Environmental Security Technology Certification Program

(ESTCP)

Demonstration/Validation of Low Volatile Organic Compound (VOC) Chemical Agent Resistant Coating (CARC)

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Final Report

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List of Acronyms

#/gal	pounds per gallon
AAAV	Advanced Amphibious Assault Vehicle
AD	Army Depot
AFRL	Air Force Research Laboratory
ALC	Air Logistics Center
ARL	Army Research Laboratory
ASTM	American Society for Testing and Materials
BTU	British Thermal Unit
CAA	Clean Air Act
CARC	Chemical Agent Resistant Coating
CIE	Commission Internationale d'Eclairage
CMM	Capability Maturity Model
COMSEC	Communications Security
COTS	Commercial Off-The-Shelf
CTIO	Coatings Technology Integration Office
Dem/Val	Demonstration/Validation
DFT	Dry Film Thickness
DFTM	Dry Film Thickness Measurements
DMB	Dry Media Blasting
DMTA	Dynamic Mechanical Thermal Analysis
DoD	Department of Defense
DS2	Decontaminating Solution 2
ECBC	Edgewood Chemical and Biological Center
EMMAQUA	Equatorial Mirror Mount with water
EO	Executive Order
EPA	Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
FCIM	Flexible Computer Integrated Manufacturing
HAP	Hazardous Air Pollutant
HD	Distilled Mustard
HEMTT	Heavy Expanded Mobility Tactical Truck
HMMWV	High Mobility Multi-Wheeled Vehicle
HVLP	High Volume Low Pressure
IAW	In Accordance With
ISO	International Organization for Standardization
LAV	Light Armor Vehicle
LVS	Logistics Vehicle System
MCB	Maintenance Center Barstow
MCLB	Marine Corps Logistics Base
MEP	Mobile Electric Power
MIL	Military

MMPP	Miscellaneous Metal Parts & Products
MOF	Mode of Failure
MSDS	Material Safety Data Sheet
NBS	National Bureau of Standards
NCO	Isocyanate
NDI	Non-Developmental Item
NESHAP	National Emission Standard for Hazardous Air Pollutants
NOV	Notice of Violation
NSN	National Stock Number
NSWC	Naval Surface Warfare Center
NSWCCD	Naval Surface Warfare Center, Carderock Division
OEM	Original Equipment Manufacturer
OH	Hydroxyl
OO-ALC	Ogden Air Logistics Center
OOAMA	Ogden Air Material Area
OSHA	Occupational Safety & Health Administration
PASGT	Personnel Armor System, Ground Troops
PATTI	Pneumatic Adhesion Tensile Testing Instrument
PEI	Principle End Item
PI	Principal Investigator
PM	Project Manager
POC	Point of Contact
POS	Pull Off Strength
PPE	Personal Protective Equipment
QPL	Qualified Products List
SATCOM	Satellite Communications
SERDP	Strategic Environmental Research and Development Program
SOR	Source of Repair
SRI/SwRI	Southwest Research Institute
SSS	Stainless Steel Shot
TAM	Table of Authorized Material
TRI	Toxics Release Inventory
TUVR	Total Ultraviolet Radiation
TYAD	Tobyhanna Army Depot
USARL	US Army Research Laboratory
USMC	United States Marine Corps
UTTR	Utah Test and Training Range
VOC	Volatile Organic Compound
WBCC	Water Borne Camouflage Coating
WD	water dispersible

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Abstract

As part of a tri-service effort funded by the Environmental Security Technology Certification Program (ESTCP), the water-dispersible (WD) Chemical Agent Resistant Coating (CARC) patented (#5,691,410) by the Army Research Laboratory (ARL) has undergone technology Demonstration/Validation (Dem/Val) testing at DoD depot facilities in order to verify its performance when applied and removed in a production environment. The tri-service team members include ARL, the Naval Surface Warfare Center, Carderock Division (NSWCCD) representing the Marine Corps, and the Air Force Research Laboratory (AFRL). Application demonstrations were held at three depot facilities, one for each of the services, including the Barstow Marine Corps Logistics Base, the Ogden Air Logistics Center and the Tobyhanna Army Depot. The WD CARC used was from production batches manufactured by the Sherwin-Williams Company, and it was applied using standard production equipment under normal environmental conditions. Production stripping demonstrations were held at these same production facilities, using aged test panels prepared during the application demonstrations. This ESTCP effort was transitioned from a similar Strategic Environmental Research and Development Program (SERDP) project that consisted of the same team members and was at the laboratory-scale research level. It verified that the WD CARC is essentially a "drop-in" substitute for the current solvent-based CARC, because it could be applied and stripped using existing equipment and processes at the depot facilities. Surveys completed by the depot applicators indicated that the WD CARC was considered overall to be a better coating than the standard CARC normally used, with up to one-third less paint required for individual items painted. The exceptional performance of the coating noted in the SERDP effort, especially its flexibility, mar resistance and outdoor durability, was confirmed at the production level. This improved performance should lengthen the time between refinishing, mitigate surface damage due to abrasion and result in less refinishing of military equipment on the basis of cosmetic appearance. While process changes at the demonstration sites made stripping comparisons more problematic, the data support the fact that strippability falls within normal production limits, and the use of WD CARC will not present a serious impact in any military depot. This report summarizes the application and removal Dem/Vals held at the three demonstration sites during the period from May 2000 until November 2001.

Demonstration/Validation of Low Volatile Organic Compound (VOC) Chemical Agent Resistant Coating (CARC)

1. Introduction

1.1 Background

When the Army first used the Chemical Agent Resistant Coating (CARC) system on tactical equipment in the early 1980s, it was in compliance with environmental regulations in effect at that time. However, Federal and local regulations have since resulted in further restrictions in the amount of Volatile Organic Compounds (VOCs) and in the Hazardous Air Pollutants (HAPs) that can be emitted during the application and curing of protective coatings. The current approach to the problem is either to incur the high cost of procuring, installing and maintaining an emission control system or to deviate from the CARC requirement and utilize a coating that meets environmental regulations but does not provide chemical agent resistance. The former approach can be economically prohibitive and the latter approach results in a severe compromise to mission readiness.

The technology to be demonstrated/validated was developed primarily under the Strategic Environmental Research and Development Program (SERDP) Project PP -1056, Low VOC CARC (1), which was initiated in FY97 and was funded by SERDP through FY99. Using recent developments in polymer and pigmentation technology, the Army Research Lab (ARL) was successful in developing a high performance, water reducible (WD) CARC polyurethane topcoat. The formulation developed under the SERDP Project succeeded in meeting the VOC objective of 1.8 #/gal and has eliminated hazardous air pollutants as well. In addition to being fully environmentally compliant, the new coating shows significant performance enhancements, as evidenced by improvements in low temperature flexibility, mar resistance and weathering durability. U.S. Patent #5,691,410 has been awarded for the WD formula that was the basis of the SERDP effort.

Currently used CARC coating formulations contain 3.5 #/gal of VOCs. The current annual usage nationwide is estimated to be 3.0 million gallons per year. A CARC targeted to a 1.8 #/gal VOC limit would save at least 5 million pounds of VOC per year in the application of the coating, proportionately reduce photochemical smog generation and avert Notices of Violation (NOV) at user facilities including depots, air logistic centers (ALCs), military bases and original equipment manufacturers (OEMs). Those VOCs that would be eliminated include: methyl isobutyl ketone, methyl isoamyl ketone, toluene, xylene and butyl acetate, most of which are hazardous air pollutants (HAPs). Furthermore, the technology developed by this project will eliminate the need to install emission control devices such as carbon absorption and/or incineration, to bring facilities into VOC compliance. This will result in a cost avoidance at a typical ALC or depot of $5 million for equipment and installation, and an annual operating cost avoidance of $250,000. Since there are approximately 10 such facilities that would require pollution controls if low VOC formulations were not developed, the total cost avoidance would be $50 million for equipment and installation and $2.5 million saved in annual operating costs.

By developing one CARC topcoat for use by all the services, substantial savings will result in procurement and logistics operations. A single CARC formulation will result in procuring larger quantities than otherwise would be possible, with increased competition tending to drive the price down. Planning, transportation and storage will be simplified by having one coating for all services, which will also result in reducing costs of these operations. Since the WD CARC is a superior product (enhanced mar resistance, flexibility, weathering durability) compared to current CARC, it is expected that its service life will greatly exceed that of the current material and will therefore not require stripping and re-painting as often.

1.2 Objectives of the Demonstration

The objective of this Dem/Val was to prove out the application of the new WD CARC formulation to defense materiel under production conditions. The performance of the cured film was tested to satisfy the requirements of all three user services. In addition to conducting trials to obtain cost and performance data pertaining to application of the coating, stripping trials were performed to validate the ability to successfully remove the coating in a cost effective manner.

The demonstration validated that the new WD coating can be applied and stripped utilizing existing equipment and processes at the depots when following the process guidelines that resulted from the previous SERDP development work (1). New disposal options were not investigated for the non-chemically-stripped CARC. Operational costs for the WD coating were tracked and compared to those of the current CARC. Success will be measured by demonstrating the "drop-in" nature of the new WD coating.

The field demonstrations were conducted at three facilities; one for each of the services that will be utilizing the new WD coating. The following locations were selected and each was contacted and agreed to participate in this project:

Demonstration Site I - Navy/Marines - Barstow Marine Corps Logistics Base, CA
Demonstration Site II - Air Force - Ogden Air Logistics Center, UT
Demonstration Site III - Army - Tobyhanna Army Depot, PA

A new military specification, MIL-DTL-64159, "Coating, Water Dispersible Aliphatic Polyurethane, Chemical Agent Resistant" has been published, based on the results of the SERDP and ESTCP Projects.

1.3 Regulatory Drivers

The Clean Air Act and its amendments have set the VOC limit for the CARC topcoat at 3.5#/gal, but local governments are permitted to set lower limits and many have already done so. Limits as low as 1.8 #/gal are required in some areas in order for the facilities to stay in production. Accordingly, the WD CARC was formulated to have a VOC no greater than 1.8 #/gal.

Guidance received from the U.S. Environmental Protection Agency (EPA) has indicated that the Miscellaneous Metal Parts & Products Surface Coating National Emission Standard for Hazardous Air Pollutants (NESHAP) will apply to CARC. This would require that the HAPs such as methyl isobutyl ketone, toluene and xylene that are used in the current formulation, must be removed or eliminated with add-on emission controls. The new WD CARC formulation has eliminated these solvents.

The following official DoD requirements statements apply:
Army: (3.2a) Improved Chemical Agent Resistant Coating (CARC) Technologies
Navy: (3.1.4.h) Non-hazardous Aircraft Paints and Coatings; (3.1.5a) Non-hazardous Paint Stripping Removal
Air Force: (No. 305) Substitute for the Ozone Depleting Hazardous Material, Chemical Agent Resistant Coating (CARC); (No. 503) Non-solvent Paint Strippers

The reformulation of the CARC topcoat addresses the above requirements by a 50% reduction in VOCs, the elimination of HAPs and the absence of ozone depleting compounds. Furthermore, emphasis was placed on validating the use of non-hazardous stripping methods, such as media blasting as opposed to the use of chemical strippers.

1.4 Stakeholder/End-User Issues
End users of this technology include Program Managers, OEMs and depots that are required to follow Army Regulation 750-1[(2)] (also followed by the Marine Corps) for chemical warfare survivability. This means that all tactical equipment (including combat, combat support, essential ground support equipment, tactical wheeled vehicles, and aircraft) must be hardened against performance degradation caused by chemical warfare agents or decontamination procedures. Therefore, virtually everything in the Army and Marine Corps inventory, plus Air Force vehicles and equipment procured through the Army requires chemical agent resistance.

With some DoD facilities already prohibited from using CARC topcoats due to existing regulations, and other facilities having been forced to install emission control systems in order to stay in production, many users have already sought the WD CARC technology. Moreover, as the NESHAP applicable to most uses of CARC coatings is enforced, the use of the current CARC topcoat will become further restricted both at the OEM level and by the depot community. The use of the technologies were expedited by this Dem/Val, as the material was used and evaluated in a production environment, thus virtually eliminating the risk usually incurred when a new coating is introduced.

The SERDP Project PP-1056 effort[(1)] resulted in formulating a new technology, WD CARC topcoat that meets or surpasses all performance requirements and meets the VOC objective of 1.8 #/gal VOC, while eliminating HAPs as well. However, all application and stripping studies had been conducted in laboratory type environments and conducted by engineers responsible for the performance of the program. This demonstration project, which was conducted by end-users in their production environment, alleviated any concerns that are inherent when a new technology is introduced and will provide a hands-on technology transfer opportunity.

Adoption of this technology will therefore be facilitated and will prevent the adoption of the more costly alternative, the use of emission control systems, which would be required if use of the current CARC were to be continued.

2. Technology Description

2.1 Technology Development and Application

As noted above, the technology for WD CARC resulted in US Patent #5,691,410 [3]. While the original goals were VOC reduction and HAP elimination, use of the WD polymer system and elimination of the problematic extender pigments used in typical low-gloss coatings led to remarkable improvements in performance. The components of a typical coating can be divided into three main groups. The polymer (commonly called the binder) provides the required performance level of the product, the pigments provide the desired color and gloss, and the solvents/additives control package and application viscosities and aid in film formation. In CARC, the aliphatic polyurethane binder [1] provides the chemical agent resistance, and the camouflage properties are provided by the appropriate selection of tinting pigments for visual color and near-infrared reflectance, plus extender pigments for gloss control.

In a typical solvent-base urethane system, a polyol reacts with a polyisocyanate to form a polyurethane. If designed properly, crosslinking in this system provides high-performance coatings such as CARC. However, the necessity to ensure water is not present in non-aqueous, two-component polyurethane formulations is paramount due to its reaction with the isocyanate. Recent developments in raw materials for waterborne polyurethane technology, particularly by the Bayer Corporation, have enabled high-performance coatings to be formulated using water dispersible polyisocyanates and hydroxyl-functional polyurethane dispersions. While there is a competing reaction occurring with water, the kinetics, raw materials and proper indexing of isocyanate (NCO) to hydroxyl (OH) groups used in the formulations ensure that sufficient crosslink density is established in the film.

The low gloss requirements for camouflage topcoats typically lead to a proportionately higher pigment to binder ratio. This works against the performance provided by the polyurethane polymer. Typical extender pigments are silica-based (siliceous), and they provide relatively inexpensive gloss reduction, but at the expense of poor mar resistance and flexibility, particularly at the high loading levels in camouflage topcoats. In evolving toward replacement of these extenders with non-siliceous varieties, multiple sources of supply and composition were considered, along with several blends of polymeric and siliceous extenders. Once polymeric beads with satisfactory performance were discovered, especially with resistance to Decontaminating Solution 2 (DS2), alkali, hydrocarbons and acids, performance (primarily flexibility and mar resistance) was the primary criterion in judging acceptability in the coating. In general, however, the most dramatic performance improvements came about due to total replacement of the siliceous portion of the extender system. This was made possible due to the greater efficiency in flattening (gloss control) associated with the polymeric beads; i.e., for a given gloss level, less weight and volume were necessary than for siliceous extenders. This led, in turn, to a more resin-rich film, with the expected improvements in performance.

2.2 Previous Testing of the Technology

Testing the application and stripping properties of the WD CARC was performed under SERDP Project PP-1056[1]. Although the new WD CARC was applied and stripped using production-type equipment, the work was carried out in laboratory environments. The SERDP work indicated that the new formulation is compatible with production processes, but this needed verification by production operators in production facilities under a variety of climatic conditions.

2.3 Factors Affecting Cost and Performance

When compared to standard CARC, the raw material cost for WD CARC is anticipated to be higher in the short run due to the change from solvent-borne to WD polyurethane chemistry, but as use increases, this differential is expected to shrink. However, the cost differential due to the use of polymeric flattening agents instead of relative inexpensive siliceous extenders is not expected to shrink as much. These two material differences, however, are the very reason for the improved performance to be discussed later. Higher material costs at application will be more than made up by the lower amount of paint used, the extended service life and less frequent refinishing necessary with the WD CARC.

2.4 Advantages and Limitations of the Technology

The substitution of an environmentally compliant CARC provides a simple, "drop-in" solution to the environmental problems associated with painting military equipment, including (but not limited to) VOC reduction, HAP elimination, and the consequent elimination of emission control equipment. It requires no specialized application equipment and can be used anywhere. It has been established that the new coating can be applied using the techniques common to depots and OEMs; i.e., conventional spray and high-volume low-pressure (HVLP) spray guns. These application studies have verified that the same equipment that is currently used can be used to accommodate the new WD coating. However, the WD material has different spray characteristics than the solvent system currently used and requires different process parameters to achieve acceptable results. Experience from the three application demonstrations indicated that these differences were easily and rapidly overcome by experienced painters. In addition, stripping tests from the SERDP effort have shown that there are differences in the rate of coating removal with several different blast media, when compared to the standard CARC. Depending on substrate and the specific media employed, the rate of stripping can be either greater or less than that of standard CARC. Similarly, the rate of WD coating removal when chemical strippers are employed can be greater or less than that of standard CARC, depending on the particular stripper employed. Although not observed in any of the application demonstrations, experience with waterborne coatings indicates that they are often more susceptible to problems with substrate cleaning and pretreatment. Finally, environmental representatives at TYAD made the observation that a facility that currently did not use waterborne coatings could conceivably be put in the position of having a new (waterborne) waste stream to deal with.

3. Demonstration Design

3.1 Performance Objectives

The performance objective of the demonstrations was to replace the current CARC topcoat with a WD CARC and to validate that the new topcoat is a "drop-in" replacement that meets or exceeds the performance requirements of the current material. Through the execution of the applicable documents as defined below, the application of the WD CARC was accomplished for selected defense equipment (typically 3-5 units) and a designated number of test panels to validate the performance of the coating and the stripping processes and obtain the metrics necessary to conduct performance and cost analysis. Through direct comparison with the current CARC topcoat as applied and stripped at the demonstration sites, an analysis was made to determine if there is a deviation from a "drop-in" substitution, and if so, what the cost implications are.

3.2 Selecting Test Platform/Facilities

The field demonstrations were conducted at three facilities; one for each of the services that will be utilizing the new WD coating. Sites selected were identified by their need, interest and qualifications to conduct the demonstrations. Also, it was desired to vary geographical locations to demonstrate the technology under various climatic conditions.

The Marine Corps demonstration site, Barstow Logistics Base, CA was unable to use any CARC topcoat due to environmental considerations and was using a waterborne polyurethane coating that was not chemical agent resistant. The facility was very interested in evaluating the WD CARC topcoat. Also, the location in the Mojave Desert represents an extreme (dry) climatic condition. This site has been used previously by the Marine Corps/Navy to demonstrate new coating materials and has performed admirably in this capacity.

The Ogden Air Logistics Center site in Utah is the only Air Force site where CARC topcoat is currently being applied. Thus, it was in an excellent position to compare the drop-in nature of the new coating for their facility.

The Army demonstration site selected was the Tobyhanna Army Depot in Pennsylvania. It is a large-scale user of CARC topcoat and is the Army Center of Excellence for painting for the depot community. Also, the site provided a relatively humid environment that added to the desired variety in climatic conditions of the demonstration sites.

3.3 Test Platform/Facility Characteristics/History

3.3.1 Maintenance Center Barstow

Maintenance Center Barstow (MCB) is an industrial facility located in the Mojave Desert approximately 150 miles southwest of Las Vegas, NV and 120 miles east of Los Angeles, CA. It is located in a desert climate with an average relative humidity between 8% - 21%, and the temperature averages between 106° F - 112° F in the summer and 28° F - 58° F in the winter. The Final Paint Facility of MCB consists of three paint booths (one sixty-foot booth and two thirty-foot booths), 10 permitted paint areas, and one drive-through drying oven. Pollution prevention technologies include an air pollution control system from Terra-Aqua Enviro Systems, with a total volume of 42,000 cu. ft. being treated. There are only two other similar facilities in the State of CA.

The facility is located on the Marine Corps Logistics Base (MCLB) Barstow in Barstow, CA. This is a Depot Maintenance Activity for the Marine Corps, providing all echelons of maintenance support to Fleet Marine Forces west of the Mississippi and from the Pacific regions. Final Paint provides coating operations for all principle end items (PEIs) including surface cleaning and preparation, and application of base coat, prime coat, and topcoat. These processes represent the major waste stream generators within the facility. The vehicle mix includes all ground tactical equipment such as: M1A1, M-88, AAVP7 tanks, Light Armor Vehicles (LAVs), all variants of 5-Ton trucks, all variants of the High

Mobility Multi-Wheeled Vehicle (HMMWV), Logistics Vehicle System (LVS) family of vehicles, and construction and engineering equipment. Cleaning and preparation processes include steam cleaning, abrasive (steel shot, garnet, plastic media) blasting, and minimal chemical stripping. The MCLB has sprayed everything from enamels, lacquers and chromates in the early Sixties to alkyds, epoxies, chemical agent resistant coatings and polyurethanes in the Eighties. Increasingly stringent VOC restrictions have prohibited the use of various coatings in significant quantities. One of these coatings is the CARC topcoat, MIL-C-46168. At the time of the Dem/Val, the MCLB was spraying Low-VOC Waterborne Camouflage Coatings (WBCC), epoxies, polyurethanes and limited amounts of CARC.

3.3.2 Ogden Air Logistics Center

Ogden Air Logistics Center (OO-ALC) is centrally located in the western United States within the northern population center of the State of Utah, approximately 30 miles north of Salt Lake City and 15 miles south of Ogden via Interstate 15. It is situated at 4,800 feet above sea level in a semi-arid region having four distinct seasons. It contains a total of 962,132 acres of land in three areas:

Area A: Hill AFB consists of 6,683 acres with 1,375 buildings, of which 229 are industrial containing four million square feet.

Area B: Utah Test and Training Range (UTTR), located approximately 90 mile west of the base, consists of 953,887 acres with 122 buildings, of which 45 are industrial with 234,261 square feet.

Area C: Survivability & Vulnerability Integration Center, located 220 miles northwest of the base, has 740 acres with 17 buildings, of which four are industrial with 2,902 square feet.

The genesis for Ogden Air Logistics Center was the Wilson-Wilcox Bill (Public Law 26), which provided for the addition of new permanent Air Corps stations and depots in August 1935. A supplemental Military Appropriation Act of 1 July 1939, authorized Ogden Air Depot, which was renamed Hill Field on 1 December 1939. Construction began in 1940 and by 1941 maintenance began on A-20s and Lockheed Hudson. B-24 maintenance was added on 14 February 1943. During World War II, the name, Ogden Air Depot, changed to Ogden Air Service Command, then Ogden Air Technical Service Command, and finally on 22 July 1946, it became Ogden Air Material Area (OOAMA). During this period, A-20, B-17, B-24, B-29, P-40 and P-61 aircraft were repaired and overhauled. The US Air Force came into being on 18 September 1947, with the passage of the Armed Forces Unification Act on 5 February 1948. Hill Field was renamed Hill Air Force Base. Work on F-84 and F-89 aircraft began in 1953. The Ogden Arsenal transferred from the Army to Hill Air Force Base on 1 April 1955. F-4 aircraft maintenance began 9 January 1962. The OOAMA was renamed the Ogden Air Logistics Center (OO-ALC) on 1 April 1974. In 1975, the MX PEACEKEEPER inter-continental ballistic missile was added to OO-ALC's responsibilities followed by the F-16 multinational fighter aircraft in December 1976. C-130 maintenance was directed in FY88.

Ogden Air Logistics Center provides worldwide logistics management, engineering, modification and depot maintenance for the F-16 Fighting Falcon aircraft. This includes providing logistics support to 19 countries and more than 3,900 F-16 aircraft. OO-ALC also provides Programmed Depot Maintenance on the C-130 Hercules, logistics management for the F-4 aircraft, including support to eight countries, and is the repair source and logistics manager for the nation's silo-based intercontinental ballistic missiles, including the Minuteman and Peacekeeper. OO-ALC operates the largest overhaul facility for aircraft landing gear, wheels and brakes, as well as a state-of-the-art composite repair facility. Items overhauled include rocket motors, air munitions, guided bombs, photonic imaging and reconnaissance equipment, shelters and other related components. In addition, OO-ALC has a premier software development, test maintenance and consultation capacity with a Level 5 Capability Maturity Model (CMM) rating. Principal end items maintained by OO-ALC are the F-16 Fighting Falcon, the C-130 Hercules, the LGM-30 Minuteman and the LG-118A Peacekeeper.

3.3.3 Tobyhanna Army Depot

The Army Signal Corps had operated a leased facility in Baltimore, MD during and after World War II. However, this facility was about to become unavailable to the Army, and the Signal Corps sought to maintain an East Coast presence by building a new depot. In determining an appropriate site, the Signal Corps required a location near eastern seaports and electronics manufacturers but outside the then-anticipated nuclear blast zone around New York City or other strategic targets. On June 17, 1951, the Army formally announced its plan to re-acquire 1,400 acres of the former Tobyhanna Military Reservation (originally established in 1912) in northeast Pennsylvania for a new $35 million supply depot. Four hundred acres were allocated to the industrial complex. Site design and preparation began later that year, and Tobyhanna Signal Depot was officially established on February 1, 1953. Today there are 143 buildings in the industrial complex.

Tobyhanna Army Depot (TYAD) is the largest full-service communications-electronics maintenance facility in the Department of Defense with over 3,000 employees. The depot's mission includes the design, manufacture, repair, overhaul and fabrication of hundreds of communications and electronics systems. Communications-Electronics systems supported by Tobyhanna include communications, command and control, surveillance and target acquisition, airborne electronics intelligence and electronic warfare, electronic support equipment, and power systems. TYAD is a leader in the areas of automatic test equipment, systems integration, and the downsizing of military communications-electronics systems. Responsibilities include Communications-Electronics Source of Repair (SOR) for such products as Communication Systems, Command and Control Systems, Surveillance and Target, Acquisition Systems, Avionics Systems, Intelligence and Electronic Warfare Systems, Automatic Data Processing Systems Power Systems, and Electronic Support Equipment and Systems. It has the Special Mission for Satellite Communications (SATCOM) Support and Communications Security (COMSEC) Support, and offers Fabrication Support for Flexible Computer Integrated Manufacturing (FCIM), NDI/COTS Equipment Ruggedizing and Hardening, C-E Systems Downsizing and Prototyping, Installation Kits, Circuit Card Assemblies, Equipment Rack Systems, Switch/Junction Boxes, Distribution Boxes/Panels, Mobile Equipment Power Plants, Power Units/Generators and Textile Goods Fabrication.

3.4 Present Operations

Depending upon the facility, the current topcoat could be one of the solvent borne CARCs, MIL-C-46168 or MIL-C-53039, or the non-CARC WBCC. The Dem/Val programs were performed to demonstrate that the WD CARC could be a drop-in substitute for any of them.

3.5 Pre-Demonstration Testing and Analysis

3.5.1 Application

The overall goal of this Dem/Val was to show that the results of the prior SERDP effort, with laboratory-size coating preparation and pilot-plant-size application, could be readily scaled up to full scale manufacture by a partner coatings manufacturer and application on the production level at the demonstration sites. Consequently, the baseline for comparison was the standard CARC in use at each facility, and the necessary data (such as the amount of paint required for each piece of hardware) could be obtained from records at each facility.

3.5.2 Stripping

Results from the SERDP effort (1) were available for use as a baseline for comparison to the production data in this ESTCP program. However, during the time between the baseline studies and the stripping Dem/Val efforts, significant changes occurred in the coating systems and the stripping methods used at the demonstration sites, and this made direct comparisons difficult in many cases. The coating differences involved the assumption that the epoxy primer used was the solvent-based MIL-P-53022, versus the water-reducible MIL-P-53030 actually used at Barstow and Tobyhanna. In addition, some of the stripping media used at all three facilities during the Dem/Vals were different from those used during the baseline work.

3.6 Testing and Evaluation Plan

3.6.1 Demonstration Set-Up and Start-Up

There were no special site-preparation activities, including equipment set-up, analytical instrumentation and required utilities. At all three Dem/Val sites, normal production application and stripping equipment were used for the application and the stripping operations. These included not only hardware (application and stripping equipment), but also paint application facilities, stripping booths and personal protective equipment (PPE). Prior to coating the defense equipment and panels, the demonstration site personnel practiced application of the WD CARC utilizing scrap hardware. This helped to expedite the fine-tuning of their application techniques and enabled adjustments (fluid fan width, fluid nozzle size, air line pressure, and stand-off distance) to be made in order to optimize the application process, prior to coating the defense equipment and panels.

3.6.1.1 Application at Maintenance Center Barstow

Prior to the ESTCP team arriving at Barstow, four vehicles were selected for the application of WD CARC. The vehicles selected were two HMMWV (USMC serial numbers 544220 and 544264), a 5-ton Truck (USMC serial number 540510), and an LAV-AT (USMC serial number 521809). All four vehicles were steam cleaned in accordance with Barstow's Level 3, International Organization for Standardization (ISO) work instructions. The steel and aluminum surfaces of the vehicles were blasted to bare metal using almandite garnet 36 mesh blast media, in accordance with the Level 3, ISO work instructions. The fiberglass areas on the HMMWVs were scuff sanded and any substrate defects repaired.

