National Aeronautics and Space Administration (NASA)
Acquisition Pollution Prevention (AP2) Office

Joint Test Report

For Validation of Alternative Low-Emission Surface Preparation/Depainting Technologies for Structural Steel

FINAL
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February 16, 2007

Prepared by
ITB, Inc.
Beavercreek, OH 45432

Submitted by
NASA Acquisition and Pollution Prevention Office

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PREFACE

This report was prepared by ITB, Inc., through the National Aeronautics and Space Administration (NASA) Acquisition Pollution Prevention (AP2) Office. The structure, format, and depth of technical content of the report were determined by the NASA AP2 Office, government contractors, and other government technical representatives in response to the specific needs of this project.

We wish to acknowledge the invaluable technical contribution of Mr. Jerry Curran, ASRC Aerospace; Mr. Richard Rider, Stennis Space Center, MS; and Mr. Roger Blake and Mr. Floyd Griffith, Mississippi Space Services; as well as the contributions provided by all the organizations involved in this project.

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1. INTRODUCTION

Headquarters National Aeronautics and Space Administration (NASA) chartered the NASA Acquisition Pollution Prevention (AP2) Office to coordinate agency activities affecting pollution prevention issues identified during system and component acquisition and sustainment processes. The primary objectives of the AP2 Office 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.

The objective of this project was to qualify candidate alternative Low-Emission Surface Preparation/Depainting Technologies for Structural Steel applications at NASA facilities. This project compares the surface preparation/depainting performance of the proposed alternatives to existing surface preparation/depainting systems or standards.

This Joint Test Report (JTR) contains the results of testing as per the outlines of the Joint Test Protocol (JTP), *Joint Test Protocol for Validation of Alternative Low-Emission Surface Preparation/Depainting Technologies for Structural Steel*, and the Field Test Plan (FTP), *Field Evaluations Test Plan for Validation of Alternative Low-Emission Surface Preparation/Depainting Technologies for Structural Steel*, for critical requirements and tests necessary to qualify alternatives for coating removal systems. These tests were derived from engineering, performance, and operational impact (supportability) requirements defined by a consensus of government and industry participants.

This JTR documents the results of the testing as well as any test modifications made during the execution of the project. This JTR is made available as a reference for future pollution prevention endeavors by other NASA Centers, the Department of Defense and commercial users to minimize duplication of effort.

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

Table 1-1 Target HazMat Summary

Target HazMat	***Current Process***	***Applications***	***Current Specifications***	***Affected Programs***	***Candidate Parts/Substrates***
Airborne particulates and contaminated particulate matter	Dry Abrasive Blasting using materials such as coal slag	Maintenance of Test Stands, Ground Support Equipment, Shuttle Support Structures, Launch Pads, Towers and general structures.	SSPC-SP-5; SSPC-SP-10	Ground Support and Facilities Maintenance	A36 Carbon Steel; Aluminum Alloy 6061

2. ENGINEERING, PERFORMANCE, AND TESTING REQUIREMENTS

A joint group led by the AP2 Office and consisting of technical representatives from NASA centers reached technical consensus on engineering, performance, and testing requirements for alternatives to current coating removal systems. The joint group defined critical tests with procedures, methodologies, and acceptance criteria to qualify alternatives against these technical requirements.

All coating removal system candidates were evaluated on approved NASA coating systems listed in the approved product list in accordance with NASA Standard 5008 (NASA-STD-5008). Qualified personnel performed all surface preparation and coating applications in accordance with best-standard practice to the appropriate coating technical documentation. The coating removal process for each alternative technology followed the manufacturers' instructions.

The objective of this project was to qualify candidate processes under the specifications for the standard system. This project compared coating removal performance of the proposed alternatives to existing coating removal systems or standards.

2.1 Field Evaluations

Table 2-1 lists field evaluations identified in the FTP that were intended to compare the performance of candidate test surface preparation/depainting technologies with current surface preparation/depainting systems when applied in an operational environment. Coating removal evaluators completed a written evaluation and documentation checklists to organize and quantify the observations of coating removal technologies' performances under actual operating conditions. These tests are defined in further detail in the NASA AP2 document *Field Evaluations Test Plan Protocol for Validation of Alternative Low Emission Surface Preparation/Depainting Technologies for Structural Steel*, dated January 31, 2005.

Table 2-1 includes acceptance criteria and the reference specifications, if any, used to conduct the field tests. The proposed test and evaluation were based on the aggregate knowledge and experience of the assigned technical project personnel and prior testing where "None" appears under *Test Method References*.

Changes to the actual field testing compared to the FTP include the following:

- Waste Generation: A subjective appraisal was performed based on information provided by the manufacturer and visual observation.
- Particulate Generation: A subjective appraisal was performed based on visual observation.

Table 2-1 Field Evaluation Engineering, Performance, and Testing Requirements for Alternative Low-Emission Surface Preparation/Depainting Technologies

Test	***FTP Section***	***Test Specimen***	***Acceptance Criteria***	***Test Methodology References***
Ease of Use	3.2.1.	Field	To be assessed by field applicator	None
Coating Strip Rate	3.2.2.	Field	Performs as well as or better than baseline process	None
SSPC Surface Cleaning Level	3.2.3.	Field	Concurrence that technology meets agreed upon cleaning level using visual determination using SSPC Surface cards at 10X magnification	SSPC-SP-10/ NACE-NO. 2 (for abrasive media) SSPC-SP-3
Surface Profile/ Roughness	3.2.4.	Field	Concurrence that technology meets agreed upon surface profile using visual determination	NACE-STD-RP0287
Waste Generation	3.2.5.	Field	Less than current abrasive blasting techniques	None
Particulate Generation	3.2.6.	Field	Less than current abrasive blasting techniques	None
Coating Removal Damage Appraisal	3.2.7.	Field	No warping/denting or metal erosion observable at 10X magnification	None

2.2 Laboratory Testing

Table 2-2 lists the common tests required by participating centers. Candidate coating removal technologies were submitted to these common tests for a more comprehensive evaluation. These tests are defined in further detail in the NASA AP2 document *Joint Test Protocol for Validation of Alternative Low Emission Surface Preparation/Depainting Technologies for Structural Steel*, dated January 31, 2005.

Table 2-2 includes acceptance criteria and the reference specifications, if any, used to conduct the laboratory tests. The proposed test and evaluation were based on the aggregate knowledge and experience of the assigned technical project personnel and prior testing where "None" appears under *Test Method References*.

Changes to the actual field testing compared to the JTP include the following:

- Waste Generation was not investigated during the laboratory testing of this project.
- Particulate Generation was not investigated during the laboratory testing of this project.
- Coating Adhesion was not conducted during the project due to a lack of interest from stakeholders and funding at the time.

Table 2-2 Common Engineering, Performance, and Testing Requirements for Alternative Low-Emission Surface Preparation/Depainting Technologies

Test	***JTP Section***	***Test Specimen***	***Acceptance Criteria***	***Test Methodology References***
SSPC Surface Cleaning Level	3.2.1.	Coupon	Concurrence that technology meets agreed upon cleaning level using visual determination using SSPC Surface cards at 10X magnification	SSPC-SP-10/ NACE-NO. 2
Surface Profile/ Roughness	3.2.2.	Coupon	Concurrence that technology meets agreed upon surface profile using visual determination	NACE-STD-RP0287
Waste Generation	3.2.3.	Coupon	Less than current abrasive blasting techniques	None
Particulate Generation	3.2.4.	Coupon	Less than current abrasive blasting techniques	None
Coating Removal Damage Appraisal	3.2.5.	Coupon	No warping/denting or metal erosion observable at 10X magnification	None

3. VENDOR TECHNOLOGY REVIEW

Five vendor demonstrations were supported at NASA Stennis Space Center, Mississippi. The following depainting technologies were evaluated:

- Plastic Blast Media (PBM): US Technology Corporation's Quickstrip®-A—PBM that can be recycled. The company will also recycle all spent media and debris. The company qualifies as an exempt activity under federal and state rules therefore; participants in the recycling program are not considered hazardous waste generators. The cost of the material includes freight of the blast media to the jobsite, freight from the jobsite to the recycling facility, recycling of the spent material, drums to contain the material, and shipping labels. Proper containment, capture equipment, and a classifier to recycle the media are required.

- Hard Abrasive Media: US Technology Corporation's Steel-Magic®—An amorphous mixture that can be used at lower pressures and recycled up to 5 times according to the manufacturer or used once at higher pressures. Steel-Magic is designed to remove heavier enhanced (i.e. epoxy, polyurethane) coatings on heavier steel substrates at twice the strip rate with less dust than media previously available and the surface profile can be controlled by adjusting the pressure or the size of the abrasive. This media can create a profile for new paint adhesion. Proper containment, capture equipment, and a classifier to recycle the media are required.

- Sponge Blast Media: Sponge-Jet®—Sponge Media imbedded with various abrasives. (The abrasive used for this demonstration was the Silver 30 Sponge Media which contains aluminum oxide.) The Sponge Media particles flatten as they strike the surface, and then expose the abrasive where they cut into the coating and substrate, profiling if needed. As the Sponge Media abrasives rebound, the porous urethane creates suction entrapping dust, paint, corrosion, and other contaminants (this process is known as Micro-containment). The process also claims to reduce chlorides which can affect subsequent coating adhesion. A vacuum can be used to capture all used Sponge Media and debris which is then put in the recycler where classification takes place. The classifier sorts out oversized waste (large paint chips and corrosion products to be disposed of), fine waste (dust and very small pieces of Sponge Media that may be recycled to a small degree) and reusable Sponge Media (which is estimated to be reused 6-15 times per the manufacturer).

