Engineering and Technical Services for Joint Group on Pollution Prevention (JG-PP) Projects

Joint Test Protocol J-00-CR-017

for Validation of a Portable LASER System for Coating Removal

February 5, 2001
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PREFACE

This report was prepared by HQ AFMC/LGP-EV. It was prepared on behalf of and under guidance provided by the Joint Group on Pollution Prevention (JG-PP) through the Joint Acquisition Sustainment Pollution Prevention Activity (JASPPA). JASPPA, government contractors, and other government technical representatives in response to the specific needs of this Joint Environmental Security Technology Certification Program (ESTCP) and JG-PP project determined the structure, format, and depth of technical content of this report.

We wish to thank the participants involved in the creation of this document for their invaluable contributions.

This Joint Test Protocol (JTP) serves to enhance technology transfer and provides the basic requirements that must be met to consider implementation of an alternative stripping process. The JTP describes the technology and performance requirements of the stripping process as applied to the substrates used on Department of Defense (DoD) weapons systems. Individual programs may have additional qualification requirements for approval of the process.

NOTE:
This JTP was revised by the technical engineers to clarify testing procedures. The first revision was made 12 Oct 01. The second revision and reformat was made 12 Mar 02. The below-listed changes are those made with concurrence of the stakeholders:

Table 4, Control Coating Systems:
As per Army representative instructions, use the MIL-P-23377G primer instead of the MIL-P-53022 primer with the MIL-C-46168 (Type IV) topcoat.

Para 3.1.1:
Measure strip rate only on one panel for specimen types that will undergo 4 de-paint cycles. For these specimens, strip rates will be measured during each strip cycle. However, strip rates will be measured on 3 panels for specimen that will not undergo 4 de-paint cycles.

Para 3.1.2c, Hardness Test Methodology:
Parameters: Add to end of sentence, “using the HR15T scale.”
Coupons Per Laser Coating Removal System: Change “Three” to read “One”
Trials Per Coupon: Change to read, “The panels shall be tested as received and after each of the four de-paint cycles resulting for a total of 5 series of tests per panel. There will be three tests in three of the four quadrants of the 12” X 12” panel.”

Para 3.1.2d, Conductivity, has been moved to Extended Testing. It is now listed as para 3.3.2.

Para 3.1.2e, Tensile Testing:
Use five uncoated and non-stripped specimen for baseline data. It is now listed as para 3.1.2d.

Para 3.1.3a(2):
Use method developed by CTIO. New method addresses intentions of the original JTP.

Para 3.2.5a:
Test after 4 de-paint cycles, not after each de-paint cycle. This reduces the number of specimen from 156 to 48.

Para 3.2.5b(1): Four Point Flexure has been moved to the Screening Test Phase. It is now listed as para 3.1.4.

Para 3.2.5c, Rotary Wing Metallic Substrate Assessment has been moved to the Screening Test Phase. It is now listed as 3.1.5.

Para 3.2.2d, Conductivity has been removed. It is now listed under Extended Tests as para 3.3.2.

Para 3.2.2e, Tensile Testing is now listed as para 3.2.2d.

Para 3.3.1: Extended Testing has been added.

Para 3.2.5b, Damage Assessment to Composite Materials has been moved to Extended Testing. It is now para 3.3.1a.

Paras 3.2.5b(2), Tension Testing; 3.2.5b(3), Compression Testing; and 3.2.5b(4), Open Hole Fatigue have been moved to the Extended Test Phase. They are now listed as paras 3.3.1a(1), 3.3.1a(2), and 3.3.1a(3), respectively.

Para 3.2.5b(4) which is now listed as para 3.3.1a(3), Open Hole Fatigue, use a reversal ratio of R= -1, instead of R=1 which was a typo.

Para 3.2.5c, Rotary Wing Metallic Substrate Assessment has been moved to Screening Testing. It is now listed as para 3.1.5. Test Procedure, change to read, “Smooth and Open Hole Fatigue shall be conducted IAW ASTM E466. The test stresses, which will be determined later, are to result in fatigue life of approximately 10k cycles to failure. Fatigue Crack Growth Rate (FCGR) tests shall be conducted IAW ASTM E647. FCGR tests and specimens shall be designed to produce data within the crack-tip stress-intensity factor range ([delta K]) of 6 ksi/in to 15ksi/in. Rotary wing metallic substrate testing parameters are outlined below: Chart titled Rotary Wing Metallic Substrates-Fatigue Testing.

Chart titled Fatigue Life and Fatigue Crack Growth Rate Specimen Dimension/Test Method Specifics: Under Requirement Description column, Row Other, Column Smooth (Standard Fatigue), delete all wording to leave blank.

Figure 3.5, Open Hole Fatigue Crack Growth Rate Specimen, change to read Figure 3.2, Open Hole Fatigue Specimen

Figure 3.6, Smooth Fatigue Crack Growth Rate Specimen, change to read Figure 3.3, Smooth Fatigue Specimen

Para 3.4.1, System Handling has been renamed to “Ease of Handling”

Due to movement of tests, the list of figures has changed as follows:

Figure 3.1 Four Point Flexure Test Specimen Configurations
Figure 3.2 Open-Hole Fatigue Specimens
Figure 3.3 Smooth Fatigue Specimens
Figure 3.4 Center Crack Fatigue Crack Growth Rate Specimens
Figure 3.5 Tension Specimen Configurations
Figure 3.6 Compression Specimen Configurations
Figure 3.7 Open-Hole Fatigue Specimen Configurations

Replace Figure 3.4, Center Crack Fatigue Crack Growth Rate Specimens, with new diagram as follows:

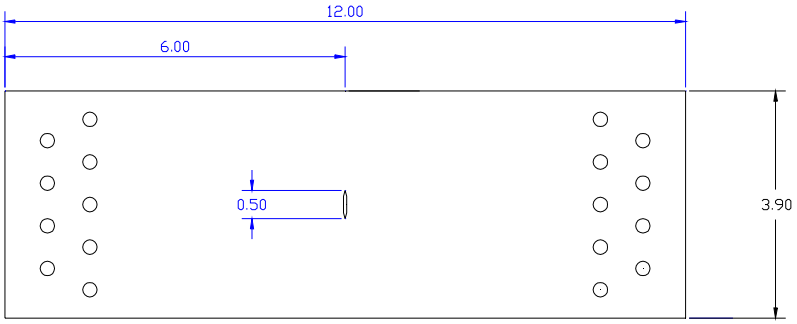

Figure 3.4, Center Crack Fatigue Crack Growth Rate Specimens

1. INTRODUCTION

The Joint Logistics Commanders (JLC) and Headquarters National Aeronautics and Space Administration (NASA) co-chartered the Joint Group on Pollution Prevention (JG-PP) to coordinate joint service/agency activities affecting pollution prevention issues identified during system and component acquisition and sustainment processes. The primary objectives of the JG-PP are to:

- Reduce or eliminate the use of hazardous materials (HazMats) or hazardous processes at manufacturing, remanufacturing, and sustainment locations.

- Avoid duplication of effort in actions required to reduce or eliminate HazMats through joint service cooperation and technology sharing.

This Joint Test Protocol (JTP) contains the critical requirements and tests necessary to qualify portable hand-held laser coating removal systems for use on metallic and non-metallic substrates. These tests were derived from engineering, performance, and operational impact (supportability) requirements defined by a consensus of government and industry 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 Department of Defense (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.

The Environmental Security Technology Certification Program (ESTCP) sponsored funding for the demonstration/validation of this technology, as well as the creation of the JTP and the JTR.

The current coating removal processes identified herein are for polyurethane, epoxy and other paint systems applied by conventional wet-spray, thermal spray and electrostatic powder coating. Table 1 summarizes the target HazMats; processes and materials; applications; affected agencies, and candidate substrates.

Table 1 Portable Laser Coating Removal System Target HazMat Summary

Target HazMat or Hazardous Waste	Current Process	Applications	Affected Services	Candidate Substrates
Methylene Chloride Methyl Ethyl Ketone	Chemical stripping. Spray & dip applications	Aircraft components Aviation equipment Ground/ Fighting equipment Weapon Systems	Air Force Army Navy USMC NASA	Aluminum Steel
Plastic Media and Coatings Residue	Dry media pressure blasting	Aircraft components Aviation equipment Ground/ Fighting equipment Weapon Systems	Air Force Army Navy USMC NASA	Fiberglass/ Epoxy (F/E) Graphite Aluminum Steel
Wheat Starch and Coatings Residue	Dry media pressure blasting	Aircraft components Aviation equipment Ground/ Fighting equipment Weapon Systems	Air Force Army Navy USMC NASA	Fiberglass/ Epoxy (F/E) Graphite Aluminum Steel
Coatings Residue	Hand Sanding	Aircraft components Aviation equipment Ground/ Fighting equipment Weapon Systems	Air Force Army Navy USMC NASA	Fiberglass/ Epoxy (F/E) Graphite Aluminum Steel

2. ENGINEERING AND TESTING REQUIREMENTS

The DoD, NASA, and industry technical representatives identified the screening, common, extended tests, and field evaluation requirements for a supplemental coating removal system. A consensus was reached for test procedures, methodologies, and criteria that provided the minimum requirements for a portable laser coating removal system. Army- and Navy-specific requirements can be found in the Extended Testing.

Once the JTP test criteria are approved, testing will be performed in a manner that will optimize the use of each test piece and/or panel. For example, where possible, more than one test should be performed on each specimen. The number and type of tests that can be run on any one specimen will be determined by the destructiveness of the test.

All portable laser coating removal system candidates will be evaluated on approved DoD, NASA, and industry standard coating systems listed in Table 4. Qualified personnel will perform all surface preparation and coating applications in accordance with best-standard practice to the appropriate coating technical documentation. Relevant process information will be documented at the time the test specimens are prepared. The coating removal process will follow all manufacturers' instructions.

NOTE: Tests in this JTP may involve use of hazardous materials, operations, and equipment. This JTP does not address all safety issues associated with its use. 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.

The objective of this project is to evaluate the performance of the candidate portable laser coating removal system for qualification as a supplemental and spot coating removal process. The JTP is structured into the following categories:

Screening Tests are preliminary tests performed on a number of candidate portable laser coating removal systems. Systems that do not meet the requirements of the screening tests will be eliminated from further testing. Systems that meet the requirements of the screening tests will be subjected to additional tests listing in this JTP.