After completion of the steam cleaning and blasting, all the metal surfaces of the vehicles were coated with a wash primer, DOD-P-15328D. The vehicles were primed by MCLB Barstow personnel with MIL-C-53030A epoxy primer, manufactured by Deft Chemical Coatings. The primer was applied to the vehicles on 5 May 00, prior to the ESTCP team members' arrival on site. The only exception was the fiberglass hoods on the HMMWVs, which were spot repaired. The appearance of the primer was uniform, with no obvious sags, runs or other defects.

Aluminum and steel test panels were provided by each service for concurrent application of the WD CARC system. These panels were used for laboratory testing by each agency involved in the project. The panels provided by NSWCCD were used for various tests to characterize the coating. These tests include adhesion, specular gloss, color difference, viscosity and Taber abrasion. The results are provided in Section 3.6.5.1 of this report. The panels provided by the Army were used for accelerated weathering, DS2 resistance and chemical agent resistance. The Air Force panels were exposed to accelerated weathering for 10 months prior to being used in the ESTCP stripping study at MCLB Barstow.

The steel panels provided by NSWCCD had a zinc phosphate pretreatment (TT-C-490 Type I) as prepared by Metal Samples, Inc., Munford, AL. The aluminum panels had a chromic acid anodized pretreatment (MIL-A-8625 Type I) as applied by All Steel Fabricators Co., Inc., Bala Cynwyd, PA. The steel panels provided by the Army also had the same type of zinc phosphate pretreatment, which was applied by the manufacturer, ACT Laboratories, Inc., Hillsdale, MI. The Air Force provided both steel and aluminum panels. The steel panels were pretreated with zinc phosphate by Metal Samples, Inc. and the aluminum panels were provided with a chromate conversion pretreatment per MIL-C-5541, Class 1A.

The epoxy primer, MIL-P-53030 manufactured by Deft, Inc., was applied to all the test panels on 9 May 2000 at MCLB Barstow. The ESTCP team was on site to witness the primer application to these test panels. The average dry film thickness (DFT) of the applied primer onto the test panels was between 1.5 and 2 mils. The coating was applied with no sags, runs, or other defects.

3.6.1.2 Application at Ogden Air Logistics Center

Prior to the ESTCP team arriving at Ogden, four Mobile Electric Power (MEP) units were selected for the application of WD CARC. They were prepared for coating according to the standard equipment procedures. These had been primed the previous day with MIL-P-23377G type II primer per standard procedures.

Aluminum and steel test panels were provided by each service for concurrent application of the WD CARC system. These panels were used for laboratory testing by each agency involved in the project. The Air Force panels were exposed to accelerated weathering for 5 and 10 months prior to being used in the ESTCP stripping study at Ogden ALC. The panels provided by the Army were used for accelerated weathering, DS2 resistance, and chemical agent resistance. The panels provided by NSWCCD were used for various tests to characterize the coating. These tests include adhesion, specular gloss, color difference, viscosity and Taber abrasion.

3.6.1.3 Application at Tobyhanna Army Depot

Since the object of the Dem/Val was to demonstrate the "drop-in" nature of the WD CARC, several pieces of defense equipment were selected to be painted along with a matrix of test panels necessary to characterize the applied coating and verify the acceptability of its performance. Prior to the actual Dem/Val, a site visit was made on 13 September 2000, at which the program background and goals were presented to TYAD personnel, along with proposed procedures to be used at the demonstration. The ESTCP team provided TYAD personnel with background information (focused on the SERDP efforts) about the coating application, anticipated performance, stripping considerations, safety and environmental issues, availability and implementation plans. The application process was to be conducted in accordance with standard Army procedures and health and safety guidelines. TYAD agreed to provide three to five production-type items for the demonstration. Subsequently, a formal memo was submitted to TYAD management. The actual Dem/Val was held during the period 30 October to 1 November 2000.

Prior to the arrival of the ESTCP team members, TYAD personnel had selected several pieces of equipment and components typical of their production. This included GMS-250 shelters, 9000-BTU air conditioning units, 5T fuel trailer legs, a 3199 antenna pedestal base, and AN/TRC-170 antenna trailer components. All had been prepared for final topcoat application on reworked equipment. This included, as appropriate, media blasting to remove corrosion, pretreatment with wash primer in accordance with DOD-P-15328, and application of anticorrosive primer MIL-P-53030A, manufactured by Deft Chemical Coatings.

Aluminum and steel test panels were provided by each service for concurrent application of the WD CARC system. These panels were used for laboratory testing by each agency involved in the project. The panels provided by NSWCCD were used for various tests to characterize the coating. These tests include adhesion, specular gloss, color difference, viscosity and Taber abrasion. The panels provided by the Army were used for color, gloss, DS2 resistance, chemical agent resistance, and accelerated weathering. The Air Force panels were exposed to accelerated weathering for 10 months prior to being used in the ESTCP stripping study at TYAD. The steel panels provided by NSWCCD had a zinc phosphate pretreatment (TT-C-490 Type I) as prepared by Metal Samples, Inc., Munford, AL. The aluminum panels had a chromic acid anodized pretreatment (MIL-A-8625 Type I) as applied by All Steel Fabricators Co., Inc., Bala Cynwyd, PA. The steel panels provided by the Army also had the same type of zinc phosphate pretreatment, which was applied by the manufacturer, ACT Laboratories, Inc., Hillsdale, MI. The Air Force provided both steel and aluminum panels. The steel panels were pretreated with zinc phosphate by Metal Samples, Inc. and the aluminum panels were provided with a chromate conversion pretreatment per MIL-C-5541, Class 1A.

The MIL-P-53030 epoxy primer, manufactured by Deft, Inc., was applied to the test panels on 30 October 2000, in the small-parts area of Building 1-A. The ESTCP team members were present during the application. The panels were laid out horizontally on a table and the primer was applied with a Graco Delta 2000 High-Volume, Low-Pressure (HVLP) siphon-feed cup gun. No runs, sags or other defects were noted. The panels were allowed to dry overnight before they were moved to Building 9, where the WD CARC application was performed.

3.6.1.4 Stripping Demonstrations (All Three Sites)

Several DoD maintenance operations representing the Navy/Marine Corps, Air Force and Army were selected for Dem/Val of the WD CARC as the initial steps in the integration of the WD CARC system into DoD operations. Test panels were prepared with procedures and materials typical to those sites, and were coated with the WD CARC. Following conditioning of the test materials meant to simulate conditions the weapons systems might experience in real life, these test materials were then used for coatings removal studies at the selected sites using coatings removal processes typically used at those sites. Strippability data acquired at the selected sites were compared, when possible, to data developed in a previous study(4) in which feasibility of the WD CARC for DoD use was established.

All of the test sites included in this effort had some level of participation in the previous study. One site, Marine Corps Logistics Base (MCLB) Albany, Albany, Georgia that supported strippability testing in this Dem/Val did not participate in the application portion. Later visits to the various Dem/Val sites were made to develop production baseline strippability data and/or supplemental strippability data that were intended to make it more feasible to assess any potential impact on production strippability.

The additional strippability assessments conducted with MCLB Albany were intended to supplement other data developed during this Dem/Val effort. Test materials used at Albany were either surplus test materials from the earlier study, surplus Dem/Val test materials prepared at other sites, and other test materials prepared by Albany. In addition to data acquired through prepared test materials, limited production strip rate data were acquired.

Another overall complication was presented by variances seen in the removal processes themselves. Process parameters used for these efforts were not always the same as those observed in the previous study at the same sites. Since the intent was to Dem/Val strippability with the processes in use at the demonstration sites at the time of the Dem/Val, testing proceeded with those process parameters.

Dem/Val strippability assessment substrate materials included: 2024-T3 bare alloy, 0.125 x 5.5 x 12.0 inch (assessments of less aggressive depaint processes) and 1010 alloy steel, 0.125 x 5.5 x 12.0 inch (assessments of aggressive depaint processes)

Dem/Val material pretreatments and preparations included: (1) Aluminum surface preparations and chromate conversion treatment in accordance with (IAW) MIL-C-5541E (TYAD) and/or Air Force T.O. 1-1-8 (OO-ALC); (2) Aluminum surface preparations IAW DOD-P-15328D (Barstow MCLB and TYAD); and (3) Steel surface preparations by blasting to produce a 1.5 to 2.5 mil profile before zinc phosphate pretreatment IAW T-T-C 490. The above pretreatments were used for test materials for Barstow MCLB and TYAD, but OO-ALC only used white metal blasting of steel test materials, which is typical to operations at that site.

Dem/Val primers and topcoats were applied IAW the applicable military specifications. Coatings used for strippability assessments included: (1) Primer, MIL-P-53030A, Primer, MIL-P-53022B, Primer, MIL-PRF-23377H, Type 1, Class C; and (2) Topcoat, MIL-PRF-85285D (used by OO-ALC as an intermediate coating) and Topcoat, MIL-PRF-64159, Type II, Green 383, Color # 34094 (WD CARC).

3.6.2 Period of Operation

Table 1 -- Demonstration Dates

Site	Application Demonstration	Stripping Demonstration
Maintenance Center Barstow	9 – 11 May 2000	16 – 19 July 2001
Ogden Air Logistics Center	28 – 30 August 2000	22 – 24 October 2001
Tobyhanna Army Depot	30 October – 1 November 2000	5 – 6 November 2001

3.6.3 Amount/Treatment Rate of Material to be Treated
The application of the WD CARC was accomplished for selected defense equipment (typically 3-5 units at each demonstration site) and a designated number of test panels to validate the performance of the coating and the stripping processes and to obtain the metrics necessary to conduct performance and cost analysis.

3.6.4 Operating Parameters for the Technology
As noted above, the only process change during an application demonstration was the substitution of the WD CARC for the topcoat normally used. At all three demonstration sites, the normal contingent of painters worked in the application booth and wore the normal PPE. Records were kept of the hardware coated, the spray application equipment used, the surface preparation applied to the substrate, the paint used, the environmental conditions at the time of application, and the timing of the events. The NSWCCD developed a Marine Corps Experimental Coating Data Sheet for this purpose (see Appendix B). In addition, immediately after finishing the paint application process, each painter completed a WD CARC Field Trial Application Survey (Appendix B), also developed by NSWCCD. The survey contained questions about the mixing and spraying characteristics of the WD CARC as compared to the coating normally used. It also asked for an overall general opinion of the WD CARC as compared to the solvent-based CARC. Similar record keeping was performed during the stripping demonstrations, which occurred approximately a year after the application demos (see Table 1 above).

3.6.5 Experimental Design
The normal schedule for an application demonstration was to apply the pretreatment and primer to the equipment and test panels on the day before the application of the WD CARC, either in the presence of the ESTCP team or prior to their arrival. The topcoat application was performed the following day, and an additional day was reserved for examination of the coated panels and equipment, preliminary measurements of film properties on the hardware such as dry film thickness and gloss, application of topcoat to remaining equipment and/or outbriefings. Each stripping demonstration was set up for a single day with one backup for examination of panels in chemical stripper baths (if applicable) and outbriefings.

3.6.5.1 Application at Maintenance Center Barstow
The mixing and application of WD CARC, manufactured by Sherwin Williams (see Appendix C for the Technical Data Sheet), on the panels and four vehicles began on 10 May 2000. The only color of WD CARC available at the time of the demonstration was color #34094 of FED-STD 595B, also known as

Green 383. Typically, the Green 383 color is applied to military equipment as the base coat, with the camouflage patterns in Brown 383 and Black applied over the base coat. Initially, two batches of paint were mixed. The component A was placed on a shaker for five minutes prior to the mixing. In each five-gallon pail, two gallons of component A were mixed with one gallon of component B using a squirrel mixer for approximately 3 minutes. Three quarts of water (0.75 parts) were then added to batch 1, for a mix ratio of 2:1:0.75, and two quarts of water to batch 2, for a mix ratio of 2:1:0.5. Each batch was then mixed for an additional three minutes. An additional quart of water was then added to the second batch making the mix ratio the same as the first.

Viscosity of the WD CARC, using Zahn #3 (Signature series) cup, was measured in order to quantify the rheological effects of water dilution with respect to paint application performance (i.e., atomization, leveling and sag resistance tendencies). Viscosity was also used to quantify the working life of the paint in the liquid state. As shown in Table 2, the viscosity of all six batches of WD CARC material used during the demonstration varied from about 14 to 16 seconds for the two batches with a ratio of 2:1:0.75 to about 20 to 26 seconds for those with a 2:1:0.5 ratio.

The WD CARC was first applied to the test panels (Figures 1 and 2) on 10 May 2000. After the panels were coated with WD CARC, a large quantity of “fish eyes” was discovered on the painted surface. The painters were requested to flush their paint lines with a water/alcohol mixture to ensure their lines were not the source of contamination. However, fish eyes still occurred when the paint was reapplied. After discussion with the painters, it was discovered that the guns, Binks HVLP Mach 1, had been soaked in oil to prevent seizing of the parts. The ESTCP team requested that new guns—same model, make and type—be used for the remainder of the demo. When utilizing the new equipment, the coating was applied without defects, including fish eyes. The average wet film thickness (WFT) applied was approximately 5 mils. It was noted that after 24 hours of cure time, the coating film on the panels appeared continuous and even, with no obvious defects.

The vehicles were then coated using the new equipment on 10 May 2000. The first two batches of paint mixed (2:1:0.75 mix ratio) were applied to both HMMWVs (Figures 3, 4 and 5). Using the new equipment, the application on all vehicles was without defects. Data was gathered on the process using the Experimental Coating Data Sheet, and one example for vehicle 544220 is shown in Appendix G. Note the detailed description of the application and the environmental conditions. Three runs or sags were noticed on each vehicle, which is acceptable considering this was the painters’ first use of the material. On the same day, the third and fourth batches of paint were mixed. The mixing process was the same as used on the first batch, except only two quarts (0.5 parts) of water were added (2:1:0.5 mix ratio). This water concentration adjustment was based on the expertise of the painters who determined that the viscosity was slightly lower than optimal for their application techniques and process goals. This paint was used for application on the 5-ton truck (Figure 6). Eight runs or sags were noted on the vehicle, which, as with the HMMWVs, is acceptable. The increase in the absolute number of sags is tempered by the size of the vehicle and thus the amount of material applied to the truck.

The last vehicle to be coated with the WD CARC was the LAV-AT. The MCLB was performing final touch-ups on the primer in the morning of 11 May 2000. The supply of the routinely used primer MIL-C-53030 had been depleted. Kar Products spray primer, a phenolic linseed alkyd resin enamel was

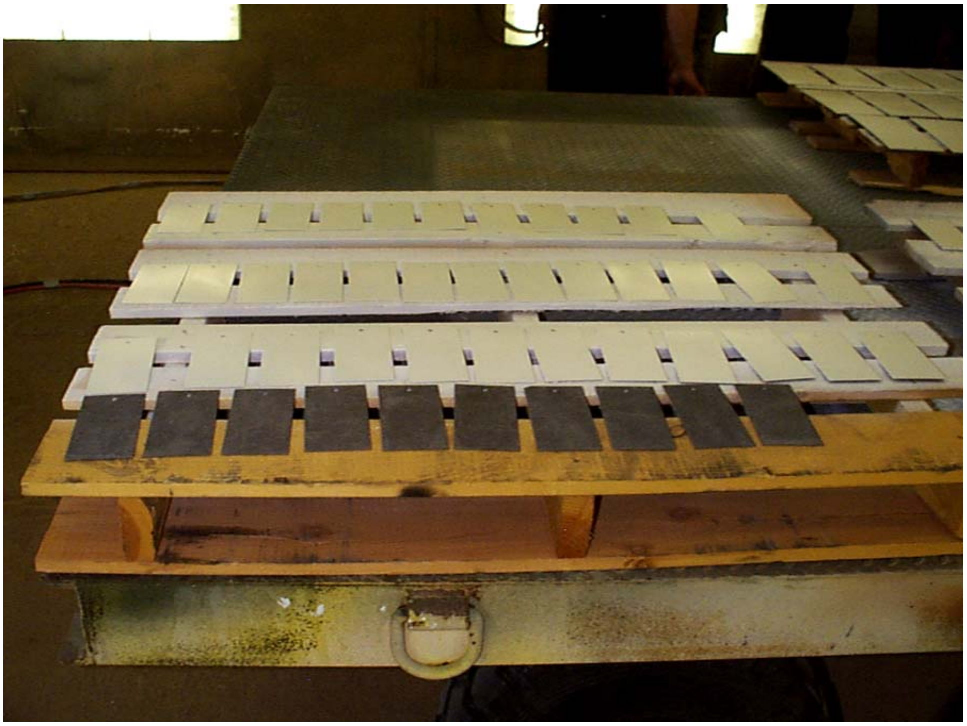


Figure 1 -- Test Panels Before Application of WD CARC at MCB

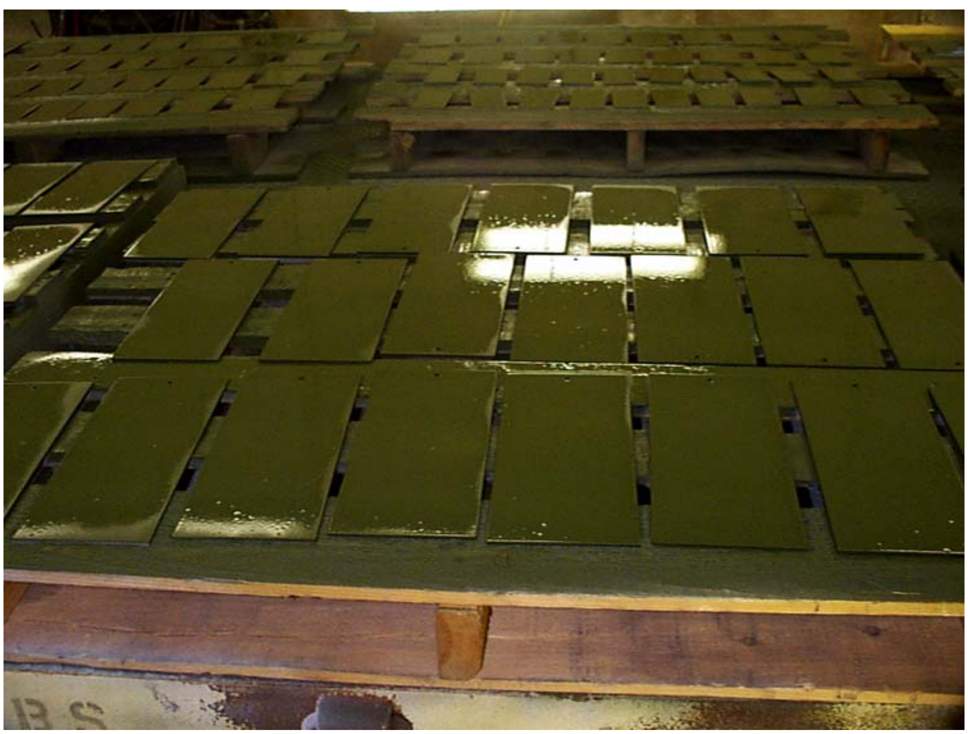


Figure 2 -- Test Panels with WD CARC Applied at MCB

Figure 3 -- Vehicle 544264 after WD CARC Application at MCB

Figure 4 -- Vehicle 544264 (Side View) with Green WD CARC, Stenciled for Pattern at MCB

Figure 5 -- Vehicle 544264 (Front View) with Green WD CARC, Stenciled for Pattern at MCB

Figure 6 -- 5-Ton Truck after WD CARC Application at MCB

Figure 7 -- LAV after WD CARC Application at MCB

substituted. Upon completion of the touch up, two batches of the WD CARC were mixed, with mix ratio 2:1:0.5, for successful application to the LAV (Figure 7). It was determined that approximately 2.5 gallons of paint were used for each HMMWV. Approximately 6 gallons of paint was used to coat the 5-ton truck. The LAV application also consumed approximately 6 gallons of paint.

Atomization, film formation and leveling were satisfactory at either water dilution concentration. However, at the lower water dilution level, which equates to a higher volume solids level (40% for 0.5 parts water versus 37% for 0.75 parts water), superior film buildup was realized, as discussed later in this section of this report. While the tendency of a paint to sag and/or run can be influenced by the physical constraints of the parts being painted (i.e. recessed areas, sharp edges, raised rivets, etc.) as well as the skill of the applicator (i.e. technique, ability to make equipment adjustments, ability to minimize duration of learning curve, etc), this tendency appeared to be minimized at 0.5 parts water based on the overall appearance and minimal runs/sags for the LAV-AT, as shown in Table 2.

Following application of the WD CARC on the four vehicles and test panels, the three painters completed a WD CARC Field Trial Application Survey developed by NSWCCD. Included in this survey were questions concerning the mixing and spraying characteristics of the WD CARC, as compared to the solvent based CARC and the Water-borne Camouflage Coating (WBCC per MIL-C-29475, an interim coating authorized for use prior to implementation of MIL-DTL-64159). In addition, a general opinion of the WD CARC as compared to the solvent-based CARC and the WBCC was also requested. One of the completed surveys from MCB is provided in Appendix C.

Table 2 -- Mix Ratio, Viscosity and Application Properties

Batch #	Mix Ratio ($A:B:H_2O$)	Admix Efflux* Time (sec)	1.5 hr Efflux* Time (sec)	3.5 hr Efflux* Time (sec)	5.5 hr Efflux* Time (sec)	Vehicle Painted (TAM #)**	Time to coat (min)	Amount used (gal)	No. of Runs/Sags
1	2:1:0.75	15.7	14	14	16.4	HMMWV (544220)	14	2.5	3
2	2:1:0.75	14.1	na	na	na	HMMWV (544264)	12	2.5	3
3	2:1:0.5	19.9	na	na	na	5-ton truck (540510)	49	6	8
4	2:1:0.5	22	na	na	na	5-ton truck (540510)	na	na	
5	2:1:0.5	24.9	na	na	na	LAV-AT (521809)	50	6	1
6	2:1:0.5	24.5	na	na	na	LAV-AT (521809)	na	na	

* Zahn #3 cup used
** TAM = Table of Authorized Material

Based on these surveys, response choices were given a rating from 1 to 5. The rating of 1 corresponds with the much more difficult, much slower, and much worse response choices. On the other extreme, the rating of 5 corresponds to the much easier, much quicker, and much better response choices. Based on the numerical ratings, the mixing of the WD CARC with regard to complexity, ease, and time required was about the same (3 rating) compared to the currently used paints. The spray properties with regard to spray ease, spray quality, application rate, and applied film quality were considered better (4 rating) compared to the currently used paints. Overall, the WD CARC was considered better (4 rating) by the depot applicators than both the solvent-based CARC and the WBCC.

3.6.5.2 Application at Ogden Air Logistics Center

The mixing and application of WD CARC, manufactured by Sherwin Williams (see Appendix C for the technical data sheet), to the panels and four MEP units began on 29 August 2000. The only color of WD CARC available at the time of the demonstration was color #34094 of FED-STD 595B, also known as Green 383. Initially, one batch of paint, shown in Figure 8, was mixed. The component A was placed on a shaker for five minutes prior to the mixing. Into each five-gallon pail, two gallons of component A were mixed with one gallon of component B using a squirrel mixer for approximately 3 minutes. Four quarts of water (1 part) were then added to batch 1, for a mix ratio of 2:1:1. The batch was then mixed for an additional three minutes. The viscosity of the WD CARC, using Zahn #3 (Signature series) cup, was measured in order to quantify the rheological effects of water dilution with respect to paint application performance (i.e., atomization, leveling and sag resistance tendencies). Viscosity was also used to quantify the working life of the paint in the liquid state. The viscosity of all batches of WD CARC material used during the demonstration varied from about 14 to 16 seconds for the two batches with a ratio of 2:1:1 to about 20 to 26 seconds for those with a 2:1:0.5 ratio.

Figure 8 -- Preparation of WD CARC at Ogden ALC

The paint was poured into a pressure pot that would supply WD CARC to Sata Jet HVLP paint guns. Pressure pots and spray equipment used are shown in Figure 9. Three batches were required to cover all the units and test panels on the first day of the demonstration.

The WD CARC was first applied to the test panels as shown in Figure 10. Upon successful application of the WD CARC to the test panels, it was decided to apply the WD CARC to three MEP 007B generators and a MEP 005A generator. Application went smoothly. The four MEP units were coated with the low VOC WD CARC. Figure 11 shows WD CARC application to the MEP 005A generator. Figure 12 shows WD CARC application to the MEP 007B generator. The painter and facility personnel remarked about how much more smoothly the WD CARC went on compared to the standard CARC. They felt it covered more surface area than the standard CARC. Figures 13 and 14 show the completed generators. Dry film thickness measurements (DFTM) were taken at various points on the MEP units. The dry film thickness (DFT) of the WD CARC topcoats for the units ranged between 1 and 4.2 mils with an average of 2.25 mils for the MEP 007B units. DFTM for the MEP 005A ranged between 1.2 and 4.6 mils with an average of 2.73 mils. Table 3 lists the DFTMs for the Dem/Val units. A second set of test panels from NSWCCD, which had been lost in shipping, was located and painted on the wall of the large vehicle paint booth in Building 847 to evaluate the sag resistance of the WD CARC. The WD CARC did not show the same type of sagging that had been seen in the SERDP application testing and in the Barstow Dem/Val.