- Liquid Nitrogen: NitroCision, LLC's NitroJet®—NitroCision has combined the advantages of water jet technology with cryogenics to create the first cryogenic jet technology in existence—NitroJet®. The NitroJet creates an ultra high-pressure stream of liquid nitrogen that has a density comparable to water without adding any moisture or particulates to the process. Contrary to traditional industrial cleaning and cutting technologies—chemicals, sand, water, walnut shell, beads, soda, wheat starch and others, the NitroJet®, without entrainment, introduces absolutely no secondary waste whatsoever. This is beneficial in situations where secondary waste is a significant process issue or where secondary waste is simply not acceptable. Additionally, the NitroJet® can reduce downtime, reduce cleanup efforts and maintain a clean environment. NitroCision accomplishes the elimination of secondary waste by relying on liquid nitrogen's nature to rapidly transform from a supercritical fluid to a gas as it depressurizes. Once a gas, it simply dissipates into the atmosphere leaving nothing behind but the debris displaced in the cleaning or cutting process. To eliminate the displaced debris, NitroCision offers a vacuum shroud system that attaches to the NitroJet®'s nozzle and encloses the work area.

- Mechanical Removal with Vacuum Attachment: DESCO Manufacturing—Specializes in dust-free surface preparation and coating removal tools as well as HEPA and Non-HEPA vacuums to be used with the tools that essentially eliminate dust.

- Mechanical Removal with Vacuum Attachment: DCM *Clean-Air* Products, Inc—DCM developed “point of generation" source capture tools and vacuum systems. The heart of system lies with the vacu-shroud™ and patented Postiv-Lok™ vacu-discs and vacu-holder™. Six vacuum holes have been punched into both the holder and disc to allow airflow into the vacu-shroud directly from the work piece. The Postiv-Lok™ system guarantees alignment of the vacu-disc holes to the holes in the vacu-disc holder every time with no extra effort from the operator.

One vendor demonstration was supported at NASA Glenn Research Center, Ohio.

- Portable Laser Coating Removal System (PLCRS): Clean-Lasersysteme GmbH’s CL 120Q Nd:YAG Class 4 Laser system with fiber optic cable with a HEPA vacuum and air filtration system—A vendor presentation of the PLCRS was performed at Glenn Research Center, Ohio. Details regarding the PLCRS demonstration is detailed in Section 6 and the full report can be found in Appendix C. The PLCRS was not tested to the extent of the other technologies during this project, but an abbreviated test plan to determine initial coating removal capabilities and possible substrate damage was conducted. Extensive work with the technology has been conducted by groups such as the Air Force and Joint Group on Pollution Prevention, however.

These coating removal processes are attractive because of their ability to reduce particulate and dust emissions and reduce waste. All have the potential to reduce wastes and many are also recyclable thus further reducing environmental impact and costs.

4. TEST METHODOLOGY

All coating removal system candidates were evaluated using approved NASA coating systems (listed in the approved product list in accordance with NASA-STD-5008). The approved coating system was applied to a steel substrate and an aluminum substrate. A third set of steel panels were un-coated and rusted. Qualified personnel performed all surface preparation and coating applications in accordance with best-standard practice to the appropriate coating technical documentation. Relevant process information was documented at the time the test specimens were prepared.

The test methodologies described in the JTP and FTP list the major parameters, test specimen descriptions, number of trials per specimen and acceptance criteria for each requirement.

4.1 Test Panel Preparation

The coating of coupons was documented using the "Coating System Application Evaluation and Inspection Report" based on the Application Record Sheet in NASA-STD-5008. For each test requiring coupons, a minimum of five (5) coupons were prepared; those with the best coating as determined by the technician were used in accordance with the number of coupons required as specified in the JTP Test Methodology. A summary of the coupon matrix is given in Table 4-1. Unless otherwise required by a specific test, all coupons were prepared as follows:

- Test panels were 12" x 12" long and of a suitable thickness.
- Test specimens were painted or coated within 24 hours of surface preparation.
- Each liquid coating system was prepared and applied in accordance with the appropriate specification and manufacturer guidelines.
- Each test was performed on identical test specimens prepared with the NASA standard coating system as a control.

Table 4-1 Coupon Matrix per System

Size	*Quantity*	*Type*	*Alloy*
12"x 12"x 3/16"	60	Flat	A-36 Steel
12"x 12"x 3/16"	60	Flat	A-36 Steel
12"x 12"x 1/8"	60	Flat	6061-T6 Aluminum

4.2 Apply Coating Systems

The coupon matrix consisted of three conditions: (1) rusted mill-scale steel, (2) coated steel and (3) coated aluminum. The mill-scale coupons were placed at the Kennedy Space Center atmospheric beach test site and allowed to form a layer of rust similar to SSPC-VIS 1, *Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning*, condition B. A Devoe zinc, epoxy, urethane coating system was applied to a set of prepared steel panels and a direct to metal urethane was applied to the aluminum panels. Details of the coating processes were collected and recorded on the "Coating System Application Evaluation and Inspection Report" forms located in Appendix A.

4.3 Perform Quality Control Checks and Dry Film Thickness Data

Dry film thickness (DFT) measurements were collected of each coating layer (primer, mid-coat, and/or topcoat) in accordance with SSPC-PA, *Measurement of Dry Coating Thickness with Magnetic Gages, 2004,* during the application process using a type II Quanix Keyless coating thickness gauge (accuracy of +/-0.04 mils + 2%). The measurement of coating thickness was important for calculating coating strip rates as discussed in Section 5-2. A summary of the applied coating thicknesses is shown in Table 4-2 for each system.

Table 4-2 Applied DFT per System

System	***Primer***	***Mid-Coat***	***Topcoat***
Rusted	n/a	n/a	n/a
Steel	2.2 mils*	3.2 mils*	5.3 mils*
Aluminum	n/a	n/a	6.9 mils*

* Average thickness of coating applied of all coupons in system

5. FIELD TESTING AND EVALUATION

Each depainting technology was evaluated in the field for ease of use, strip rate, surface cleanliness, surface profile/roughness, and substrate damage. The coating removal processes were evaluated in the field using the above criteria and the results are as follows. Blasting operations were evaluated on 12”x12” test panels and on a Stennis Space Center rocket motor test stand flame deflector (Figure 5-1). Documentation for each test can be found on the “Depainting System Field Evaluation and Inspection Report” in Appendix B.

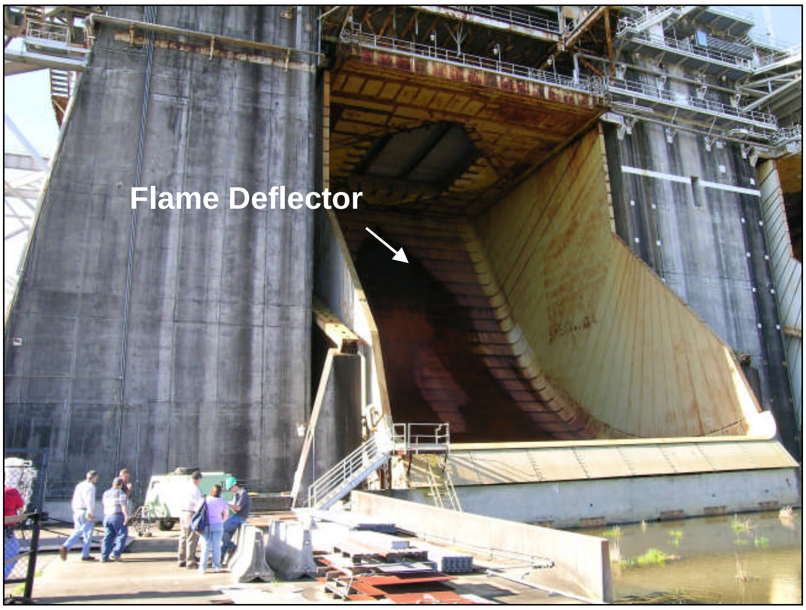

Figure 5-1 Stennis Space Center Rocket Motor Test Stand

5.1 Ease of Use

This procedure was used to determine how easily a coating removal technology may be used. Noise levels were measured using a Type II Sound Level Meter set at slow response and recorded for comparison between the various technologies by a representative of Stennis Space Center Industrial Health during the tests. The purpose of this test was to identify and eliminate those candidate coating removal technologies that are difficult to properly use under normal maintenance operation conditions. The results are summarized in Table 5-1 below.

Table 5-1 Ease of Use Testing Results

Depainting Technology	***Set-up Time***	***Ease of Use****	***Noise Levels*** *(@12-15 feet)*
Quickstrip®-A	1 hour	Similar	88 db
Steel-Magic®	1 hour	Similar	90 db
Sponge-Jet®	1 hour	Similar	100 db
NitroJet®	4 hours	Specialized	101 db
DESCO	0.5 hour	Hand Tool	98 db
DCM	0.5 hour	Hand Tool	95 db

*compared to abrasive blasting

5.2 Coating Strip Rate

This procedure was used to determine the rate of coating removal for candidate coating removal technologies. Paint strip rate test data was based on a minimum test area on the structure equal to 16 ft^2 and on the 12”x12” test panels. All coatings were removed down to the substrate and achieved a minimum of SSPC-VIS1 SP-10/NACE-No. 2, near-white condition. The coating strip rate of the coating removal technology must meet or exceed strip rates established by NASA participants. Acceptance criteria for the coated substrates are 1.7 ft^2 per minute at 6 mils nominal thickness (Figure 5-2). The data points graphed in Figure 5-2 are from the coating removal rates on a typical 16 square foot section of the flame deflector steel structure. The area depicted equal to or above the criteria line is acceptable. The results are summarized below in Tables 5-2 through 5-5.