Common Tests are requirements agreed upon by the participant DoD services, NASA, and the aerospace industry for portable laser coating removal systems that pass the screening tests.

Extended Tests are tests that are unique to a particular service or agency mission profile rather than the entire DoD, NASA, and aerospace industry.

Field Evaluation Tests are intended to test performance requirements of candidate portable laser coating removal systems and compare the alternatives in an operational environment. Upon approval from the appropriate weapons systems program manager, the field evaluations will be performed using only the candidate portable laser coating removal systems that adequately met acceptance criteria in the screening and common tests or agreed to by the stakeholders and extended tests as applicable.

Table 2 summarizes the test requirements for validating candidate portable laser coating removal systems. This listing includes applicable acceptance criteria and the references, if any, used in developing the tests. Where "none" appears under references, the test is based on the aggregate knowledge of the technical project personnel, previous testing knowledge, and stakeholder input as necessary.

All testing will be in accordance with the latest version of the applicable performance specification or technical directive.

Candidate systems must comply with applicable Federal Environmental and Occupational Safety and Health Administration (OSHA) requirements. Disposal of all removed coatings must be in accordance with Federal and local regulations.

Table 2 Test Requirements

Test Category	JTP Section	Test Name	Acceptance Criteria	Reference(s)
SCREENING	3.1	These are preliminary tests performed on a number of candidate portable laser coating removal systems. Systems that meet the requirements of the screening tests will be subjected to additional tests listed in this JTP.		
	3.1.1	Coating Strip Rate	Acceptance criteria based on requirement analysis or survey results and/or 0.06 ft^2 per minute at 6 mils nominal thickness	Air Force Engineering Qualification Plan (AF EQP)
	3.1.2a	Warping/Denting	No warping/denting observable at 10X magnification	
	3.1.2b	Metal/Composite Erosion	No metal/composite erosion observable at 10X magnification	
	3.1.2c	Hardness	No significant change in hardness	ASTM E18
	3.1.2d	Tensile Testing	No statistically significant degradation between baseline and test articles	ASTM E8
	3.1.3a(1)	Confirmation of Cladding Penetration	A black indication means “fail.” No black indication means “pass”	
	3.1.3a(2)	Determination of Cladding Loss	No more than 20 percent cladding removed after four de-paint cycles	
	3.1.3b	Surface Profile/Roughness	2024-T3 (Alclad): Not to exceed 125 micro inches 2024-T3 (Bare): Not to exceed 125 micro inches	SAE MA4872
	3.1.3c	Determination of Substrate Temperatures During Coating Removal Process	7075-T6 (Alclad): 300ºF maximum spike condition Graphite Epoxy Laminate: 200ºF maximum spike condition	
	3.1.3d	Resin Erosion and Fiber Damage of Composite Materials	No evidence of resin erosion or fiber damage of composite material	

Test Category	JTP Section	Test Name	Acceptance Criteria	Reference(s)
	3.1.4	Four-Point Flexure	No statistically significant degradation between baseline and test articles	ASTM D6273
	3.1.5	Rotary Wing Metallic Substrate Assessment		Air Force EQP ASTM E466, ASTM E647
COMMON	3.2	These tests are the requirements agreed upon by the participant DoD services, NASA, and the aerospace industry for portable laser coating removal systems that pass the screening tests.		
	3.2.1	Coating Strip Rate	Acceptance criteria based on requirements analysis or survey results and/or $0.25ft^2$ per minute at 3 mils nominal thickness	AF EQP
	3.2.2a	Warping/Denting	See JTP Section 3.1.2a	
	3.2.2b	Metal/Composite Erosion	See JTP Section 3.1.2b	
	3.2.2c	Hardness	See JTP Section 3.1.2c	
	3.2.2d	Tensile Testing	See JTP Section 3.1.2d	
	3.2.3a	Wet Tape Adhesion Test Procedure	Adhesion performance greater than or equal to 4a as specified in ASTM D3359	ASTM D3359
	3.2.4a	Clad Penetration Tests	See JTP Section 3.1.3a	
	3.2.4a(1)	Confirmation of Cladding Penetration	See JTP Section 3.1.3a(1)	
	3.2.4a(2)	Determination of Cladding Loss	See JTP Section 3.1.3a(2)	
	3.2.4b	Surface Profile/Roughness	See JTP Section 3.1.3b	
	3.2.4c	Determination of Substrate Temperatures During Coating Removal Process	See JTP Section 3.1.3c	
	3.2.4d	Resin Erosion and Fiber Damage of Composite Materials	See JTP Section 3.1.3d	
	3.2.5a	Damage Assessment to	Testing detail and results shall be	ASTM D1781, ASTM C393, AF

Test Category	JTP Section	Test Name	Acceptance Criteria	Reference(s)
		Composite Laminates and/or Honeycomb Structural Materials (Sandwich Construction)	documented for review and determination of pass/fail values	EQP
EXTENDED	3.3	These tests are unique to a particular service or agency mission profile rather than the entire DoD, NASA, and aerospace industry.		
	3.3.1a	Tension Testing	Testing detail and results shall be documented for review and determination of pass/fail values	ASTM D638
	3.3.1b	Compression Testing	Testing detail and results shall be documented for review and determination of pass/fail values	ASTM D695
	3.3.1c	Open Hole Fatigue	Testing detail and results shall be documented for review and determination of pass/fail values	ASTM E647
	3.3.2	Conductivity	No significant change in electrical conductivity	Eddy-Current Method
	3.3.3	Fixed Wing Metallic Substrates – Fatigue Crack Growth Rate	This test will only be conducted if the Rotary Wing Testing in JTP Section 3.1.5 fails	
FIELD EVALUATION	3.4	These tests are intended to test performance requirements of candidate portable laser coating removal systems and compare the alternatives in an operational environment.		
	3.4.1	Ease of Handling	The system can remove coatings with manning of two. System can be moved and manipulated around equipment by two persons. Portable Laser Gun Head weighs less than 5 pounds	
	3.4.2	Full Unit Operational Testing	The system performs at the depot/field location as it did in previous screening and common tests.	

Table 3 Test Panel Specimen Codes and Substrate Descriptions

Panel Specimen Code	**Substrate Descriptions**
Al-1a	Aluminum alloy: 2024-T3 (Alclad) 12” X 12” X 0.025”; cleaned according to ASTM F22-65, chromate conversion coated, conforming to MIL-C-5541E, Chemical Conversion Coatings on Aluminum and Aluminum Alloys, Nov 30, 90, Class 1A. Standard DoD/NASA coating applied per the coating manufacturer specifications.
Al-1b	Aluminum alloy: 2024-T3 (Bare) 12” X 12” X 0.025”; cleaned according to ASTM F22-65, chromate conversion coated, conforming to MIL-C-5541E, Chemical Conversion Coatings on Aluminum and Aluminum Alloys, Nov 30, 90, Class 1A. Standard DoD/NASA coating applied per the coating manufacturer specifications.
Al-2a	Aluminum alloy: 7075-T6 (Alclad) 12” X 12” X 0.025”; cleaned according to ASTM F22-65, chromate conversion coated, conforming to MIL-C-5541E, Chemical Conversion Coatings on Aluminum and Aluminum Alloys, Nov 30, 90, Class 1A. Standard DoD/NASA coating applied per the coating manufacturer specifications.
Al-2b	Aluminum alloy: 7075-T6 (Bare) 12” X 12” X 0.025”; cleaned according to ASTM F22-65, chromate conversion coated, conforming to MIL-C-5541E, Chemical Conversion Coatings on Aluminum and Aluminum Alloys, Nov 30, 90, Class 1A. Standard DoD/NASA coating applied per the coating manufacturer specifications.
Al-3b	Aluminum alloy: 2024-T3 (Bare) 12” X 12” X 0.025”; cleaned according to ASTM F22-65, Chromic Acid Anodized per MIL-A-8625, Type IB. Standard DoD/NASA coating applied per the coating manufacturer specification.
Al-5a	Aluminum alloy: 7075-T6 (Bare) 12” X 12” X 0.016”; cleaned according to ASTM F22-65, Chromate conversion coated, conforming to MIL-C-5541E, Chemical Conversion Coatings on Aluminum and Aluminum Alloys, Nov 30, 90, Class 1A. Standard DoD/NASA coating applied per the coating manufacturer specifications.
Al-6a	Aluminum alloy 2024-T3 (Alclad) 12” X 12” X 0.032”; cleaned according to ASTM F22-65, Chromate conversion coated, conforming to MIL-C-5541E, Chemical Conversion Coatings on Aluminum and Aluminum Alloys, Nov 30, 90, Class 1A. Standard DoD/NASA coating applied per the coating manufacturer specifications.
Al-7a	Aluminum alloy: 7075-T6 (Alclad) 12” X 12” X 0.032”; cleaned according to ASTM F22-65, Chromate conversion coated, conforming to MIL-C-5541E, Chemical Conversion Coatings on Aluminum and Aluminum Alloys, Nov 30, 90, Class 1A. Standard DoD/NASA coating applied per the coating manufacturer specifications.

Al-7b	Aluminum alloy: 7075-T6 (Bare) 12” X 12” X 0.032”; cleaned according to ASTM F22-65, Chromate conversion coated, conforming to MIL-C-5541E, Chemical Conversion Coatings on Aluminum and Aluminum Alloys, Nov 30, 90, Class 1A. Standard DoD/NASA coating applied per the coating manufacturer specifications.
AH	Aluminum Honeycomb materials in compliance with MIL-C-7438. FM 73 adhesive.
ST	Steel, 4130. 12” X 12” X 0.025”
FE	Fiberglass Epoxy (GM 3006) woven 4-ply (0/45)S 12” X 12”
GE-4	Graphite Epoxy (IM7/977-3) 14-ply (0/0/+45/-45/0/+45/-45)S 12” X 12”
GE-5	Graphite Epoxy (IM7/977-3) 14-ply (67.5º, $\pm$22.5º, -67.5º, $\pm$22.5º, 67.5º)S 12” X 12”
K	Kevlar (AMS 3902 and MIL-R-9300) 12” X 12”
MH	Metallic Honeycomb core: face 2024-T3 0.020”; core 5056-H39 A1, 3/16” cell, 0.002” foil, 0.625” thick.