Figure 9 -- Pressure Pot for WD CARC Application at Ogden ALC

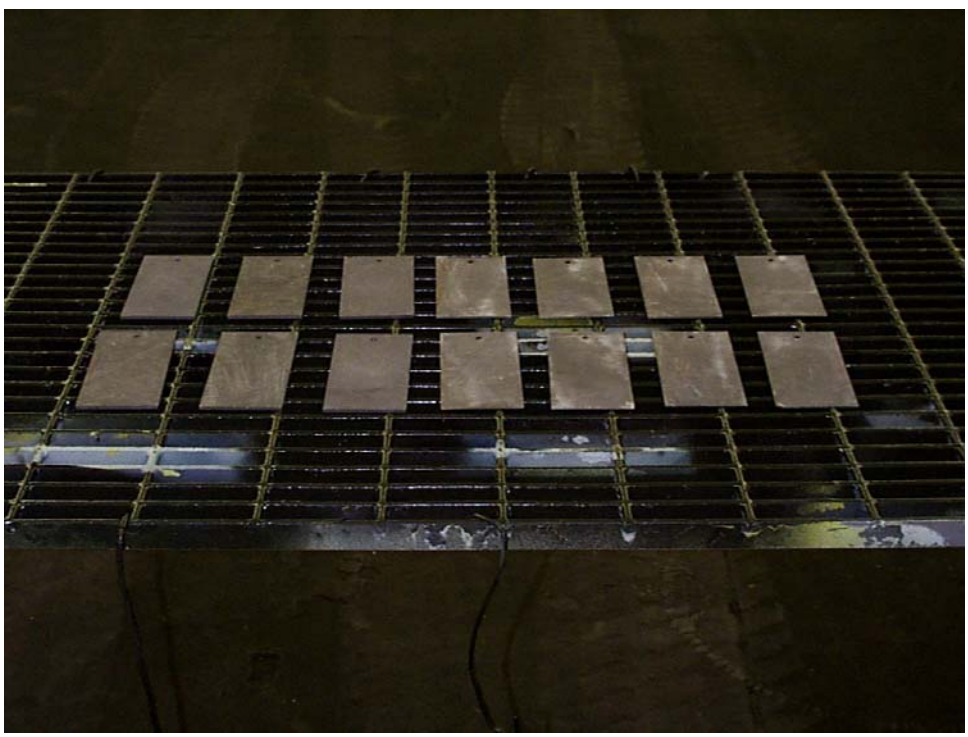


Figure 10 -- Test Panels Before Application of WD CARC at Ogden ALC

Figure 11 -- Application of WD CARC to MEP-005A Generator at Ogden ALC

Figure 12 -- Application of WD CARC to MEP-007B Generator at Ogden ALC

Figure 13 -- MEP-007B Generator after Application of WD CARC at Ogden ALC

Figure 14 -- MEP-005A Generator after Application of WD CARC at Ogden ALC

Table 3 -- Dry Film Thickness Measurements for Ogden ALC Generator Sets

MEP-007B #1				MEP-007B #2				MEP-007B #3				MEP-005A			
Locations	w/Precoat	w/Topcoat	Δ DFTM	Locations	w/Precoat	w/Topcoat	Δ DFTM	Locations	w/Precoat	w/Topcoat	Δ DFTM	Locations	w/Precoat	w/Topcoat	Δ DFTM
F1	3.86	5.90	2.04	F1	3.70	5.80	2.10	F1	3.92	6.30	2.38	F1	3.90	7.40	3.50
F2	3.47	5.50	2.03	F2	4.80	6.70	1.90	F2	3.76	6.20	2.44	F2	2.63	6.50	3.87
F3	3.48	5.20	1.72	F3	4.70	5.90	1.20	F3	3.22	5.60	2.38	F3	3.33	5.70	2.37
F4	3.99	5.50	1.51	F4	3.98	6.10	2.12	F4	3.25	5.70	2.45	B1	4.70	6.70	2.00
F5	4.10	5.60	1.50	F5	4.20	6.60	2.40	F5	3.70	6.60	2.90	B2	2.29	6.30	4.01
F6	3.74	5.40	1.66	F6	5.00	6.80	1.80	F6	4.10	5.10	1.00	B3	3.68	6.20	2.52
F7	3.33	5.00	1.67	F7	3.87	6.20	2.33	F7	3.28	5.10	1.82	S1	5.90	7.20	1.30
F8	3.94	5.70	1.76	F8	4.60	5.70	1.10	F8	2.88	5.10	2.22	S2	5.60	7.60	2.00
B1	4.60	6.10	1.50	B1	4.10	6.10	2.00	B1	3.70	6.30	2.60	S3	4.90	9.50	4.60
B2	4.10	6.00	1.90	B2	3.60	5.50	1.90	B2	4.10	6.40	2.30	T1	4.60	7.30	2.70
B3	3.12	5.60	2.48	B3	4.10	5.90	1.80	B3	3.49	6.30	2.81	T2	3.67	7.70	4.03
B4	3.16	5.40	2.24	B4	3.90	6.10	2.20	B4	3.57	5.70	2.13	T3	4.10	6.70	2.60
B5	3.18	6.70	3.52	B5	3.94	6.60	2.66	B5	3.66	4.90	1.24	T4	5.80	8.50	2.70
B6	3.18	5.70	2.52	B6	4.90	6.80	1.90	B6	3.83	5.10	1.27	T5	4.90	7.90	3.00
B7	4.00	5.90	1.90	B7	3.90	6.20	2.30	B7	3.42	5.10	1.68	T6	4.70	7.10	2.40
B8	3.50	5.60	2.10	B8	3.11	5.70	2.59	B8	3.18	5.10	1.92	T7	5.00	7.40	2.40
T1	3.50	5.80	2.30	T1	4.30	7.90	3.60	T1	3.60	6.20	2.60	T8	5.90	7.10	1.20
T2	3.38	5.60	2.22	T2	4.50	7.00	2.50	T2	3.90	5.80	1.90	T9	4.80	6.70	1.90
T3	2.94	4.90	1.96	T3	4.90	8.10	3.20	T3	3.64	6.70	3.06	Avg.	4.47	7.19	2.73
T4	3.06	4.80	1.74	T4	5.10	8.10	3.00	T4	4.70	7.00	2.30			Std Dev =	0.95
T5	3.34	6.60	3.26	T5	4.30	7.20	2.90	T5	2.98	4.80	1.82				
T6	3.21	6.40	3.19	T6	4.20	7.70	3.50	T6	3.20	6.10	2.90				
T7	3.22	5.70	2.48	T7	4.90	6.30	1.40	T7	2.80	7.00	4.20				
T8	2.96	5.80	2.84	T8	4.30	7.00	2.70	T8	4.10	6.90	2.80				
Avg.	3.52	5.68	2.17	Avg.	4.29	6.58	2.30	Avg.	3.58	5.88	2.30				
		Std Dev =	0.57			Std Dev =	0.65			Std Dev =	0.68				

Subsequent to application of the WD CARC on the four MEP units and test panels, the painter completed a WD CARC Field Trial Application Survey developed by NSWCCD. Included in this survey were questions concerning the mixing and spraying characteristics of the WD CARC, as compared to the solvent based CARC. In addition, a general opinion of the WD CARC as compared to the solvent-based CARC was also requested. One of the completed surveys from Ogden ALC is provided in Appendix C.

Based on these surveys, response choices were given a rating from 1 to 5. The rating of 1 corresponds with the much more difficult, much slower, and much worse response choices. On the other extreme, the rating of 5 corresponds to the much easier, much quicker, and much better response choices. Based on the numerical ratings, the mixing of the WD CARC with regard to complexity, ease, and time required was worse (1 rating) compared to the currently used paints.

This was due to the extra mixing step in the mixing process. The spray properties with regard to spray ease, spray quality, application rate, and applied film quality were considered better (4 rating) compared to the currently used paints. Overall, the WD CARC was considered better (4 rating) by the depot applicators than both the solvent-based CARC and the WBCC. This was similar to the painters' experience with the WD CARC at Barstow MCLB.

3.6.5.3 Application at Tobyhanna Army Depot

The mixing and application of the WD CARC topcoat began at about 0900 on 31 October 2000. It was manufactured by the Sherwin-Williams Company. Component A, the pigmented polyol base, was product number F93G502, S-W internal sales #6016-24133, lot #0X2090, manufactured in Wichita, KS in Jul 2000. The color was Green 383, matching color number 34094 of FED-STD-595. The isocyanate catalyst was product #V93V502, Sherwin-Williams internal sales #6016-18077, lot #0X2360, manufactured in Wichita, KS in Aug 2000. The mixing ratio of the coating was two parts by volume of Component A to one part by volume of Component B. ARL and Sherwin-Williams recommended reduction of this admix with 0.75 volumes of deionized water for spray application. Two gallons of Component A were mechanically mixed on a paint shaker for approximately 10 minutes and poured into a mixing container. One gallon of component B was added, and the admix was stirred for 3 minutes using a hydraulically powered squirrel cage mixer. Then 0.75 gallon of deionized water was added to the paint and mixed for 3 minutes using a hydraulically powered squirrel mixer. At the end of the mixing procedure, the viscosity was checked with a #3 Zahn cup for the proper application viscosity, between 13 and 18 seconds, and the paint was transferred to the pressure pot for the application process (Figure 15). The environmental conditions were noted (temperature and relative humidity) prior to application of the paint.

Before the TYAD painters began to paint the selected equipment, they practiced on various substrates in the spray booth to familiarize themselves with WD CARC application properties. In all cases, Graco Delta 2000 High-Volume, Low-Pressure (HVLP) siphon-feed cup guns were used. They then painted the primed test panels (Figure 16) for subsequent performance testing. As noted in 3.6.1.3 above, the equipment had been appropriately prepared for topcoat application.

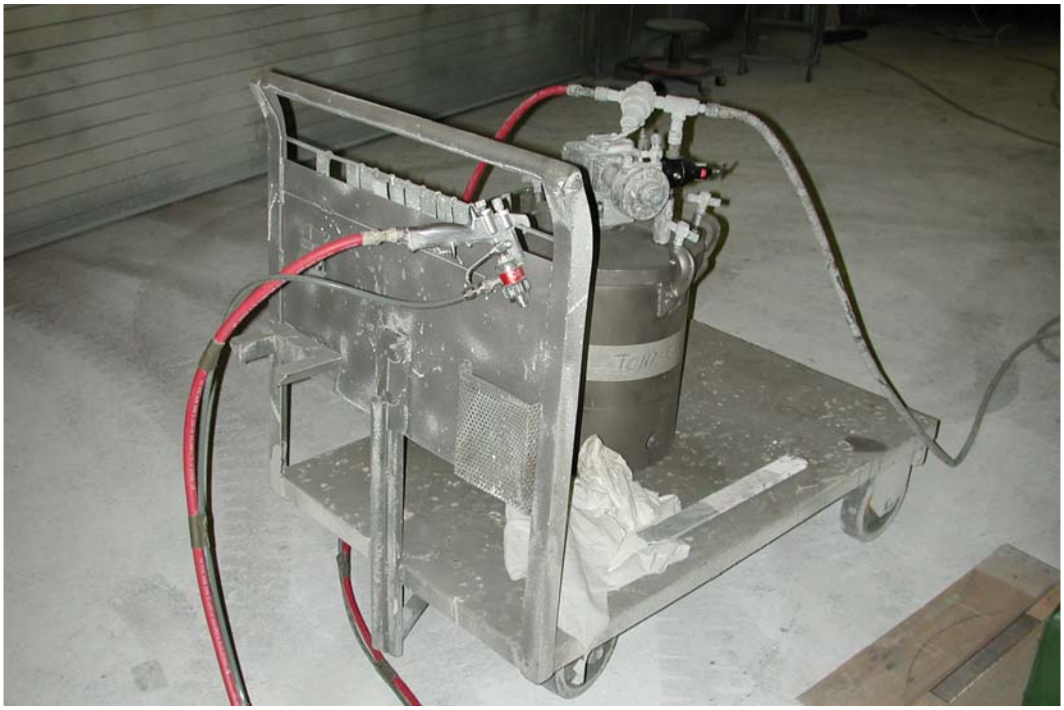


Figure 15 -- Application Pressure Pot, Spray Gun and Associated Lines at Tobyhanna AD

Figure 16 -- Test Panels before Application of WD CARC at Tobyhanna AD

Between the times 1000 and 1500, the following components were painted (see Figures 17 – 24):

3 - Small AC Units (9000 BTU) each with dimensions of about 26"L x 26"W x 16"H
1 - Large Antenna Pedestal Base (#3199) [pyramidal-frame-shaped, each leg ~ 4-5']
1 - Small Tri-Pod (each leg ~ 3' long)
4 - AN/TRC-170 Antenna Trailer Components (~ 5'L, ~ 1' Diameter)
4 - Legs to a 5 Ton Fuel Trailer (~ 3' L, 12' Base, 6" Diameter shaft)
2 – Gichner Mobile Systems GMS-250 Shelter

Although an occasional sag was observed, application went well. In general, atomization, leveling and film formation were satisfactory. While the tendency of a paint to sag and/or run depends on the technique of the applicator in making adjustments to his equipment and on the design of the items being painted (i.e., recessed areas, sharp edges, raised rivets, etc.) the painters learned quickly how much wet coating to apply to provide the needed dry film thickness of about 2 mils without generating sags. At the end of the shift, about 1 gal was unused. Since 3.75 gallons were prepared at the start of the day, 2.75 gallons were consumed in painting the various components and test panels.

On 1 November 2000 at about 0845, another kit of the Sherwin-Williams WD CARC was prepared as previously described. The viscosity was checked with a #3 Zahn cup for proper application viscosity. The equipment painted was one Gichner Mobile Systems GMS-280 shelter with approximate dimensions of 12′ L x 6′ W x 7′ H. As with the day before, the painters indicated that the coating applied well, and while a few sags were observed, upon most of the solvent flashing off, the film was uniform, with few defects.

Upon completion of the WD CARC application each day, the painters were asked to complete a WD CARC Field Trial Application Survey developed by NSWCCD. The survey contained questions about the mixing and spraying characteristics of the WD CARC as compared to the solvent-based MIL-C-53039 normally used at TYAD. In addition, it asked for an overall general opinion of the WD CARC as compared to the solvent-based CARC. One of the completed surveys from Tobyhanna AD is provided in Appendix C. By assigning numbers to the qualitative assessments, it became possible to generate average ratings. The lowest number (1) reflected the much more difficult, much slower, and much worse rating, and the highest number (5) reflected the much easier, much quicker, and much better rating. The overall average opinion for the four painters indicated that the mixing of the WD CARC with regard to complexity, ease and time required was slightly worse (rating ≈ 2) than MIL-C-53039, the spray properties with regard to spray ease, spray quality, application rate, and applied film quality were better (rating ≈ 4), and overall, the WD CARC was considered better (rating ≈ 4). The mixing preference for MIL-C-53039 is likely due to the fact that it is a single component product not requiring the premixing of two components, nor reduction for spray application in most cases. Information about the WD CARC, including the Technical Data Sheet and Material Safety Data Sheet (MSDS) is contained in Appendix C.

Figure 17 – 9000-BTU AC Unit before Application of WD CARC at Tobyhanna AD

Figure 18 -- GMS-250 Shelter before Application of WD CARC at Tobyhanna AD

Figure 19 -- Small Tripod Legs before Application of WD CARC at Tobyhanna AD

Figure 20 -- GMS-250 during Application of WD CARC at Tobyhanna AD

Figure 21 -- Antenna Pedestal Base during Application of WD CARC at Tobyhanna AD

Figure 22 -- 9000 BTU AC Unit after Application of WD CARC at Tobyhanna AD

Figure 23 -- GMS-250 after Application of WD CARC at Tobyhanna AD

Figure 24 -- GMS-250 after Application of WD CARC at Tobyhanna AD

3.6.5.4 Stripping Demonstrations (All Three Sites)

Materials conditioning processes were applied to test materials to either simulate natural aging, or accelerated coatings curing. However, all test materials were given a minimum of 7 days cure at room temperature (75 ± 5º F) prior to any other conditioning. Accelerated coatings curing/aging by oven has been used by the Air Force for several years for conditioning strippability test materials, and it is also similar to practices sometimes followed in maintenance operations to accelerate production throughput for painted materials. The oven aging used for this project consisted of exposure for 96 hours at 210° F.

The process used to simulate natural aging is a method of accelerated outdoor exposure. This method is based on maximum daily exposure to the sun, which is accomplished by mounting test materials in a system that tracks the sun throughout the daylight hours. The exposure is also accelerated by focusing sunlight onto the specimen with optical devices. The test panels conditioned by this procedure were somewhat constrained in size by the conditioning apparatus and were the maximum size (5 ½ in x 12 in) that could be placed into the exposure rack.

Exposure was conducted IAW ASTM D 4141 Procedure C. This procedure requires a Fresnel reflector exposure rack and a test cycle that included 3-minute deionized water sprays every 15 minutes during the night hours. Test materials were given exposure periods of 5 or 10 months with this process. The exposure site was Buckeye, Arizona, and the exposure periods produce coatings conditioning approximated as 2 and 4 years of Arizona desert sunlight exposure. WD CARC topcoat color measurements were made during the conditioning periods for all test panels. These color data are typically used to characterize any changes of color of test materials over some period of time and exposure conditions.

A very small quantity of the test materials used in this study received no additional conditioning other than room temperature. Several panels had been prepared at Albany as part of a demonstration of special coatings application equipment. These materials were comprised of sets of panels coated with one of two different formulations of WD CARC and were used to assess strippability characteristic only for the different formulations.

The dry media blast (DMB) strippability assessments were conducted with various depaint processes in association with the following sites:

Maintenance Site	DMB Media/Processes
MCLB Barstow	Type V Plastic Media, Steel Grit and Garnet Media
OO-ALC	Quick Strip™ Media and Type V Media
TYAD	Zirconia-Alumina Media and Stainless Steel Shot Media
MCLB Albany	Garnet Media, Type II Plastic Media and Type III Plastic Media

All blast depaint processes were assessed in characteristic production modes, i.e., blast processes were applied manually and with process parameters typical for that specific depaint operation. Nozzle standoff distances and blast impingement angles are approximate and varied somewhat through operator response to stripping effectiveness at the time of the assessment.

The process parameters for each of blast processes that were used for the strippability assessments conducted in this study are given below. As an intrinsic part of the intent of the Dem/Val effort, production Dry Media Blasting (DMB) processes used for all assessments were at whatever parameters each site opted to use at that time. As may be seen below, and has been annotated below, these processes sometimes varied somewhat between visits to a given site. In many instances the blast technicians have the latitude to alter the process parameters to better suit the substrate, and/or production requirements (e.g., faster coatings removal).

The DMB processes and parameters associated with the participating sites are as follows:

Barstow MCLB

Type V - Blast Pressure = 90 psi
Standoff Distance of 8 - 12 inches
Blast Impingement Angle of 60° - 80°
Media Size = 20/30 mesh
Nozzle – 1/4 inch Diameter (#4) Standard Venturi
Note: Parameters used for Dem/Val data acquisition in a glovebox blast cabinet

Type V - Blast Pressure = 100 psi
Standoff Distance of 5 - 6 inches
Blast Impingement Angle of 80° - 90°
Media Size = 20/30 mesh
Nozzle – 1/4 inch Diameter (#4) Standard Venturi
Note: Parameters used for production baseline data acquisition in a glovebox blast cabinet

Type V - Blast Pressure = 75 psi
Standoff Distance of 12 - 18 inches
Blast Impingement Angle of 80° - 90°
Media Size = 20/30 mesh
Nozzle – 1/2 inch Diameter Standard Venturi
Note: Parameters used for production baseline data acquisition in a large blast booth

Steel Grit - Blast Pressure = 90 psi
Standoff Distance of 6 - 8 inches
Blast Impingement Angle of 80° - 90°
Media Size = 50 grit
Nozzle – 3/8 inch Diameter (#6) Standard Venturi
Note: Parameters used for Dem/Val data acquisition

Steel Grit - Blast Pressure = 80 psi

Standoff Distance of 3 - 4 inches
Blast Impingement Angle of 80° - 90°
Media Size = 80 grit
Nozzle – 3/8 inch Diameter (#6) Standard Venturi
Note: Parameters used for production baseline data acquisition

Garnet Abrasive - Blast Pressure = 50 psi
Standoff Distance of 12 - 16 inches
Blast Impingement Angle of 60° - 80°
Media Size = 30/60 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for Dem/Val data acquisition

Garnet Abrasive - Blast Pressure = 100 psi
Standoff Distance of 18 - 30 inches
Blast Impingement Angle of 60° - 90°
Media Size = 30/60 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for production baseline data acquisition

OO-ALC

Type V - Blast Pressure = 40 psi
Standoff Distance of 6 - 8 inches
Blast Impingement Angle of 60° - 80°
Media Size = 20/30 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for Dem/Val data acquisition only

Quick Strip™ - Blast Pressure = 45 psi
Standoff Distance of 12 - 18 inches
Blast Impingement Angle of 60° - 80°
Media Size = 20/30 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for Dem/Val data acquisition

Quick Strip™ - Blast Pressure = 50 psi
Standoff Distance of 24 - 36 inches
Blast Impingement Angle of 60° - 80°
Media Size = 10/20 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for production baseline data acquisition

Quick Strip™ - Blast Pressure = 60 and 75 psi
Standoff Distance of 8 - 12 inches
Blast Impingement Angle of 60° - 80°
Media Size = 10/20 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for production baseline data acquisition

Quick Strip™ is described by the media manufacturer, U.S. Technology Corporation, as an amino thermoset plastic, combined with glass oxide particles.

TYAD

Zirconia-Alumina - Blast Pressure = 80 psi
Standoff Distance of 8 - 12 inches
Blast Impingement Angle of approximately 60°
Media Size = Fine
Nozzle - 3/16 inch Diameter Standard Venturi
Note: Parameters used for Dem/Val data acquisition

Zirconia-Alumina - Blast Pressure = 80 psi
Standoff Distance of 4 - 6 inches
Blast Impingement Angle of 60° - 80°
Media Size = Fine
Nozzle - 3/16 inch Diameter Standard Venturi
Note: Parameters used for production baseline data acquisition

Stainless Steel Shot - Blast Pressure = 100 psi
Standoff Distance of 18 - 24 inches
Blast Impingement Angle of 60° - 80°
Grit Size = 50
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for Dem/Val and production baseline data acquisition

Stainless Steel Shot - Blast Pressure = 60 psi
Standoff Distance of 18 - 24 inches
Blast Impingement Angle of 60° - 80°
Grit Size = 50
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for production baseline data acquisition

Albany MCLB

Type II - Blast Pressure = 100 psi
Standoff Distance of 8 - 12 inches

Blast Impingement Angle of 60° - 80°
Media Size = 16/20 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for supplemental data acquisition

Type III - Blast Pressure = 90 psi
Standoff Distance of 8 - 12 inches
Blast Impingement Angle of 60° - 80°
Media Size = 16/20 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for supplemental and production baseline data acquisition

Garnet Abrasive - Blast Pressure = 100 psi
Standoff Distance of 18 - 24 inches
Blast Impingement Angle of 60° - 80°
Media Size = 30/60 mesh
Nozzle - 1/2 inch Diameter Standard Venturi
Note: Parameters used for production baseline data acquisition

Strippability assessments were made on the basis of coating system strip rates which were calculated through measuring the area stripped completely, for the elapsed time for the stripping. Irregular stripped areas or areas of a test panel that did not comprise the entire panel had several measurements made in a given direction, and the average of these dimensions was used to calculate area. Elapsed time was measured with a stopwatch and recorded to the nearest 0.1 second. Strip rates are then given as the area stripped (ft^2) per elapsed time (min), or ft^2/min.

Whenever possible, dry film thickness measurements (DFTM) were made on production parts to help characterize the coating system to be stripped. However, it was not possible to accurately determine the coating system that was stripped in the production operations. The identification of the parts stripped during this effort are usually descriptive, and do not necessarily represent the correct nomenclature for these parts. All prepared test materials had DFTMs for each panel. In this instance, these measurements represented a measure of quality control. Sets of panels for Dem/Val strippability tests could be grouped in a manner that did not weight a given set by overall coating thickness.

The original scope of the overall ESTCP Dem/Val study did not include strippability assessments for chemical stripping processes. In the course of coordinating efforts with the Dem/Val participants, it became apparent that two of the three sites had an interest in some minimal assessment of a chemical process used at their site.

Small sets of test materials were compiled to satisfy these requests of Barstow MCLB and TYAD. The data these sets provided were intended to be the basis of a feasibility assessment rather than comparing processes to determine possible production impact.

Both chemical processes assessed in this study are immersion bath, maintained at an elevated temperature. The Barstow process is actually intended for corrosion removal on ferrous materials, but has been known to remove the coatings system when the system is not in good condition. The process used by TYAD is a coatings removal process used for small parts that are difficult to successfully strip with other processes.

The specific parameters for each process are as follows:

Barstow MCLB

Chemical Bath - Sodium Hydroxide/Sodium Gluconate at 70:30 by volume ratio
Temperature - 200° F
Dwell - 12 to 24 hours nominal

TYAD

Chemical Bath - Turco Product No. 6776 (benzyl-alcohol base)
Temperature - 120° F
Dwell - 24 hours nominal.

3.6.6 Product Testing

The performance of the WD CARC was evaluated with a variety of methods, including those appropriate to the application process, to the performance of coated test panels prepared during the application process, and to the stripping process as performed on aged coated test panels. The Common Test Descriptions were the descriptions of the test procedures performed on the test panels and were used to asses the performance of the WD CARC applied during the application demonstration. The WD CARC Field Trial Application Survey was used to gather information on what the painters thought about the preparation, application and cleanup of the WD CARC when compared to the coating they normally used. The Field Trial Panel Matrix was the list of test panels coated during the application demonstration that were provided by the team members for later performance testing. A US Marine Corps Experimental Coating Data Sheet was used to track the equipment painted, the surface preparation used, the coating system applied and the environmental conditions at the time of application. All four may be found in Appendix B.

3.6.6.1 Barstow Test Results

Gloss

Specular gloss characteristics were quantified using a portable HunterLab ProGloss-3 at 20^o, 60^o and 85^o orientations. Specular gloss measurements orient the light source and the detection optics on opposite sides of the sample at equal angles of incidence. In general, as the gloss of a topcoat decreases, the probability of visual detection correspondingly decreases. Thus, superior survivability properties are obtained with gloss values that are minimized. Typically, minimized gloss values are obtained by the scattering of light by pigments that protrude through the upper surface of a topcoat [5], although gloss can also be manipulated via alteration of the polymer reactivity of distinct regions of a polymeric blend.

On 11 May 2000, the day following application, gloss data was collected for the two HMMWVs and the 5-ton truck. The data is tabulated in Tables 4, 5, and 6. These tables clearly show that 60^o and 85^o gloss values averaged for each vehicle were all very low and less than the maximum allowable per the MIL-C-46168 specification and the proposed WD CARC specification, which are 1.0 maximum and 3.5 maximum for 60^o and 85^o gloss, respectively.

As shown in Tables 4 and 6, there were two data points (1.5, 1.1) that were just slightly greater than the specification requirement for 60^o gloss. These non-conforming gloss values were clearly not indicative of the entire vehicle since they represent only one of nine and one of eleven discrete test areas. The authors of this report do not expect these variant gloss readings to compromise the tactical and operational effectiveness of these vehicles. All of the individual 85^o gloss (or sheen) values collected over the surface of the vehicles were well within the specification requirement. The individual 20^o gloss data were all very low and very reproducible (i.e., 0 to 0.2). Although gloss data at the 20^o orientation is not a CARC specification requirement, it was collected since it is an orientation that is widely used in the automotive industry, and it also helps to more thoroughly characterize this property over the widest possible range of standard viewing angles.

Color

Color was quantified using a portable spectrophotometric colorimeter (Applied Color Systems, Inc., Datacolor PCS-500D) conforming to ASTM D 2244 using the CIE (Commission Internationale d'Eclairage) LAB color scale with D65 illuminant and 10^o observer instrument settings. Color difference (ΔE) is mathematically defined as:

$$\Delta E = [(L_{std} - L_{test})^2 + (a_{std} - a_{test})^2 + (b_{std} - b_{test})^2]^{1/2}$$

A ΔE value of 1.0 or less is considered imperceptible to individuals with normal vision. The instrument settings were identical to those used in a previous study [6]. The CIE LAB standard values are based on color #34094 of FED-STD-595B (Green 383). Color data was generated for the two HMMWVs and the 5-ton truck at approximately the same time as the gloss tests described above. ΔE data for the two HMMWVs and the 5-ton truck ranged from 1.695 to 1.982 as shown in Tables 4, 5, and 6.

The values obtained for all the vehicles are slightly superior to the lab data (ΔE=2.76) generated previously [1]. Also, ΔE for the vehicles when converted to the NBS color system units (i.e., 1.36, 1.42, 1.49) were clearly within the 2.0 NBS units required in the CARC topcoat specifications.

Film Thickness

Dry film thickness (DFT) of the WD CARC system, which includes the thickness of the primer, was obtained at the same time as the gloss and color data on 11 May 2000. This data is also displayed in Tables 4, 5, and 6. To calculate the WD CARC topcoat thickness, the average primer DFT for the

Table 4 -- Gloss, Color, and Thickness of SERDP WD CARC on HMMWV (544220)

		Left Side					Right Side					Vehicle	
		Tail Top	Aft	Mid	Forward	Nose	Forward	Mid	Aft	Aft	Tail Top	Avg	SD
Gloss	20°	0.2	0.2	0.2	0.1		0.2	0.2	0.2	0	0.1	0.156	0.073
	60°	0.7	1.5	0.8	0.8		1	0.7	0.8	0.9	0.6	0.867	0.265
	85°	0.5	1.3	0.9	2.1		1.8	0.6	0.8	1.2	0.4	1.067	0.587
Color	L	32.54	32.4	31.81	32.26		33.33	31.86	32.1	31.9	32.86	32.35	0.505
	a	-4.8	-4.8	-4.85	-4.9		-4.82	-5	-4.8	-4.6	-4.91	-4.831	0.108
	b	8.6	8.58	8.75	8.86		8.48	8.78	8.58	8.52	8.31	8.607	0.169
	ΔE (LAB)	1.5873	1.67	1.988	1.5662		1.4407	1.926	1.89	2.06	1.6962	1.695	0.215
	ΔE (NBS)											1.361	
Thickness	TC WFT (mils)	6	6	3	5.5	6	7	2.5				5.143	1.701
	Total DFT (mils)	5.1	6.1	7.2	6.3		5.1	7.1	6.1	5.6	5.2		
		5.7	5.7	7	6.4		5	5.7	6.4	5	5		
		4.7	5.2	7.6	6.6		4.7	5.8	5.4	5.5	5.8	5.815	0.796
	Pr DFT (mils)											4.62	
	TC DFT (mils)											1.195	

Note: ΔE determined with respect to Fed STD 595 color #34094 where L*= 33.42, a* = -4.97, and b* = 9.91

Table 5 -- Gloss, Color, and Thickness of SERDP WD CARC on HMMWV (544264)

		Left Side					Right Side					Vehicle	
		Tail Top	Aft	Mid	Forward	Nose	Forward	Mid	Aft	Rear	Tail Top	Avg	SD
Gloss	20°	0.1	0.1	0.2	0.2		0.2	0.1	0.2	0.2	0.2	0.167	0.050
	60°	0.8	0.8	0.8	1		1	0.8	0.9	0.8	0.9	0.867	0.087
	85°	0.8	0.9	1.3	1.1		1.6	1.2	1	0.8	1	1.078	0.259
Color	L	32.43	32.8	31.14	33.21		33.1	32.35	32.3	32.6	33.33	32.58	0.659
	a	-4.63	-4.7	-4.81	-4.62		-4.79	-4.78	-4.8	-4.5	-4.7	-4.698	0.114
	b	8.76	8.59	8.42	8.3		8.12	8.58	8.89	7.93	8.22	8.423	0.311
	ΔE (LAB)	1.5551	1.5	2.728	1.6609		1.8273	1.718	1.5	2.21	1.7138	1.728	0.404
	ΔE (NBS)											1.420	
Thickness	TC WFT (mils)	4	6	6	5	4	5	5	6		5	5.111	0.782
	Total DFT (mils)	4.1	4.2	6	4.4		5.3	5.4	5.5	4.2	5.3		
		3.6	4.9	5.6	4.3		4.7	5.3	4.7	4.2	4.4		
		4.3	4.1	5.1	4.7		5.2	5.2	4.9	4	4.4	4.741	0.594
	Pr DFT (mils)											3.45	
	TC DFT (mils)											1.291	

Note: ΔE determined with respect to Fed STD 595 color #34094 where L*= 33.42, a* = -4.97, and b* = 9.91

Table 6 -- Gloss, Color, and Thickness of SERDP WD CARC on 5-Ton Truck (540510)

		Left Side						Right Side					Vehicle	
		Tail	Aft	Mid	Door	Forward	Nose	Forward	Door	Mid	Aft	Tail	Avg	SD
Gloss	20°	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.173	0.047
	60°	0.9	0.8	0.7	0.8	0.8	0.9	0.9	0.8	0.8	1.1	0.8	0.845	0.104
	85°	0.8	0.7	0.4	0.6	0.9	0.8	0.8	1	0.9	1	0.6	0.773	0.185
Color	L	31.88	31.34	31.56	31.39	32.05	31.15	31.96	32.04	31.93	32.02	31.99	31.76	0.33
	A	-5.05	-4.85	-4.97	-4.98	-4.99	-4.52	-4.87	-4.87	-4.96	-4.98	-4.83	-4.897	0.143
	b	9.06	8.69	9.14	8.74	8.8	8.8	8.66	8.81	8.78	8.98	8.75	8.837	0.154
	ΔE (LAB)	1.7608	2.4144	2.0131	2.3431	1.7633	2.5666	1.9246	1.7676	1.8701	1.6808	1.8466	1.982	0.304
	ΔE (NBS)												1.486	
Thickness	Total DFT (mils)	4.3	4.2	4.8	4.4	4.8	4.2	4.1	3.4	4.4	4.8	4.8		
		4.9	4.8	4.9	4.5	5	3.1	3.7	3.1	8.3	5.6	5.5		
		5.1	6.8	5.8	4.6	4.9	5	5.1	2.9	6.9	4.8	4.7	4.794	1.083
	Pr DFT (mils)												2.77	
	TC DFT (mils)												2.02	

Note: ΔE determined with respect to Fed STD 595 color #34094 where L*= 33.42, a* = -4.97, and b* = 9.91

vehicles, previously obtained, were subtracted from the total system DFT. The topcoat thickness values (1.2, 1.3 and 2.0 mils) were clearly not optimum for two of the three vehicles. Although the low film thickness on the two HMMWVs was obviously undesirable, it is nonetheless encouraging that the 5-ton truck attained the desired average vehicle DFT of just above the 1.8 mil DFT, as required in MIL-C-53072. This was most likely due to the reduced amount of water used to mix the batches of WD CARC for the 5-ton (from 0.75 part water for the HMMWV batches to 0.5 part water for the remaining batches), which correspondingly increased the volume solids level from about 37% to 40%.