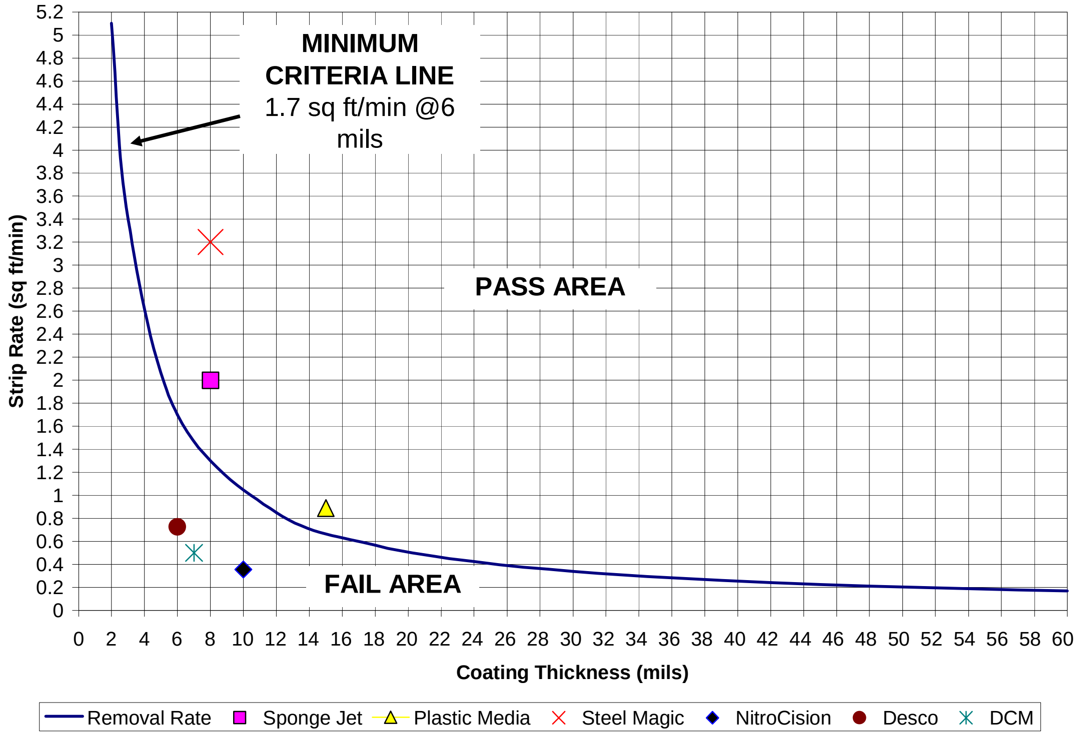

Figure 5-2 Flame Deflector Coating Removal Strip Rate

Table 5-2 Flame Deflector Strip Rate Results (Based on 16 sq ft)				
Depainting Technology	***Coating Thickness (mils)***	***Time (min)***	***Strip Rate (ft^2/min)***	***Pass Criteria?***
Quickstrip®-A	15	18	0.9	Yes
Steel-Magic®	8	5	3.2	Yes
Sponge-Jet®	8	8	2.0	Yes
NitroJet®	10	45	0.4	No
DESCO	6	22	0.8	No
DCM	7	32	0.5	No

Table 5-3 Coated Steel Coupon Strip Rate Results (1 sq ft)				
Depainting Technology	***Coating Thickness (mils)***	***Time (min)***	***Strip Rate (ft^2/min)***	***Pass Criteria?***
Quickstrip®-A	11.7	1.5	0.7	No
Steel-Magic®	11	0.85	1.2	Yes
Sponge-Jet®	11	0.5	2.0	Yes
NitroJet®	11	4	0.3	No
DESCO	11	1.2	0.9	Yes
DCM	11	2	0.5	No

Table 5-4 Coated Aluminum Coupon Strip Rate Results (1 sq ft)				
Depainting Technology	***Coating Thickness (mils)***	***Time (min)***	***Strip Rate (ft^2/min)***	***Pass Criteria?***
Quickstrip®-A	6.8	1.28	0.8	No
Steel-Magic®	7.1	0.73	1.4	Yes
Sponge-Jet®	6.7	0.63	1.6	Yes
NitroJet®	7	4	0.3	No
DESCO	8	3.4	0.3	No
DCM	8	3.2	0.4	No

Table 5-5 Rusted Steel Coupon Strip Rate Results (1 sq ft)		
Depainting Technology	***Time (min)***	***Strip Rate (ft^2/min)***
Quickstrip®-A	1.5	0.7
Steel-Magic®	0.85	1.2
Sponge-Jet®	0.5	2.0
NitroJet®	4	0.3
DESCO	1.2	0.9
DCM	2	0.5

5.3 Surface Cleanliness

Abrasive media candidate technologies were compared to SSPC-VIS 1, *Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning*, and must achieve a rating similar to SSPC-SP-10, *Near-White Blast Cleaning – NACE No. 2*. The hand tools were compared to SSPC-SP-3, *Power Tool Cleaning*.

The results are summarized below in Tables 5-6 and 5-7.

Table 5-6 Test Stand Surface Cleanliness

Depainting Technology	***SSPC VIS-1 Rating***
Quickstrip®-A	SP-10 / NACE #2
Steel-Magic®	SP-10 / NACE #2
Sponge-Jet®	SP-10 / NACE #2
NitroJet®	SP-6 / NACE #3[1]
DESCO	SP-3
DCM	SP-3

Table 5-7 Coupon Surface Cleanliness

Depainting Technology	***SSPC VIS-1 Rating***
Quickstrip®-A	SP-5 / NACE #1[2]
Steel-Magic®	SP-5 / NACE #1[2]
Sponge-Jet®	SP-5 / NACE #1[2]
NitroJet®	SP-6 / NACE #3[1]
DESCO	SP-11[3]
DCM	SP-11[3]

[1]SSPC-SP-6 *Commercial Blast Cleaning – NACE N. 3*: A lesser degree of cleaning than near-white blast cleaning (SSPC-SP-10/NACE No. 2)

[2]SSPC-SP-5 *White Metal Blast Cleaning – NACE No. 1*: A greater degree of cleaning than near-white blast cleaning (SSPC-SP 10/NACE No. 2)

[3]SSPC-SP-11 *Power Tool Cleaning To Bare Metal*: A greater degree of cleaning than SP-3, which requires only the removal of loosely adherent materials and does not require producing or retaining a surface profile, whereas SP-11 provides a a roughened, clean, bare metal surface.

5.4 Surface Profile

This test serves to evaluate substrate damage to the test panels as a result of using the coating removal technology. Surface roughness was measured in accordance with NACE-STD-RP0287, *Field Measurements of Surface Profile of Abrasive Blast Cleaned steel Surfaces Using a Replica Tape, revised 2002*. Surface profiles were measured on the blasted areas of the test stand and on the test panels before (Pre) and after (Post) the removal technology. A minimum of five readings were performed along different directions and different places in the panel and recorded. The averaged results are summarized below in Table 5-8.

Table 5-8 Average Test Panel Surface Profile Results

Depainting Technology	***Mill Scale***		***Steel***		***Aluminum***	
	Pre	***Post***	***Pre***	***Post***	***Pre***	***Post***
Quickstrip®-A	0	2.2	2.5	2.7	3.0	2.8
Steel-Magic®	0	3.0	2.5	3.0	3.0	3.5
Sponge-Jet®	0	4.1	2.5	4.0	3.0	4.7
NitroJet®	0	n/a	2.5	2.5*	3.0	3.0*
DESCO	0	4.0	2.5	4.2	3.0	5.0
DCM	0	2.2	2.5	2.6	3.0	2.2

*no change

5.5 Waste and Particulate Generation

Generation of regulated wastes and waste quantity are cost factors to consider in selection of depainting technologies. Additionally, waste stream containment and the ability of the selected method to control visible emissions will determine the requirement of containment structures that require cost consideration.

Table 5-9 gives a comparison of the alternative technologies to the baseline process and is based on information provided by the manufacturers and visual observations during the field demonstration.

Table 5-9 Waste and Particulate Generation

Depainting Technology	***Waste Generation***	***Particulate Generation***[5]
Quickstrip®-A	None[1]	Similar
Steel-Magic®	None[1]	Similar
Sponge-Jet®	Medium[2]	Low
NitroJet®	Low[3]	Low
DESCO	Low[4]	None
DCM	Low[4]	None

[1] All used media that cannot be further recycled (secondary waste) along with the removed coating/corrosion debris (primary waste) are collected and sent to the manufacturer for recycling. Therefore, technically there is no waste and the facility is not considered a manufacturer of hazardous waste.

[2] The media can be recycled thus reducing the amount of used media (secondary waste) that must be disposed of as waste along with the removed coating/corrosion debris (primary waste).

[3] There is no secondary waste as the liquid nitrogen quickly reverts back to a gas and is absorbed into the atmosphere leaving only the removed coating/corrosion debris (primary waste).

[4] Hand tools do not use a media so there is no secondary waste, only the removed coating/corrosion debris (primary waste) to be disposed of.