Preparation of non-metallic test panels:
Clean with suitable solvent (i.e., methyl propyl ketone [MPK], MIL-T-81772, Type 1, polyurethane thinner, or A-A-857 lacquer thinner) to remove mold release. Roughen/activate surfaces with 180-240 grit sandpaper or Scotch-Brite for maximum adhesion. Remove sanding debris and re-clean with suitable solvent (i.e., methyl propyl ketone [MPK], MIL-T-81772, Type 1, polyurethane thinner, or A-A-857 lacquer thinner).

Preparation of metallic test panels:
Preparation of metallic test panels shall be as specified in Table 3 for each respective substrate.

Table 4 Control Systems

Service/ Agency	Primer	Topcoat	Substrate	Required Topcoat Color FED-STD-595	Total Thickness (Primer and Topcoat [mils])
Army USMC	MIL-P-23377G MIL-P-53030	MIL-C-46168, Type IV CARC MIL-C-64159, Type II	ST	383 Green 383 Green	3 or 6 3 or 6
NASA	10PW22-2 Super Koropon 515-K01A	As Received (None)	AL/ GE AL/ GE	17925 17925	3 3
USAF	MIL-PRF-23377	MIL-PRF-85285, Type I	AL/ GE	36251	3 or 6
USAF	PR1432GP	MIL-PRF-85285, Type I	AL/ GE	36495	4 or 8

3. TEST DESCRIPTIONS

Tests identified in Table 2 are further defined in this section to include the test specimens/panel description and test methodology. Any major or unique equipment requirements, data reporting, and analysis procedures are included. The test methodology lists the major parameters, test specimen descriptions number of trials per specimen and acceptance criteria.

Unless otherwise specified, test panels will be 12" X 12" long and of a suitable thickness (typically 0.025"). Test specimens must be painted or coated within 24 hours of the application of the pre-treatment (e.g., conversion coating or anodize seal). Each test will be performed on identical test specimens prepared with the DoD, NASA, and Aerospace Industry standard coating systems.

Each liquid coating system will be prepared and applied in accordance with the appropriate specification. The coating system may be applied in one or more coats to achieve the dry film thickness specified in Table 4. Application should be conducted at a minimum temperature of 70º Fahrenheit and 50 percent +/- 10 percent relative humidity (RH) unless otherwise specified. To ensure uniform coating thickness, coating applications shall be conducted per American Society for Testing and Materials (ASTM) D823, Standard Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels.

Unless otherwise specified, a topcoat is applied over the primer. The topcoat must be applied over the primer within the manufacturer's recommended time. The topcoat should be applied to

the total dry film thickness specified in Table 4. Unless otherwise specified, all panels shall be artificially aged for 7 days at room temperature followed by 7 days at 150º Fahrenheit (+/- 5º).

> **NOTE: Unless otherwise specified, all panels shall be subjected to the artificial aging process every time they are re-coated. Age and scuff sand per TO 1-1-8 between first coat of topcoat and second coat of primer for the thicker coated panels.**

Each powder coating system will be prepared and applied in accordance with the appropriate manufacturer's specification over a clean, bar or pretreated substrate. No primer is required for this test; however, the powder topcoat material may be applied over a powder coated base coat for added protection. The coating system will be applied electro statically to achieve the topcoat dry film thickness range of 3-5 mils for Polyester Triglycidyl Isocyanurate (TGIC) powder coatings and 1-3 mils for polyester urethane powder coatings. Total film thickness may be higher if a basecoat is applied. Powder coating application should be conducted at a minimum temperature of 70ºF (+/-10º). To ensure uniform coating thickness, coating applications shall be conducted per ASTM D823, Standard Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels.

Users of this JTP should check the project's JTR, if available, for additional test details or minor modifications that may have been necessary in the execution of testing. The technical stakeholders will have agreed upon any testing procedure modifications.

3.1 Screening Tests

This section contains information for screening tests for candidate portable laser coating removal systems. Portable laser coating removal systems that meet the requirements of the screening tests will be subjected to the additional tests listed in this JTP. Candidate portable laser coating removal systems that do not meet the requirements of the screening tests will be eliminated from further testing unless otherwise directed by the testing authorities and the stakeholders.

3.1.1 Coating Strip Rate

Test Description

This procedure is used to determine the rate of coating removal using a portable laser system. Paint strip rate test data shall be based on a minimum test area equal to 1 ft^2. The equipment manufacturer's instructions shall be followed for operation of the laser system. Measure strip rate only on one panel for specimen types that will undergo four de-paint cycles. For these specimens, strip rates will be measured during each strip cycle. However, strip rates will be measured on three panels for specimen that will not undergo four de-paint cycles.

Metal – Shall be stripped to substrate (< or equal to 0.2 mils primer remaining)

Non-metals – Shall be stripped to substrate (> or equal to 50 percent substrate exposed)

Rationale

This screening test is conducted to validate strip rates of the portable laser coating removal system and establish equipment design requirements. The coating strip rate of the portable laser coating removal system must meet or exceed strip rates established by the DoD, NASA, and industry participants. Acceptance criteria shall be based on requirement analysis or survey results and/or 0.06 ft^2 per minute at 6 mils nominal thickness.

> **NOTE: The test panels used for coating removal rate will be evaluated immediately after coating removal for surface damage. Due to this fact, it is imperative that the surface of all test panels/specimens be examined for any irregularities prior to the coating application. Test coupons exhibiting irregularities shall not be used.**

Prior to coating removal rate evaluation, each test panel shall have dry film thickness readings made at a minimum of nine symmetric locations on the panel for the primer coat and the total coating thickness (primer plus topcoat). Coating thickness measurements shall be to a resolution of 0.1 mil (0.0001 inch). This documentation shall be provided with strip rate data for each test panel.

Test Methodology

Parameters- Recorded during or Immediately following Test trial	Total stripping time per each coating (minutes) Stripping surface area (ft^2) Average Coating Thickness (mils) of each coating stripped. Process parameters must be recorded and reported, including: Average power, pulse width, pulse frequency, pulse energy, beam spot size at work surface, scan/raster rate or traverse rate.
Coupons Per Laser System	Three 6" X 6" areas on one 12" X 12" panel. Three of each substrate (Al-1a, Al-3b, ST, FE, GE-4) for each Control Coating System, 6 mils thickness Three panels of Substrate K with MIL-P-53030 primer and MIL-C-64159, Type I, topcoat, 6 mils thickness Test panels: Three of substrate Al-1a with Powder Coating, 6 mils thickness Test panels: Three of substrate Al-1a with GEM Coat as supplied by OO-ALC
Trials Per Coupon	One. Three 6" X 6" areas of one 12" X 12" panel shall be stripped.
Acceptance Criteria – Coating Removal Rate	Acceptance criteria based on requirement analysis or survey results and/or 0.06 ft^2 per minute at 6 mils nominal thickness.

Data Analysis

Paint strip rate data shall be presented as ft^2/minute for a given set of constant process parameters, paint thickness (layered and non-layered coatings) and per coatings system. This

data shall be the arithmetic mean value of three tests. An assessment of the degree of coatings removal shall be submitted with the strip rate data. A description of the methods used to maintain constant parameters and equipment settings shall be documented.

Stakeholders will down-select those control coatings with the slowest strip rate to go to damage, mechanical, and erosion tests.

3.1.2 Coating Removal Damage Appraisal

Test Description

The following tests serve to evaluate preliminary substrate damage as a result of using the alternate laser coating removal systems. Test materials/substrates shall be examined for Warping/Denting and Metal/Composite Erosion. Observations for substrate damage shall be made immediately following the coating removal process. Any surface abnormalities shall be noted and photographed.

Rationale

Due to the potential for substrate damage posed by any coatings removal process, a preliminary appraisal must be made to estimate the magnitude of this potential.

3.1.2a Warping/Denting

As applicable, examine all metallic substrate materials after application of the de-paint process for any indications of warping and/or denting. Warping will be seen as a curling of the test panel. Denting will be most easily observed on the rear surface, or the surface opposite to that to which the de-paint process is applied. This is expected to be an engineering evaluation and shall be substantiated by a brief written description supported by photographic documentation of the substrate surface following application of the de-painting process. This evaluation shall be conducted after each of four removal cycles.

3.1.2b Metal/Composite Erosion

Document any tendency for a de-paint process to remove or erode either a metallic surface or the surface matrix layer of a composite lay-up. Any pitting or apparent abrasion of either surface type should be considered potential substrate erosion.

These types of assessments may be made under magnification by comparison of stripped versus “as received” materials. Provide a brief written description and photographic documentation of the substrate surface following the application of the de-painting process. Examine for surface cracking, pitting, or roughening. This evaluation shall be conducted after each of the four removal cycles.

Test Methodology

Parameters	10X Magnification of Stripped Surface for warping/denting; metal/composite erosion
Coupons Per Laser Coating Removal System	Three of each substrate (Al-1a; Al-3b; ST; FE; GE-4) for each down-selected Control Coating System, 6 mils thickness. Note: Use test coupons from the Coating Strip Rate (paragraph 3.1.1).
Trials Per Coupon	One (examine the entire surface of the coupon). The coupons shall be tested after each removal cycle.
Acceptance Criteria	No warping/denting; metal/composite erosion observable at 10X magnification.

Note: Control panels will not be created. Rather, tests before and after will be accomplished.

3.1.2c Hardness

Superficial Hardness testing shall be conducted on two materials, unclad 2024-T3 and unclad 7075-T6 coated with MIL-PRF-23377 and MIL-PRF-85285, Type I, color 36495, 6 mils thickness. The panels shall be tested as received and after each of the four de-paint cycles resulting in a total of 5 series of tests per panel. There will be three tests in three of the four quadrants of the 12" X 12" panel. Testing shall be conducted per ASTM E18, Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials.

Test Methodology

Parameters	Verification of Superficial Hardness per ASTM E18 using the HR15T scale.
Coupons Per Laser Coating Removal System	One of Al-1b and Al-2b coated with MIL-PRF-23377 and MIL-PRF 85285, Type I, color 36495, 6 mils thickness.
Trials Per Coupon	Three. The coupons shall be tested after each of the four de-paint cycles. Note: Hardness values/readings must be obtained prior to the initial paint process for comparison of before and after data.
Acceptance Criteria	No significant change in hardness.