This strongly suggests that in order to get the proper film build it is advantageous to use the lower water concentration mix ratio of 2:1:0.5. While the deficient thickness of the topcoat on the HMMWVs is not expected to cause any major problems, overcoating the Green 383 with black and brown to complete the camouflage pattern of 41% green, 41% black, 12% brown, should help to allay these concerns.

Note: gloss, color and thickness data could not be generated for the LAV-AT since the WD CARC was applied to that vehicle on the morning of 11 May 2000, which was the last day of the field application demonstration.

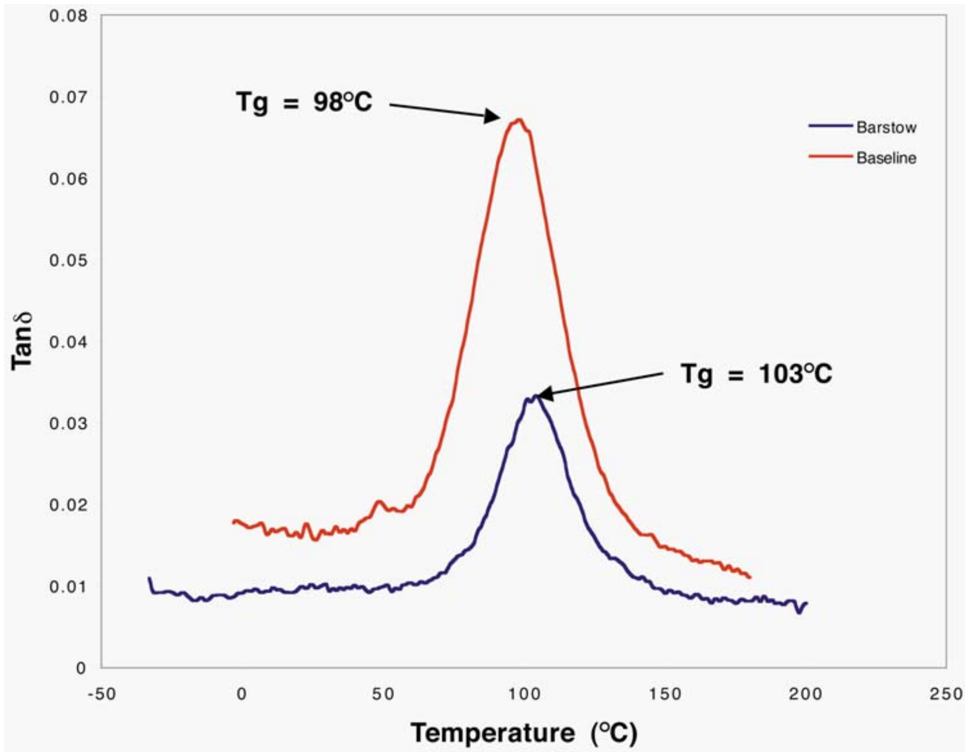
Dynamic Mechanical Thermal Analysis

Materials respond to an external stress or strain by storing energy elastically and/or by dissipating energy via the generation of heat. Materials that exhibit purely elastic behavior are governed by Hooke's Law, which states that the stress is directly proportional to the strain. The proportionality constant is known as the elastic or storage modulus (E'). Purely viscous materials are subject to Newton's Law, which states that the stress is directly proportional to the strain rate—the proportionality constant is the viscous or loss modulus (E''). Most materials exhibit both viscous and elastic properties and are, therefore, known as visco-elastic materials. Dynamic Mechanical Thermal Analysis (DMTA) is used to measure a material's response to an applied stress or strain. The dynamic (oscillatory) nature of DMTA results in a sinusoidal stress-strain relationship. It is convenient to define a complex modulus (E^*), which is a linear combination of the viscous (E'') and elastic (E') moduli. The ratio of the elastic modulus to the viscous modulus is known as the tanδ ($\tan\delta = E''/E'$) or the loss tangent, and is an indicator of the damping properties of a material. In this project, E', E'', and tanδ values were measured as a function of temperature using DMTA via dynamic temperature ramp tests at an oscillation frequency of 1 Hz and a ramp rate of 3°C per minute. Glass transition temperature (T_g) was defined as the temperature corresponding to the peak of the loss tangent response.

A Dynamic Mechanical Thermal Analyzer manufactured by Rheometric™ Scientific (Model DMTA IV) is a mechanical spectrometer that can measure stress-strain relationships of materials as described above. Mechanical deformation and environmental control of the test specimen is provided by the Test Module, which is controlled by an Electronics and Data Collection unit. Sub-ambient temperature control is achieved via the liquid nitrogen-fed Cryogenic System.

The Barstow and baseline WD CARC materials were applied to 1010 cold rolled steel substrates and tested in dual cantilever or 3 point bending load cells. Figure 25 shows a Tanδ versus Temperature plot

Figure 25 -- Determination of Glass Transition Temperature of Laboratory and Field Samples



comparing the Barstow specimen with a laboratory baseline sample. The glass transition temperature shifted only slightly from 98° C to 103° C. This is a good indication that the bulk properties are very similar and have remained essentially unchanged. The observed difference in the height of the Tanδ peaks can be attributed to different dry film thickness (primer and topcoat) of the two test panels.

Tensile Adhesion Testing (ASTM D4541)

Tensile adhesion tests performed on the coated panels are used to quantify the amount of force necessary to break the bond of the coating to the substrate and identify the mode of failure (MOF). A Type VI Pneumatic Adhesion Tensile Testing Instrument (PATTI) self-alignment adhesion tester was used with an F-8 piston per ASTM D4541-95, "Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers." Adhesion is determined by measuring the force necessary to pull off a button adhered to the surface of the test panel. After adhering the button to the surface to be tested, a piston with an air collar is attached to the button and compressed air is forced into the collar until the button is pulled off the surface and the pull-off-strength (POS) noted. MOF is noted as a percentage with the failure either being cohesive (within a particular coating layer) or adhesive (between two layers).

The test was performed on four 3" x 6" x 1/8" panels coated at Barstow MCLB with the standard Marine Corps primer, MIL-P-53030, and topcoated with the WD CARC coating. A two component epoxy (Miller-Stephenson 907) adhesive was used to adhere two test buttons to the surface of each of the painted panels. The objective of the testing was to compare the data obtained from the Barstow application to that obtained from baseline testing of the same coating system applied in a laboratory setting.

Results of the PATTI adhesion testing produced an average pull-off-strength (POS) of 2312 pounds per square inch (psi), as shown in Table 7. This correlates well with the results obtained from the baseline SERDP testing, which produced an average POS of 2,543 psi for WD CARC to steel and 1,992 psi for primer (MIL-P-53030) and WD CARC to steel. Since MOF results were not recorded during the SERDP testing, a comparison cannot be made. However, it is important to note that most of the failures were considered adhesive between the epoxy adhesive and the WD CARC or between the adhesive and the surface of the button. This suggests that the adhesive strength of the epoxy was exceeded prior to the adhesive or cohesive strength of the WD CARC.

Table 7 -- Patti Adhesion Results for Barstow Panels

			Mode of Failure						
Panel	POS	Tile Avg	Adhesive: Substrate/ Primer	Cohesive: Primer	Adhesive: Primer/ Topcoat	Cohesive: Topcoat	Adhesive: Topcoat/ 907	Cohesive: 907	Adhesive: 907/ Button
1.1	1991	2195					65%		35%
1.2	2398		20%				75%		5%
2.1	2439	2419					60%		40%
2.2	2398		60%				20%		20%
3.1	1950	2154	50%				10%		40%
3.2	2358		40%				35%		25%
4.1	1788	2480	5%				5%		90%
4.2	3172		20%				15%		65%
	AVG	**2312**							
	SD	**427.9**							

Abrasion Resistance

Resistance to abrasion was determined using ASTM D4060-95, “Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser.” The WD CARC was applied at a uniform thickness to flat 4” x 4” steel panels. After the WD CARC had completely cured, the surfaces were abraded by rotating the panels under weighted abrasive wheels. Abrasion resistance was calculated as total weight loss, as weight loss per cycle (wear index), and as percent loss in coating thickness.

Initially, baseline laboratory samples were tested using the Taber abrader with resilient calibrase wheels (No. CS-17 with a 1000g weight). Four samples were evaluated. Each sample was abraded for 1500 cycles, and after every 500 cycles, the coating was examined, weight loss recorded, and film thickness measured. The CS-17 wheels were resurfaced after every 500 cycles by running for 50 cycles over an abrasive (S-11) disk. This data was previously reported [(1)] and is provided as Table 8 to establish the baseline property. After 500, 1000, and 1500 cycles, cumulative weight losses of 15 mg, 34 mg, and 41 mg are observed, respectively. An overall thickness loss of 0.67 mils (using the harshest wheel and weight allowed by ASTM D 4060) was observed after 1500 cycles. Note that the recorded increase in weight up to about 300 cycles was attributed to the imbedding of fine rubber particles on the surface. These values indicate that Green 383 WD CARC is a very abrasion resistant coating.

Table 8 -- Taber Abrasion Results of WD CARC (Green 383)

# of Cycles	Weight Loss (mg)	Cumulative Weight Loss (mg)	Total Thickness Loss (mils)
100	-23	-23	n/a
200	5	-18	n/a
300	3	-15	n/a
400	20	5	n/a
500	10	15	n/a
600	3	18	n/a
700	7	25	n/a
800	9	34	n/a
900	-14	20	n/a
1000	14	34	n/a
1100	-9	25	n/a
1200	13	38	n/a
1300	5	43	n/a
1400	-23	20	n/a
1500	21	41	0.67

Note: CS-17 wheel, 1000-gram weight
Note: Final appearance of test area - dulled wear rack

To gain more significant wear data in an efficient time span such that minor changes in application processes could be characterized, the authors felt it necessary to deviate from the ASTM method. Instead of using the resilient (rubber and abrasive grain) wheels, a much more rigid and coarse H-10 (vitrified) wheel with a 500 g weight was chosen. The baseline WD CARC (Green 383) lost approximately 68 mg or 0.8 mils while the solvent-borne CARC (MIL-C-46168D) lost 380 mg or 3.4 mils after 750 cycles at the harsher conditions (6).

The modified ASTM procedure was used to evaluate the Barstow specimens. The data is presented in Table 9. After 750 cycles, the total (average) weight loss was 84.5mg and the reduction in DFT was 1.0 mil. These results are comparable to the baseline WD CARC samples from above, and indicate that the Barstow samples exhibited excellent abrasion resistance and obvious superior abrasion resistance compared to the solvent-borne system (MIL-C-46168D).

Table 9 -- Taber Abrasion Results of Barstow Panels

Sample	Total Weight Loss (mg)			Wear Indices			DFT (mils)		Thickness Loss (%)
	250 Cycles	*500 Cycles*	*750 Cycles*	*250 Cycles*	*500 Cycles*	*750 Cycles*	*Initial*	*Final*	
1	28.0	43.0	75.0	112	86	75	4.6	3.8	17.4
2	49.0	69.0	92.0	196	138	92	4.7	3.7	21.3
3	41.0	81.0	92.0	164	162	92	4.4	3.4	22.7
4	28.0	69.0	79.0	112	138	79	4.7	3.5	25.5
AVG	**36.5**	**65.5**	**84.5**	**146**	**131**	**85**	**4.6**	**3.6**	**21.7**

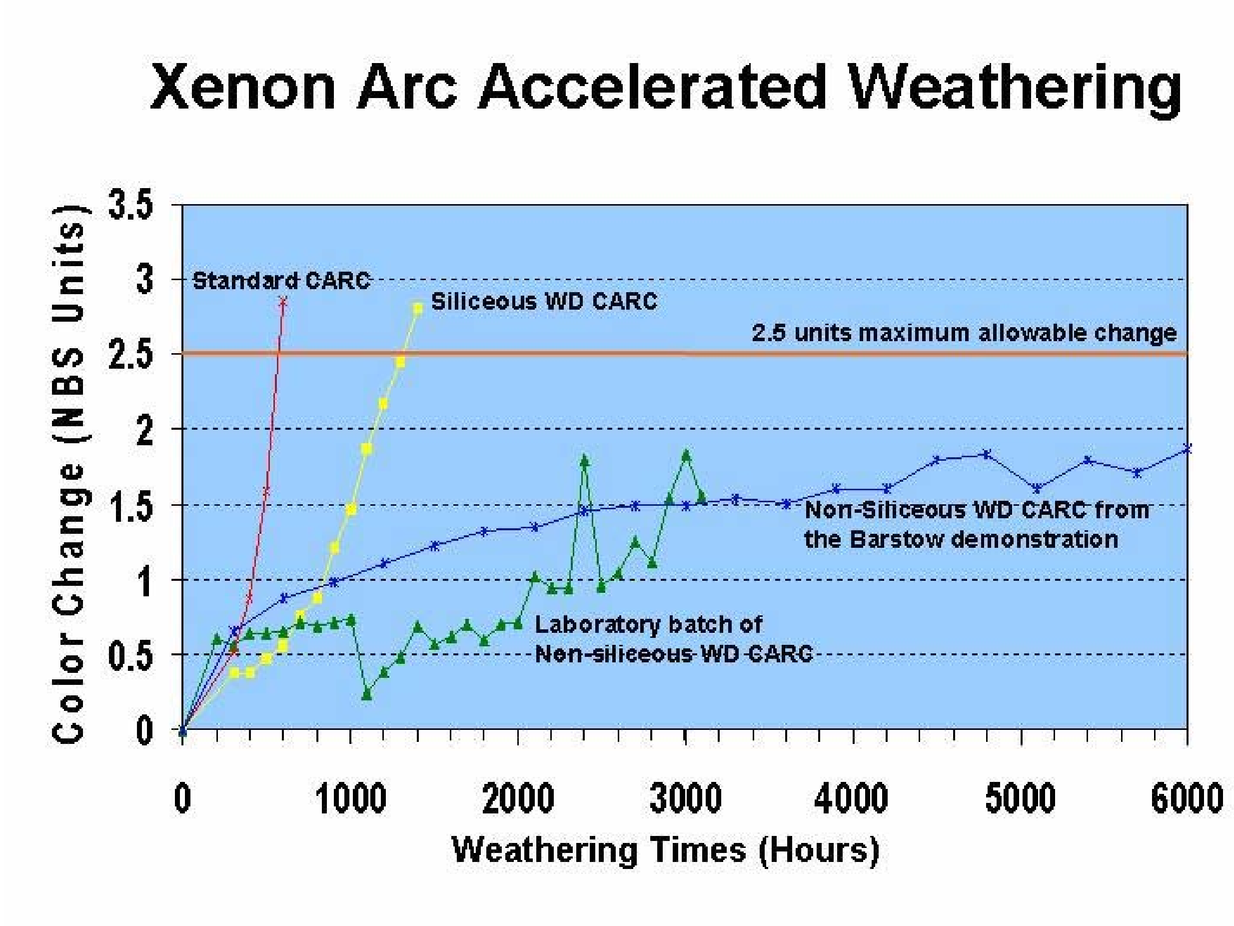
Note: H-10 wheel, 500 gram weight
Note: Final appearance of test area - smooth green surface. even coating wear, no exposed substrate.

Accelerated Weathering (Performed by ARL)

The panels coated for the Army were used for accelerated weathering testing. Results of this testing were used to determine how the coating would perform with regard to colorfastness. The Xenon Arc accelerated weathering included exposure in an Atlas Ci-65 chamber with 108 minutes of light and 12 minutes of light plus deionized water spray on the front of the panels. The panels were exposed for 6,000 hours in accordance with ASTM G155-00, "Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials." The results are shown in Figure 26.

The National Bureau of Standards (NBS) color difference is shown versus total hours of exposure. A color change value of 2.5 units is the maximum allowable color change as specified in MIL-C-46168. An NBS color change of about 1.9 units at 6,000 hours of exposure has been obtained with the WD CARC applied at Barstow. The solvent borne CARC (MIL-C-46168D) and WD CARC with siliceous extenders (MIL-DTL-64159, Type I) did not perform as well as the WD CARC with polymeric beads (MIL-DTL-64159, Type II). The WD CARC with polymeric beads, applied in the laboratory and at Barstow, demonstrates exceptional accelerated weathering resistance and consequent outdoor durability.

Figure 26 -- Accelerated Weathering Results for Barstow Demonstration



3.6.6.2 Ogden Test Results

AFRL Depaint Panel Testing

Ten steel panels (10.5 inches by 5.5 inches by 0.125 inches) were prepared according to the standard Ogden ALC procedures, which was white metal blasting. They were coated along with the ARL and NSWCCD test specimens as described paragraph 3.6.5.2 above. These panels were intended to demonstrate the removal properties of the WD CARC using the Ogden ALC coating removal processes. The panels were given a minimum of seven days cure at room temperature (75 ± 5° F) before further conditioning.

The depaint test panels were sent to the Q-Lab Weathering Research Service Facility near Tucson, Arizona. There, they underwent accelerated aging using the Q-Trac Natural Sunlight Concentrator, which would give the equivalent aging of two years exposure after six months for five of the panels and four years after ten months for the remaining five panels.

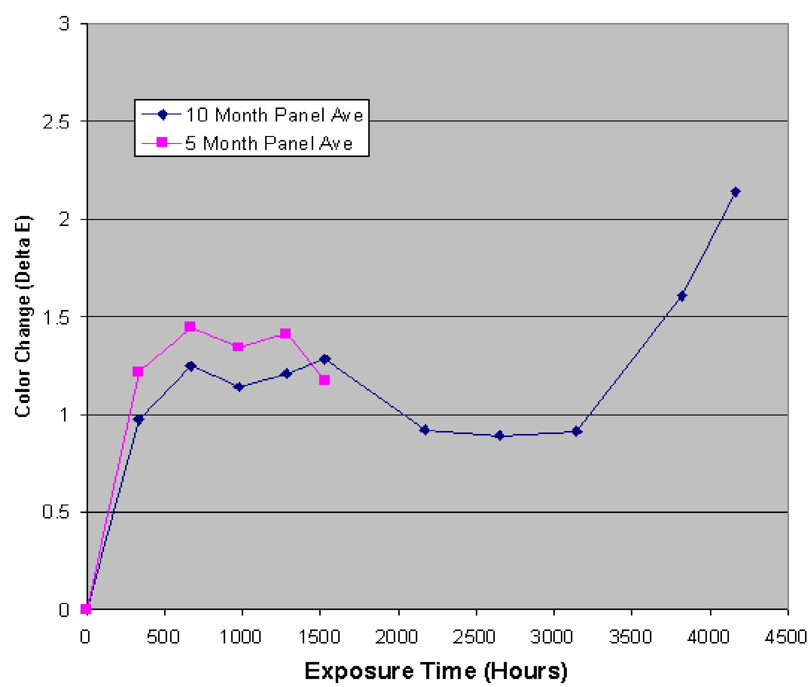
The depaint panels started exposure on 21 September 2000. Delta E and Radiation exposure were measured and reported monthly for each of the remaining five panels. Color data was measured with a HunterLab Ultrascan XE using the CIE L*a*b* color scale with a C type illuminant and a 2° observer.

After five months of accelerated outdoor exposure, the panels received over 16,650 MJ/m2 and total ultraviolet radiation (TUVR) of over 344 MJ/m2. Delta E values ranged from 0.98 to 1.55. The average delta E was 1.23 for the ten depaint panels.

After ten months of accelerated outdoor exposure, the remaining five panels received over 38,160 MJ/m2 and total ultraviolet radiation (TUVR) of over 946 MJ/m2. Delta E values ranged from 1.81 to 2.63. The average delta E was 2.14 for the depaint panels.

Figure 27 plots the color change data over approximate hours of exposure. The Q-lab color change data is a little lower than the ARL data except for the last two months of exposure. This can be explained in part by the differences in the Xenon Arc and the Q-Trac equipment and the differences in the NBS and CIE color systems.

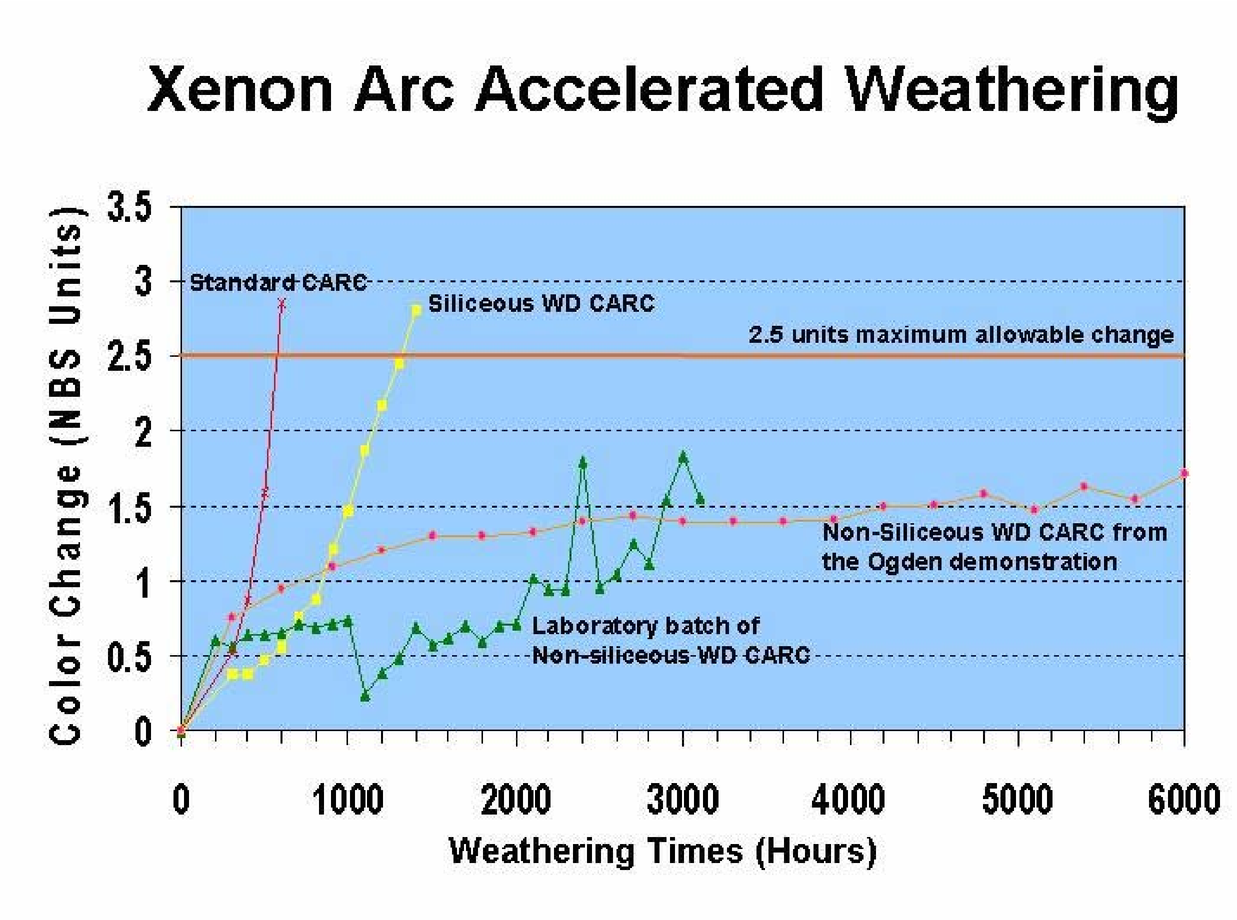
Figure 27 -- Q-Lab Accelerated Aging of WD CARC Applied at Ogden ALC



Accelerated Weathering (Performed by ARL)

The panels coated for the Army were used for accelerated weathering testing. Results of this testing were used to determine how the coating would perform with regard to colorfastness. The Xenon Arc accelerated weathering included exposure in an Atlas Ci-65 chamber with 108 minutes of light and 12 minutes of light plus deionized water spray on the front of the panels. The panels were exposed for 6,000 hours in accordance with ASTM G155-00, "Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials." The results of the colorfastness were graphed as shown in Figure 28. The NBS color difference is shown versus total hours of exposure. A color change value of 2.5 units is the maximum allowable color change as specified in MIL-C-46168. The solvent borne CARC (MIL-C-46168D) and WD CARC with siliceous extenders (MIL-DTL-64159, TY I) did not perform as well as the WD CARC with polymeric beads (MIL-DTL-64159, TY II). The WD CARC with polymeric beads, applied in the laboratory and at Ogden, demonstrates exceptional accelerated weathering resistance.

Figure 28 -- Accelerated Weathering Results for Ogden Demonstration



Abrasion Resistance (Performed by NSWCCD)

Resistance to abrasion was determined using ASTM D4060-95, "Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser." The WD CARC was applied at a uniform thickness to flat 4" x 4" steel panels. After the WD CARC had completely cured, the surfaces were abraded by rotating the panels under weighted abrasive wheels. Abrasion resistance was calculated as total weight loss, as weight loss per cycle (wear index), and as percent loss in coating thickness.

Initially, baseline laboratory samples were tested using the Taber abrader with resilient calibrase wheels (No. CS-17 with a 1000g weight). Four samples were evaluated. Each sample was abraded for 1500 cycles, and after every 500 cycles, the coating was examined, weight loss recorded, and film thickness measured. The CS-17 wheels were resurfaced after every 500 cycles by running for 50 cycles over an abrasive (S-11) disk. This data was previously reported and was provided as Table 8 to establish the baseline property. After 500, 1000, and 1500 cycles, cumulative weight losses of 15 mg, 34 mg, and 41 mg are observed, respectively. An overall thickness loss of 0.67 mils (using the harshest wheel and weight allowed by ASTM D 4060) was observed after 1500 cycles. Note that the recorded increase in weight up to about 300 cycles was attributed to the imbedding of fine rubber particles on the surface. These values indicate that Green 383 WD CARC is a very abrasion resistant coating.