[5] The visible Particulate Matter (PM) generated during the removal process was compared to that of the baseline process.

- "Similar" means that it produces the same amount of PM as the baseline.
- "Low" means that is produces less PM as the baseline.
- "None" means that no PM is produced.

5.6 Substrate Damage Appraisal

Substrate damage appraisals were performed to evaluate substrate damage as a result of using alternate coating removal technologies on each of three test substrates: un-blasted steel, blasted steel, and blasted aluminum. The test coupons were visually examined for warping/denting defects and thickness measurements recorded using a hand-held ultrasonic thickness gauge. Warping was assessed by placing a straight edge along the surface of the coupon diagonally from corner to corner and measuring the maximum gap, if any, between the two. It was also noted if the coupon was warped in a convex or concave condition relative to the top surface. Erosion of the substrate was determined by taking random thickness measurements and comparing them with the preliminary measurements. Test coupons were re-evaluated for each alternate coating removal technology and compared with the preliminary assessments (Tables 5-9 and 5-10).

None of the coating removal technologies were detrimental to the steel substrates; however the abrasive blast technologies caused the aluminum test panels to warp significantly. This damage could have been eliminated by reducing blast nozzle pressure and increasing the working distance from nozzle to surface as necessary.

Table 5-10 Steel Substrate Damage Appraisal (3/16" Thickness)

Depainting Technology	*Warping*	*Denting*	*Erosion*
Quickstrip®-A	None	None	None
Steel-Magic®	None	None	None
Sponge-Jet®	None	None	None
NitroJet®	None	None	None
DESCO	None	None	None
DCM	None	None	None

Table 5-11 Aluminum Substrate Damage Appraisal (1/8" Thickness)

Depainting Technology	*Warping*	*Denting*	*Erosion*
Quickstrip®-A	1/8"	None	None
Steel-Magic®	3/16"	None	None
Sponge-Jet®	3/16"	None	None
NitroJet®	None	None	None
DESCO	None	None	None
DCM	None	None	None

6. LASER COATING REMOVAL TECHNOLOGY TESTING

A vendor presentation of the PLCRS was performed the week of October 24-28, 2005, at NASA Glenn Research Center, Ohio, using a CL 120Q Nd:YAG Laser system with fiber optic cable (Figure 6-1). The PLCRS system was evaluated with the goal of determining if the process is effective in removing typical coatings used on facility and ground support equipment and whether it is detrimental to the underlying substrate.

Figure 6-1 CL 120Q Nd:YAG Laser System

The evaluation process involved four different tests on coated steel and aluminum test panels:

- Surface Cleaning Level
- Surface Profile/Roughness
- Coating Removal Damage Appraisal
- Metallography

6.1 Test Panels

The steel test panels were A36 Hot Rolled Carbon Steel; 3/16" x 12" x 12"; Blast Cleaned to SSPC-SP5; 1.5-2.5 mil profile. They were coated with a three coat zinc, epoxy, urethane system with a combined thickness of 11.0 – 12.0 mils (.011"-.012").

The Aluminum test panels were bare 6061-T6;1/8" x 12" x 12"; Blast Cleaned using Garnet; 2.5-3.0 mil profile. They were coated with a single coat urethane system with an average thickness of 6.0-7.0 mils (.006"-.007").

6.2 Surface Cleaning Level

The laser depainted test panels were compared to SSPC-VIS 1, *Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning* and must achieve a rating similar to SP-10/NACE-No 2, near-white abrasive blast cleaning. According to SSPC-VIS 1, a SP-10/NACE-No 2, near-white metal blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter.

As seen in the following photographs, the PLCRS system did not achieve the minimum requirements of surface cleaning established in the JTP Section 3.2.3 during the demonstration (Figure 6-2). The laser depainting showed better performance on the aluminum coated substrate, but trace amounts of coating still remain on the surface.

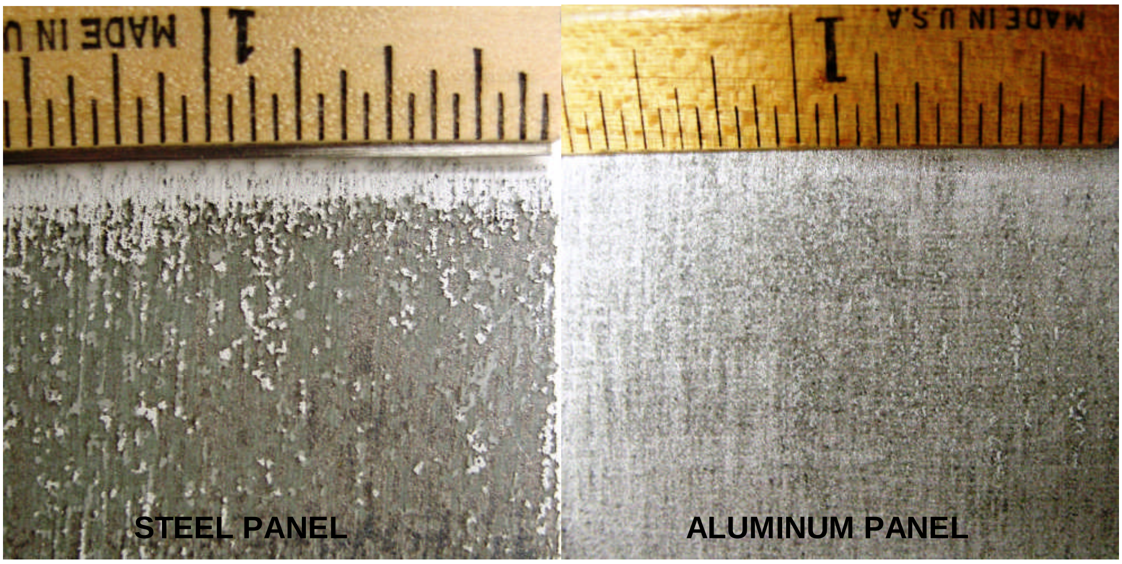

Figure 6-2 Laser Depainted Surfaces

6.3 Surface Profile/Roughness

This test served to evaluate substrate damage to the new test panels as a result of using the coating removal technology and provide profile data the technology can provide. Surface roughness was measured in accordance with NACE-STD-RP0287, *Field Measurements of Surface Profile of Abrasive Blast Cleaned steel Surfaces Using a Replica Tape*, revised 2002. Surface profiles were measured on the test panels before and, if applicable, after the removal technology.

Measurements of surface profile on the coated steel panels were not performed due to the PLCRS system not removing 100% of the coating. However, the laser was applied to the surface of an uncoated aluminum coupon for a period of time to see if the surface profile was altered.

There were no measurable changes to the before and after surface profile measurements. Before and after magnified photographs show similar surface roughness (Figure 6-3).

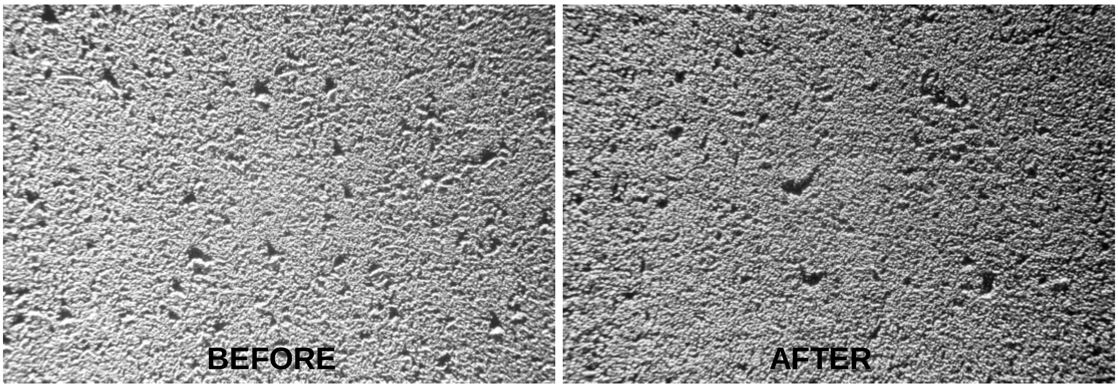

Figure 6-3 Surface Roughness on Aluminum Panel

6.4 Coating Removal Damage Appraisal

Substrate damage appraisals were performed to evaluate substrate damage as a result of the PLCRS system on each of two test substrates, blasted steel and blasted aluminum. Preliminary appraisals of the test coupons were visually examined for warping/denting defects and thickness measurements recorded using a hand-held ultrasonic thickness gauge. Warping was assessed by placing a straight edge along the surface of the coupon diagonally from corner to corner and measuring the maximum gap, if any, between the two. It was also noted if the coupon was warped in a convex or concave condition relative to the top surface. Denting of the substrate was performed by visually observing the surface. Erosion of the substrate was determined by taking random thickness measurements and comparing them with the preliminary measurements. Test coupons were re-evaluated and compared with the preliminary assessments.

The PLCRS system did not cause any warping, denting, or erosion to the steel or aluminum substrates.

6.5 Metallography

Test materials/substrates were submitted to the KSC Material Science Laboratory for evaluation of the laser depainted surface morphology as compared to untreated reference panels. Tests included micro-hardness analysis, cross-section analysis of properly prepared surfaces, and scanning electron microscope images of surface.

The laser depainted samples for both the steel and aluminum substrates exhibited only superficial mechanical deformation of the surface with no metallurgical discrepancies noted.

The complete report in its entirety can be found in Appendix C.