3.1.2d Tensile Testing

Tensile strength shall be verified per ASTM E8, Standard Test Methods for Tension Testing of Metallic Materials.

Test Methodology

Parameters	Tensile Strength per ASTM E8
Coupons Per Laser Coating Removal System	Five ASTM E8 specimens of Al-1b and Al-2b coasted with MIL-PRF-23377 and MIL-PRF-85285, Type I, color 36495, 6 mils thickness. Five of Al-1b and Al-2b uncoated and non-stripped (Control Samples for comparison values).
Trials Per Specimen	One.
Acceptance Criteria	No statistically significant degradation between baseline and test articles.

Data Analysis
Statistical analysis will be conducted to determine if there is a difference between the values of the means obtained in baseline and test article coupons. A 90 percent confidence level will be the basis for comparison.

Major or Unique Equipment
Tensile Testing Equipment

3.1.3 Metal/Composite Substrate Damage Assessment

Test Description
The following tests serve to evaluate substrate damage as a result of using the portable laser coating removal systems. Tests materials/substrates shall be examined for cladding erosion; surface roughness; thermal effects; resin erosion and fiber damage. Any surface abnormalities shall be noted and photographed.

Rationale
Due to the potential for substrate damage posed by any coatings removal process, preliminary appraisal must be made to estimate the magnitude of this potential.

3.1.3a Clad Penetration Tests

Cladding erosion evaluation shall be conducted to confirm that the coating removal process does not remove any significant portions of cladding. If chemical film remains over entire surface, then cladding removal is 0 percent removed. No further cladding test is required. If visual examination shows obvious signs of complete cladding removal, use the procedure found in paragraph 3.1.3a(1) to confirm cladding penetration. In no visual indications or if testing per SAE MA4872 does not indicate penetration, then utilize the procedure below in paragraph 3.1.3a(2) for determining cladding loss.

3.1.3a(1) Confirmation of Cladding Penetration

Test Description
This test is to determine if damage penetrates through the cladding layer and into the base material. No special apparatus is required. Test panels shall be metallic panels measuring 12" X 12" X 0.025" [(Al-1a) 2024-T3 (Alclad)]. Prepare, paint and age specimens.

Test Procedure
Solvent clean the area to be tested. Mask off damage to prevent staining of adjacent areas by test solution. The solution used for determining penetration through the cladding and into the base material shall consist of the following proportions:

(1)Potassium nitrate (KN03): 200 g
(2)Sodium hydroxide (NaOH): 100 g
(3)Water to make 1 liter of solution

Apply one drop of cladding penetration test solution with a sharp point of a toothpick to the deepest point of the damage. Use the minimum amount of test solution necessary to penetrate to the bottom of the damage. Do not allow this caustic solution to contact any other area than that to be tested.

When the bottom of the damage reveals a distinct black indication, the damage has penetrated the cladding to the base material. Immediately rinse with water the test area thoroughly after observing the black indication.

If no black indication occurs after 3 minutes, then the damage has not penetrated through the cladding to the base material. Immediately rinse with water the test area thoroughly.

A black indication shall be reported as a "fail." No black indication shall be reported as a "pass."

3.1.3a(2) Determination of Cladding Loss

Test Procedure
Cladding erosion evaluations shall be made as a determination of weight loss, per cumulative de-paint cycle, except where obvious signs of cladding penetration have occurred. (See cladding penetration SAE MA4872). The complete cladding erosion data set shall be comprised of four data points representing the mean cladding loss value derived from three different specimens per de-paint cycle for 1 through 4 cycles of the de-paint process (3 specimens for each de-painting cycle).

Twelve 6" X 6" X 0.025" [(Al-1a) 2024-T3 (Alclad)] will be coated with the appropriate primer and topcoat combination. The primer and topcoat combination will be determined by the slowest strip rate (see 3.1.1). Prior to painting and surface preparation, the panels will be weighed to the nearest mg. The panels will be surface prepared according to MIL-C-5541 and reweighed. After each de-paint cycle, three panels of each system will be set aside for clad erosion testing. The remaining panels will be prepared (non-abrasive), repainted and returned for laser stripping. This

process will be repeated until all panels have been stripped. There will be three panels having undergone 1, 2, 3, and 4 stripping cycles (total of 12 panels per laser system).

Any residual paint on the panels will be stripped with a methylene chloride-based stripper. Panel weight and weight loss will be plotted as a function of number of strip cycles. Analysis of variance will be used to determine if any demonstrated weight loss from panels is significant, and whether it is a function of the coating system, or a particular laser system.

The cladding erosion data shall be presented in tabular form as an approximate percent cladding erosion per specimen, per de-paint cycle, and the mean approximate percent loss for three specimens per de-paint cycle for 1 to 4 cycles. The approximate percentage of cladding erosion resulting from applications of the de-paint process may be derived from the weight measurements by the assumption that the surface to which the process is applied to is nominally 5 percent of the total thickness of the test specimen. The mean cladding erosion values are to be presented in graphical form as cladding erosion plotted as a function of de-paint cycle for 0 through 4 de-paint cycles. A 6" X 6" X 0.025" Aluminum panel weighs approximately 40 grams. Five percent of the weight is 2.0 grams. Since the clad is on both sides, but only one side is stripped, the weight loss of 100 percent of the clad from one side would be 1 gram. The 20 percent criteria, therefore, requires a weight loss of no more than 200 mg.

The specimen for each cyclic value that are most representative of the mean cladding erosion percent value derived from the three specimens per cycle group shall be micro graphically examined and documented to assess the profile of the eroded surface. The procedures that shall be followed to prepare the specimen(s) for this assessment shall be done by mounting, polishing, and etching, as necessary a cross-sectioned portion of the specimen using standard metallographic methods. The documentation shall be of the form of photographs at a magnification of 250X of the individual cross-sectioned specimens. An additional specimen from each group of three will be reserved for the measurement of process imparted surface roughness (paragraph 3.1.3b).

Test Methodology

Parameters	Mean percentage of cladding lost during de-paint cycles.
Coupons Per Laser Coating Removal System	Three (Al-1a) panels coated with the most difficult common coating system to remove based on results from paragraph 3.1.1 for each of the four de-paint cycles (12 total).
Trials Per Coupon	One trial (de-paint cycles) per test coupon.
Acceptance Criteria	No more than 20 percent cladding removed after four de-paint cycles.

Major or Unique Equipment

Scale capable of resolution of 0.001 g.

3.1.3b Surface Profile/Roughness

Test Description

Use test description and test procedures based on SAE MA4872. Profilometry measurements shall be conducted on test coupons to determine surface roughness.

Test Procedure

This test is to determine if the paint stripping process changes the roughness of the surface. The apparatus required for this test will be a Surtronic 3 profilometer with a standard pickup probe Type 112/1503, cutoff 0.8/0.3 LS (long stroke) or equivalent. Test specimen shall be 12" X 12" X 0.025", (Al-1a) 2024-T3 (Alclad) and (Al-1b) 2024-T3 (Bare). Measure the surface roughness prior to painting using a Surtronic 3 profilometer with a standard pickup probe Type 112/1503, cutoff 0.8/0.3 LS (long stroke) or equivalent. A minimum of five readings performed along different directions and different places in each panel. Record each of the five readings as the baseline for each specimen. Paint and age the specimens.

Test Methodology

Strip specimen and clean if necessary to remove stripping residues. Measure the surface roughness. A minimum of five readings shall be performed along different directions and different places in the panel. Record each of the readings. Repeat the process until a minimum of four strip cycles have been completed.

Results shall be expressed in micrometers Ra (micro inches Ra). Any reading greater than 3.2 um (125 uin) shall be reported as a "fail."

Test Methodology

Parameters	Surface Roughness representing root-mean-square (RMS) and average peak-to-valley roughness.
Coupons Per Laser Coating Removal System	Three (Al-1a; Al-1b) panels coated with the most difficult common coating system to remove based on results from paragraph 3.1.1, 6 mils thickness.
Trials Per Coupon	Five readings per removal cycle (after one cycle and after four cycles)
Control Coupons Required	None
Acceptance Criteria	2024-T3 (Alclad): Not to exceed 125 micro inches. 2024-T3 (Bare): Not to exceed 125 micro inches.

Major or Unique Equipment

Surtronic 3 profilometer with a standard pickup probe Type 112/1503, cutoff 0.8/0.3 LS (long stroke) or equivalent.

3.1.3c Determination of Substrate Temperatures During Coating Removal Process

Test Description

This procedure assists in determining metallic and non-metallic substrate temperatures resulting from the coating removal process.

Rationale

Temperature response to the coating removal process is critical in determining potential mechanical or physical property degradation of the immediate substrate or internal components.

Test Methodology

The metal and graphite epoxy laminate will have chromel-alumel thermocouples and self-stick temperature indicator labels in order to monitor substrate temperature response during paint stripping as follows:

12” X 12” X 0.025” (Al-2a) 7075-T6 (Alclad)
12” X 12” Modified GE-4 with a chromel-alumel thermocouple embedded between the first and second ply (approximately 0.0676 inches)

Paint one side each panel:

Coat one side of each panel with the hardest (slowest) to remove common coating system based on test results from paragraph 3.1.1, Coating Strip Rate.

Dry 7 days, ambient temperature
Age 7 days, 150° F

Drill two holes in back (unpainted) side of aluminum panel to a depth of 0.010” to accommodate a chromel-alumel thermocouple in each; bond thermocouples with conductive adhesive (Wakefield 152 Blue Epoxy Resin/Wakefield Hardener C4 Hardener). Mount two additional thermocouples on back of panel with conductive adhesive (Wakefield 152 Blue Epoxy Resin/Wakefield Hardener C4 Hardener).

Mount two additional thermocouples on back side of graphite epoxy panel with conductive adhesive (Wakefield 152 Blue Epoxy Resin/Wakefield Hardener C4 Hardener).

Add three self-stick visual temperature indicator labels on back of each panel, with minimum indicator points of 200°, 230°, 250°, 270°, and 300° F.

Record thermocouple temperature readings during continuous stripping of the test panels to substrate. Report peak temperatures and length of time at peak along with results from visual temperature indicator strips.

