not stack items with exposed critical surfaces.

3.1. Determine type of contaminants, type of materials to be cleaned, and select proper solvent for the cleaning operation from Table 3-1.
### TABLE 3-1 SOLVENT USAGE

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Solvent</th>
<th>Flammable (See Caution)</th>
<th>Type of Material (See Note)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil, grease, and shop soils, mill markings and tape or decal residue</td>
<td>Solution Q, Solution WW</td>
<td>No</td>
<td>All metals and their alloys, Painted surfaces and all non-metals except elastomeric (rubber) materials</td>
</tr>
<tr>
<td>Identification inks &amp; Most Other Contaminants</td>
<td>Solution S</td>
<td>Yes</td>
<td>Elastomerics (rubber) materials, All metals and their alloys except magnesium and its alloys</td>
</tr>
<tr>
<td>All contaminants</td>
<td>Solution XX, Solution NN</td>
<td>No</td>
<td>All metals and their alloys, Painted surfaces and all non-metals, Elastomerics (rubber) materials</td>
</tr>
<tr>
<td>Grease pencil markings, layout dye, some mill markings and tape residue</td>
<td>Solution PP, Solution DD</td>
<td>Yes</td>
<td>All metals and their alloys except magnesium and its alloys</td>
</tr>
</tbody>
</table>

**WARNING**

Use non-flammable solvent whenever possible.
Use Solutions S, WW, DD, and PP only in well vented areas approved by Industrial Safety.
Whenever a solvent splash is possible, Industrial Safety approved eye protection shall be worn.

3.2. Remove loose particulate matter from parts by blowing-off with filtered GN₂.
WARNING
Solvent resistant gloves, eye protection, and body protection shall be worn to prevent skin contact with solvents.

3.3. Dispense solvent onto a clean wiper. Do not dip wiper into solvent.

3.4. Rub or scrub to dislodge the contamination. To spot clean, work around the spot toward its' center to avoid spreading contaminants onto the cleaned surface.

CAUTION
Precautions shall be taken to avoid entrapment of solvents in seams, crevices, between fraying surfaces, etc. If such entrapment does occur remove solvent by blowing with air or GN₂.

3.5. Continue the wiping operation, as necessary, using additional clean wipers and solvent until all contamination is completely removed as indicated by visual examination.

3.6. Wipe dry all accessible surfaces with a clean, dry wiper.

NOTE
Do not return used solvent to the original container. Used wipers shall be placed in Industrial Safety approved containers.

WARNING
Wear eye protection approved by Industrial Safety.
3.7. Dry entrapment areas with filtered GN₂. As an alternate, allow entrapment areas to dry at ambient temperature for 30 minutes minimum.

3.8. Visually examine parts for evidence of oil, grease, layout dye, grease pencil markings, shop soils, or any similar residues. Parts that evidence visual contaminants shall be re-cleaned.

**NOTE**
Solvent cleaned surfaces shall exhibit no evidence of attack such as etching or pitting of metallic surfaces, softening, smearing, swelling or crazing of non-metallic surfaces, or loss of adhesion at joined material interfaces.

**NOTE**
Solvent cleaned surfaces shall be visibly dry and free of solvent.

**NOTE**
Handle parts, after processing, in a manner to prevent recontamination by dirt, grease, fingerprints, moisture, and any other soil. Personnel handling parts shall wear clean, low-lint gloves. Prepared parts that will require short-term storage shall be protected by wrapping with polyethylene material or placing parts in polyethylene bags.

**NOTE**
When interim packaging is used during processing, it shall be adequate to protect details from contamination, corrosion or damage during handling and storage.