7. CONCLUSION

Based on the criteria set forth in the Joint Test Protocol and Field Test Plan; the Sponge-Jet®, Steel-Magic®, and Quickstrip®-A technologies performed best for the removal of coating systems on large structural elements.

Table 7-1 gives a summary of all testing results and shows whether the results for each alternative were Pass (P) or Fail (F) based on the "Acceptance Criteria" given in Tables 2-1 and 2-2. Where "Similar" is shown, it means that the alternative performed similarly to the known properties of the baseline material.

It can be concluded that based on the requirements set forth by the project stakeholders, the Sponge-Jet® technology was the superior technology for the identified need. Sponge-Jet® (as demonstrated) proved to be a low-dusting alternative that achieved adequate paint strip rates on carbon steel. Other benefits of Sponge-Jet® include the high recyclability of the media, ease of use, and the high levels of worker visibility.

The second best technology was the Steel-Magic®. Steel-Magic® benefits included its high strip rate, recyclability of media, and ease of use. There were concerns, however, about the amount of dusting that the media exhibited during the demonstration. The dust was not reduced when compared to the baseline process.

Where hand-tool cleaning is the only option, both DESCO Manufacturing and DCM *Clean-Air* Products, Inc., technologies performed adequately.

The laser technology reviewed as part of this project shows promise as a future technology for specific, small area applications pending further development. At the time of testing, however, the PLCRS did not achieve the minimum requirements of surface cleaning established in the JTP section 3.2.3, nor was it successful in removing all of the applied coatings.

Table 7-1 Summary of Pass/Fail Test Results

Test	*Quickstrip®-A*	*Steel-Magic®*	*Sponge-Jet®*	*NitroJet®*	*DESCO*	*DCM*	*PLCRS*
Ease of Use	P	P	P	F	P	P	NA
Noise Level	P	P	P	P	P	P	NA
Set-up Time	P	P	P	F	P	P	NA
Strip Rate - Field Test	P	P	P	F	F	F	NA
Strip Rate - Steel Panels	F	P	P	F	P	F	NA
Surface Cleaning Level	P	P	P	F	P	P	F
Surface Profile	P	P	P	P	P	P	F
Waste Generation	P	P	P	P	P	P	NA
Particulate Generation	P	P	P	P	P	P	NA
Warping -Steel	P	P	P	P	P	P	P
Warping -Al	F	F	F	P	P	P	P
Denting	P	P	P	P	P	P	P
Erosion	P	P	P	P	P	P	P
Metallography	NA	NA	NA	NA	NA	NA	P

APPENDIX A

Coating System Application Evaluation and Inspection Report Forms

COATING SYSTEM EVALUATION AND INSPECTION REPORT*						
DATE- **2/28/05**	PROJECT REF. NO. **System 8**				PAGE **1**	OF **1**
PROJECT NAME: **ISO Free Coatings**				INSPECTOR: **Curran**		
PRODUCT MANUFACTURER / NAME: **Devoe Devathane 134 HB**						
BATCH NUMBERS- **"A" 359B3501/ "B" 359C0910**						
1. DESCRIPTION OF ITEMS AND /OR AREAS: **12"x12" flat aluminum**						
2. DESCRIPTION OF WORK PERFORMED / REMARKS: **Spraying Test Coupons**						
3. ENVIRONMENTAL CONDITIONS						
TIME	**8:30**	**9:30**	**10:30**	**11:30**	:	:
AIR TEMP °F	**70**	**68**	**68**	**70**		
RELATIVE HUMIDITY	**57%**	**63%**	**60%**	**56%**	%	%
DEWPOINT	**54**	**55**	**53**	**53**		
SURFACE TEMPERATURE	**70**	**67**	**67**	**69**		
4. PRE-WORK SURFACE CONDITIONS / SURFACE PREPARATION						
Applied directly to substrate.						
5. COATING APPLICATION						
METHOD OF APPLICATION: **Conventional Spray**	START TIME **9:00** STOP TIME **11:00** APPROXIMATE SQ. FT. COATED **12**					
EQUIPMENT DESCRIPTION: **Binks 2001 66ss/63pb 565 needle Fluid 25 psi/ Air 60 psi**	GALS COATING APPLIED **.75** WET FILM THICKNESS (AVG) **7-8** MILS					
EASE OF USE—Technician Evaluation- **Easy mixing, good flow, good atomization with one coat coverage.**						
POT LIFE—Technician Evaluation						
Room Temperature sprayable after 4 hrs.						
Heated not sprayable after 2 hrs.						
6. POST CURE INSPECTION						
DRY FILM THICKNESS (AVG) **5-6** MILS (See Attached Documentation)						
DRY-TO-TOUCH (SANDING) EVALUATION- **No effect.**						
EVALUATION WITH UNAIDED EYE- **Smooth glossy appearance with uniform color.**						
EVALUATION WITH 10X MAGNIFICATION- **No defects or irregularities observed.**						
GLOSS READING (per ASTM D 523) 60^0 **57.3 G.U.**	COLOR READING (per ASTM D 2244) **(L*,a*,b*) 96.51, -1.92, 1.46**					
REMARKS						
INSPECTOR'S SIGNATURE					DATE	

COATING SYSTEM EVALUATION AND INSPECTION REPORT*		
DATE- **2/28/05**	PROJECT REF. NO. **System 8**	PAGE **1** OF **1**
PROJECT NAME: **ISO Free Coatings**		INSPECTOR: **Curran**
PRODUCT MANUFACTURER / NAME: **Devoe Devathane 134 HB**		
BATCH NUMBERS- **"A" 359B3501/ "B" 359C0910**		
1. DESCRIPTION OF ITEMS AND /OR AREAS: 12"x12" flat steel coupons		
2. DESCRIPTION OF WORK PERFORMED / REMARKS: Spraying Test Coupons		

3. ENVIRONMENTAL CONDITIONS

TIME	8:30	9:30	10:30	11:30	:	:
AIR TEMP °F	70	68	68	70		
RELATIVE HUMIDITY	57%	63%	60%	56%	%	%
DEWPOINT	54	55	53	53		
SURFACE TEMPERATURE	70	67	67	69		

4. PRE-WORK SURFACE CONDITIONS / SURFACE PREPARATION

Applied over Devran 201 epoxy tie coat.

5. COATING APPLICATION

METHOD OF APPLICATION: **Conventional Spray**	START TIME **9:00** STOP TIME **11:00** APPROXIMATE SQ. FT. COATED **12**
EQUIPMENT DESCRIPTION: **Binks 2001 66ss/63pb 565 needle Fluid 25 psi/ Air 60 psi**	GALS COATING APPLIED **.75** WET FILM THICKNESS (AVG) **7-8** MILS

EASE OF USE—Technician Evaluation- **Easy mixing, good flow, good atomization with one coat coverage.**

POT LIFE—Technician Evaluation

Room Temperature sprayable after 4 hrs.

Heated not sprayable after 2 hrs.

6. POST CURE INSPECTION

DRY FILM THICKNESS (AVG) **5-6** MILS (See Attached Documentation)

DRY-TO-TOUCH (SANDING) EVALUATION- **No effect.**

EVALUATION WITH UNAIDED EYE- **Smooth glossy appearance with uniform color.**

EVALUATION WITH 10X MAGNIFICATION- **No defects or irregularities observed.**

GLOSS READING (per ASTM D 523) 60^0	COLOR READING (per ASTM D 2244)
57.3 G.U.	**(L*,a*,b*) 96.51, -1.92, 1.46**

REMARKS

INSPECTOR'S SIGNATURE DATE

APPENDIX B

Depainting System Field Evaluation and Inspection Report

DEPAINTING SYSTEM EVALUATION AND INSPECTION REPORT		
DATE: **4/12/05**	PROJECT REF. NO.	PAGE OF
PROJECT NAME: **Depainting Technologies**	LOCATION **Stennis**	
INSPECTION ORGANIZATION: **ASRC**	INSPECTOR **Curran**	
PRODUCT MANUFACTURER / NAME: **Sponge Jet** **Silver #30 Grit AlO_2 (40 lb bags)**		
1. EASE OF USE—Technician Evaluation		
Only cover-alls and full-face respirator required. Limited containment needed.		
Set-up of portable compressor and blast pot (30 min – 1 hr)		
Noise Levels- 12'/ 100 db Pot & Compressor- 85 db		
2. COATING STRIP RATE		
AVERAGE COATING THICKNESS **8** mils		
TOTAL STRIPPING TIME min **8**	CALCULATED STRIP RATE **2** ft^2/min	
STRIPPING SURFACE AREA ft^2 **16**		
AVERAGE POWER CONSUMED: **Air volume: 375 cfm Air psi: 125 lbs @ compressor**		
COMMENTS		
3. SSPC SURFACE CLEANING LEVEL		
SP-10/NACE #2		
4. LEVEL OF WASTE GENERATED		
5. PARTICULATE GENERATION		
6. COATING REMOVAL DAMAGE APPRAISAL		
WARPING / DENTING—Technician Evaluation		
None		
METAL / COMPOSITE EROSION—Technician Evaluation		
None		
COMMENTS		
7. SURFACE PROFILE / ROUGHNESS		
READING #1 **4**	READING #6 **n/a**	
READING #2 **4**	READING #7 **n/a**	
READING #3 **4**	READING #8 **n/a**	
READING #4 **4.4**	READING #9 **n/a**	
READING #5 **4.8**	READING #10 **n/a**	
COMMENTS		
INSPECTOR'S SIGNATURE	DATE	