Test Methodology

Parameters	**EXTERNAL SURFACES (TOP AND BOTTOM) AND MID-DEPTH SECTION TEMPERATURE READINGS. RECORD TEMPERATURE READINGS FROM ALL THERMOCOUPLES AND TEMPERATURE INDICATOR LABELS.**
Coupons Per Laser Coating Removal System	12" X 12" X 0.025" Al-2a panel 12" X 12" Graphite Epoxy (GE-4) laminate test panel, 14 ply
Trials Per Coupon	One paint removal cycle. Continuous reading of temperature during stripping process
Acceptance Criteria	7075-T6 (Alclad): 300°F maximum spike conditions. Graphite Epoxy Laminate: 200°F maximum spike conditions.

Data Analysis
Record thermocouple readings during entire stripping process. Report peak temperatures and length of time at peak. Note the results of the visual indicator strips.

Major or Unique Equipment
Thermocouples inserted in the lay-up process of the composite materials.
Visual temperature indicator strips.

3.1.3d Resin Erosion and Fiber Damage of Composite Materials

Test Description
The indications of gross substrate damage for the composite materials will be evidence of resin erosion and any indications of fiber damage within the matrix. These types of assessments may be made under magnification by comparison of stripped versus "as received" materials. Samples will be cross-sectioned for examination under optical magnification to determine the extent of any damage.

Test Methodology
All specimens used in the materials characterization shall undergo artificial aging/elevated temperature curing of the coating systems. After the artificial aging process has been completed, the test specimens shall be subjected to the de-paint process (4 cycles minimum).

> **NOTE: The test panels from the thermal effects evaluation in paragraph 3.1.3c will be used for this evaluation. When performing cross section, do not conduct on areas where thermocouples were inserted.**

Test Methodology

Parameters	Composite Sample: Resin Erosion and Fiber Damage.
Coupons Per Laser Coating Removal System	Use Graphite/Epoxy Test Coupons from the Thermal Effects test in 3.1.3c.
Trials Per Coupon	Cross-section after one and four paint removal cycles.
Acceptance Criteria	No evidence of resin erosion or fiber damage of composite material.

Major or Unique Equipment
Equipment for micro sectioning of substrates.
Magnification equipment.

3.1.4 Four-Point Flexure

Test Procedure
Four-point flexure testing shall be conducted per ASTM D6273. Composite coupons shall undergo ultrasonic nondestructive inspection to verify the structural integrity of the material prior to de-painting. Laminate materials found to be free from defects shall be de-painted, re-inspected, and tested per the appropriate standard.

Determine the flexure properties of the laminate per ASTM D6273. The laminate flexure test shall be conducted using Test Method I. Because of the relatively thin laminates, the specimen length will also be short to meet the span-to-depth requirements. If the measured flexural modulus is not what would be predicted from theory, flexural tests shall be conducted using span-to-depth ratio of 60:1. The tests shall also be conducted using Procedure A because the composite materials are expected to fail at relatively small deflections.

> **NOTE: Test the paint-de-paint side of the coupon in the compressive mode, i.e., that side of the test coupon will be placed in the upward position of the test fixture.**

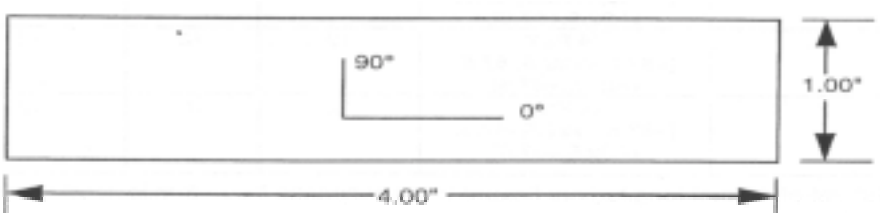

Figure 3.1 Four Point Flexure Test Specimen Configuration

Damage Assessment to Composite Materials

Parameters	Four Point Flexure per ASTM D6273
Coupons Per Laser Coating Removal System	Five each of GE-4 coated with MIL-PRF-23377 and MIL-PRF-85285, 3 mils Five controls of GE-4 (uncoated/no de-paint processing on these panels.
Trials Per Coupon	One examination per coupon(s) after four de-paint cycles.
Acceptance Criteria	No statistically significant degradation between baseline and test articles.

Data Analysis

Statistical analysis will be conducted to determine if there is a difference between the values of the means obtained in baseline and test article coupons. A 90 percent confidence level will be the basis for comparison.

3.1.5 Rotary Wing Metallic Substrate Assessment

Test Description

Rotary Wing Metallic Substrates shall be tested for Fatigue Life on Smooth and Open Hole Specimens and Fatigue rack Growth on Center Crack Specimens. For additional testing reference please refer to the Air Force EQP. For Clad Alloys: Rotary wing tests use 0.025; fixed wing tests use 0.032. If 0.025 data are acceptable, then fixed wing systems will accept rotary data. (Will not require testing per JTP Section 3.3.3.)

Test Procedure

Smooth and Open Hole Fatigue shall be conducted IAW ASTM E466. The test stresses, which will be determined later, are to result in fatigue life of approximately 10k cycles to failure. Fatigue Crack Growth Rate (FCGR) tests shall be conducted IAW ASTM E647. The FCGR tests and specimens shall be designed to produce data within the crack-tip stress-intensity factor range ([delta K]) of 6 ksi/in to 15 ksi/in. Rotary wing metallic substrate testing parameters are outlined below:

Rotary Wing Metallic Substrates – Fatigue Testing

	Smooth	**Open Hole**	**Center Crack**
CLAD 7075-T6 (0.025 inches) Test Coupon Code: Al-2a	6 Baseline (R=+.1) 6 Substrate (R=+.1)	6 Baseline (R=+.1) 6 Substrate (R=+.1)	6 Baseline (R=+.1) 6 Substrate (R=+.1)
CLAD 2024-T3 (0.025 inches) Test Coupon Code: Al-1a	6 Baseline (R=+.1) 6 Substrate (R=+.1)	12 Baseline (R=+.1) 12 Substrate (R=+.1)	6 Baseline (R=+.1) 6 Substrate (R=+.1)
BARE 7075-T6 (0.016 inches) Test Coupon Code: Al-5a	6 Baseline (R=+.1) 6 Substrate (R=+.1)	6 Baseline (R=+.1) 6 Substrate (R=+.1)	6 Baseline (R=+.1) 6 Substrate (R=+.1)

Note: Four cycles of stripping to substrate and to saturate. (120 Specimens)
If decrease of greater than 5% due to stripping process occurs, then will need to run fixed wing testing of the two clad alloys at specimen thickness of 0.032" per JTP Section 3.3.3.

Data Analysis

Any statistically significant difference between the means at confidence level of 90 percent will require more refined fatigue testing to provide better definition of the de-painting process effects on materials fatigue characteristics.

Requirement Description	**Smooth** (Standard Fatigue)	**Open Hole Fatigue** (Standard Fatigue)	**Center-crack** (Fatigue Crack Growth Rate)
Specimen Dimension	7” X 0.754”	7” X 1”	7” X 1”
Roll Direction	7”	7”	7”
Dogbone Cut Specifics		N/A	N/A
Narrow Width	0.5”		
Narrow Length	5”		
Narrow Radius	4”		
EDM Diameter	None	None	.03” for 7075-T6 .05” for 2024-T3
EDM Length	N/A	N/A	
Centered Hole Diameter	None	D-0.125” Centered	None
RHR Surface Finish	RHR 75	RHR 75	RHR 75
Testing Procedure Specifics	Per ASTM E466		Per ASTM E647
Stress Ratio (R=)	0.1		.1
Frequency	10 Hz		10 Hz
Other			FCGR tests and specimens shall be designed to produce data within the crack-tip stress intensity factor range ([delta K]) of 6 ksi/in to 15 ksi/in
Fatigue Life and Fatigue Crack Growth Rate Specimen Dimension/Test Method Specifics			