To gain more significant wear data in an efficient time span such that minor changes in application processes could be characterized, the authors felt it necessary to deviate from the ASTM method. Instead of using the resilient (rubber and abrasive grain) wheels, a much more rigid and coarse H-10 (vitrified) wheel with a 500 g weight was chosen. The baseline WD CARC (Green 383) lost approximately 68 mg or 0.8 mils while the solvent-borne CARC (MIL-C-46168D) lost 380 mg or 3.4 mils after 750 cycles at the harsher conditions [(6)].

Table 10 -- NSWCCD Taber Abrasion Results for WD CARC Applied at Ogden ALC

	Total Weight Loss (mg)			Wear Index			DFT (mils)		
Sample	250 Cycles	500 Cycles	750 Cycles	250 Cycles	500 Cycles	750 Cycles	Initial	Final	Thickness Loss (%)
1-p	18.6	23.8	33.7	74.40	47.60	44.93	4.10	3.41	16.72
2-p	5.9	20.2	25.7	23.60	40.40	34.27	3.72	3.26	12.43
3-p	19.7	24.5	27.7	78.80	49.00	36.93	4.32	3.49	19.11
4-p	23.3	40.1	45	93.20	80.20	60.00	4.10	2.99	26.98
p Ave	16.87	27.15	33.02	67.50	54.30	44.03	4.06	3.29	18.81
1-u	26.8	37	64.5	107.20	74.00	86.00	2.47	1.57	36.51
2-u	13.7	28.5	35	54.80	57.00	46.67	2.35	2.06	12.55
3-u	29.6	39.9	45.1	118.40	79.80	60.13	2.67	2.04	23.69
4-u	37.6	45.5	45.5	150.40	91.00	60.67	3.20	2.25	29.61
u Ave	26.93	37.73	47.53	107.70	75.45	63.37	2.67	1.98	25.59
Ave	21.90	32.44	40.28	87.60	64.88	53.70	3.36	2.63	22.20

The modified ASTM procedure was used to evaluate the Ogden specimens. The data is presented in Table 10. After 750 cycles, the total (average) weight loss was 40.3mg and the reduction in DFT was 2.63 mil, which was a thickness loss of 22%. These results are comparable to the baseline WD CARC samples in Table 8, and indicate that the Ogden samples exhibited excellent abrasion resistance and obvious superior abrasion resistance compared to the solvent-borne system (MIL-C-46168D).

ASTM D4541 Tensile Adhesion Testing (Performed by NSWCCD)

Tensile adhesion tests performed on the coated panels are used to quantify the amount of force necessary to break the bond of the coating to the substrate and identify the mode of failure (MOF). A Type VI PATTI self-alignment adhesion tester was used with an F-8 piston per ASTM D4541-95, "Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers." Adhesion is determined by measuring the force necessary to pull off a button adhered to the surface of the test panel. After adhering the button to the surface to be tested, a piston with an air collar is attached to the button and compressed air is forced into the collar until the button is pulled off the surface and the pull-off-strength (POS) noted. MOF is noted as a percentage with the failure either being cohesive (i.e., within a particular coating layer) or adhesive (i.e., between two layers).

The test was performed on four 3" x 6" x 1/8" panels coated at Ogden ALC with the standard ALC primer, MIL-PRF-23377G, and topcoated with the WD CARC coating as shown in Figure 3. A two-component epoxy (Miller-Stephenson 907) adhesive was used to adhere two test buttons to the surface of each of the painted panels. The objective of the testing was to compare the data obtained from the Barstow application to that obtained from baseline testing of the same coating system applied in a laboratory setting.

Table 11 -- NSWCCD Adhesion Results for WD CARC Applied at Ogden ALC

Panel	POS	Standard deviation
1	1015	-
2	955	-
3	751	-
4	731	-
5	772	-
6	873	-
Avg. w/adhesive cure time effect	849.5	117.3
Avg. w/o adhesive cure time effect	902.2	113.6
Paint application date – 30 August 2000 Adhesive application date – 21 November 2000 PATTI test date – 22 November 2000		

Results of the PATTI adhesion testing produced an average pull-off-strength (POS) of 849.5 pounds per square inch (psi), as shown in Table 11. This is less than half the adhesion strength when compared with the results obtained from the baseline SERDP testing, which produced an average POS of 2,543 psi for WD CARC to steel and 1,992 psi for primer (MIL-P-53030) and WD CARC to steel [6]. This could be explained by the fact that different primers were used in the SERDP testing than were used in ALC production. Since MOF results were not recorded during the SERDP testing, a comparison cannot be made. However, it is important to note that most of the failures were considered adhesive between the epoxy adhesive and the WD CARC or between the adhesive and the surface of the button. This suggests that the adhesive strength of the epoxy was exceeded prior to the adhesive or cohesive strength of the WD CARC.

3.6.6.3 Tobyhanna Test Results

The verification tests performed by ARL were extracted from the list contained in the Field Trial Panel Matrix noted in 3.6.6. The list includes color, specular gloss, accelerated weathering, DS2 resistance, chemical agent resistance, EMMAQUA (Equatorial Mirror Mount with water) weathering (exterior weathering for panels prior to use at stripping demonstrations), coating thickness, pull-off adhesion testing, impact resistance, flexibility, abrasion resistance, sag resistance, and Dynamic Mechanical Thermal Analysis (DMTA). Specifically, ARL performed the tests related to survivability, both camouflage and chemical warfare, and durability; i.e., color and infrared reflectance, gloss, DS2 resistance, chemical agent resistance, dry film thickness, and accelerated weathering.

Color

The color of the applied WD CARC was measured using a DataColor International CS-5 Chroma Sensor spectrophotometer in accordance with ASTM D 2244 using standard Illuminant C and the 2° observer data (see Figure 29). The visual reflectance was 8.05, the chromaticity was (0.3217, 0.3616), the infrared reflectance average was 43.33%, the red region reflectance was 7.53%, and the infrared to red reflectance ratio was 5.75. All results fell within the requirements for camouflage Green 383.

Specular Gloss

The specular gloss of the applied WD CARC was measured with a Byk-Gardner haze-gloss reflectometer in accordance with ASTM D 523. The 60° gloss was 0.7 and the 85° gloss was 1.6, both of which were well within the requirements for camouflage topcoats of 1.0 maximum and 3.5 maximum at 60° and 85°, respectively.

DS2 Resistance

The DS2 resistance test was performed in accordance with the requirements of MIL-DTL-64159. The procedure is essentially a spot test, in which the cured coating is exposed to DS2 for a half hour, rinsed, and checked for such defects as blistering, film softening, wrinkling, or color change. The only defect noted was a very slight color change of 0.5 NBS units, well within the allowable maximum color change of 2.5 NBS units.

Figure 29 -- Reflectance Results for TYAD Demonstration Green 383

Batch Results

Sample - Tobyhanna ESTCP demo
Illuminant - C 2 Deg

Visible	380-480	490-590	600-700	Red avg. data		
		7.11	7.31			
		7.73	7.10			
	5.32	8.34	7.13	620 nm	7.13	
	5.44	8.96	7.31	630 nm	7.31	
	5.44	9.27	7.43	640 nm	7.43	X 2
	5.45	9.15	7.47	650 nm	7.47	X 3
	5.57	8.72	7.88	660 nm	7.88	X 3
	5.69	8.15	8.55			
	5.87	7.72	9.56			
	6.12	7.59	11.62			
	6.52	7.54	14.47			

X	Y	Z	x	y
7.16	8.05	7.05	0.3217	0.3616

Infrared	710-800	810-900	910-1000	1010-1100	IR avg. data
	19.19	48.23	49.48	55.74	24.06
	24.06	48.09	50.10	55.91	34.07
	29.15	47.99	50.76	55.90	42.44
	34.07	47.88	51.49	55.80	45.36
	38.54	47.84	52.23	55.54	47.17
	42.44	47.89	53.01	55.09	48.25
	45.36	47.98	53.70	54.51	48.23
	47.17	48.21	54.37	53.76	47.99
	48.05	48.51	54.91	52.89	47.88
	48.25	48.94	55.40	51.87	47.89

Chemical Agent Resistance

The chemical agent resistance test was performed in accordance with the requirements of MIL-DTL-64159. The procedure was updated in a joint effort between ARL and the Edgewood Chemical and Biological Center (ECBC) at Aberdeen Proving Ground, and incorporates advances in instrumentation since the procedure developed for the original CARC topcoat specifications. The test method is available in Appendix B. The result for Sherwin-Williams formula F93G502/V93V502 was less than 10 $\mu g/cm^2$, well below the maximum allowable of 180 $\mu g/cm^2$ for the agent distilled mustard (HD).

Dry film thickness

The film thickness of the MIL-P-53030 primer applied to the test panels was measured with an electronic film thickness tester after the overnight cure and before the WD CARC topcoat was applied. One reading was taken for each of the 50 panels, and the electronic tester provided the resultant statistics. The average was 2.01 mils, with a standard deviation of 0.21 mils. The maximum reading was 2.37 mils, and the minimum reading was 1.43 mils. While this is slightly thicker than necessary, the results are acceptable in accordance with a minimum thickness of 1.5 mils indicated by MIL-C-53072, Chemical Agent Resistant Coating (CARC) System Application Procedures and Quality Control Inspection. The WD CARC film thickness was checked for the test panels and for the GMS-280 shelter painted on the second day of the demonstration. In the case of the test panels, the film thickness was measured after application of the topcoat to the primed panels. This was determined to be an average of 5.07 mils, with a standard deviation of 0.52 mils, yielding (by subtraction) about 3 mils of topcoat. Again, this is slightly thicker than required, but acceptable per MIL-C-53072. In the case of the shelter, bare test panels were affixed to the shelter on the ID plates, which had been masked to keep the paint off. The film thicknesses of two such test panels was determined to be 3.02 mils with a standard deviation of 0.15 mils, and 2.62 mils with a standard deviation of 0.16 mils. This indicates that not only was the thickness on the painted equipment acceptable, but also that it was reasonably close to the film thickness obtained for the validation test panels.

Accelerated Weathering

The accelerated weathering was performed to evaluate the color durability of the WD CARC. Four panels each were subjected to 6000 hours of ASTM G 155, Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials, and 6000 hours of ASTM G 154, Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials. Xenon arc exposure used the standard procedure of 108 minutes of light exposure and 12 minutes of light exposure and direct deionized water spray in each two hour cycle. The UV exposure used the standard procedure of eight hours of light exposure and four hours of darkness with condensation in each 12 hour cycle.

Color data for one of the four panels tested in each type of accelerated weathering are shown in Table 12 (Xenon Arc) and Table 13 (UV). The tristimulus values (X, Y, and Z) and chromaticity coordinates (x, y), and the NBS color difference are listed after each increment of exposure, 300 hours in the case of Xenon Arc, and 500 hours in the case of UV. The average results for the four panels in Xenon Arc are

Table 12 -- Xenon Arc Weathering Data (Panel A)

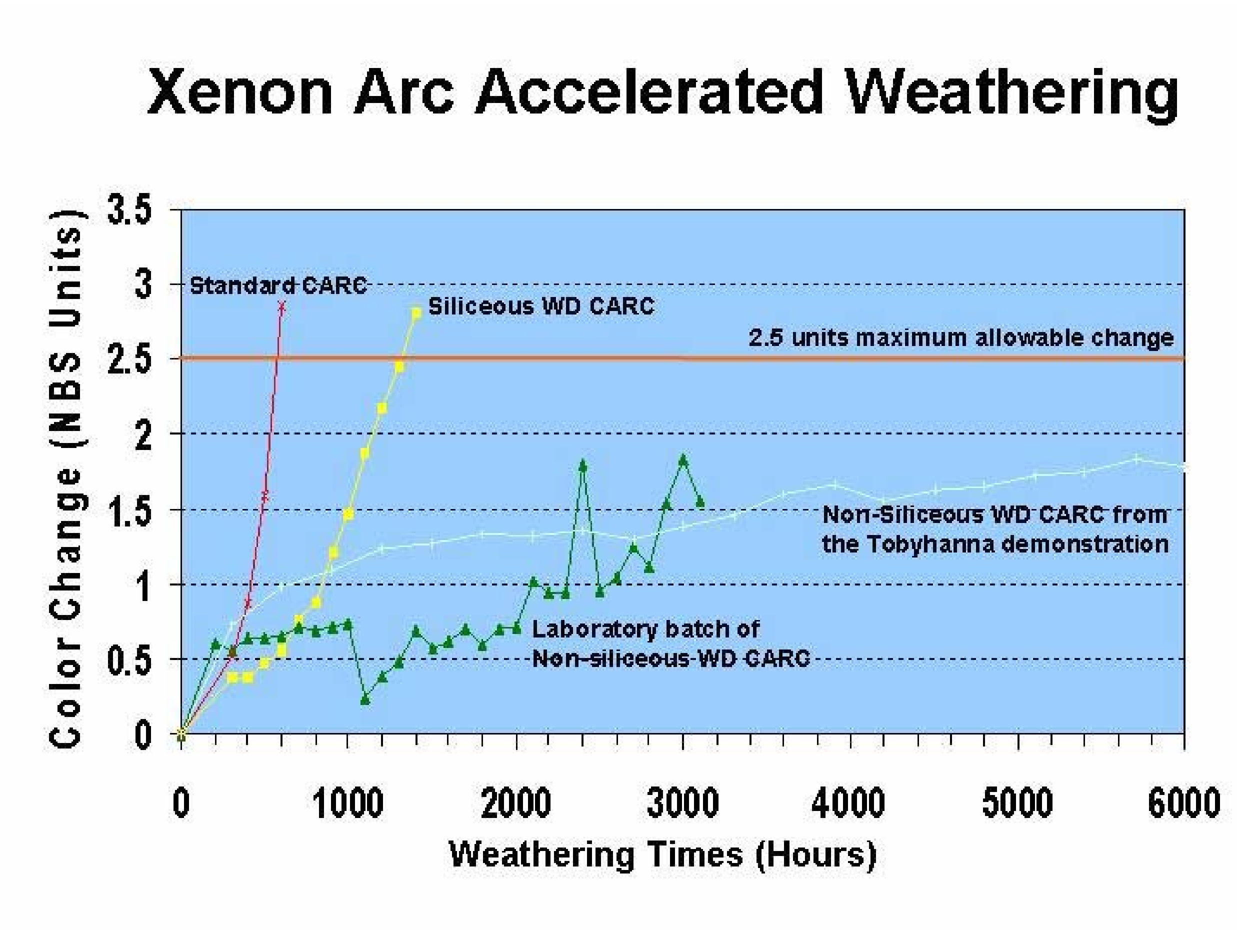
	X	Y	Z	x	y	ΔE_{NBS}
START	7.14	8.03	7.05	0.321	0.361	0.00
300 hours	7.49	8.45	7.49	0.320	0.361	0.81
600 hours	7.59	8.58	7.61	0.319	0.361	1.08
900 hours	7.63	8.62	7.66	0.319	0.361	1.13
1200 hours	7.64	8.66	7.68	0.319	0.361	1.32
1500 hours	7.65	8.68	7.68	0.319	0.362	1.37
1800 hours	7.65	8.69	7.67	0.319	0.362	1.42
2100 hours	7.63	8.67	7.63	0.319	0.362	1.39
2400 hours	7.60	8.64	7.58	0.319	0.363	1.36
2700 hours	7.61	8.64	7.57	0.319	0.363	1.27
3000 hours	7.61	8.65	7.55	0.320	0.363	1.33
3300 hours	7.61	8.67	7.54	0.319	0.364	1.47
3600 hours	7.63	8.71	7.56	0.319	0.364	1.63
3900 hours	7.63	8.71	7.55	0.319	0.365	1.63
4200 hours	7.60	8.67	7.49	0.320	0.365	1.53
4500 hours	7.62	8.69	7.49	0.320	0.365	1.53
4800 hours	7.66	8.75	7.53	0.320	0.365	1.70
5100 hours	7.66	8.76	7.52	0.320	0.366	1.78
5400 hours	7.68	8.79	7.53	0.320	0.366	1.86
5700 hours	7.67	8.78	7.51	0.320	0.366	1.86
6000 hours	7.65	8.76	7.50	0.320	0.366	1.86

Table 13 -- UV Weathering Data (Panel A)

	X	Y	Z	x	y	ΔE_{NBS}
START	7.15	8.05	7.05	0.321	0.362	0.00
500 hours	7.54	8.50	7.49	0.320	0.361	0.76
1000 hours	7.60	8.58	7.57	0.320	0.361	0.93
1500 hours	7.61	8.59	7.59	0.320	0.361	0.95
2000 hours	7.65	8.63	7.64	0.320	0.361	1.01
2500 hours	7.73	8.72	7.72	0.320	0.361	1.14
3000 hours	7.70	8.69	7.67	0.320	0.361	1.08
3500 hours	7.76	8.77	7.71	0.320	0.362	1.21
4000 hours	7.80	8.83	7.75	0.320	0.362	1.35
4500 hours	7.80	8.82	7.74	0.320	0.362	1.29
5000 hours	7.82	8.86	7.74	0.320	0.363	1.40
5500 hours	7.84	8.89	7.77	0.320	0.363	1.47
6000 hours	7.83	8.88	7.75	0.320	0.363	1.46

plotted in Figure 30, along with data from the baseline Green 383 from MIL-C-46168, and lab batches of MIL-DTL-64159, Type I (siliceous extenders) and MIL-DTL-64159, Type II (SERDP/ESTCP WD CARC). The WD CARC exhibits resistance to accelerated weathering that can only be described as exceptional, since the color change after 6000 hours of exposure is less than the 2.5 units allowed for solvent-borne CARC topcoats after 300 hours exposure; i.e., half to two-thirds of the allowable color change after twenty times the exposure period.

Figure 30 -- Accelerated Weathering Results for Tobyhanna Demonstration



Tensile Adhesion (Performed by NSWCCD)

Tensile adhesion tests were performed on the coated panels to quantify the amount of force necessary to break the bond of the coating to the substrate. Testing was performed in accordance with ASTM D 4541 using a Type VI PATTI self-alignment adhesion tester with an F-8 piston. The test was performed on six 3" x 6" x 1/8" panels. The objective was to compare the data to that obtained from the baseline testing of the same coating system applied in a laboratory setting. Results of the PATTI adhesion testing produced an average pull-off-strength (POS) of roughly 800 to 900 pounds per square inch (psi), as shown in Table 14. This is actually a slight improvement from the thin panel results obtained from the baseline SERDP testing, which produced an average POS of about 500 psi for primer and WD CARC to steel, although the primer used in the baseline testing was MIL-P-53022.

Table 14 -- PATTI pull off adhesion strength (psi)

primer	test date	#1	#2	#3	#4	#5	#6	average	std. dev.
53030	27-Nov-00	914	935	935	935	935	894	925	17
none	27-Nov-00	833	853	812	812	853	n/a	833	21

Direct Impact Resistance (Performed by NSWCCD)

Impact resistance testing was performed to provide insight into the flexibility characteristics of the cured film and to validate the expected physical properties of the cured film. The testing was in accordance with ASTM D 2794, and the substrate was 2024 aluminum alloy (0 temper) with chromic acid anodize pretreatment (MIL-C-8625, Type I). Results are summarized in Table 15, and are consistent with panel results obtained from the baseline SERDP testing.

Table 15 -- Impact Resistance and Flexibility

primer	Impact Resistance		GE Impact Flexibility (%)	Mandrel Bend Resistance
	Direct (in-lb)	Reverse (in-lb)		
none	15	<1	5	0.125"
53030	7	<1	2	1

Cylindrical Mandrel Bend (Performed by NSWCCD)

Mandrel bend flexibility and elongation characteristics were also determined to obtain further insight into the flexibility characteristics of the cured film and to validate the expected physical properties of the cured film. The testing was performed in accordance with ASTM D 522 on a 2024 aluminum alloy (0 temper) with chromic acid anodize pretreatment (MIL-C-8625, Type I) substrate. These results are also shown in Table 15 and are consistent with panel results obtained from the baseline SERDP testing.

Strippability *(Performed by AFRL)*

The Air Force responsibility in the Dem/Val was to validate that stripping the WD CARC could be accomplished as a "drop-in" procedure, using current production equipment. The test panels prepared at this demonstration were both steel and aluminum panels. The steel panels were pretreated with zinc phosphate by Metal Samples, Inc. and the aluminum panels were provided with a chromate conversion pretreatment per MIL-C-5541, Class 1A. Roughly one-fourth of the total was dedicated to each of four possible stripping processes: plastic media blast, steel shot blast, garnet blast, or chemical stripping. The panels were to be EMMAQUA weathered for approximately 10 months before the stripping demo, performed in November 2001.

3.6.6.4 Stripping Test Results

3.6.6.4.1 WD CARC Dem/Val Strippability Results

Barstow MCLB

The strip rate data for the Dem/Val DMB strippability trials at Barstow are tabulated below. The data has been arranged by blast process, and then by test material conditioning. The mean DFTMs for all the different Dem/Val test sets are also tabulated below.

Table 16 -- Strip Rate Data Developed for Barstow Dem/Val DMB Stripping Processes

Stripping Process	Mean Strip Rate for Oven Aged, ft^2/min	Mean Strip Rate for 5 Month* Accelerated Aging, ft^2/min	Mean Strip Rate for 10 Month** Accelerated Aging, ft^2/min
Garnet	1.98 ± 0.40	1.82 ± 0.36	1.62 ± 0.28
Type V	0.03 ± 0.00	0.22 ± 0.07	0.22 ± 0.10
Steel Grit	0.53 ± 0.08	0.32 ± 0.07	0.31 ± 0.06

* Considered to be equivalent to approximately 2 years of natural exposure in the Arizona desert area.

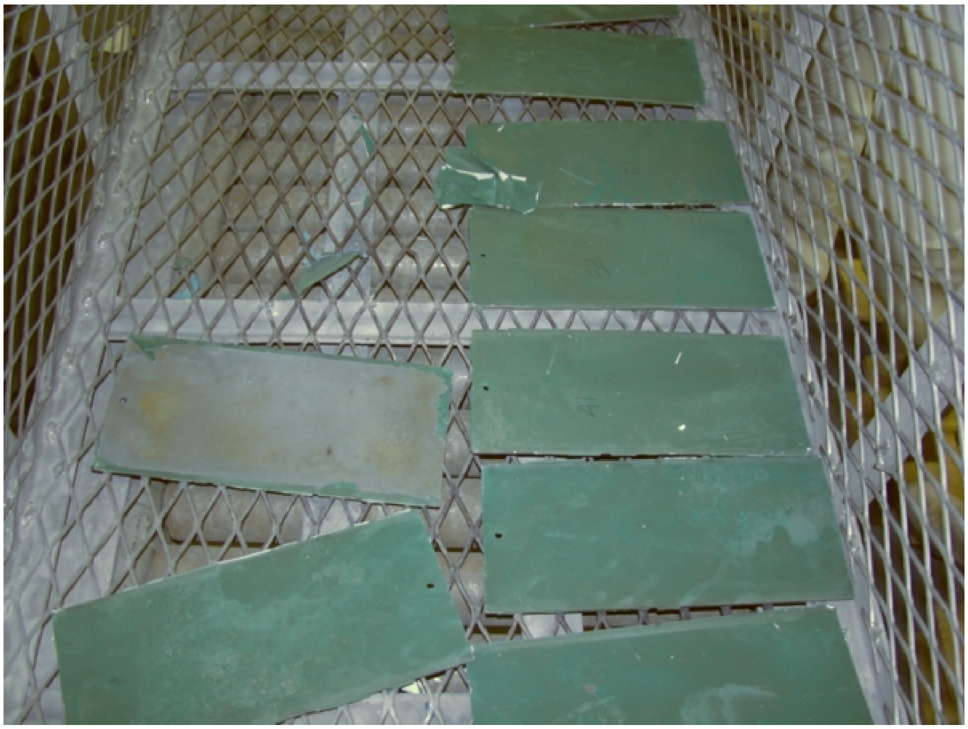
** Considered to be equivalent to approximately 4 years of natural exposure in the Arizona desert area.

Table 17 -- DFTM for Barstow Dem/Val Strippability Test Materials

Stripping Process	Mean DFTM for Oven Aged Test Panels, mils	Mean DFTM for 5 Month Accelerated Aged Test Panels, mils	Mean DFTM for 10 Month Accelerated Aged Test Panels, mils
Garnet	4.30 ± 0.22	4.08 ± 0.23	4.20 ± 0.26
Type V	5.13 ± 0.27	5.33 ± 0.46	5.13 ± 0.14
Steel Grit	4.11 ± 0.47	4.17 ± 0.37	4.32 ± 0.22
Chemical Bath	4.06 ± 0.45	3.97 ± 0.48	4.16 ± 0.29

The test panels that were exposed to the chemical corrosion removal process exhibited some indications of damage to the coating system, but signs of complete, or even approaching complete stripping were very limited as may be seen in Figure 31. A couple of the panels did not appear to have any damage at all from the chemical bath.

Figure 31 -- Typical Chemical Test Panels at Barstow MCLB



Ogden ALC

The strip rate data for Dem/Val strippability trials conducted at OO-ALC are presented below in Tables 18 and 19. The data have been tabulated for tests conducted with steel panels prepared and coated by OO-ALC, and for tests that were conducted on aluminum panels coated and partially stripped at Barstow MCLB. Table 20 presents the DFTM data for the above test panels.

The panels originally prepared by Barstow were done as part of the ESTCP application Dem/Val conducted at that site. The panels were partially stripped at Barstow, but were retained for stripping with another Type V media process (OO-ALC was the original site for the SERDP Type V media process testing) since the Barstow Type V process was at best, only similar to the original Type V process tested.

The OO-ALC prepared Dem/Val panels were stripped with a process based on Quickstrip™ media, which is a combination of plastic and glass oxide. This is a new process in regard to this study since there are no baseline data associated with this process. However, this is the current process used by OO-

ALC for the stripping operations on parts which have CARC. It should also be noted that the oven aged panels were top coated with MIL-C-46168 (solvent borne CARC), and that all of the OO-ALC prepared panels include an intermediate coat (MIL-PRF-85285) between the primer and CARC. The primer for these panels was MIL-PRF-23377.

Table 18 -- Strip Rate Data for OO-ALC Dem/Val Steel Test Panels

Stripping Process	Mean Strip Rate for Oven Aged, ft^2/min	Mean Strip Rate for 5 Month Accelerated Aging, ft^2/min	Mean Strip Rate for 10 Month Accelerated Aging, ft^2/min
Quick Strip™	0.29 ± 0.09	0.26 ± 0.02	0.21 ± 0.03

Table 19 -- Data for Barstow Dem/Val Al Panels Stripped with OO-ALC Type V DMB Process

Stripping Process	Mean Strip Rate for Oven Aged, ft^2/min	Mean Strip Rate for 5 Month Accelerated Aging, ft^2/min	Mean Strip Rate for 10 Month Accelerated Aging, ft^2/min
Type V	0.03 ± 0.01	0.43 ± 0.17	0.47 ± 0.09

Table 20 -- DFTM for OO-ALC Dem/Val Strippability Test Materials

Stripping Process	Mean DFTM for Oven Aged Test Panels, mils*	Mean DFTM for 5 Month Accelerated Aged Test Panels, mils	Mean DFTM for 10 Month Accelerated Aged Test Panels, mils
Quick Strip™	13.74 ± 0.50	9.28 ± 0.24	9.43 ± 0.46
Type V	5.13 ± 0.27	5.33 ± 0.46	5.13 ± 0.14

* These panels were top coated with an older CARC, MIL-C-46168, which by the nature of this coating tends to be sprayed on in a thicker coating than the WD CARC.

Tobyhanna Army Depot

The TYAD Dem/Val strippability data are presented below in Tables 21 and 22. Figure 32 shows one of the test panels used in the strippability feasibility assessment for the TYAD chemical process. These data represent the stripping trial results for test panels prepared by TYAD as part of this ESTCP Dem/Val. The pretreat conditions are also given below to differentiate aluminum test panels that were given different pretreatment conditions.

Note that there are no Dem/Val strippability results for panels that were given 10-month accelerated aging since these panels were lost by the shipper when they were in the process of being returned to Southwest Research Institute (SwRI).

Table 21 -- DMB Strip Rate Data Developed for TYAD Dem/Val Aluminum and Steel Test Panels

Stripping Process	Pretreatment	Mean Strip Rate for Oven Aged, ft^2/min	Mean Strip Rate for 5 Month Accelerated Aging, ft^2/min
Zirconia-Alumina	Chromate Conversion	0.39 ± 0.05	0.26 ± 0.02
Zirconia-Alumina	Wash Primer	n/a	0.38 ± 0.13
SS Shot	zinc phosphate	8.43 + 1.85	6.29 + 1.32

Table 22 -- Chemical Stripping Data for TYAD Dem/Val Test Panels

Panel #	Conditioning	Substrate	Pretreatment	Elapsed Time, Hours	Average Time, hours
102	Oven	1010 Steel	Zinc phosphate	≤ 55	53
104	Oven	1010 Steel	Zinc phosphate	≤ 55	
112	Oven	1010 Steel	Zinc phosphate	≤ 48	
105	Q5*	1010 Steel	Zinc phosphate	≤ 24	24
110	Q5	1010 Steel	Zinc phosphate	≤ 24	
115	Q5	1010 Steel	Zinc phosphate	≤ 24	
18	Q5	2024-T3	Wash Prime	≤ 24	32
20	Q5	2024-T3	Wash Prime	≤ 48	
21	Q5	2024-T3	Wash Prime	≤ 24	

* Panels given 5-month accelerated aging.