DEPAINTING SYSTEM EVALUATION AND INSPECTION REPORT		
DATE: **4/12/05**	PROJECT REF. NO.	PAGE OF
PROJECT NAME: **Depainting Technologies**		LOCATION **Stennis**
INSPECTION ORGANIZATION: **ASRC**		INSPECTOR **Curran**
PRODUCT MANUFACTURER / NAME: **US Technologies/ Quickstrip A 10/20 Grit 40 lb bags**		
1. EASE OF USE—Technician Evaluation		
Cover-alls and air supplied blasting hood required. Full containment required.		
Set-up of portable compressor and blast pot (30 min – 1 hr)		
Noise Levels- 12'/ 88 db 75'/78 db		
2. COATING STRIP RATE		
AVERAGE COATING THICKNESS **15** mils		
TOTAL STRIPPING TIME min **18**	CALCULATED STRIP RATE **0.9** ft^2/min	
STRIPPING SURFACE AREA ft^2 **16**		
AVERAGE POWER CONSUMED: **Air volume: 375 cfm Air psi: 40 lbs @ compressor**		
COMMENTS		
3. SSPC SURFACE CLEANING LEVEL		
SP-10/NACE #2		
4. LEVEL OF WASTE GENERATED		
5. PARTICULATE GENERATION		
6. COATING REMOVAL DAMAGE APPRAISAL		
WARPING / DENTING—Technician Evaluation		
None		
METAL / COMPOSITE EROSION—Technician Evaluation		
None		
COMMENTS		
7. SURFACE PROFILE / ROUGHNESS		
READING #1 **2.8**	READING #6 **n/a**	
READING #2 **3.0**	READING #7 **n/a**	
READING #3 **3.5**	READING #8 **n/a**	
READING #4 **3.1**	READING #9 **n/a**	
READING #5 **3.0**	READING #10 **n/a**	
COMMENTS		
INSPECTOR'S SIGNATURE		DATE

DEPAINTING SYSTEM EVALUATION AND INSPECTION REPORT		
DATE: **4/12/05**	PROJECT REF. NO.	PAGE OF
PROJECT NAME: **Depainting Technologies**	LOCATION **Stennis**	
INSPECTION ORGANIZATION: **ASRC**	INSPECTOR **Curran**	
PRODUCT MANUFACTURER / NAME: **Steel Magic** **50 lb bags**		
1. EASE OF USE—Technician Evaluation		
Cover-alls and air supplied blasting hood required. Full containment required.		
Set-up of portable compressor and blast pot (30 min – 1 hr)		
Noise Levels- 12'/ 88 db 75'/78 db		
2. COATING STRIP RATE		
AVERAGE COATING THICKNESS **8** mils		
TOTAL STRIPPING TIME min **8**	CALCULATED STRIP RATE **2** ft^2/min	
STRIPPING SURFACE AREA ft^2 **16**		
AVERAGE POWER CONSUMED: **Air volume: 375 cfm Air psi: 60 lbs @ compressor**		
COMMENTS		
3. SSPC SURFACE CLEANING LEVEL		
SP-10/NACE #2		
4. LEVEL OF WASTE GENERATED		
5. PARTICULATE GENERATION		
6. COATING REMOVAL DAMAGE APPRAISAL		
WARPING / DENTING—Technician Evaluation		
None		
METAL / COMPOSITE EROSION—Technician Evaluation		
None		
COMMENTS		
7. SURFACE PROFILE / ROUGHNESS		
READING #1 **3.7**	READING #6 **n/a**	
READING #2 **3.9**	READING #7 **n/a**	
READING #3 **3.3**	READING #8 **n/a**	
READING #4 **3.5**	READING #9 **n/a**	
READING #5 **3.5**	READING #10 **n/a**	
COMMENTS		
INSPECTOR'S SIGNATURE	DATE	

DEPAINTING SYSTEM EVALUATION AND INSPECTION REPORT			
DATE: **8/9/05**	PROJECT REF. NO.		PAGE OF
PROJECT NAME: **Depainting Technologies**		LOCATION **Stennis**	
INSPECTION ORGANIZATION: **ASRC**		INSPECTOR **Curran**	
PRODUCT MANUFACTURER / NAME: **NitroCision LLC**			
1. EASE OF USE—Technician Evaluation			
Cover-alls and full-face respirator required. Limited containment needed.			
Set-up of equipment (4 hr). Specialized equipment and training required.			
Noise Levels- 101 db @ 20'			
2. COATING STRIP RATE			
AVERAGE COATING THICKNESS **10** mils			
TOTAL STRIPPING TIME min **45**		CALCULATED STRIP RATE **0.4** ft^2/min	
STRIPPING SURFACE AREA ft^2 **16**			
AVERAGE POWER CONSUMED: **100 psi air for rotating tip, 100kw portable generator, and**			
COMMENTS **400 gallons liquid nitrogen**			
3. SSPC SURFACE CLEANING LEVEL			
SP-6/NACE #3 Commercial Blast Cleaning			
4. LEVEL OF WASTE GENERATED			
Only paint waste			
5. PARTICULATE GENERATION			
0			
6. COATING REMOVAL DAMAGE APPRAISAL			
WARPING / DENTING—Technician Evaluation			
None			
METAL / COMPOSITE EROSION—Technician Evaluation			
None			
COMMENTS			
7. SURFACE PROFILE / ROUGHNESS			
READING #1	**3.5**	READING #6	**n/a**
READING #2	**3.0**	READING #7	**n/a**
READING #3	**3.5**	READING #8	**n/a**
READING #4	**4.5**	READING #9	**n/a**
READING #5	**3.7**	READING #10	**n/a**
COMMENTS			
INSPECTOR'S SIGNATURE		DATE	

DEPAINTING SYSTEM EVALUATION AND INSPECTION REPORT		
DATE: **7/19/05**	PROJECT REF. NO.	PAGE OF
PROJECT NAME: **Depainting Technologies**		LOCATION **Stennis**
INSPECTION ORGANIZATION: **ASRC**		INSPECTOR **Curran**
PRODUCT MANUFACTURER / NAME: **Desco Mechanical Removal w/ Vacuum Attachments**		
1. EASE OF USE—Technician Evaluation		
Portable lightweight tools with HEPA vacuum to collect paint debris. Labor intensive.		
(Needle gun, Cutter hub, and Grinders needed to achieve surface cleanliness)		
Noise Levels- 98 db @ 8'		
2. COATING STRIP RATE		
AVERAGE COATING THICKNESS **6** mils		
TOTAL STRIPPING TIME **22** min	CALCULATED STRIP RATE **0.7** ft^2/min	
STRIPPING SURFACE AREA ft^2 **16**		
AVERAGE POWER CONSUMED: **110v or air powered.**		
COMMENTS		
3. SSPC SURFACE CLEANING LEVEL		
SP3 Power Tool Cleaning		
4. LEVEL OF WASTE GENERATED		
Paint debris only, contained in HEPA Vacuum		
5. PARTICULATE GENERATION		
0		
6. COATING REMOVAL DAMAGE APPRAISAL		
WARPING / DENTING—Technician Evaluation		
None		
METAL / COMPOSITE EROSION—Technician Evaluation		
None		
COMMENTS		
7. SURFACE PROFILE / ROUGHNESS		
READING #1 **4.0**	READING #6 **n/a**	
READING #2 **3.0**	READING #7 **n/a**	
READING #3 **2.8**	READING #8 **n/a**	
READING #4 **3.2**	READING #9 **n/a**	
READING #5 **4.0**	READING #10 **n/a**	
COMMENTS		
INSPECTOR'S SIGNATURE	DATE	

DEPAINTING SYSTEM EVALUATION AND INSPECTION REPORT		
DATE: **7/20/05**	PROJECT REF. NO.	PAGE OF
PROJECT NAME: **Depainting Technologies**	LOCATION **Stennis**	
INSPECTION ORGANIZATION: **ASRC**	INSPECTOR **Curran**	
PRODUCT MANUFACTURER / NAME: **DCM Clean Air Products**		
1. EASE OF USE—Technician Evaluation		
Portable lightweight tools with HEPA vacuum to collect paint debris. Labor intensive.		
(Needle gun, Cutter hub, and Grinders needed to achieve surface cleanliness)		
Noise Levels- 95 db @ 8'		
2. COATING STRIP RATE		
AVERAGE COATING THICKNESS **7** mils		
TOTAL STRIPPING TIME **32** min	CALCULATED STRIP RATE **0.5** ft^2/min	
STRIPPING SURFACE AREA **16** ft^2		
AVERAGE POWER CONSUMED: **110v or air powered.**		
COMMENTS		
3. SSPC SURFACE CLEANING LEVEL		
SP3 Power Tool Cleaning		
4. LEVEL OF WASTE GENERATED		
Paint debris only, contained in HEPA Vacuum		
5. PARTICULATE GENERATION		
0		
6. COATING REMOVAL DAMAGE APPRAISAL		
WARPING / DENTING—Technician Evaluation		
None		
METAL / COMPOSITE EROSION—Technician Evaluation		
None		
COMMENTS		
7. SURFACE PROFILE / ROUGHNESS		
READING #1 **2.5**	READING #6 **n/a**	
READING #2 **3.5**	READING #7 **n/a**	
READING #3 **1.6**	READING #8 **n/a**	
READING #4 **1.6**	READING #9 **n/a**	
READING #5 **2.4**	READING #10 **n/a**	
COMMENTS		
INSPECTOR'S SIGNATURE	DATE	

APPENDIX C

NASA KSC-MSL-2005-0561 Laser Depainting Metallurgical Report

NASA
Center Operations Directorate
Materials Science Laboratory
Kennedy Space Center, Florida

March 10, 2006

KSC-MSL-2005-0561

SUBJECT: Analysis of Steel and Aluminum Laser De-Painted Panels

CUSTOMER: Jerry Curran/ASRC/ASRC-20

1.0 ABSTRACT

Steel and aluminum panels were submitted to the laboratory for evaluation of the laser de-painted surface morphology as compared to untreated reference panels. Each of the steel and aluminum panel surfaces was examined macroscopically and, with the exception of residual paint and primer, the metallic surfaces were unremarkable. Cross-sections were mounted and polished for metallurgical evaluation and micro hardness measurements, and no discernable anomalies were noted. High magnification scanning electron microscopy (SEM) of the laser de-painted surface showed some minor smearing and plastic deformation of the surface contour; however, the effects were limited to the immediate surface and posed no metallurgical detriment. Surface roughness measurements were performed using a diamond stylus, and results indicated slight increases in roughness (Ra values) for both the steel and aluminum substrates, confirming the deformation observed via SEM. Metallurgical analysis indicated that there was no significant detriment caused by the laser de-painting process on either the steel or aluminum substrates.