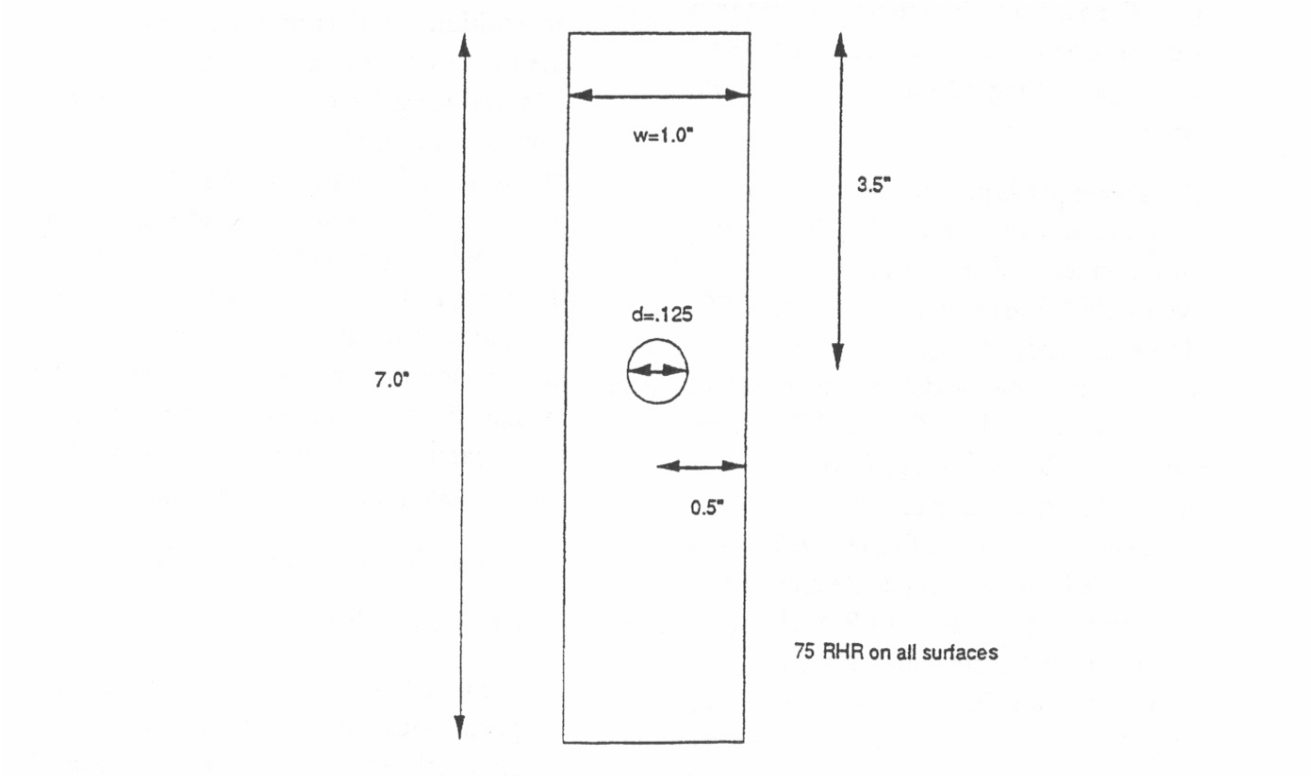

Figure 3.2 Open Hole Fatigue Specimen

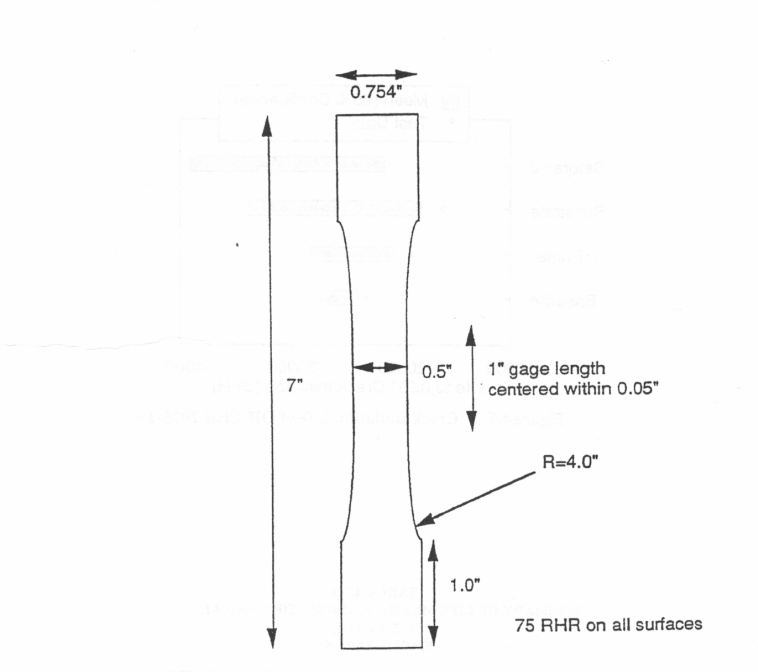

Figure 3.3 Smooth Fatigue Specimens

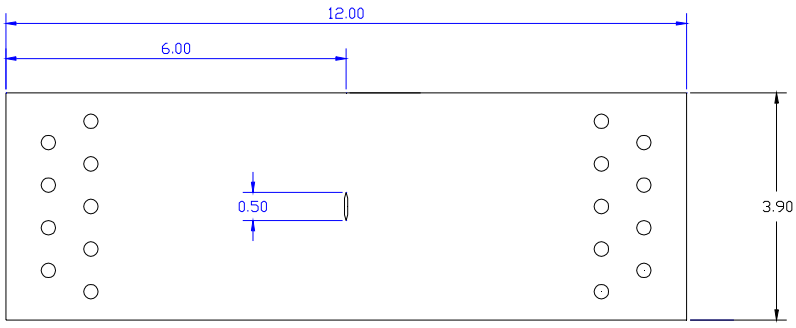

Figure 3.4 Center Crack Fatigue Crack Growth Rate Specimens

NOTE: Those laser systems that meet the requirements of the screening test will be carried on to the common tests. See JTR for modifications.

3.2 Common Tests

NOTE: The candidate laser systems that have successfully passed the screening tests will be tested utilizing the slowest strip rate coating system. Common tests will be conducted for damage, mechanical, and erosion type testing.

3.2.1 Coating Strip Rate

Test Description

This procedure is used to determine the rate of coating removal using a portable laser system. Paint strip rate test data shall be based on a minimum test area equal to 1 ft^2. The equipment manufacturer's instructions shall be followed for operation of the laser system.

Metal – Shall be stripped to substrate (< or equal to 0.2 mils primer remaining)

Non-metals – Shall be stripped to substrate (> or equal to 50% substrate exposed)

Rationale

This common test is conducted to validate strip rates of the portable laser coating removal system and establish design requirements. The coating strip rate of the portable laser coating removal system must meet or exceed strip rates established by the DoD, NASA, and industry participants. Acceptance criteria shall be based on requirements analysis or survey results and/or 0.25 ft^2 per minute at 3 mils nominal thickness.

NOTE: The test panels used for coating removal rate will be evaluated immediately after coating removal for surface damage. Due to this fact, it is imperative that the surface of all test panels/specimens be examined for any irregularities prior to the coating application. Test coupons exhibiting irregularities shall not be used.

Prior to coating removal rate evaluation, each test panel shall have dry film thickness readings made at a minimum of nine symmetric locations on the panel for the primer coat, and the total coating thickness (primer plus topcoat). Coating thickness measurements shall be a resolution of 0.1 mil (0.0001 inch). This documentation shall be provided with strip rate data for each test panel.

Test Methodology

Parameters – Recorded during or Immediately following Test trial	Total stripping time per each coating (minutes) Stripping surface area (ft^2) Average Coating Thickness (mils) of each coating stripped. Process parameters must be recorded and reported, including: Average power, pulse width, pulse frequency, pulse energy, beam spot size at work surface, scan/raster rate or traverse rate.
Coupons Per Laser System	Three of each substrate (Al-1a; Al-3b; ST; FE; GE-4) for the down selected Coating System, 3 mils thickness
Trials Per Coupon	One. Three 6" X 6" areas of one 12" X 12" panel shall be stripped.
Acceptance Criteria- Coating Removal Rate	Acceptance criteria based on requirements analysis or survey results and/or 0.25 ft^2 per minute at 3 mils nominal thickness.

Data Analysis

Paint strip rate data shall be presented as ft^2/minute for a given set of constant process parameters, paint thickness (layered and non-layered coatings) and per coatings system. This data shall be the arithmetic mean value of three tests. An assessment of the degree of coatings removal shall be submitted with the strip rate data. A description of the methods used to maintain constant process parameters and equipment settings shall be documented.

3.2.2 Coating Removal Damage Appraisal

Duplicate test as in Screening – See JTP Section 3.1.2 for specific details.

3.2.2a Warping/Denting

Duplicate test as in Screening – See JTP Section 3.1.2a for specific details.

3.2.2b Metal/Composite Erosion

Duplicate test as in Screening – See JTP Section 3.1.2b for specific details.

3.2.2c Hardness

Duplicate test as in Screening – See JTP Section 3.1.2c for specific details.

3.2.2d Tensile Testing

Duplicate test as in Screening – See JTP Section 3.1.2d for specific details.

3.2.3 Paint Adhesion Testing Following De-painting and Reapplying Coatings

Rationale
The following tests are for the determination of potential adhesion problems to the substrate surface after the de-painting process with the portable laser coating removal system. Wet tape adhesion testing will also be conducted to ensure that there are no surface adhesion issues.

3.2.3a Wet Tape Adhesion Test Procedure

Test panels shall be stripped with the portable laser coating removal system per the manufacturer's instructions. After the de-painting process is complete, the original coatings shall be reapplied in the stripped area per the coating manufacturer's recommended instructions. For this test procedure, the following primers and topcoats and substrates shall be used for the re-coating process and evaluation:

Aluminum Alloys: MIL-PRF-23377
MIL-PRF-85285

Steel Alloys: MIL-P-23377G,
MIL-C-46168, Type IV

Upon complete cure/artificial aging of the test panels, select five areas within two inches of the edges of the panels and test each panel as follows:

Immerse each test panel in distilled water at room temperature for 24 hours IAW FED-STD-141C, Method 6301.2. Remove each panel from the water and wipe dry with a soft cloth. Within one minute of removing a panel from the water, scribe two parallel lines one inch apart and scribe an "X" between the parallel lines (note that this is a modification of the scribing described in FED-STD-141C, Method 6301.2).

Evaluate the adhesion of each coating system to the substrate as specified in ASTM D3359, Test Method A. 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 D3359.

Test Methodology

Parameters	Wet Tape Adhesion: ASTM D3359 rating related to amount of coating removal.
Coupons Per Laser Coating Removal System	One each (Al-1a; Al-3b; ST) panels from the Coating Strip Rate Removal test (para 3.2.1) for this evaluation.
Trials Per Coupon	Five tests per panel.
Acceptance Criteria	Adhesion performance greater than or equal to 4a as specified in ASTM D3359.

3.2.4 Metal/Composite Substrate Damage Assessment

Duplicate test as in Screening – See JTP Section 3.1.3 for specific details.

3.2.4a Clad Penetration Tests

Duplicate test as in Screening – See JTP Section 3.1.3a for specific details.

3.2.4a(1) Confirmation of Cladding Penetration

Duplicate test as in Screening – See JTP Section 3.1.3a(1) for specific details.

3.2.4a(2) Determination of Cladding Loss

Duplicate test as in Screening – See JTP Section 3.1.3a(2) for specific details.

3.2.4b Surface Profile/Roughness

Duplicate test as in Screening – See JTP Section 3.1.3b for specific details.

3.2.4c Determination of Substrate Temperatures During Coating Removal Process

Duplicate test as in Screening – See JTP Section 3.1.3c for specific details.

3.2.4d Resin Erosion and Fiber Damage of Composite Materials

Duplicate test as in Screening – See JTP Section 3.1.3d for specific details.

3.2.5 Composite Mechanical Test Program

Test Description
The following evaluations are an expansion on the materials characterization in 3.2.2 and 3.2.4. For additional testing reference for this section, please refer to the Air Force EQP.

3.2.5a Damage Assessment to Composite Laminates and/or Honeycomb Structural Materials (Sandwich Construction)

Test Description
The intent of this damage assessment task is to determine the type and the extent of damage that could occur with composite materials/structures as a result of de-paint procedures. All testing

and analysis specimen fabrication and preparation shall be performed in accordance with an appropriate standard or specification.