Please note that the chemical stripping data presented for each panel show the approximate elapsed time for stripping. The panels were not monitored sufficiently to determine a precise time for acceptable stripping for each panel.

Figure 32 -- Chemical Strippability -- Nearly Complete Removal with TYAD Chemical Process

3.6.6.4.2 Production DMB Strippability Results

Production strippability data were developed for several DoD maintenance operations. These production data were intended to provide some type of baseline data for comparison with Dem/Val strippability data to determine whether or not the Dem/Val strip rates fell within some "normal" production range. These data, and the sites at which the data were developed, are presented in the following sections. Whenever available, photographs of the parts stripped in the production DMB strippability data are also provided below.

Barstow MCLB

The production baseline strip rate data were developed for as many parts as time and workload would allow at the time of the visit to this site. The substrate materials varied by process, and tended to be matched to the relative aggressiveness of the individual processes. Parts stripped in the Type V glovebox are typically lighter alloy and/or composite materials and use less aggressive process parameters (see Paragraph 3.6.5.4). Parts stripped by the steel grit process are typically small, sheet metal type of applications. The stripping done in the larger scale Type V operation usually consists of larger parts with more robust substrate materials. The stripping is done with this process, rather than the garnet media process to preserve pretreat conditions such as zinc-oxide coatings. The garnet media process is the most aggressive, and due to that nature of the process typical applications are on heavier steel components.

Whenever possible, dry film thickness measurements (DFTM) were made to help characterize the coating system to be stripped. It was not possible to accurately determine the coating system that was stripped in these operations. The identification of the parts stripped during this effort are simply descriptive, and do not necessarily represent the correct nomenclature for these parts. Strip rate and DFTM data are presented below for individual parts in Tables 23, 24 and 25.

Table 23 -- Strip Rate Data for Barstow Type V Production DMB Processes

DMB Stripping Process	Part Stripped	Mean DFTM, mils	Strip Rate per Part, ft^2/min
Type V (glovebox)	Column Housing - #1	9.2 ± 4.2	0.24
	Column Housing - #2	9.0 + 1.7	0.11
	Column Housing - #3	9.6 ± 3.7	0.14
	Column Housing - #4	9.2 ± 3.5	0.56
	Small Lid * - Inside Surface	n/a	1.02
	Small Lid - Outside Surface	n/a	1.01
	Large Lid/Tray	n/a	0.68
Type V (large booth)	Cylindrical Housing #1	6.2 ± 2.6	2.32
	Cylindrical Housing #2	5.0 ± 2.3	2.90
	Cylindrical Housing #3	6.2 ± 2.6	4.49
	Tie Rod #1	7.7 ± 1.2	1.08
	Tie Rod #2	6.6 ± 0.8	1.04
	Rail #1**	2.2 ± 0.4	5.67
	Rail #2	2.6 ± 0.5	6.49

* This was a composite material which, due to the instrumentation used for DFTM precluded obtaining any thickness measurements.
** The coating system on these both rail parts was in pretty poor condition. Much of the coating system was flaking off the substrate surface.

Table 24 -- Strip Rate Data for Barstow Steel Grit Production DMB Process

Part Stripped	Mean DFTM, mils	Strip Rate per Part, ft^2/min
Valve Cover – Top Surface	5.9 ± 0.6	0.45
Valve Cover – Side Surface	5.2 ± 0.7	0.31
Small Cover #1	4.9 ± 1.0	0.14
Small Cover #2	4.6 ± 0.7	0.10

Table 25 -- Strip Rate Data for Barstow Garnet Grit Production DMB Process

Part Stripped	Mean DFTM, mils	Strip Rate per Part, ft^2/min
Frame Member	13.6 ± 6.4	1.78
Bed/Ramp*	5.6 ± 1.2	7.20

* The coating system on this part appeared to be very weathered.

Ogden ALC

Limited production strip rate data were developed for both variations of the Quick Strip™ DMB process. A single data point was acquired for the standard Quick Strip™ process, and only three data points were acquired for the Quick Strip™ custom blend process. In the first instance, work was slowed down in that particular booth due to an impending inspection. The operations in the booth using the Quick Strip™ blend were stopped due to a media flow problem with the equipment.

The substrate materials varied by area of operation, and the relative aggressiveness of the individual processes were matched to the potential substrate damage of the equipment in the two areas. The Quick Strip™ process using the 843 blend was designed for coatings removal on communications and power generation equipment components that are typically made of thin aluminum or steel materials, while the other process is used for more robust applications, such as structures with steel substrate materials. Figures 33 and 34 below show the pieces of equipment stripped for this effort.

Whenever possible, dry film thickness measurements (DFTM) were made to help characterize the coating system to be stripped. It was not possible to accurately determine the coating system that was stripped in these operations. The identification of the parts stripped during this effort are simply descriptive, and do not necessarily represent the correct nomenclature for these parts. Strip rate and DFTM data are presented below in Table 26.

Table 26 -- DFTM and Production Strip Rate Data for OO-ALC Quickstrip™ DMB Processes

DMB Stripping Process	Part Stripped	Mean DFTM, mils	Strip Rate per Part, ft^2/min
Quickstrip™	Beam	3.6 ± 0.7	1.9
Custom Blend Quickstrip™	#1 Cover - Inside	2.7 ± 0.6	2.1
	#1 Cover - Outside	9.1 ± 0.6	0.6
	#2 Cover - Inside	3.0 ± 0.3	2.8
	#2 Cover - Outside	8.4 ± 1.9	1.9
	#3 Cover* – Inside	1.9 ± 0.2	3.4
	#3 Cover - Outside	2.9 ± 0.4	3.4

* The blast pressure used for this part was increased from 60 to 75 psi at the discretion of the blast technician to improve strip rate/production.

Figure 33 -- Beam Blasted in OO-ALC, Building 847 Blast Booth

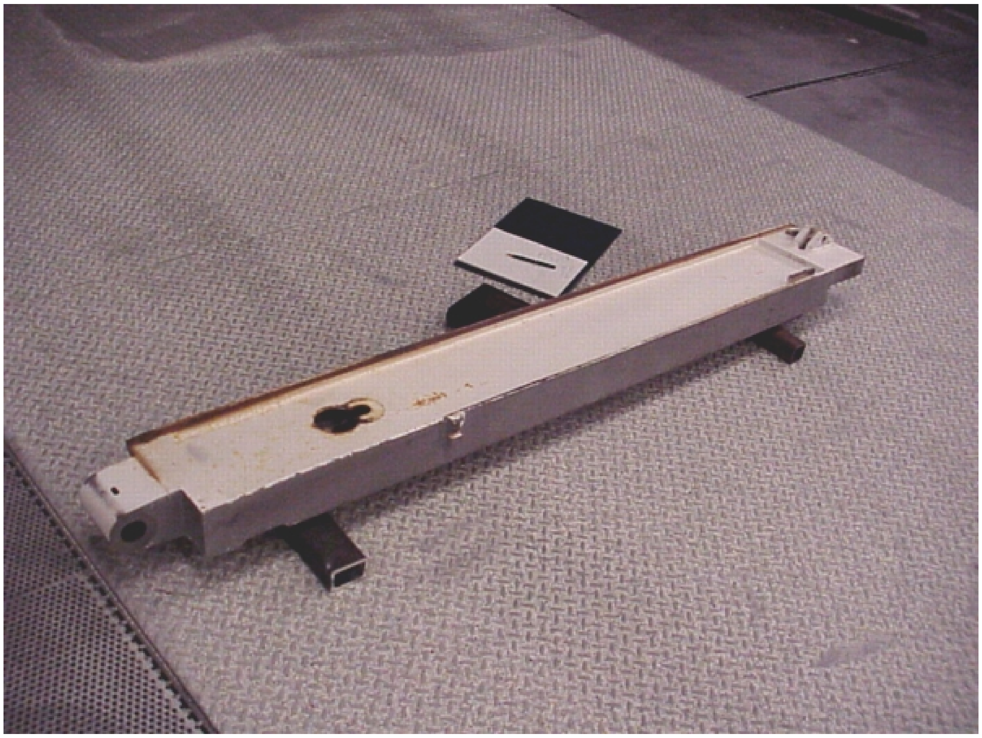


Figure 34 -- Covers Blasted in OO-ALC, Building 843 Blast Booth

Tobyhanna Army Depot

Production DMB baseline strippability data acquired from TYAD DMB processes were more comprehensive than data developed at the other sites that supported this particular effort. This is especially true for the zirconia-alumina process, since the stainless steel shot process yielded only single data points for two variations of the process. The most significant aspect of these data were that this was the one Dem/Val site that had relative consistency of the DMB process parameters for all phases of strippability testing conducted at this site. The strippability data for the individual parts, mean DFTM for the parts and DMB process used for stripping are tabulated below. Photographs showing some of the parts used for this study are seen in Figures 35 and 36.

Table 27 -- Strip Rate Data for TYAD Production DMB Processes

DMB Process	Part Stripped	Mean DFTM, mils	Strip Rate ft^2/min
Zirconia-Alumina	Communications Box w/Lid Top - #1	3.1 ± 0.1	0.91
	Communications Box w/Lid Bottom - #1	5.3 ± 0.1	0.54
	Communications Box w/Lid Top - #2	3.7 ± 0.3	0.66
	Communications Box w/Lid Bottom - #2	6.1 + 1.1	0.32
	Small Communications Box w/Mount - #1	5.1 ± 2.8	0.65
	Small Communications Box w/Mount - #2	8.1 ± 3.0	0.35
	Small Communications Box w/Mount - #3	5.0 ± 0.7	0.40
	Small Communications Box w/Mount - #4	5.5 ± 1.3	0.34
	Small Communications Box w/Mount - #5	6.7 ± 1.8	0.34
	Small Communications Box w/Mount - #6	4.3 ± 0.9	0.41
	Small Communications Box Lid - #1	1.9 ± 0.3	0.88
	Small Communications Box Lid - #2	3.7 ± 1.1	0.41
	Small Communications Box Lid - #3	7.2 ± 0.9	0.15
	Small Communications Box Lid - #4	2.7 ± 0.3	0.69
	Small Communications Box Lid - #5	5.6 ± 1.0	0.38
	Small Communications Box Lid - #6	5.1 ± 0.8	0.25
	Fan Housing - #1	3.9 ± 0.7	0.90
	Fan Housing - #2	3.1 ± 0.5	1.09
	Fan Housing - #3	3.8 ± 0.5	0.94
	Fan Housing - #4	3.6 ± 0.4	0.96
	Communications Box Cover	3.1 ± 0.1	0.87
SS Shot - 60psi	Utility Trailer - Front Surface	4.0 ± 0.8	1.0
	Utility Trailer - Rear Gate	3.7 ± 0.8	1.1
	Utility Trailer - Left Side Surface	4.2 ± 1.0	1.1
	Utility Trailer - Right Side Surface	4.9 ± 1.2	1.6
SS Shot - 100psi	Three Quarter Ton Cargo Trailer	14.1 ± 3.2	1.2

Figure 35 -- Communications Box with Lid used for Strippability Testing at TYAD

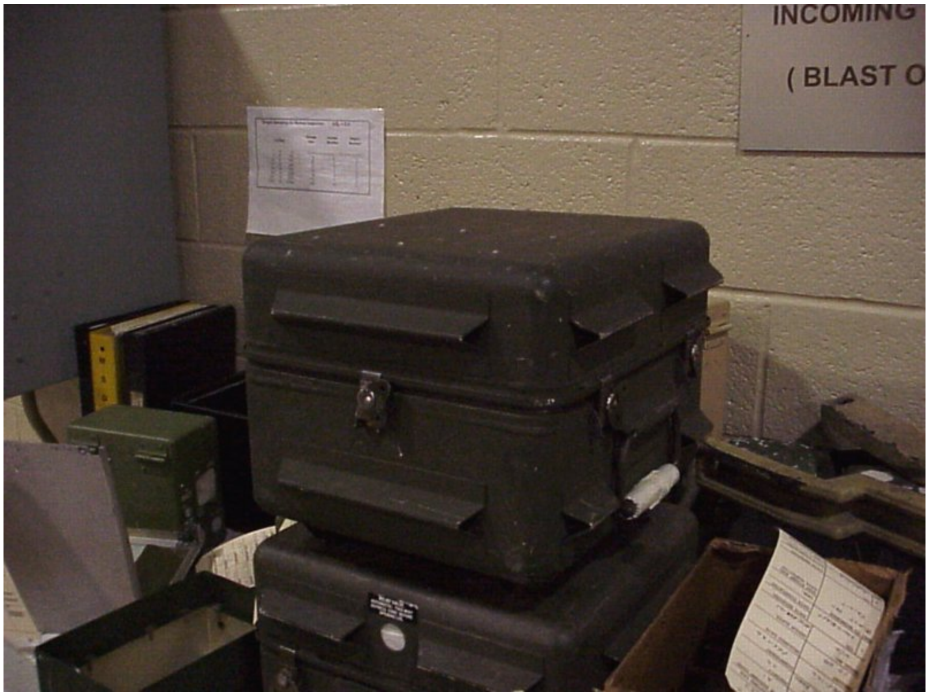


Figure 36 -- Small Communications Boxes with Wall Mounts

Albany MCLB

Production DMB data was acquired at Albany MCLB to provide additional data for impact assessment of the WD CARC. Albany uses a garnet media DMB process similar to that used by Barstow, and was included in this study to gain more comprehensive data for that generic process. The Type III plastic media DMB process currently in use at Albany does not have any historical data or counterpart in the other participating sites. Testing with this DMB process was conducted in order to get a better understanding of production capabilities associated with Albany operations.

Production DMB strippability data, with DFTM data for each part, are tabulated below. Figures 37 through 39 below show the parts stripped for this effort.

Table 28 -- DFTM and Production Strip Rate Data for Albany DMB Processes

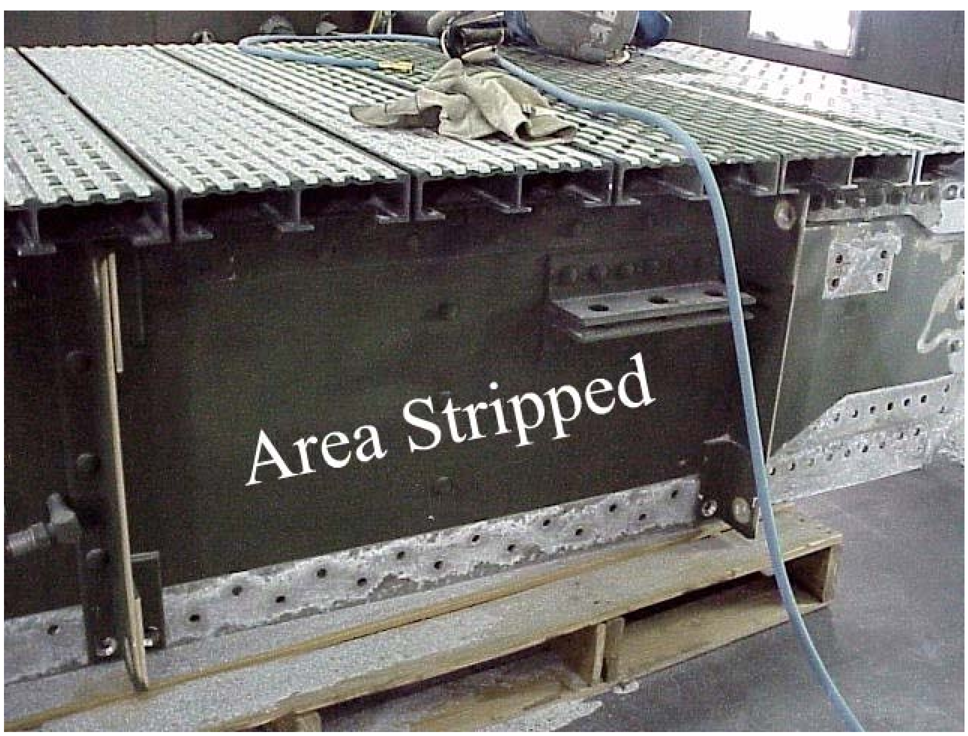
DMB Stripping Process	Part Stripped	Mean DFTM, mils	Strip Rate per Part, ft^2/min
Garnet	Tool Box Side #1	6.5 ± 2.9	2.3
	Tool Box Side #2	6.2 ± 3.0	1.2
	Tool Box Side #3	6.0 ± 2.8	2.2
	Tool Box Side #4	5.2 ± 1.9	1.4
	AAV Fenders*	5.0 ± 1.1	3.6
Type III	Army ‘Bridge’**	12.6 ± 2.8	0.6

* Strip rate given as combination for both fenders due to the manner they were stripped by the blast technician.
** Army nomenclature for this part as stenciled on the surface is “*Panel Assembly Center Female*”, and it was believed to be coated with MIL-C-46168

Figure 37 -- Marked Tool Boxes Stripped with Garnet DMB at Albany MCLB

Figure 38 -- AAV Fenders Prior to Stripping with Garnet DMB at Albany MCLB

Figure 39 -- Area of 'Bridge' Section Stripped with Type III DMB Process at Albany MCLB



3.6.6.4.3 Supplementary DMB Strippability Results

The supplementary strippability assessments were conducted with the purpose of developing additional data to provide better correlation with previous testing, and, in one case, to provide data to determine if WD CARC strippability might be dependent on the formulator of the WD CARC.

Ogden ALC

Test panels that were surplus from the original SERDP study were included in these stripping trials to provide additional data for comparison with the formulation of CARC used originally with the formulation used in this study since the OO-ALC Type V DMB process was used in the original assessment. These surplus panels had not been given any type of artificial aging, and these aluminum panels were chromate conversion treated IAW T.O. 1-1-8. Data for these panels are tabulated below.

Table 29 -- Strip Rate Data for Surplus SERDP Panels with OO-ALC Type V DMB Process

DMB Process	Primer	Topcoat	Mean DFTM for Test Panels, mils	Mean Strip Rate, ft^2/min
Type V	MIL-P-23377	WD CARC	2.99 ± 0.30	1.86 ± 0.53
Type V	MIL-P-53022	WD CARC	3.14 ± 0.34	0.86 ± 0.71

Tobyhanna Army Depot

The data presented below in Table 30 are for test materials prepared earlier by the Coatings Technology Integration Office (CTIO) for the original SERDP study. The inclusion of the panels prepared earlier was done to develop additional data that might be compared to strippability data from the previous study. These aluminum panels were chromate conversion treated IAW T.O. 1-1-8

Table 30 -- Strip Rate Data for Surplus SERDP Panels with TYAD Zirconia-Alumina DMB Process

DMB Process	Primer	Topcoat	Mean DFTM for Test Panels, mils	Mean Strip Rate, ft^2/min
Zirconia-Alumina	MIL-P-23377	WD CARC	2.95 ± 0.38	0.99 ± 0.28
Zirconia-Alumina	MIL-P-53022	WD CARC	3.07 ± 0.32	0.73 ± 0.24

Albany MCLB

Table 31 presents data developed by strippability tests done with a Type II Plastic DMB process which is comparable to the process used at this site for the SERDP study. The test panels were surplus Dem/Val panels had been prepared during the TYAD applications Dem/Val. Table 32 presents strippability data based on the current Albany Type III Plastic DMB process with test panels that were surplus from the SERDP study. Table 33 presents the data developed for two different formulations of the WD CARC topcoat. These panels were coated by Albany using two different methods (normal spray application and application with multiple component spray equipment). These panels also differ from test panels prepared for the strippability Dem/Val test materials in that the primer used by Albany is MIL-P-53022, which is one of the primers used in the previous study.

Table 31 -- Strip Rate Data for Surplus Dem/Val Panels with Albany MCLB Type II Plastic DMB Process

Substrate	Primer	Topcoat	Mean DFTM for Test Panels, mils	Mean Strip Rate, ft^2/min
1010 Steel	MIL-P-53030	WD CARC	2.49 ± 0.32	0.90 ± 0.13
2024-T3 Aluminum	MIL-P-53030	WD CARC	3.41 ± 1.76	1.08 ± 0.22

Table 32 -- Strip Rate Data for Surplus SERDP Panels with Albany MCLB Type II Plastic DMB Process

Substrate	Primer	Topcoat	Mean DFTM for Test Panels, mils	Mean Strip Rate, ft^2/min
1010 Steel	MIL-P-53022	WD CARC	2.49 ± 0.32	0.69 ± 0.08
2024-T3 Aluminum	MIL-P-53022	WD CARC	3.41 ± 1.76	1.76 ± 0.19
2024-T3 Aluminum	MIL-P-23377	WD CARC	3.41 ± 1.76	4.23 ± 0.66

Table 33 -- Strip Rate Data for Application and Formulation Variations with Albany MCLB Type III Plastic DMB Process

Formulator	Substrate	Application Method	Mean DFTM for Test Panels, mils	Mean Strip Rate, ft^2/min
Hentzen	Aluminum	Plural Component-HVLP*	5.62 ± 0.09	1.74 ± 0.58
Sherwin-Williams	Aluminum	Plural Component-HVLP	3.02 ± 0.11	2.53 ± 0.94
Hentzen	Steel	Normal-HVLP**	2.36 ± 0.36	1.03 ± 0.09
Sherwin-Williams	Steel	Normal-HVLP	1.51 ± 0.17	1.16 ± 0.07

* Special equipment that mixes the coatings components with the system just prior to spraying.

** Coatings applications are normally done by application with high volume low pressure spray guns with the coatings components already mixed.

3.3.6.6.4 Strippability Discussions

The results of this study were developed primarily from some form of dry media blasting (DMB), and the various processes used to develop these data represented a range of aggressiveness. DMB processes based on media such as steel shot and/or garnet are used for the more robust applications. DMB processes using plastic media and/or media blends are used for applications where the substrate tends to be more susceptible to blast induced damage. As has been noted previously, limited chemical stripping trials were also conducted at the request of two of the Dem/Val participating sites. The results for all stripping processes and associated sites documented above are summarized in Table 34, followed by discussions of these results.

Table 34 -- Summary of Dem/Val Strippability Testing by Site and Process

Facility	Process ID	Description/Basic Component	Remove WD CARC, Yes/No	Comments
Barstow MCLB	Garnet	Garnet Media	Yes	Low end of production rate
	Steel Grit	Steel Grit Media	Yes	Comparable to production rates
	Type V	Acrylic	Yes	Oven aged panels much slower to strip
	Chemical	Sodium Hydroxide/Sodium Gluconate	*Limited*	Normally effective only with old or damaged coatings
Ogden ALC	Quickstrip™	Amino Thermoset plastic/Glass	Yes	Lower than production rates where a comparison was possible
	Quickstrip™ 843*	Amino Thermoset plastic/Glass	Not Tested	Dem/Val rates substantially lower than production rates
	Type V**	Acrylic	Yes	Results comparable to results from a similar process at Barstow
Tobyhanna AD	Zirconia Alumina	Zirconia Alumina Media	Yes	Low range of production rates
	Stainless Steel Shot	Stainless Steel Shot Media	Yes	Higher than production rates
	Chemical	Turco 6776 (Benzyl-alcohol)	Yes	Longer strip times due to better condition of panels
Albany MCLB*	Garnet	Garnet Media	Yes***	Comparable to rates developed at Barstow
	Type II	Urea	Yes	Production strip rates measured lower than SERDP testing
	Type III	Melamine	Yes	Hentzen formulation had ostensibly lower strip rates than the Sherwin-Williams

* Process not tested as part of the original ESTCP Strippability Dem/Val.
** Normally an aircraft depaint process not used for removal of CARC systems at this maintenance operation.
*** Based on test results from the earlier SERDP study

Barstow MCLB

Garnet DMB - Testing with materials prepared in this project (with MIL-P-53030) produced lower strip rates than those produced in the previous study using the WD CARC, and stripped with a similar DMB process. A comparison of test data with production data for this site indicate that the strip rates are at the low end of the range for the production data, but are within that range.

Steel Grit DMB - There were no strippability data developed for this DMB process in the earlier study. Test data compare very well with production data.

Type V (acrylic) DMB - There were no strippability data developed in the earlier study for comparison with the variation of the Type V DMB process used at Barstow for the prepared test materials. Production data from the test Type V process and from a larger scale (more aggressive parameters) Type V process do not compare well with any previous data since the parameters for either process are very different than those from the earlier study. A comparison of the test data and the production data with the same process indicates that the strip rates seen from materials that underwent outdoor conditioning compare quite well. Strip rates for materials conditioned by a heating method fell well below production rates.

Chemical - The strippability of the Dem/Val test panels were considered fairly typical in that full stripping was limited. The normal expectation for Barstow with this process is for stripping of the coating system to be accomplished only with very old and/or damaged coatings systems.

Ogden ALC

Quickstrip™ (blend of different media) DMB - The Quickstrip™ process used at OO-ALC is another DMB process that was not tested in the earlier study. Data were acquired for two variations of DMB processes based on the Quickstrip™ media, i.e., a difference in the composition of the media blend to produce a slightly less aggressive mixture. The test materials used for the Dem/Val were prepared at OO-ALC and strippability data were acquired with the more aggressive variation. The strip rates determined for these trials were substantially below the strip rates acquired for production coatings removal. It should be noted that the production data were very limited.

Type V (acrylic) DMB - The strippability testing done with this DMB process was not part of the planned Dem/Val effort. The strippability testing was done with surplus materials from the earlier study, and materials that were also used for testing at Barstow. The strip rates seen with the test materials also used at Barstow were generally higher than those developed at Barstow, but were lower than any strip rates acquired earlier with this process and any coating system used in the earlier study. The surplus materials from the earlier study produced strip rates comparable to the earlier study with WD CARC and MIL-P-53022 primer. The strip rates determined for WD CARC and MIL-P-23377 primer system were lower than those developed with a similar coating system. The test materials that were surplus from the earlier study had not been given any type of conditioning, and what affect this conceivably could have on strippability is not known.

Tobyhanna Army Depot

Zirconia-Alumina DMB - Dem/Val and production strippability data were developed with this process. This process was also used for strippability assessments in the previous study. Strip rate data for the

Dem/Val test materials are clearly lower than strip rate data developed previously. Strip rate data for surplus panels from the previous study, and stripped with the same process, match strip rate data from the earlier study. A comparison of the Dem/Val strip rate data with production strip rate data indicates that, while at the low portion of the production range, these rates are well within the range developed during this effort.

Stainless Steel Shot DMB - Dem/Val and production strippability data were developed with this process. This process was also used for strippability assessments in the previous study. Strip rate data for the Dem/Val test materials were higher than those from the previous study, and higher than the production strip rates acquired at this time.

Chemical - The strippability of the test materials used in this Dem/Val effort is generally within an acceptable range, or expected dwell period. The panels that were outside this range were prepared in a manner that might not be considered typical to parts stripped with this process, i.e., heat/oven treated coating system. It is also worth noting that all of the test panels had coatings systems that were in much better condition than is typical to this maintenance operation, which may have contributed to the longer dwell period for the oven treated panels. It should also be noted that longer dwell periods, while not necessarily desirable, are not unusual with this process, and that all of the panels were stripped eventually.

Albany MCLB

Garnet DMB - The strippability data acquired for this process were for production operations only. These data, when compared to data from a similar process used at Barstow, were quite similar. The strip rates measured at Albany were within the range of those obtained at Barstow.

Type II (urea) DMB - The Albany Type II DMB process was a process tested at this site during the earlier study. Surplus Dem/Val test materials were tested at this time for comparison with previous strippability data. The strip rate data developed with these test materials were lower than most of the strip rates measured from the earlier study, which were based on somewhat different coating systems.

Type III (melamine) DMB - Albany is currently using a Type III DMB process instead of the Type II process tested previously. The Type III media is slightly harder than the Type II and is considered a slightly more aggressive media. Three sets of panels were tested with this process. Two of the sets were comprised of panels that were coated with one of two different formulations of the WD CARC. The other significant difference in these sets was the method of application of the WD CARC and subsequent conditioning. One set was prepared and coated by typical Albany procedures, and this set underwent elevated temperature conditioning. The other set had no conditioning other than storage at room temperature, and the WD CARC was applied with a special, multiple component spray unit. The strip rates for the different formulations exhibited strippability differences for both sets. The test materials with the Hentzen formulation, manufacturer of the WD CARC used in the SERDP study, had lower strip rates than the materials with the Sherwin-Williams formulation for both sets.