2.0 FOREWORD

Steel and aluminum panels subjected to a laser de-painting process were submitted for metallurgical analysis. The steel substrates examined included a bare reference, a primer coated surface that was partially de-painted by the laser treatment, and a primer plus epoxy topcoat surface that was partially subjected to the laser de-paint process. The aluminum panel was strictly a bare reference with a portion of the surface subjected to the laser de-paint process; no actual coating was removed.

3.0 PROCEDURES AND RESULTS

3.1 The panels were photographed as-received (Figure 1), showing the bare steel reference surface along with the epoxy plus primer, primer only, and bare aluminum samples. The two coated steel panels have a linear strip where the coating was removed with the laser. The bare aluminum sample has a square section that was exposed to the laser, but no coating was removed.

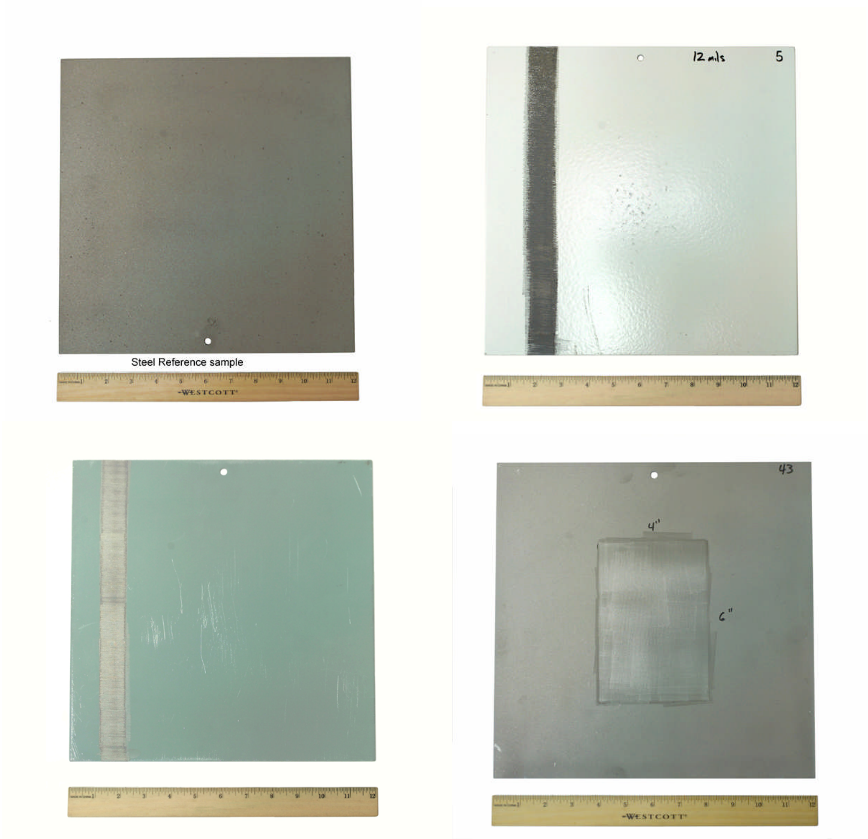

Figure 1
As-received panels showing the steel reference (upper left), white epoxy painted (upper right; includes primer underneath), green primer only (lower left), and bare aluminum (lower right). Scale is standard (inches).

3.2 Optical stereomicroscopic examination showed that the laser treated surfaces of both the painted and primed steel samples had islands of residual coating still embedded in the course contours of the surface, and the exposed base metal appeared slightly coarser than the steel reference. The aluminum sample surface exposed to the laser showed macroscopic delineations along the length of the treated area that appear to correspond to the width of each laser pass. Higher magnification optical inspection revealed subtle changes in color, but little difference in the surface morphology. The original matte grey finish of the untreated area was brighter in the areas exposed to the laser, likely due to removal of prolonged oxidation on the surface (Figures 2-5).

Figure 2
Surface morphology of the steel reference sample. Magnification: 5X

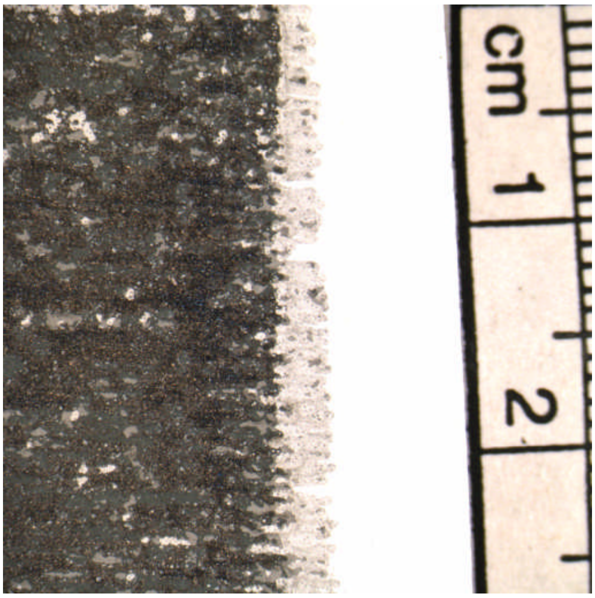

Figure 3
Surface morphology of the painted/primed steel sample. Magnification: 5X

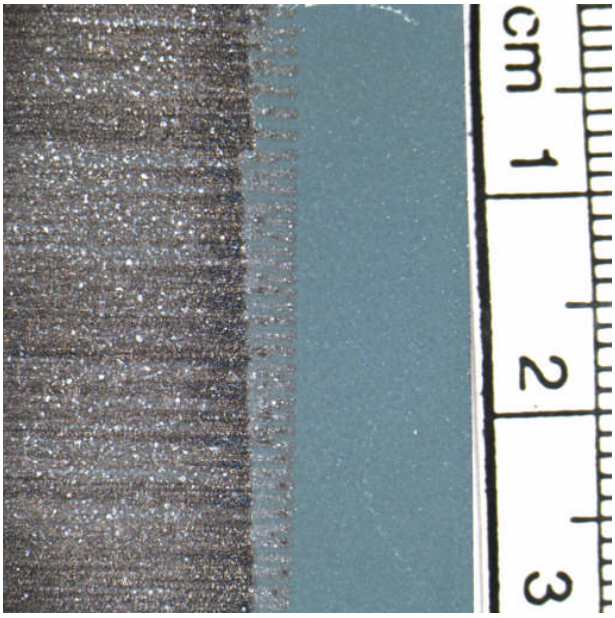

Figure 4
Surface morphology of the primed steel sample. Magnification: 5X

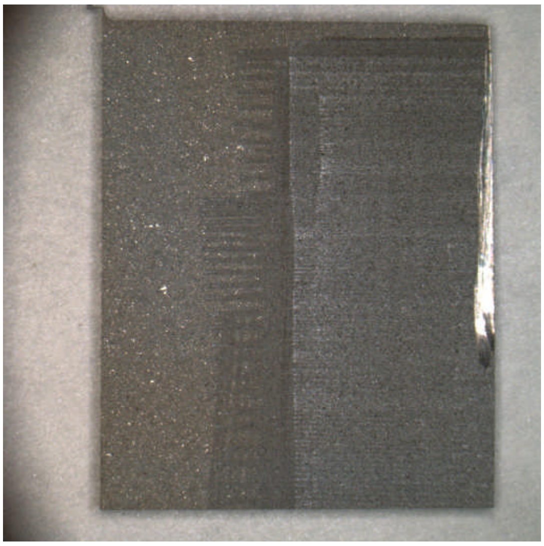

Figure 5
Surface morphology of the aluminum reference sample showing the laser treated surface (left) adjacent to the untreated side (right). Magnification: 5X

3.3 The surfaces were cleaned and analyzed via SEM. The surfaces of both the aluminum and steel exposed to the laser showed slight mechanical deformation (smearing) compared to the reference samples (Figure 6-9). The steel specimens also showed the smeared regions containing islands of residual coating not removed by the laser.