Test Procedure

The materials tested within this portion of the qualification plan represent typical composite laminates and/or honeycomb structures (metallic and composite laminate face sheets). Each of the material/structural combinations that will be examined shall be prepared in accordance with the following specifications. The following paragraphs will also describe the experimental conditioning procedures that shall be observed per type of material/structure.

All aluminum honeycomb materials shall comply with MIL-C-7438. Composite laminates (fiber/matrix) shall be constructed using the lay-up required by the appropriate test method.

Composite Materials/Constructions Properties Testing:
For a paint removal process to be effective, the process cannot degrade the integrity of the structure to which it has been applied. Various types of tests, dependent on the material and structural makeup, shall be conducted to assess possible degradation of these materials due to the de-paint process. The test methods that shall be used may include non-destructive inspection and/or mechanical testing. The succeeding paragraphs outline the various tests and any pertinent standards/specifications that shall be conducted for each type of material and/or combination.

Test materials that are to be inspected by ultrasonic techniques (C-scan) other than aluminum face/honeycomb materials, shall be large enough that a test section may be described on that panel that is, at a maximum, half of the total area of the panel. This is to avoid errors due to water intrusion along the free edges if the inspection operations are conducted in a fluid.

The following mechanical properties test on aluminum face sheet/honeycomb core structures shall be conducted: 1) Determine the peel resistance of the adhesive bond between the face sheet and the honeycomb core per ASTM D1781 and 2) Determine the flexural properties of flat sandwich constructions per ASTM C393.

The composite laminate/aluminum honeycomb structures shall be examined by NDI methods and mechanical properties testing. Ultrasonic evaluations per ASTM E114 shall be conducted on all specimen test sections prior to application of the de-paint process to ascertain the structural integrity of the test specimen and provide baseline data. Any materials that are found to have defects by these methods shall not be used for paint stripping evaluations. If the primer coating has remained intact throughout the conditioning procedures, it shall not be necessary to perform another inspection of the test materials until after the final de-paint cycle. Any discontinuities found in the material shall be documented by location, frequency, and when possible, by graphical reproduction of the ultrasonic signal. If discontinuities are produced by the de-painting process, these defects shall be quantified by size, planar location, and depth if possible. Mechanical testing shall be conducted to assess the flexural properties of the sandwich construction using a long-beam flexure specimen and MIL-STD-401, which includes a reference to ASTM C393. The order of precedence for the long-beam flexure test shall be this document, followed by MIL-STD-401, and then ASTM C393.

Damage Assessment to Composite Laminate and/or Honeycomb Structural Materials

Parameters	Peel Resistance of adhesive bond between the face sheet and the honeycomb core per ASTM D1781. Flexural Properties of flat sandwich constructions per ASTM C393. NDI per AF EQP. For additional information, refer to the AF EQP.
Coupons Per Laser Coating Removal System	Peel Resistance: Six each of AH and MH. Six controls of AH and MH (uncoated/no de-paint processing on these panels). Flexural Properties per ASTM C393: Six each of AH and MH (uncoated/no de-paint processing on these panels). NDI per AF EQP: Use the panels prepared for Peel Resistance and Flexure (noted above). Coupon coating – standard coating (23377/85285)
Trials Per Coupon	Test after four de-paint cycles.
Acceptance Criteria	Testing detail and results shall be documented for review and determination of pass/fail values.

3.3 Extended Tests

3.3.1 Damage Assessment to Composite Materials

Test Description

Tension, Compression, and Open Hole Fatigue, shall be conducted on the composite materials outlined in the following paragraphs. The materials and tests outlined in this section are based on previous plastic media blast (PMB) and Flashjet investigations performed for the NAVY.

3.3.1a Tension Testing

Test Procedure

Tension testing shall be conducted per ASTM D638. Composite coupons shall undergo ultrasonic nondestructive inspection to verify the structural integrity of the material prior to de-painting. Laminate materials found to be free from defects shall be de-painted, re-inspected and then tested per the appropriate standard.

> **NOTE: A biaxial strain gauge will be bonded to the tool side of the composite test specimen, and a unidirectional strain gauge will be bonded to the bag-side of specimen to record specimen strain during testing.**

Composite tabs for gripping will be bonded to the specimen before test, but after stripping cycles. Bond 8 ply fiberglass tabs, bonded with EA934 epoxy adhesive with 5-mil glass beads or fiber mesh to control the bond line thicknesses. ASTM D638 specimen diagram has a different shape, dog bone, but use a rectangular specimen.

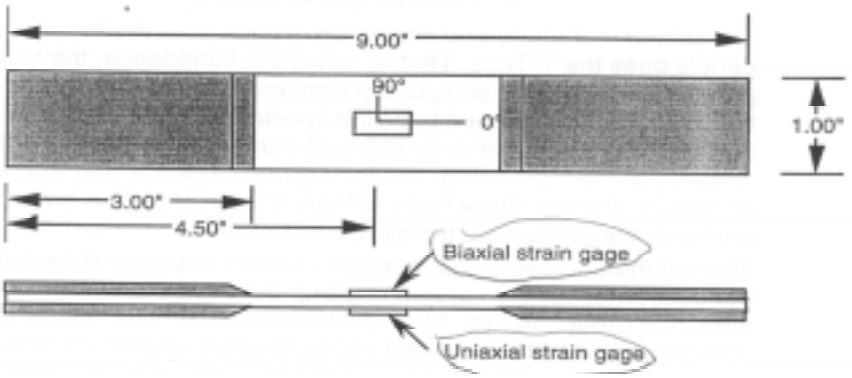

Figure 3.5 Tension Specimen Configuration

Damage Assessment to Composite Materials

Parameters	Tension Testing per ASTM D638
Coupons Per Laser Coating Removal System	Five each of GE-5 coated with MIL-PRF-23377 and MIL-PRF-85285, 3 mils. Five controls of GE-5 (uncoated/no de-paint processing on these panels).
Trials Per Coupon	One examination per coupon(s) after four de-paint cycles.
Acceptance Criteria	Testing detail and results shall be documented for review and determination of pass/fail values.

Data Analysis

Statistical analysis will be conducted to determine if there is a difference between the tensile strength and Poisson's Ratio means between the stripped and un-stripped specimens. A 90 percent confidence level will be the basis for comparison.

3.3.1b Compression Testing

Test Procedure

Compression testing shall be conducted per ASTM D695. Composite coupons shall undergo ultrasonic nondestructive inspection to verify the structural integrity of the material prior to de-painting. Laminate materials found to be free from defects shall be de-painted, re-inspected and tested per the appropriate standard.

NOTE: A biaxial strain gauge will be bonded to the tool side of the composite test specimen, and a unidirectional strain gauge will be bonded to the bag-side of specimen to record specimen strain during testing.

Record compression strength, compression modulus and Poisson's ratio. ASTM D695 specimen diagram has a different shape, dog bone, but use a rectangular specimen.

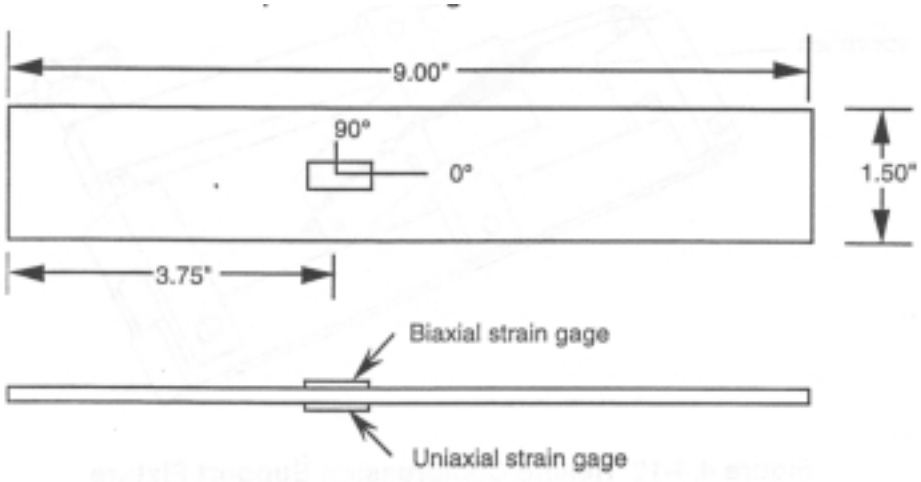

Figure 3.6 Compression Specimen Configurations

Damage Assessment to Composite Materials

Parameters	Compression Testing per ASTM D695
Coupons Per Laser Coating Removal System	Five each of GE-5 coated with MIL-PRF-23377 and MIL-PRF-85285, 3 mils Five controls of GE-5 (uncoated/no de-paint processing on these panels).
Trials Per Coupon	One examination per coupon(s) after four de-paint cycles.
Acceptance Criteria	Testing detail and results shall be documented for review and determination of pass/fail values.

Data Analysis

Statistical analysis will be conducted to compare compression strength, compression modulus and Poisson's Ratio means between the stripped and un-stripped specimens, at a confidence level of 90 percent.

3.3.1c Open Hole Fatigue

Test Procedure

Open Hole Fatigue Testing shall be conducted per ASTM E647. Composite coupons shall undergo ultrasonic nondestructive inspection to verify the structural integrity of the material

prior to de-painting. Laminate materials found to be free from defects shall be de-painted, re-inspected and tested per the appropriate standard.

NOTE:
1. All specimens shall be tested under constant amplitude tension/compression (R=-1) at a loading of 60 percent ultimate and cycle rate of 4 Hz. The 100 percent level for the fatigue tests will come from the value of the tension tests.

2. Three additional Open Hole Fatigue specimens will be required to be tested to determine the average ultimate compressive strength. This average compressive strength will be used to determine the strength to test the Open Hole Fatigue specimens.

3. Open Hole Fatigue specimens will be tested at 60 percent of the average ultimate compressive strength of the three control specimens.