However, the concern that prompted this particular assessment were the apparently lower strip rates of the Dem/Val test materials, which were coated with a Sherwin-Williams formulation of the WD CARC topcoat. The strip rates developed with the steel test panels do exhibit a statistically significant difference between the formulations, based on a Students T-test conducted at a 90% confidence level, but it is reasonable to say that the difference is not necessarily significant in a realistic sense. This is due to the fact that the difference is not very large, and that the coating thickness of the Hentzen coated panels is substantially higher. This difference in coating thickness is even more significant with the aluminum test materials, and would be expected to make the coating system more difficult to remove with this type of DMB process. The larger thickness differences between the test materials coated with the two formulations tend to weaken any arguments that the strippability differences are strictly due to formulation differences. These data do not support the hypothesis that the reduced Dem/Val strippability might be attributed to differences in coatings formulations.

The third set of panels was a mixture of substrate and primers that were associated with test panels from the previous study. The strip rates from this set of panels were either very comparable to, or higher than the previous SERDP strip rates.

3.6.7 Demobilization

Demobilization was not applicable to this effort, because standard production equipment was used for all of the application and stripping demonstrations. The only change to any of the processes (application and stripping) was that the coating applied or removed was WD CARC rather than the CARC topcoat normally used.

3.7 Selection of Analytical/Testing Methods

As noted in 3.6.6 above, testing was performed on panels coated with the WD CARC prepared during the application demonstrations at all three locations. The tests performed on the panels were drawn from MIL-C-53072, Chemical Agent Resistant Coating (CARC) System Application Procedures and Quality Control Inspection, for performance related specifically to CARC, and from a variety of sources such as ASTM for general coating performance evaluation. They are summarized in the Common Test Descriptions found in Appendix B. In addition, the Field Trial Application Survey, also found in Appendix B, was used to gather the painters' assessment of the applicability of the WD CARC, especially as compared to the standard CARC they normally applied.

3.8 Selection of Analytical/Testing Laboratory

Panel testing and the result evaluation processes were distributed according to the responsibilities and/or capabilities of the participating activities; i.e., since the Army was responsible for the formulation portion of the effort, it handled the survivability testing, such as chemical agent resistance, DS2 resistance, and resistance to color change (outdoor durability). The Navy, responsible for the application portion of the effort, performed the tests related to the coating and characterization of the film properties. The Air Force, responsible for the stripping portion of the effort, had the test panels aged and organized the subsequent stripping tests. Except for the use of the Q-Lab Weathering

Research Service Facility in Arizona for the accelerated outdoor weathering process, all testing in this program was performed by the participating activities.

4. Performance Assessment

4.1 Performance Criteria

Table 35 -- Performance Criteria

Performance Criteria	Description	Primary or Secondary
Product Testing	The tests are found in the Common Test Descriptions found in Appendix B. ASTM methods include D 2244, D523, G 155, G 154, D 4541, D2797, and D 522.	*Primary*
Hazardous Materials	The HAPs eliminated include methyl isobutyl ketone, methyl isoamyl ketone, toluene, xylene and butyl acetate. The WD CARC contains no HAPs, and the VOC content is half the standard CARC. No known hazardous materials are introduced with this technology.	*Primary*
Process Waste	The process waste generated by this technology is similar to any coating operation (e.g., equipment cleanup and overspray). Since the HAPs in WD CARC are volatile, no real differences are anticipated.	*Secondary*
Factors Affecting Technology Performance	The only significant differences observed during the application and stripping demonstrations were the slightly more complex mixing and slower drying of the WD CARC. In addition, the choice of primer may affect the stripping rate of the system.	*Secondary*
Reliability	No issues	*Secondary*
Ease of Use	Painters had no problem with the mixing procedure, which was similar to that used in preparation of MIL-C_46168. They quickly learned how to adjust their application technique from standard CARC to WD CARC. There were no issues with stripping.	*Primary*
Versatility	The WD CARC should be a "drop in" product at any facility currently spraying CARC	*Secondary*
Maintenance	No issues.	*Primary*
Scale-Up Constraints	No issues	*Secondary*

Since the demonstrations were designed to show the "drop in" nature of the WD CARC, the performance criteria were established to verify this. In addition, reduction or elimination of pollutants was important. The WD CARC has half of the VOC content of the standard CARC, and contains no HAPs, thus eliminating the methyl isobutyl ketone, methyl isoamyl ketone, toluene, xylene and butyl acetate found in standard CARC. Because the applied film of paint, whether WD CARC or standard CARC, contains no lead or hexavalent Chromium, issues associated with stripping residues were comparable. In summary, the major benefits of the switch to WD CARC are that it is a direct HAP-free substitute that performs better at a much reduced VOC emission level.

4.2 Performance Confirmation Methods

As the demonstration plan indicated, the process to validate the effort was to confirm performance of the coating by showing it could be applied without change to production equipment or process parameters, testing panels prepared in the application demonstrations, and verifying that stripping the WD CARC would not affect normal production processes. That is, panels, as described in the Field Trial Panel Matrix (Appendix B) were tested by the NSWC, ARL, and AFRL. Panels, which are identified in the Field Trial Panel Matrix (Appendix B) as "Air Force Test Panels", were subjected to an Accelerated Outdoor Exposure (ASTM D 4141, Procedure C) for a ten-month period prior to conducting the stripping demonstration. This resulted in a condition which is approximately equivalent to four years of natural outdoor exposure. The stripping trials were conducted by Ogden ALC personnel under the direction of personnel of the AFRL at Wright Patterson Air Force Base, OH. The protocol for the stripping trials was provided by Air Force team member personnel prior to performing the stripping operations. Then, the data from the panels tested during the ESTCP demonstrations was compared to data generated, via the same tests, under the SERDP effort. Performance levels were determined by comparing the results from ESTCP testing with the average and standard deviations observed in the SERDP testing. The statistical comparison allowed for detection of statistically significant differences in the results. Tests identified in current specifications were used to determine "pass/fail" status, while those not listed in specifications were assessed qualitatively (e.g. worse, same, better than SERDP results). The following table summarizes the results.

Table 36 -- Expected Performance and Performance Confirmation Methods

Performance Criteria	Expected Performance Metric (pre demo)	Performance Confirmation Method	Actual Performance (post demo)
PRIMARY CRITERIA (Performance Objectives) (Quantitative)			
Product Testing			
- Color	IAW MIL-C-46168	ASTM D 2244	Acceptable
- Gloss at 60 and 85 degrees	IAW MIL-C-46168	ASTM D 523	Acceptable
- Chemical agent resistance	IAW MIL-C-46168	¶ 4.4.25	Acceptable
- DS2 resistance	IAW MIL-C-46168	¶ 4.4.24	Acceptable
- Flexibility	IAW MIL-C-46168	ASTM D 522	Acceptable
- Accelerated Weathering	IAW MIL-C-46168	ASTM G154/155	Acceptable
- Impact resistance	None	ASTM D 2794	Acceptable
- Tensile adhesion	None	ASTM D 4541	Acceptable
- Abrasion resistance	None	ASTM D 4060	Acceptable
- DMTA	None	None	Acceptable
Hazardous Materials - Target Hazardous Material Eliminated/Reduced	Eliminate HAPS Reduce VOCs by 50%	Lab Analysis Lab Analysis	Acceptable Acceptable
- Generated	None	Lab Analysis	Acceptable
Process Waste -Generated	None	Operating experience	Acceptable
Factors Affecting Performance (Pollution Prevention)	No change from standard CARC	Operating experience	Acceptable
PRIMARY CRITERIA (Performance Objectives) (Qualitative)			
Better durability of part/component	More flexible	ASTM D 522	Acceptable
	More durable	ASTM G154 & ASTM G155	Acceptable Acceptable
Drop In Replacement	No change from standard CARC	Operating experience	Acceptable
Ease of Use	No operator training required	Operating experience	Acceptable
SECONDARY PERFORMANCE CRITERIA (Qualitative)			
Reliability	No breakdowns	Record keeping	
Safety - hazards - protective clothing	No change from standard CARC	Operating experience	Acceptable
Versatility -other applications	Yes, by any facility currently using standard CARC	Operating experience	Currently in use by USMC and Canada military
Maintenance -required -eliminated	No change from standard CARC	Operating experience	Acceptable

Scale-Up Constraints -engineering -flow rate	No change from standard CARC	Operating experience	Acceptable

4.3 Data Analysis, Interpretation and Evaluation

While direct comparison of the ESTCP stripping demonstrations to the baseline data developed in the SERDP effort were in many cases not possible due to process differences and different primers, the data from the application demonstrations was positive. The overall results indicate that the WD CARC has been confirmed to be a suitable replacement for standard CARC with minimal disruptions to the production process. In addition, it offers the benefits of reduced pollution and vastly improved performance.

Barstow MCLB

The application of the WD CARC on the four vehicles at MCLB Barstow demonstrated the "drop-in" nature of the WD CARC system. The WD CARC was applied to the vehicles with similar application performance compared to the standard CARCs. The surveys completed by the depot applicators at MCLB Barstow indicated that the WD CARC was considered overall to be a better coating than both MIL-C-46168D and MIL-C-29475. In addition, the laboratory testing completed on the coated panels resulted in similar test results to the SERDP program testing of the baseline WD CARC.

The DFT values obtained on the vehicles indicated that in order to obtain the proper film build, it is necessary to use a lower water concentration mix ratio (2:1:0.5). Therefore, it is recommended that the WD CARC be mixed at 2 parts A: 1 part B: 0.5 part water, providing environmental conditions and equipment allow. Any increase in the amount of water should be made in small increments to avoid unnecessary recoating.

The cost analysis indicated that the WD CARC is similar to the MIL-C-46168D based on paint material costs, coverage, and life cycle. When the expected durability based on critical laboratory performance data are considered, the cost analysis indicates that the WD CARC is superior to MIL-C-46168D and MIL-C-29475. The economic benefit of WD CARC should be realized, in comparison to MIL-C-53039, as full production and widespread implementation of the WD CARC material is accomplished. After taking into account the environmental cost benefits, the WD CARC is lucidly shown to be the most cost efficient and thus the most prudent option

Ogden ALC

The application of the WD CARC on the four MEP units at Ogden ALC demonstrated the "drop-in" nature of the WD CARC system. The WD CARC was applied to the vehicles with similar application performance compared to the standard CARC topcoats. The surveys completed by the depot applicators at Ogden ALC indicated that the WD CARC was considered overall to be a better coating than the current MIL-C-46168D solvent borne CARC though they did not like the additional mixing step. In addition, the laboratory testing completed on the coated panels resulted in similar test results to the SERDP program testing of the baseline WD CARC.

The cost analysis indicated that the WD CARC is similar to the MIL-C-46168D based on paint material costs, coverage, and life cycle. When the expected durability based on critical laboratory performance data are considered, the cost analysis indicates that the WD CARC is superior to MIL-C-46168D. The economic benefit of WD CARC should be realized as full production and widespread implementation of the WD CARC material is accomplished. After taking into account the environmental cost benefits, the WD CARC is lucidly shown to be the most cost efficient and thus the most prudent option. These conclusions are consistent with the other Dem/Val results[(6)].

As discussed earlier, as the project was progressing, the CARC workload at Ogden ALC was in the process of being transferred to new facilities in Building 843. These include two paint booths, one large and one small, and a Clemco dry media blast booth. These facilities will be conducting the CARC work at Ogden ALC. Based on the results of this demonstration/validation project, the WD CARC will also work as the best coating option economically and environmentally.

Tobyhanna Army Depot

The application of the WD CARC to the variety of military hardware at Tobyhanna Army Depot demonstrated the “drop-in” nature of the WD CARC system. The WD CARC was a production batch manufactured by the Sherwin-Williams Company, and it was applied using standard production equipment under normal environmental conditions. Surveys completed by the depot applicators indicated that the WD CARC was considered overall to be a better coating than the MIL-C-53039 normally used. In addition, laboratory testing completed on the coated panels indicates similar test results to the SERDP program testing of the baseline WD CARC. This improved performance in outdoor durability should lengthen the time between refinishing, and the improved mar resistance and flexibility should mitigate surface damage due to abrasion and result in less refinishing of military equipment on the basis of cosmetic appearance.

Stripping (All sites)

While the data developed by this study are informative, unfortunately these data are not really sufficient for support of firm conclusions. Comparisons to production data are also limited by the lack of comprehensive data, dissimilarities between the condition of the coatings systems on the production parts and the Dem/Val test materials, and the composition of the coatings systems on the production parts for which data were developed. The trends that may be cited on the basis of these data is that, in general, it appears that a coatings system comprised of the WD CARC topcoat and MIL-P-53030 primer will be a tough coating system to be removed with the processes assessed in this study. Furthermore, it is not possible to eliminate the possibility that the apparent impact on strippability is due primarily to that particular primer, and not necessarily due to the WD CARC. In most instances the strippability of this system falls within the production range defined by this study, but generally at the lower end of this range. This trend also seems to be more pronounced in association with the less aggressive DMB processes.

The data produced in this study comparing strippability of the processes tested in this study with similar processes used in the previous study tend to support the conclusions of the previous study. Based on the Dem/Val efforts of this study, within the limitations stated previously, the use of the WD CARC topcoat will not present a serious impact on the production operations that participated in this study.

5. Cost Assessment

5.1 Cost Reporting

Since the goal of this effort was to demonstrate that the WD CARC was a "drop in" replacement for the solvent based CARC used by the three participating activities, the cost reporting and assessment focused on the differences that were discovered that could be attributed to the change in coatings. Those differences consist mainly of trying to balance the current raw material cost differential (although the difference in cost per gallon is expected to diminish as the volume of WD CARC increases) against the exceptional performance improvement (and subsequent longer service life) that should drastically extend the repaint cycle. Due to the "drop-in" nature of the new technology, the startup costs were shown to be minimal, with only a brief, initial fine-tuning or practice session to enable the paint operators to perfect their technique and make adjustments (fluid fan width, fluid nozzle size, air line pressure, stand-off distance) prior to spraying equipment and panels. No additional equipment was needed for the new technology demonstrations. There were no observable differences due to application of WD CARC noted for process labor, maintenance, consumables, utilities and production rates, and costs for the new technology in the area of compliance and environmental management should be minimal due to the elimination of hazardous air pollutants from the formulation. Compliance audits, hazardous waste management plan development and maintenance, Toxics Release Inventory (TRI) reporting and Occupational Safety & Health Administration (OSHA) training requirements may be reduced after implementation. Examples based on two of the demonstrations are included in the next section.

5.2 Cost Analysis

Barstow MCLB

The cost of the WD CARC, along with data on the other topcoats approved for use on USMC tactical vehicles and support equipment, is shown in Table 37. The paint cost data was provided by the paint manufacturer (Sherwin Williams) that participated in this ESTCP sponsored demonstration. The amount of WD CARC and time required to apply this paint to the vehicles during this demonstration are shown in Table 38. Based on similar process variables, the amount of time and material required to paint a vehicle with MIL-C-29475 is essentially identical to that of WD CARC. Thus, application-related labor and the overhead/facilities costs do not have an effect on this analysis.

Table 37 -- Cost Analysis Based on Paint Materials Cost and Coverage

Product Name	Admixed (% Solids)	$/Gal (100 gal order)	Coverage 1 mil DFT (Sq Ft)	$/Sq Ft (@ 1 mil DFT)	$/Sq Ft (@1.8 mils DFT)	$/Sq Ft/Yr (@ 1.8 mils DFT)
MIL-DTL-64159, Type II	39.8	51.67	638.392	0.08094	0.14569	0.01619
MIL-C-46168D, Type IV	38.1	47.30	611.124	0.07740	0.13932	0.02322
MIL-C-53039	51	38.00	818.04	0.04645	0.08361	0.01394
MIL-C-29475	48.2	44.61	773.128	0.05770	0.10386	0.01731

Note: coverage data is based on 100% application transfer efficiency
Note: recommended DFT for all CARC is 1.8 mils (minimum)
Note: paint life cycle is based on the following data: 9 yr for 64159 Type II vs. 6 yr for others

Table 38 -- Cost Analysis Based on Painting Cost and Life Cycle Extension

Materiel	Prepare Surface (MH)	Paint (MH)	Labor cost ($)	Topcoat used (gal)	CARC topcoat cost @ ($40/gal)	Primer used (gal)	Primer cost @ ($25/gal)	Total Material cost ($)	TCOP ($/unit)	TCOP 480 units/ year ($M)	Cost Savings/ year ($M)
HMMWV	18	9	1890	10	400	3	75	475	2365	1.14	0.38
M-1 Tank	24	12	2520	13	520	4	100	620	3140	1.51	0.50
HEMMT	48	16	3780	17	125	5	125	805	4585	2.20	0.73

Note: Depot labor estimated at $70/hour (actual range $65 - $80)
Note: Depot processing rate estimated to be ~40 units per month per depot
Note: TCOP = Total cost of painting
Note: Cost savings based on 50% life cycle extension (ie 6yr to 9 yr)

Based solely on cost per gallon of the various paints for a 100 gallon order, these values range from $38.00 to $51.67 for the MIL-C-53039 and WD CARC, respectively. The cost per square foot at the recommended dry film thickness (1.8 mils) ranges from $0.08361 to $0.14569 for the MIL-C-53039 and WD CARC, respectively. Thus, assuming that a vehicle has a wetted surface of 1,000 square feet, it would cost $83.61 for the MIL-C-53039 versus $145.69 for the WD CARC based on the cost and the theoretical coverage characteristics of the paint. This does not reflect the reduced amount of paint required as documented at the other sites, primarily due to the equipment problems (oil contamination) noted in paragraph 3.6.5.1. The cost per square foot of MIL-C-29475 (the current standard topcoat used at MCLB Barstow) would obviously fall between that of the MIL-C-53039 and WD CARC.

The cost analysis above is more relevant to immediate or short term costs, while a long term or life cycle cost analysis would certainly take into account the durability or frequency of repainting required. Based on laboratory-generated data which indicates that superior weatherability (greater than 6 times exposure duration), abrasion resistance (~ 3 to 4 times less weight and thickness loss), and flexibility (~ 3 times impact resistance) of the WD CARC compared to the standard CARCs, it could be assumed that up to a 800% increase in life span can be obtained. While vehicle overhaul frequency is usually based on the requirements set by commanding officers and/or vehicle usage duration/mileage, it is estimated that these types of vehicles generally receive depot level repainting every 6 years. Using a conservative estimate that the durability enhancement offered by the WD CARC would produce a 50% increase in life span (instead of a liberal estimate of 800% based on laboratory data), the average vehicle repaint cycle would be increased from about six years for the standard system to nine years for the novel WD CARC system. As shown in Table 37, the cost per square foot per year of service for the WD CARC drops to a level that is less than both the MIL-C-46168 and the MIL-C-29475. It is important to note that while the data for the MIL-C-53039 material in this table indicates that the MIL-C-53039 CARC is the most cost effective, the price per gallon of the WD CARC is expected to decrease significantly with the full scale production and wide-spread implementation. This economic and manufacturing equilibration should negate and probably surpass the cost advantage currently held by the MIL-C-53039 material.

Other factors, not included in the above cost analysis, that would affect cost can be attributed to decreased VOC emissions, decreased waste generation, and increased worker safety. Cost avoidance in the form of fines from regulatory agencies up to $25,000 per day per facility (in certain environmental/process scenarios) can be realized by facilities that implement the low VOC WD CARC in lieu of using any of the higher VOC CARCs. Avoidance of the need to implement hard controls (i.e., thermal/catalytic/regenerative oxidizer, adsorption filter equipment, etc.), which can cost up to $5M per depot facility along with the associated operating costs which can be as high as $250,000 per year per facility can be attained with the implementation of this type of low VOC technology versus the higher VOC CARCs. Also, VOC credits can be generated from the reduction in tons of VOC emitted by a facility which vary in value from state to state with respect to ozone non-attainment areas.

CARC related paint and de-paint waste generation has been found to be approximately 3,000 tons per year in the DoD. Based on waste disposal costs of $0.35 per pound and extending life cycle from the current six year average to an estimated nine year average, approximately 1,000 tons and $700K for the entire DoD or about $70K per depot per year would be saved. Based on previously presented information which takes into account the total processing cost of painting three types of vehicles (Table 38), it is estimated that the total cost of painting (excluding cost of waste disposal discussed above) is $1.14 to $2.2M per year per facility. Thus a 50% increase in life cycle from six to nine years produces cost savings of $0.38 to $0.73M per year per facility depending on the type of vehicles repainted.

Ogden ALC

The paint and depaint facilities for applying CARC to the MEP units have been changed to Building 843. The facilities are state of the art for paint application and removal. However, the coating application and removal processes are the similar to those used in the Dem/Val effort. The Dem/Val results should apply for CARC application in the new facility.

Ogden ALC personnel estimate that once the Building 843 painting operations get working up to speed, they will be painting approximately 200 to 250 generator sets requiring CARC per year. This includes MEP-005A, MEP-006A, MEP-007B, and MEP-009B units. Additionally, Ogden ALC personnel support remote location paint jobs and unknown items that require CARC application. These are estimated to account for 25 to 40 items requiring CARC. Based on their experience, Ogden personnel estimate that it takes approximately one gallon of the solvent borne CARC to cover a MEP unit.

Based on a yearly requirement of 200 units plus an additional 25 remote location CARC coating jobs and other unknown units, there would be a requirement for 225gallon kits of CARC per year. Using a price of $47.30 per gallon kits of solvent borne CARC translates into a cost of $10,642.50 per year for use by Ogden ALC. Estimates from the suppliers of the low VOC WD CARC place the cost of gallon kits at $51.67 per kit. Based on the coverage exhibited during the Application Demonstration, where three gallons of the low VOC WD CARC were required to cover the four MEP units, similar coverage increases can be expected with implementation of the low VOC WD CARC by Ogden ALC. That would translate into a yearly usage of 150 gallons of low VOC WD CARC by the ALC. The yearly cost of using the low VOC WD CARC would be $7,750.50. Thus, Ogden ALC could save almost a third of its CARC costs by switching to the low VOC WD CARC. This analysis does not include improvements in weathering, wear-ability, and other mechanical property improvements demonstrated in laboratory testing by the low VOC WD CARC. These would lower the in service costs because of less touch ups between Programmed Depot Maintenance (PDM) cycles.

Other factors, not included in the above cost analysis, that would affect cost can be attributed to decreased VOC emissions, decreased waste generation, and increased worker safety. Cost avoidance in the form of fines from regulatory agencies up to $25,000 per day per facility (in certain environmental/process scenarios) can be realized by facilities that implement the low VOC WD CARC in lieu of using any of the higher VOC CARC. Avoidance of the need to implement hard controls (i.e., thermal/catalytic/regenerative oxidizer, adsorption filter equipment, etc.) can be attained with the implementation of this type of low VOC technology versus the higher VOC CARC materials. These controls can cost up to $5M per depot facility along with the associated operating costs, which can be as high as $250,000 per year per facility. In addition, VOC credits can be generated from the reduction in tons of VOC emitted by a facility that vary in value from state to state with respect to ozone non-attainment areas.

CARC related paint and depaint waste generation has been found to be approximately 3000 tons per year in the DoD. Based on waste disposal costs of $0.35 per pound and extending life cycle from the current 6 year average to an estimated 9 year average, approximately 1000 tons and $700K for the entire DoD or about $70K per depot per year would be saved. Based on previously presented information, it is estimated that the total cost of painting (excluding cost of waste disposal discussed above) is $1.14 to $2.2M per year per facility. Thus, a 50% increase in life cycle from 6 to 9 years produces cost savings of $0.38 to $0.73M per year per facility depending on the type of units repainted.

Since the WD CARC utilizes polymeric bead extenders in place of silica extender pigments (which are contained in all the other CARC topcoats), health-related ailments of maintenance workers exposed to air-borne silica (i.e., silicosis) would be avoided along with the associated costs related to health remediation and/or litigation. Utilization or realization of any of these environmental cost benefits individually and/or collectively would easily decrease the overall cost of the WD CARC to significantly less than the other standard CARC topcoats from a life cycle standpoint.

6. Implementation Issues

6.1 Environmental Permits

The Health and Safety and/or the Environmental Office at each demonstration facility examined pertinent data for the WD CARC, such as the technical data sheet and MSDS, prior to each application and stripping demonstration, and as anticipated, no changes to existing permits was indicated.

6.2 Other Regulatory Issues

The primary motivation for developing reduced-VOC protective coatings in general, and WD CARC in particular, has been the regulations evolving from the Clean Air Act and its amendments. As noted in paragraph 1.3 above, states and local governments can and often do set limits lower than those in the CAA. Although initial guidance from the U.S. Environmental Protection Agency (EPA) had indicated that the MMPP NESHAP would apply to CARC, at this point, it appears that DoD will have its own NESHAP entitled “Defense Land Systems and Miscellaneous Equipment” that will nonetheless still regulate HAP content of the protective coatings used for military equipment. Additional drivers, from a broader perspective, arise from Executive Orders, such as EO 11738, “Providing for administration of the Clean Air Act and the Federal Water Pollution Control Act with respect to Federal contracts, grants or loans,” EO 12856, “Federal Compliance With Right-to-Know Laws and Pollution Prevention Requirements,” and EO 13148, “Greening the Government Through Leadership in Environmental Management.”

6.3 End-User/Original Equipment Manufacturer (OEM) Issues

End users of this technology include Program Managers, OEMs and depots that are required to follow Army Regulation 750-1[(2)], which is also followed by the USMC, for chemical warfare survivability. This means that all tactical equipment (including combat, combat support, essential ground support equipment, tactical wheeled vehicles, and aircraft) must be hardened against performance degradation caused by chemical warfare agents or decontamination procedures. Therefore, virtually everything in the Army and Marine Corps inventory, plus Air Force vehicles and equipment procured through the Army requires agent resistance.

A new specification, MIL-DTL-64159 (dated 20 January 2002), was prepared and published shortly after the conclusion of this ESTCP Demonstration Project. This specification will provide a means of procurement of the new topcoat. The Qualified Products List (QPL) for the specification, QPL-64159 was first published 28 February 2002, and the current revision includes four suppliers. In addition, ARL has completed revision of the CARC quality control and application specification, MIL-DTL-53072C (formerly MIL-C-53072B), to incorporate MIL-DTL-64159. National Stock Numbers (NSNs) are available for four different kit sizes and they are included in MIL-DTL-53072C. Many facilities, both DoD and OEM, have indicated that they use MIL-DTL-53072 to implement CARC, and inclusion of MIL-DTL-64159 will facilitate use of the WD CARC technology.

As of the date of this report, the Army is moving quickly to implement this coating system. Army Personnel Armor System, Ground Troops (PASGT) helmets made by MSA Gallet employ this coating. Modifications to contracts are being enacted to permit PMs such as Bradley, Abrams, M113 Family of Vehicles (FOV), Heavy Expanded Mobility Tactical Truck (HEMTT), and Stryker to paint their vehicles with WD CARC in place of the existing solvent-based CARC (MIL-C-46168 and/or MIL-C-53039). Additional efforts are ongoing with the Army aviation community to use this coating for the Black Hawk helicopter and other aircraft. Sikorsky and Boeing are evaluating its use on the rotorcraft, which they manufacture. The USMC has fully implemented WD CARC at all of their facilities worldwide, including Albany MCLB, Barstow MCLB, Pearl Harbor Naval Shipyard, and the Okinawa USMC base. Typical Marine Corps assets now being painted with WD CARC include the LAV-AT, HMMWV, and AAAV. Finally, the Canadian department of defense is using this paint on a variety of their military vehicles as well

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8. Points of Contact

Point Of Contact	Organization	Phone/Fax/Email	Role in Project
Jeffrey Duncan	USARL AMSRL-WM-MA Building 4600, Deer Creek Loop APG, MD 21005-5069	Ph: 410-306-0690 FAX: 410-306-0676 Email: jduncan@arl.army.mil	Project Manager & PI
John Escarsega	USARL AMSRL-WM-MA Building 4600, Deer Creek Loop APG, MD 21005-5069	Ph: 410-306-0693 FAX: 410-306-0676 Email: jescarse@arl.army.mil	Co-PI
Lisa Weiser	NSWCCD-SSES Code 624 5001 S. Broad Street Philadelphia, PA 19112-5083	Ph: 215-897-1612 FAX: 215-897-8450 E-mail: weiserlm@nswccd.navy.mil	Co-PI
Anthony Eng	NSWCCD-SSES Code 624 5001 S. Broad Street Philadelphia, PA 19112-5083	Ph: 215-897-7937 FAX: 215-897-8450 E-mail: engat@nswccd.navy.mil	Co-PI
William Hoogsteden	AFRL/MLSSO Coatings Technology Integration Office B652 Rm. 122 2179 12th St WPAFB, OH 45433-7718	Ph: 937-656-4223 FAX: 937-255-0954 Email: William.Hoogsteden@ wpafb.af.mil	Co-PI
Charles Cundiff	SRI Coatings Technology Integration Office PO Box 7748 Warner Robins, GA 31095-7448	Ph: 478-929-9364 FAX: 478-929-9354 Email: Chuck.Cundiff@robins.af.mil	Contractor support to AFRL
Allan Schnur	Marine Corps Logistics Base (MCLB) Support Business Center Barstow, CA 92311-5001	Ph: 760-577-7297 FAX: 760-577-7294 E-mail: shnuraj@barstow.usmc.mil	Barstow demonstration site POC

Keith Womack	Ogden ALC 7563 Wardleigh Rd Bldg 847 Hill AFB, UT 84056-5734	Ph: 801-586-4148 FAX: 801-777-2894 E-mail: keith.womack@hill.af.mil	Ogden demonstration site POC
Patrick Tierney	Tobyhanna Army Depot 11 Hap Arnold Blvd., Tobyhanna, PA 18466-5002	Ph: 570-894-6724 FAX: 570-895-6539 E-mail: Patrick.Tierney@ tobyhanna.army.mil	Tobyhanna demonstration site POC
Mark Wytiaz	The Sherwin-Williams Company 549 E. 115th St. Chicago, IL 60628-5703	Ph: 773-821-3196 FAX: 773-821-3037 Email: mjwytiaz@sherwin.com	Industrial partner/paint supplier for demos

Appendix B: Analytical Methods Supporting the Experimental Design

COMMON TEST DESCRIPTIONS

This section describes the tests that will be performed by the Naval Surface Warfare Center, Carderock Division (NSWCCD) for validating the application of the water reducible chemical agent resistant coating (WRCARC) during the ESTCP demonstrations at a Marine Corps, an Army , and an Air Force facility. The validation will consist of three distinct evaluations: application, dynamic mechanical thermal analysis, and performance of the cured film. Each test description includes an objective, rationale, number of test samples and preparation, test method/equipment, and reportable results.