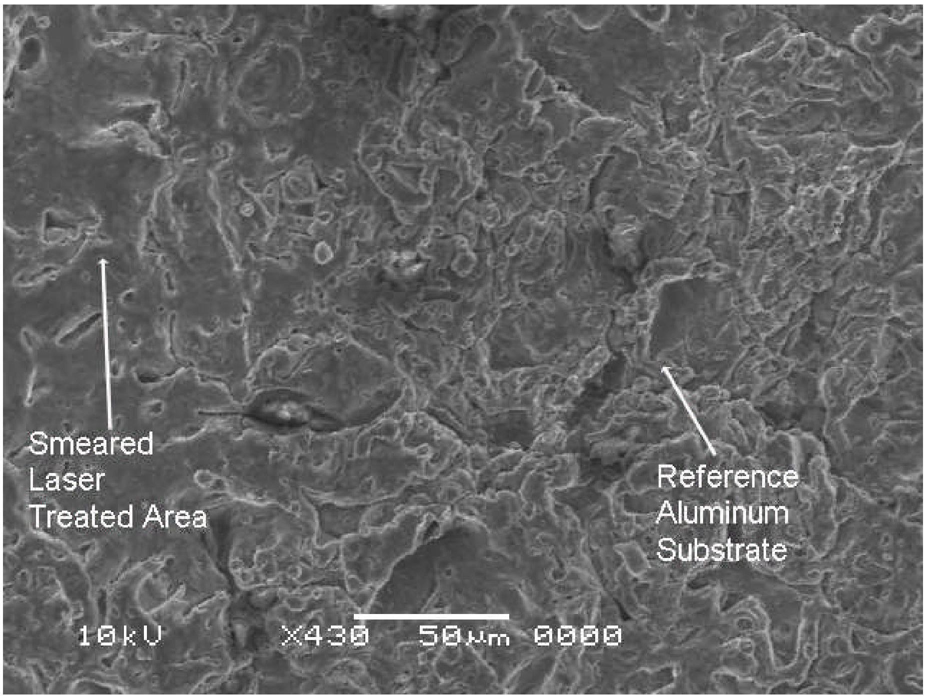

Figure 6
SEM micrograph of aluminum sample, showing the laser treated substrate on the left and the virgin base metal on the right. Magnification: 430X

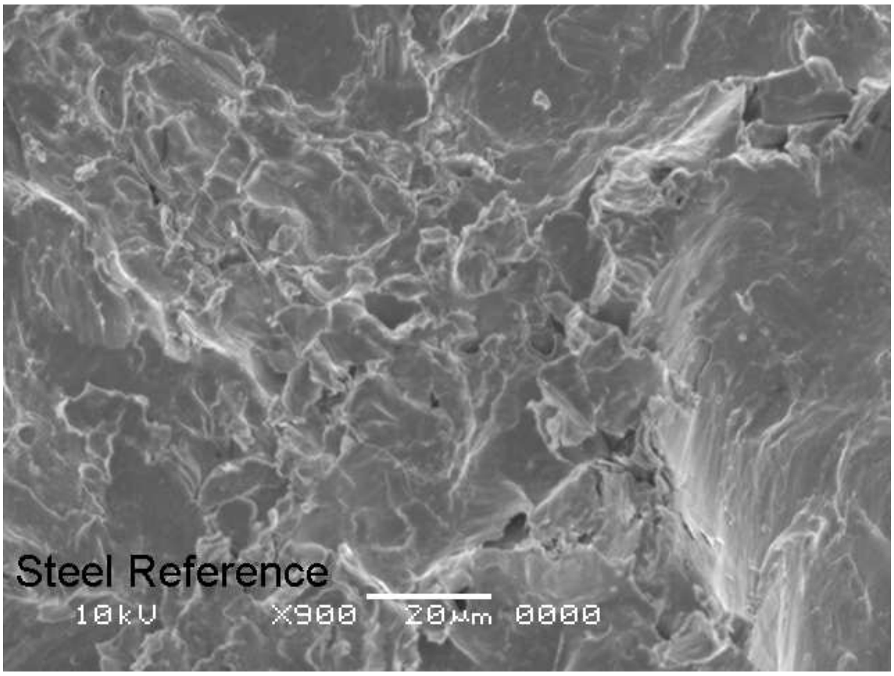

Figure 7
SEM micrograph of steel substrate reference, not exposed to the laser. Magnification: 900X

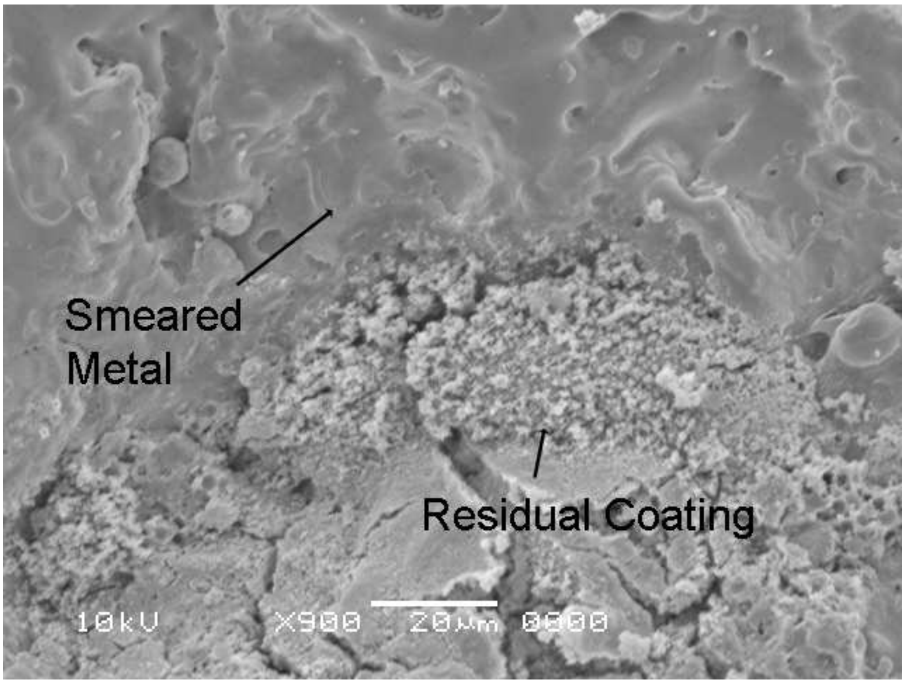

Figure 8
SEM micrograph showing the smeared surface and residual coating of the primed and painted sample exposed to the laser de-paint process. Magnification: 900X

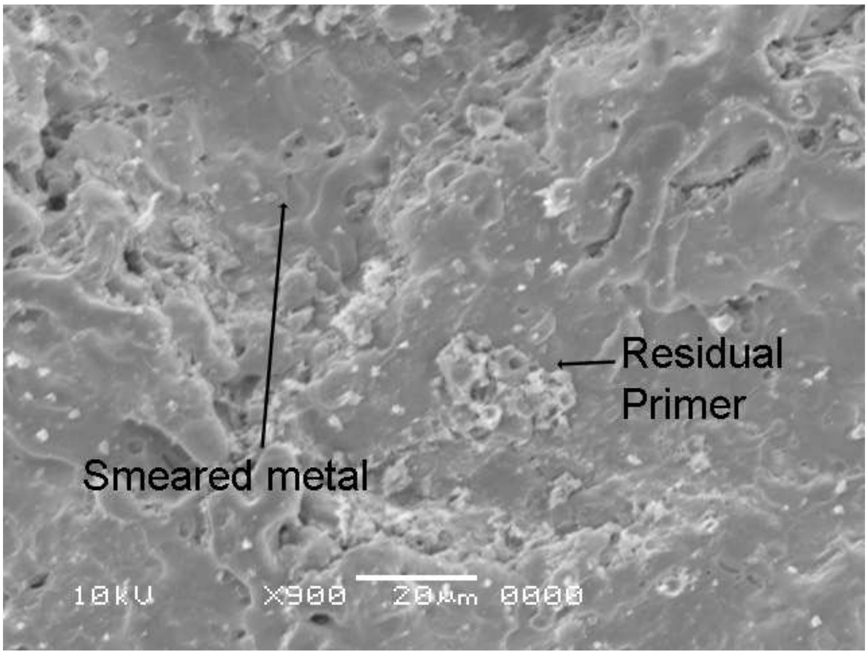

Figure 9
SEM micrograph showing the smeared surface and residual coating of the steel sample with only the green primer applied. Magnification: 900X

3.4 Metallographic examination showed a uniform microstructure for both the aluminum and steel substrates, with no apparent anomalies due to the laser de-painting process.

3.5 Micro hardness traverse measurements were taken in a linear pattern across the polished cross-section from the untreated regions into the laser treated regions of both the aluminum and steel. The converted hardness values for the aluminum sample averaged Rockwell B 59 in both the laser treated and untreated regions, typical for a 6xxx series aluminum. The converted hardness values for the steel specimens averaged Rockwell B 80, typical for a mild steel in the annealed condition. There were no discernible differences in the hardness values for any of the laser treated regions as compared to the untreated references.

3.6 Surface roughness measurements were taken on both the steel and aluminum panels using a diamond stylus. Results showed an increase of 14 micro-inches (Ra) average roughness for the aluminum exposed to the laser while the steel showed and increase of 6 micro-inches (Ra).

4.0 CONCLUSION

The laser de-painted samples for both the steel and aluminum substrates exhibited only superficial mechanical deformation of the surface with no metallurgical discrepancies noted.

EQUIPMENT: SEN, S/N MP17700061
Zeiss Metallograph, S/N 000857
Micro hardness tester, S/N B-D58073

CONTRIBUTORS: P. J. Marciniak/TA-H1-M1

PRIMARY INVESTIGATOR: ____
Don Parker/TA-H1-M1