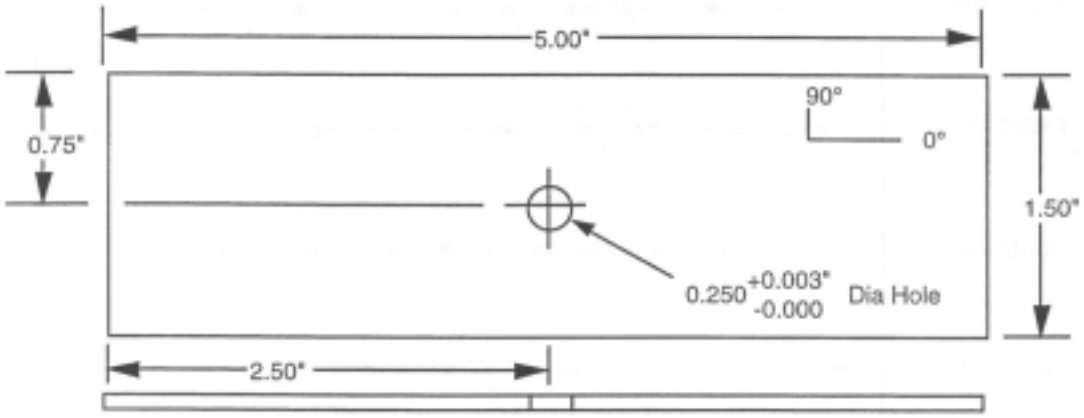

Figure 3.7 Open Hole Fatigue Specimen Configuration

Damage Assessment to Composite Materials

Parameters	Open Hole Fatigue per ASTM E647
Coupons Per Laser Coating Removal System	Five each of GE-5 coated with MIL-PRF-23377 and MIL-PRF-85285, 3 mils Five controls of GE-5 (uncoated/no de-paint processing on these panels).
Trials Per Coupon	One examination per coupon(s) after four de-paint cycles.
Acceptance Criteria	Testing detail and results shall be documented for review and determination of pass/fail values.

Data Analysis
Statistical analysis will be conducted to compare differences in fatigue life log means between stripped and un-stripped specimens at 90 percent confidence level.

3.3.2 Conductivity

Laser-stripped panels from the screening phase will be evaluated after the fourth de-paint cycle to assess the merits of this test. Preliminary testing using this method revealed no change in the conductivity between laser-stripped and chemically stripped panels. Conductivity testing shall be conducted on two materials, unclad 2024-T3 and unclad 7075-T6 coated with MIL-PRF-23377 and MIL-PRF-85285, Type I, color 36495, 6 mils thickness. The panels shall be tested as received and after each of the four de-paint cycles resulting in a total of 5 series of tests per panel. There will be three tests of the four quadrants of the 12" X 12" panel. Testing will be conducted by high frequency electromagnetic (Eddy-Current) method.

Test Methodology

Parameters	High Frequency electromagnetic (Eddy-Current) method.
Coupons Per Laser Coating Removal System	One 12" X 12" coupon each of Al-1b and Al-2b coated with MIL-PRF-23377 and MIL-PRF-85285, Type I, color 36495, 6 mils thickness.
Trials Per Coupon	Three. The coupons shall be tested after each of the four de-paint cycles. Note: Electrical Conductivity values/readings must be obtained prior to the initial paint process for comparison of before and after data.
Acceptance Criteria	No significant change in electrical conductivity.

Major or Unique Equipment

Eddy-Current Instrument

3.3.3 Fixed Wing Metallic Substrates – Fatigue Crack Growth Rate

NOTE: This test will only be conducted if the Rotary Wing testing in JTP Section 3.1.5 fails.

Fixed Wing Metallic Substrates – Fatigue Crack Growth Rate

	Smooth	Open Hole	Center Crack
CLAD 7075-T6 (0.032 inches) Test Coupon Code: Al-7a	10 Baseline (R=+.1) 10 Substrate (R=+.1)	10 Baseline (R=+.1) 10 Substrate (R=+.1)	10 Baseline (R=+.1) 10 Substrate (R=+.1)
CLAD 2024-T3 (0.032 inches) Test Coupon Code: Al-6a	10 Baseline (R=+.1) 10 Substrate (R=+.1)	10 Baseline (R=+.1) 10 Substrate (R=+.1)	10 Baseline (R=+.1) 10 Substrate (R=+.1)
BARE 7075-T6 (0.032 inches) Test Coupon Code: Al-7b	10 Baseline (R=+.1) 10 Substrate (R=+.1)	10 Baseline (R=+.1) 10 Substrate (R=+.1)	

3.4 Field Evaluation

3.4.1 Ease of Handling

Test Description

This test determines if two persons, moving the system from place to place and running the system to remove coatings, can handle the entire laser system.

Rationale

This test will prove whether the system can be fielded and used successfully. It must not be a labor-intensive operation, and the system must be easily handled and operated by two persons; otherwise, the system will not be used by field units or by the depots.

Test Methodology

Parameters	Ease of Handling
Test Specimen Per Laser Coating Removal System	Use on components that are likely to need de-coating of hard to reach areas, areas of complex geometry and/or irregular surfaces.
Trials Per Specimen	One (or more)
Control Specimens Required	None
Acceptance Criteria	The system can remove coatings with manning of two. System can be moved and manipulated around equipment by two persons. Portable Laser Gun Head weighs less than 5 pounds.

Data Analysis
Report the ability of two trained technicians to move the laser system and if only two technicians are required to perform coating removal operations using the laser system.

3.4.2 Full Unit Operational Testing

Test Description
This test evaluates coating removal systems applied to a specified piece of DoD or NASA equipment. The pieces of equipment provided for coating removal will have similar coatings removal requirements. The test will compare the performance of the laser systems and the results. More than on laser system could be tested on one piece of equipment if this area of coating removal is of similar geometry for a fair comparison of the laser systems.

Place the equipment in service at locations selected by the appropriate DoD or NASA stakeholder.

Conduct inspection and evaluation of the coating removal systems in use for 6 months and 12 months.

Rationale
Laboratory testing is useful in comparing the relative performance of laser coating removal systems when exposed to identical simulated environments; however, exposure to authentic field environments is necessary to establish high levels of confidence in coating removal performance in actual service,

Test Methodology

Operational Parameters	Geographic Depot Location Coating Removal Evaluation
DoD/NASA Equipment and Laser Coating Removal Systems	Equipment will be determined and agreed upon by the appropriate DoD/NASA technical representative(s) prior to field evaluation.
Inspections	Every 6 months for 1 year and/or after every 50 hours of use and total of 100 hours of use, whichever comes first.
Acceptance Criteria	The system performs at the depot/field location as it did in previous screening and common tests.

Data Analysis
Coating removal system evaluation should include a descriptive narrative of each observed service on the checklist provided for system evaluation. Each test location will develop a silhouette of the equipment showing the sides, top, forward and aft section of the equipment. The local coating removal evaluator will document the area and amount of coatings removed by annotating on the silhouette. The coating evaluator will also define the severity of each area to include a description of the thickness of the coating, the size of the location. The evaluator will also document the coating type. Visual assessment of the equipment shall include photo/video documentation of the equipment unit coating removal condition where coating removal has been

identified. Interviews with squadron maintenance personnel shall be recorded to provide historical information regarding service conditions and coating removal maintenance experience.

4. REFERENCE DOCUMENTS

The documents listed in Table 5 were referenced in the development of the JTP.

Reference Document	Title
Air Force Engineering Qualification Plan (EQP)	DoD Test Method Standard, Aerospace Coating System Removal for Typical Airframe Substrate Materials-Process Testing Methodology and Reporting
ASTM C393	Standard Test Method for Flexural Properties of Flat Sandwich Constructions
ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D695	Standard Test Method for Compressive Properties of Rigid Plastics
ASTM D790	Standard Test methods for Flexural Properties of Un-reinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D1781	Standard Test Method for Climbing Drum Peel for Adhesives
ASTM D3359	Standard Test Method for Measuring Adhesion by Tape Test
ASTM E8	Standard Test Methods for Tension Testing of Metallic Materials
ASTM E18	Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of metallic Materials
ASTM E647	Standard Test Method for Measurement of Fatigue Crack Growth Rates
ASTM E1004	Standard Practice for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method
ASTM E114	Standard Practice for Ultrasonic Pulse-Echo Straight-Bean Examination by the Contact Method
MIL-STD-401	Sandwich Constructions and Core Materials, General Test Methods
SAE MA4872	Paint Stripping of Commercial Aircraft – Evaluation of Materials and Processes
MIL-C-46168	Coating, Aliphatic Polyurethane, Chemical Agent Resistant
MIL-C-5541	Chromate Conversion Coating for Aluminum Alloys
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-C-7438	Core Material, Aluminum, for Sandwich Construction
MIL-PRF-85285	Coating, Polyurethane, High Solids
MIL-PRF-85582	Primer Coating, Epoxy, Waterborne

MIL-PRF-23377	Primer Coating, Epoxy, High Solids
TT-P-2760	Primer Coating, Polyurethane, Elastomeric
MIL-C-64159	
MIL-P-53030	Primer Coating, Epoxy, Water Reducible, Lead and Chromate Free
MIL-P-23377G	
10PW 22-2	Non-chrome Primer Coating, Epoxy Waterborne
Super Koropon 515-K01A	PRC Desoto
PR1432GP	Corrosion Inhibitive Elastomeric Primer

APPENDIX A

Participating Organizations and Representatives

Organization	Representative(s)	Organization Type
ARMY	Martha Ahner	Contractor, Semcor
	Jeffrey Conrad	JASPPA
	Mark Feathers	Contractor, Radium, Inc.
	James Holiday	Corpus Christi Depot
	Thomas Landy	TACOM
	Tony Pollard	Anniston Army Depot
Air Force	Richard Buchi	Hill AFB
	Jerry Chaplin	AETC/LGM
	Barnard Ghim	AFRL/MLQL
	Frederick Johnston	Warner Robins Depot
	James Long	AETC/EMV
	Ken Patterson	AFRL/Composites Hill AFB
	Richard Slife	Warner Robins Depot
	John S. Stephens	Warner Robins Depot
Marine Corps	Durwood Pollock	MATCOM
	A.J. (Skip) Schnur	Barstow MC Logistics Base
NASA	Carla Ward	AP2
	Dennis Jarvi	AP2
Businesses	Jimmy Aldridge	Lockheed-Martin
	Ken Sabo	Lockheed-Martin
	Thomas Berkel	Boeing, St Louis, MO
	Sheldon Lee Toepke	Boeing, St Louis, MO
	Eric Eichinger	Boeing, Long Beach, CA
	Warren Gardner	ARINC

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