3.9. Return to degreasing at paragraph 2.3.
## TABLE 3-2 CLEANING MATERIALS AND SOLUTIONS

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>MATERIAL/SOLUTION</th>
<th>APPLICATION/USE LIMITS</th>
<th>MANUFACTURER/SPECIFICATION</th>
<th>TEMP.</th>
<th>CONC. BY WT/GAL</th>
<th>ANALYTICAL CONTROLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>CAUSTIC SCALE REMOVER</td>
<td>SAFE ON STAINLESS STEEL &amp; CARBON STEEL</td>
<td>MIL-C-14460 TYPE I</td>
<td>190° ± 20° F</td>
<td>4.0 TO 6.0 LB/GAL (EQUALS 2-3 LBS NaOH)</td>
<td>TITRATE WEEKLY</td>
</tr>
<tr>
<td>S</td>
<td>ISOPROPYL ALCOHOL</td>
<td>DEGREASING, FLUSHING AND SAMPLING</td>
<td>FED-SPEC TT-I-735</td>
<td>AMBIENT</td>
<td>AS PROCURED</td>
<td>PER SE-S-0073, TABLE 6.3-25, WEEKLY</td>
</tr>
<tr>
<td>Q</td>
<td>TRICHLOROTRIFLUOROETHANE</td>
<td>VAPOR DEGREASING, ULTRASONICS AND VALIDATION</td>
<td>MIL-C-81302 MSC-SN-C-0037</td>
<td>110° ± 5° AND AMBIENT</td>
<td>AS PROCURED</td>
<td>ULTRASONICS AND VALIDATION - H₂O: 60PPM MAX ALCOHOL: 0.3% MAX CHLORIDES: 0.3PPM MAX TWICE WEEKLY</td>
</tr>
<tr>
<td>DD</td>
<td>ACETONE</td>
<td>PASSIVATION TEST MIL-STD-753 METHOD 102</td>
<td>FED-SPEC D-A-51</td>
<td>AMBIENT</td>
<td>AS PROCURED</td>
<td>N/A</td>
</tr>
<tr>
<td>JJ</td>
<td>HIGH PURITY WATER - DM (DEMINERALIZED) WATER, DI (DEIONIZED) WATER, DISTILLED WATER</td>
<td>RINSE, SOLUTION ADDITIVE, VALIDATION FLUID</td>
<td>SE-S-0073 GRADE A</td>
<td>VARIOUS</td>
<td>AS PROCURED</td>
<td>N/A</td>
</tr>
<tr>
<td>MM</td>
<td>SURFACTANT DEGREASER</td>
<td>DEGREASING SOLUTION, ULTRASONICS</td>
<td>BRULIN 815 GD</td>
<td>140°-180° F</td>
<td>3% - 10% BY VOL.</td>
<td>TEST DAILY &gt; 8 pH</td>
</tr>
<tr>
<td>NN</td>
<td>BIOACT PCG</td>
<td>SPECIALIZED DEGREASING, GLUE AND DECAL REMOVAL</td>
<td>ASTM D-740</td>
<td>AMBIENT</td>
<td>&gt; 85%</td>
<td>GAS CHROMATOGRAPH FOR PURITY</td>
</tr>
<tr>
<td>PP</td>
<td>MEK</td>
<td>SPECIALIZED PAINT, GLUE AND DECAL REMOVAL</td>
<td>ASTM D-740</td>
<td>AMBIENT</td>
<td>AS PROCURED</td>
<td>N/A</td>
</tr>
<tr>
<td>OO</td>
<td>ANTI-FOAM SURFACTANT DEGREASER</td>
<td>DEGREASING SOLUTION, HIGH PRESSURE SPRAY</td>
<td>BRULIN 1990 GD</td>
<td>130°-150° F</td>
<td>1% - 5% BY VOL.</td>
<td>&gt; 8 pH</td>
</tr>
<tr>
<td>QQ</td>
<td>NON-IONIC SURFACTANT</td>
<td>SURFACTANT, DEGREASING SOLUTION, VALIDATION SOLUTION</td>
<td>DUPONT ZONYL FSN</td>
<td>AMBIENT TO 140° F</td>
<td>25 PPM IN DM WATER</td>
<td>TEST DAILY OR CONCURRENTLY WITH USE, SURFACE TENSION 28-42 DYNE/CM; NEUTRALITY 6.0-8.0 pH</td>
</tr>
<tr>
<td>WW</td>
<td>VERTREL MCA</td>
<td>SOLVENT DEGREASING SOLUTION</td>
<td>DUPONT SE-S-0073 TABLE 6.3-XX</td>
<td>AMBIENT</td>
<td>AS PROCURED</td>
<td>TWICE WEEKLY PER SE-S-0073 TABLE 6.3-XX</td>
</tr>
<tr>
<td>XX</td>
<td>HFE-7100</td>
<td>VERIFICATION FLUID / FLUORINATED LUBRICANTS AND LIGHT HYDROCARBONS</td>
<td>SE-S-0073 TABLE 6.3-XX</td>
<td>AMBIENT</td>
<td>AS PROCURED</td>
<td>TWICE WEEKLY PER SE-S-0073 TABLE 6.3-XX</td>
</tr>
</tbody>
</table>

**Note:** Released - Printed documents may be obsolete; validate prior to use.