Application

Objective:
To validate the compatibility of existing industrial application processes with the WRCARC

Rationale:
The WRCARC was designed and formulated to be a "drop-in" substitute for the currently used coatings at USMC, Army, and AF facilities. Successful application with existing processes will ensure this "drop-in" feature.

Number of Test Samples and Preparation
For this evaluation, the number of samples is equal to the number of pieces of equipment being coated. Depending on the facility and availability of equipment this will be 3 – 5 pieces of equipment, plus additional panels for other validation testing (see DMTA and performance evaluations below).

Test Method/Equipment
The application evaluation focuses on the observation and documentation of the application, including application equipment, surface preparation, mixing of components, wet film thickness applied, environmental conditions, wet film surface appearance (e.g. sags, runs, pinholes, orange peel, or other surface defects). Additionally the entire chronology of the application process will be documented. To supplement this information, depot personnel will be provided a survey requesting their feedback on the effects of the WRCARC on the existing processes.

Reportable Results
The Marine Corps Experimental Coating Data Sheet is the application documentation form and the Field Trial Application Survey is the survey which will be distributed.

Dynamic Mechanical Thermal Analysis (DMTA) of Coatings

Objective:
To validate the mechanical properties and proper cure (via crosslink density) of the WRCARC via DMTA techniques

Rationale:

DMTA is being used to characterize the cure characteristics of the WRCARC coating. Properties determined via DMTA will include (1) glass transition temperature, (2) viscous and elastic modulus, and (3) crosslink density. All three properties will be determined (in whole or in part) by a DMTA procedure, known as Dynamic Temperature Ramp (DTR). Glass transition temperature (T_g) and modulus data will follow directly from DMTA testing (as per ASTM E 1640). Crosslink density (XLD) calculation will incorporate the DMTA data with the method of Hill[1].

Glass transition temperature as described by Hill[2] is a "unifying basic concept concerning the behavior of polymeric materials which help to systematize mechanical property data" and "it is difficult to overemphasize the importance of T_g in determining the mechanical properties of coatings." Glass transition temperature along with density have both been shown to be relevant and sensitive indicators of degradation, and both tend to increase when subjected to accelerated aging.[1 – 5] Nichols and Darr stated that the "majority of chemical changes that can occur in clearcoats during weathering produce polar groups [which] allows for increased hydrogen bonding in the polymer matrix giving rise […] to the often observed increase in T_g [and that] weathering progresses [and] chemical aging can also cause densification and occurs when the polymer undergoes chemical composition changes, due to degradation or continued curing, over the course of time."
Rodgers et al.[5] concluded that changes to T_g via water/acid absorption involve a non-reversible chemical reaction and that the onset T_g decreases as this exposure time increases.

Number of Test Samples and Preparation
Sample Preparation for Metallic Substrates.

- Metallic substrate shall have dimensions of 3″ × 6″ × 0.032″ .
- Substrate shall consist of 1010 cold rolled steel with zinc phosphate treatment per TT-C-490 Type I.
- No substrate preparation other than solvent wiping is necessary prior to painting.
- Prior to application of topcoat, test specimen shall consist of 8 unprimed panels and 8 primed panels @ 1-1.5 mils DFT with MIL-P-53022 or MIL-P-53030, or @ 2-5 mils DFT with MIL-P-23236 (i.e., Bar Rust 235) for a total of 16 test specimens.
  Note: primer shall be applied to one face of the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).
  Note: primer shall be allowed to dry until set to touch (usually 30 to 60 minutes) but shall not be allowed to dry for greater than 24 hours before application of topcoat.

Sample Preparation for Free Films

- Free films to be applied over PVF-coated Leneta paper, approximately 7″ × 11″, which will be pre-prepared and supplied to the depot.
- Prior to application of topcoat, test specimen shall consist of 2 unprimed PVF sheets and 2 primed PVF sheets @ 1-1.5 mils DFT with MIL-P-53022 or MIL-P-53030, or @ 2-5 mils DFT with MIL-P-23236 (i.e., Bar Rust 235) for a total of 16 test specimens

Note: primer shall be applied to one face of the test sheets in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).
Note: primer shall be allowed to dry until set to touch (usually 30 to 60 minutes) but shall not be allowed to dry for greater than 24 hours before application of topcoat.

Test Method/Equipment

DMTA Equipment

A Dynamic Mechanical Thermal Analyzer (DMTA) manufactured by Rheometric™ Scientific (Model DMTA IV) was used to determine modulus and glass transition data. The DMTA is a mechanical spectrometer that can measure stress-strain relationships of materials.

The Test Module provides mechanical deformation and environmental control to the test specimen. The Test Module thermal and mechanical behavior are controlled by an electronics unit, which also collects data during testing. Sub-ambient temperature control is achieved via a liquid nitrogen Cryogenic System.

Procedure

The DMTA is being used to characterize the coatings with respect to glass transition temperature (T_g), viscous modulus (E′), elastic modulus (E″), and crosslink density. By observing how E′ and E″ change with temperature (at a particular frequency), the region of glass transition is observed and a T_g determined. It is well known that during the glass transition of a polymeric material (coating), the ratio E″/ E′ —this is tanδ—increases, reaching a peak, then decreases. By definition, the temperature where tanδ is a maximum is the glass transition temperature (T_g).

The preliminary study included Dynamic Mechanical Thermal Analysis (DMTA) of pertinent primers, topcoats, and systems (primer with topcoat). These materials were studied as free films and over various substrates. To date, the majority of DMTA analysis has been focused on the determination of glass transition temperature (T_g) for the various primers, topcoats, and systems. A Dynamic Temperature Ramp (DTR) Test was used to determine T_g—this consists of ramping the temperature at a given rate, while measuring changes in the elastic and viscous moduli of the material. Most DTR tests were conducted at 2˚C/min or 5˚C/min; typically, higher ramp rates tend to shift T_g to a higher value.

Depending on the substrate, different test geometries were used to secure the test specimens. For free films and wire mesh substrates—which ideally contribute negligibly to the material modulus, and thus mimic a free film—a rectangular, tension orientation was used. For metallic (rigid) substrates, either a dual cantilever or three-point bending geometry was employed. In a dual cantilever set-up, the test specimen is pinned at both ends and in the center, while an oscillatory stress is applied to the sample center. In three-point bending, the specimen is not rigidly fastened during the application of stress to the sample center. A step-by-step procedure is given below.

1. Identify Sample Type: (1) Free Film, (2) coated wire mesh, or (3) metal substrate.

2. Determine the proper test configuration, based on substrate. For free films and wire-mesh substrates, a rectangular tension set up is used. When metallic (rigid) substrates are employed, three-point bending or dual cantilever geometries are chosen.

3. Based on the sample type, determine the clamping force required to mount the sample and the sample dimensions.

4. Load the sample using the appropriate test fixture.

5. Certain key parameters must now be established before the test is run. The DMTA unit is computer controlled, and Rheometric™ Scientific provides software for controlling the test conditions, and parameters. The test geometry and sample dimensions must be entered using the software.

6. Prior to running a DTR, the region of linear strain must be determined. This is accomplished by performing a **dynamic strain sweep** (DSS) test. A strain value from this linear region will then be used as a test parameter in the DTR test. Typical software settings for the DSS test are listed below.

Testing
1. Enter Test type ______ Strained-Controlled ___
2. Enter Measurement type ______ Dynamic ______

Select **Test setup**
1. Dynamic Strain Sweep test
2. Test Parameters
   a. Enter Frequency value ______ 1 Hz ______
   b. Enter Temperature value ______ desired temperature ___
   c. Enter Sweep Mode ______ logarithmic ______
   d. Enter Initial Strain ___ minimum (i.e., 0.01) ___
   e. Enter Final Strain ___ maximum (i.e., 0.5)
   f. Enter Point per Decade ______ 5 ______

3. **Options**
   a. Select Options
   b. Select Delay Before Test ______ 30 sec
   c. Auto Tension Adjustment
   d. Select Mode Static Force Tracking Dynamic Force
   e. Select Auto Tension Direction ______ Tension

f. Enter Initial Static Force value 100 g
g. Enter Static>Dynamic Force by value 15%
h. Enter Minimum Static Force value 1 g

7. Run the DSS and determine a strain value in the linear region.

8. Proceed to DTR (load a new sample for this test).

9. Enter test parameters for the DTR test.

Testing
1. Enter Test type Strained-Controlled
2. Enter Measurement type Dynamic

Select **Test setup**
1. Dynamic Temperature Ramp test
2. Edit Test
   a. Enter Frequency value 1 Hz
   b. Enter Initial Temperature value desired temperature
   c. Enter Final Temperature value desired temperature
   d. Enter Ramp Rate 2^{o}C/min
   e. Enter Soak Time after Ramp 10
   f. Enter Time per Measure 10
   g. Enter Strain linear strain value from DSS

3. Options
   a. Select Options
   b. Enter Delay Before Test 30 sec
   c. Click Auto Tension Adjustment Box
   d. Select Mode Static Force Tracking Dynamic Force
   e. Select Auto Tension Direction Tension
   f. Enter Initial Static Force value +20% of Force @ median linear strain/stress value
   g. Enter Static>Dynamic Force by value 15%
   h. Enter Minimum Static Force value 1 g

4. Click End of Test(in the Test form)
   a. Turn off Temperature Controller No
   b. Set end of Test Temperature Yes
   c. Set end of Test Temperature to 25^{o}C
   d. Turn off Motor No
   e. Turn Hold on No

5. Select Control

a. Click Instrument Control Panel
b. Temperature ______ desired temperature
c. Temperature control ______ Oven (Air, Chiller, LN2 Dewar)
d. Environmental Controller ______ On
e. Liquid Nitrogen Dewar ______ On
f. LN2 Solenoid Control ______ Predicted Duty Cycle
g. Motor Power ______ On

10. Perform the DTR test

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Reportable Results

Data will be reported in terms of Tg, modulus, and cross-link density and compared against those values obtained during laboratory evaluation.

Performance

A. Pull-off Adhesion Testing

Objective

To validate the adhesion of the WRCARC as a result of production level application processes

Rationale

Proper application of the WRCARC should result in adhesion values similar to or greater than those obtained during the laboratory evaluation. This test is used to quantify the amount of force necessary to break the bond of the coating to the substrate and identify the mode of failure. Adhesion is determined by measuring the force necessary to pull (in tensile) a button, adhered to the surface of the coating system, off of the coating.

Number of Test Samples and Preparation

- # of Panels: 4
- Size of Panels: 3" X 6" X 1/8", each of the four panels will be sprayed at test site. Prior to testing, the panels will be adhered to a 12" X 12" X 1/4" backing plate to reduce any effects of warpage during testing.
- System Applied: Standard primer (either MIL-P-53030 or MIL-P-53022) at recommended thickness (1.5-3 mils DFT) topcoated with MIL-P-64159 Type II (SERDP CARC) at recommended thickness.

Test Method/Equipment

A Type VI PATTI self-alignment adhesion tester will be used.

Testing will be performed in accordance with ASTM D4541-95, (Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers, approved 15 February 1995).

Method Synopsis: Apply primer to a specimen according to the manufacturer's recommendations, allow for sufficient cure, apply topcoat in accordance with manufacturer's suggestions, allow for sufficient cure. Maintain the specimen at ambient temperature and 50 ± 5% relative humidity prior to adhesion testing, as recommended by ASTM D3924-80 (Standard Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials, approved 2 September 1980, re-approved 1996).
Adhere a pull off stud normal to the surface being tested. After the adhesive is cured, a gradually increasing force is applied to the stud by a testing apparatus until a plug of the material is detached. The total force needed is recorded in pounds/square inch. Also the mode of failure (either adhesive or cohesive) is obtained.

Reportable Results

The data will report 1) psi at failure and, 2) mode of failure. Results shall be compared to previous SERDP testing of a similarly applied coating system.

B. Specular Gloss Measurement

Objective

This test is used to quantify specular gloss for validating effective mixing and application of the WRCARC. Specular gloss is the relative luminous reflectance factor of light incident to the sample at a specified angle as compared to a black glass standard.

Rationale

Effective mixing of the multiple components and proper application of the WRCARC should result in the proper color and gloss being achieved. Improper mixing or poor application will cause color changes and effect final gloss measurements.

Number of Test Samples and Preparation

- # of Panels: 4
- Size of Panels: 3" X 6" X 1/8"
- System Applied: Standard primer (either MIL-P-53030 or MIL-P-53022) at recommended thickness (1.5-3 mils DFT) topcoated with MIL-P-64159 Type II (SERDP CARC) at recommended thickness.

Test Method/Equipment

Testing will be performed in accordance with ASTM D523-89, (Standard Test Method for Specular Gloss, approved 31 March 1989, re-approved 1994).

Method Synopsis: Apply primer to a specimen according to the manufacturer's recommendations, allow for sufficient cure, apply topcoat in accordance with manufacturer's suggestions, allow for sufficient cure. Maintain the specimen at ambient temperature and 50 ± 5% relative humidity prior to adhesion testing, as recommended by ASTM D3924-80 (Standard Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials, approved 2 September 1980, re-approved 1996).

Take at least three readings per panel with glossmeter on each panel. Only 60 and 85° readings are necessary, however, the glossmeter takes 20, 60 and 85° readings simultaneously, therefore all three will be reported.

Reportable Results

Data obtained will be gloss at 20, 60, and 85°. Results shall be compared to previous SERDP testing of a similarly applied coating system.

C. Color Difference (ΔE) Measurement

Objective

To validate the color achieved when applying WRCARC via production processes. This test is used to quantify the change in color of tested samples from a know standard.

Rationale

Effective mixing of the multiple components and proper application of the WRCARC should result in the proper color and gloss being achieved. Improper mixing or poor application will cause color changes and effect final gloss measurements.

Number of Test Samples and Preparation

- # of Panels: 4
- Size of Panels: 3" X 6" X 1/8"

- System Applied: Standard primer (either MIL-P-53030 or MIL-P-53022) at recommended thickness (1.5-3 mils DFT) topcoated with MIL-P-64159 Type II (SERDP CARC) at recommended thickness.

Test Method/Equipment

Testing will be performed in accordance with ASTM D224-93, (Standard Test Method for Calculation of Color Differences From Instrumentally Measured Color Coordinates, approved 15 September 1993).

Method Synopsis: Apply primer to a specimen according to the manufacturer's recommendations, allow for sufficient cure, apply topcoat in accordance with manufacturer's suggestions, allow for sufficient cure. Maintain the specimen at ambient temperature and 50 ± 5% relative humidity prior to adhesion testing, as recommended by ASTM D3924-80 (Standard Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials, approved 2 September 1980, re-approved 1996).

Take at least three readings per panel with colorimeter on each panel. Compute the difference between actual readings and the known standard for the particular color being tested.

Reportable Results

Data obtained will be change in color (ΔE) and also, actual CIELAB data (L^*, a^*, b^*). Results shall be compared to previous SERDP testing of a similarly applied coating system.

D. Direct Impact Resistance

Objective

To validate the application demonstration of the SERDP CARC at the designated field activity via direct impact resistance.

Rationale

This test will provide insight into the flexibility characteristics of the cured film. This, along with the DMTA data (modulus), will validate expected physical property performance of the cured film.

Number of Test Samples and Preparation

- Substrate shall have dimensions of 3"x6"x0.025".
- Substrate shall consist of 2024 T0 aluminum with chromic acid anodize (MIL-A-8625 Type I)
- No substrate preparation other than solvent wiping is necessary prior to painting.
- Prior to application of topcoat, test specimen shall consist of 6 unprimed panels and 6 primed panels @ 1-1.5 mils DFT with MIL-P-53022 or MIL-P-53030, or @ 2-5 mils DFT with MIL-P-23236 (i.e., Bar Rust 235) for a total of 12 test specimens.
  Note: primer shall be applied to one face of the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be

consistent).
Note: primer shall be allowed to dry until set to touch (usually 30 to 60 minutes) but shall not be allowed to dry for greater than 24 hours before application of topcoat.

- Topcoat shall be applied at 2 to 2.5 mils to all 12 test specimens.
  Note: topcoat shall be applied to the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).

Test Method/Equipment
The test shall conform to ASTM D 2794, "Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)".

Reportable Results
The data shall be documented within a range of 0 to 160 in-lb. Results shall be compared to previous SERDP testing of a similarly applied coating system**.**

E. Cylindrical Mandrel Bend

Objective
To validate the application demonstration of the SERDP CARC at the designated field activity via cylindrical mandrel bend flexibility.

Rationale
This test will provide insight into the flexibility and elongation characteristics of the cured film. This, along with the DMTA data (modulus), will validate expected physical property performance of the cured film.

Number of Test Samples and Preparation
- Substrate shall have dimensions of 3"x6"x0.025".
- Substrate shall consist of 2024 T0 aluminum with chromic acid anodize (MIL-A-8625 Type I).
- No substrate preparation other than solvent wiping is necessary prior to painting.
- Prior to application of topcoat, test specimen shall consist of 6 unprimed panels and 6 primed panels @ 1-1.5 mils DFT with MIL-P-53022 or MIL-P-53030, or @ 2-5 mils DFT with MIL-P-23236 (i.e., Bar Rust 235) for a total of 12 test specimens.
  Note: primer shall be applied to one face of the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).
  Note: primer shall be allowed to dry until set to touch (usually 30 to 60 minutes) but shall not be allowed to dry for greater than 24 hours before application of topcoat.
- Topcoat shall be applied at 2 to 2.5 mils to all 12 test specimens.
  Note: topcoat shall be applied to the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).

Test Method/Equipment
The test shall conform to ASTM D 522, "Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings".

Reportable Results
The data shall be documented as either pass or fail at a range of 1/8" to 1" diameter. Results shall be compared to previous SERDP testing of a similarly applied coating system.

F. Sag Resistance

Objective
To validate the application demonstration of the SERDP CARC at the designated field activity via sag resistance

Rationale
Often, scale-up of a coatings formulation from laboratory to production mode could result in material with varying rheological characteristics. This test will validate that the rheological properties of the production mode materials are adequate for industrial processes.

Number of Test Samples and Preparation

- Substrate shall have dimensions of 3"x6"x0.025" with a fastener head protrusion at the top of the panel.
- Substrate shall consist of 1010 cold rolled steel with zinc phosphate treatment per TT-C-490 Type I).
- No substrate preparation other than solvent wiping is necessary prior to painting.
- Prior to application of topcoat, test specimen shall consist of 6 unprimed panels and 6 primed panels @ 1-1.5 mils DFT with MIL-P-53022 or MIL-P-53030, or @ 2-5 mils DFT with MIL-P-23236 (i.e., Bar Rust 235) for a total of 12 test specimens.
- Note: primer shall be applied to one face of the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).
  Note: primer shall be allowed to dry until set to touch (usually 30 to 60 minutes) but shall not be allowed to dry for greater than 24 hours before application of topcoat.
- Topcoat shall be applied to one unprimed and one primed specimen with one paint spray deposition pass while being supported in a vertical position.
  Note: topcoat shall be applied to the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).
- Flow defects and wet film thickness shall be documented.
- Each additional set of panels shall receive one additional paint spray deposition pass and flow defects and wet film thickness data shall again be documented.
  Note: when the entire procedure is completed, test panel sets with 1 through 6 passes of paint would have been produced

Test Method/Equipment
This test does not conform to any ASTM or FED-STD Method.

Reportable Results
The data shall be documented as either pass or fail at WFT (or DFT) corresponding to 1 through 6 paint spray passes.

G. Viscosity (Zahn#2)

Objective
To validate the application demonstration of the SERDP CARC at the designated field activity via Zahn cup viscometer

Rationale
Often, scale-up of a coatings formulation from laboratory to production mode could result in material with varying rheological characteristics. This test will validate that the rheological properties of the production mode materials are adequate for industrial processes.

Number of Test Samples and Preparation
No substrates, nor substrate preparation, are required in this test.

Test Method/Equipment
The test shall conform to ASTM D 4212, "Standard Test Method for Viscosity by Dip-Type Viscosity Cups". The data shall be collected at admix, 1 hr, 2, hr, 3 hr, and 4 hr dwell times. Note: each data point shall be an average of three successive readings.

Reportable Results
The data shall be documented as the elapsed time in seconds. Results shall be compared to previous SERDP testing of a similarly applied coating system.

H. Taber Abrasion Resistance

Objective
To validate the application demonstration of the SERDP CARC at the designated field activity via Taber abrasion resistance.

Rationale
The WRCARC has demonstrated superior abrasion resistance to the currently approved CARC coatings, in the laboratory. This test is to validate the improved performance when applied in a production mode.

Number of Test Samples and Preparation
- Substrate shall have dimensions of 4"x 4"x0.032" with a 0.25" hole in the center.

- Substrate shall consist of 1010 cold rolled steel.
- No substrate preparation other than solvent wiping is necessary prior to painting.
- Prior to application of topcoat, test specimen shall consist of 4 unprimed panels and 4 primed panels @ 1-1.5 mils DFT with MIL-P-53022 or MIL-P-53030, or @ 2-5 mils DFT with MIL-P-23236 (i.e., Bar Rust 235) for a total of 8 test specimens.
  Note: primer shall be applied to one face of the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).
  Note: primer shall be allowed to dry until set to touch (usually 30 to 60 minutes) but shall not be allowed to dry for greater than 24 hours before application of topcoat.
- Topcoat shall be applied at 2 to 2.5 mils to all 8 test specimens.
  Note: topcoat shall be applied to the test panels in an identical manner as applied to operational equipment (i.e., nozzle size, gun/line pressure, # of passes, deposition rate, etc. shall be consistent).

Test Method/Equipment

The test shall conform to ASTM D 4060, "Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser".

Reportable Results

The data shall be documented as weight loss (mg) and thickness loss (mils). Results shall be compared to previous SERDP testing of a similarly applied coating system.

MIL-P-64159 TYPE II WRCARC FIELD TRIAL APPLICATION SURVEY

Fill out the correct column, based on which coating is currently used

WBCC

How would you describe the mixing of this material when compared to WBCC?

1. With respect to complexity of mix ratio:
□ Much Easier □ Easier □ Same
□ More Difficult □ Much More Difficult

2. With respect to mixing:
□ Much Easier □ Easier □ Same
□ More Difficult □ Much More Difficult

3. With respect to time:
□ Much Slower □ Slower □ Same
□ Quicker □ Much Quicker

Additional comments:

How would you describe the spray characteristics of this material when compared to WBCC?

1. With respect to spraying:
□ Much Easier □ Easier □ Same
□ More Difficult □ Much More Difficult

2. With respect to spray quality:
□ Much Worse □ Worse □ Same
□ Better □ Much Better

3. With respect to application rate:
□ Much Slower □ Slower □ Same
□ Quicker □ Much Quicker

4. With respect to wet film quality (i.e. orange peel, pinholes, sags, etc.):
□ Much Worse □ Worse □ Same
□ Better □ Much Better

Additional comments:

What is your general opinion of this material compared to WBCC?

□ Much Worse □ Worse □ Same
□ Better □ Much Better

Please use back of form to provide <u>any</u> additional comments about the material.

Solvent Based CARC

How would you describe the mixing of this material when compared to solvent based CARC?

1. With respect to complexity of mix ratio:
□ Much Easier □ Easier □ Same
□ More Difficult □ Much More Difficult

2. With respect to mixing:
□ Much Easier □ Easier □ Same
□ More Difficult □ Much More Difficult

3. With respect to time:
□ Much Slower □ Slower □ Same
□ Quicker □ Much Quicker

Additional comments:

How would you describe the spray characteristics of this material when compared to solvent based CARC?

1. With respect to spraying:
□ Much Easier □ Easier □ Same
□ More Difficult □ Much More Difficult

2. With respect to spray quality:
□ Much Worse □ Worse □ Same
□ Better □ Much Better

3. With respect to application rate:
□ Much Slower □ Slower □ Same
□ Quicker □ Much Quicker

4. With respect to wet film quality (i.e. orange peel, pinholes, sags, etc.):
□ Much Worse □ Worse □ Same
□ Better □ Much Better

Additional comments:

What is your general opinion of this material compared to solvent based CARC?

□ Much Worse □ Worse □ Same
□ Better □ Much Better

Please use back of form to provide <u>any</u> additional comments about the material.

Additional Comments:

Field Trial Panel Matrix

AGENCY	TEST	TEST METHOD	SUBSTRATE	# PANELS	DIMENSIONS	SURFACE PREP	PRE-TREATMENT	PRIMER	TOPCOAT
MARINE CORPS	DMA (Metallic Substrate)	See CTD	1010 CRS	8	3" x 6" x 1/32"	None	TT-C-490 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Glass Transition		1010 CRS	8	3" x 6" x 1/32"	None	TT-C-490 Type I	None	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Modulus (E' & E")								
	Crosslink Density								
	DMA (Free Film)	See CTD	PVF coated Leneta	2	7" x 11"	None	None	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Glass Transition		PVF coated Leneta	2	7" x 11"	None	None	None	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Modulus (E' & E")								
	Crosslink Density								
	Pull-Off Adhesion Testing	ASTM D4541-95	1010 CRS	4 *	3" x 6" x 1/8"	1.5 - 2.5 mils ATP	TT-C-490 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Specular Gloss (20^o, 60^o, 85^o)	ASTM D523-89	1010 CRS	4 *	3" x 6" x 1/8"	1.5 - 2.5 mils ATP	TT-C-490 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Color Difference (delta E)	ASTM D224-93	1010 CRS	4 *	3" x 6" x 1/8"	1.5 - 2.5 mils ATP	TT-C-490 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Direct Impact Resistance	ASTM D 2794	2024 TO Al	6	3" x 6" x 1/40"	None	MIL-A-8625 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
			2024 TO Al	6	3" x 6" x 1/40"	None	MIL-A-8625 Type I	None	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Cylindrical Mandrel Bend	ASTM D522	2024 TO Al	6	3" x 6" x 1/40"	None	MIL-A-8625 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
			2024 TO Al	6	3" x 6" x 1/40"	None	MIL-A-8625 Type I	None	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Sag Resistance	See CTD	1010 CRS	6	3" x 6" x 1/40"	None	TT-C-490 Type I	1 - 1.5 mils DFT MIL-P-53030	See CTD
			1010 CRS	6	3" x 6" x 1/40"	None	TT-C-490 Type I	None	See CTD
	Viscosity (Zahn #2)	ASTM D4212	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Taber Abrasion Resistance	ASTM D4060	1010 CRS	4	4" x 4" x 1/32"	None	None	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
			1010 CRS	4	4" x 4" x 1/32"	None	None	None	2.0 - 2.5 mils DFT MIL-P-64159 Type II
ARMY	EMMAQUA Weathering	ASTM D 4141 -C	1010 CRS	16	3" x 6" x 1/32"	1.5 - 2.5 mils ATP	ACT b952/p60	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Agent Resistance	MIL-P-64159	1010 CRS	14	3" x 3" x 1/32"	1.5 - 2.5 mils ATP	ACT b952/p60	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	DS2 Resistance	MIL-P-64159	1010 CRS	2	3" x 6" x 1/32"	1.5 - 2.5 mils ATP	ACT b952/p60	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
AIR FORCE	Plastic Media (Type V) Blast	**	AL	18	5-1/2" x 12" x 1/8"	N/A	CRO4 Conversion Coat	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Garnet Blast	**	ST	18	5-1/2" x 12" x 1/8"	1.5 - 2.5 mils ATP	TT-C-490 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Steel Shot Blast	**	ST	18	5-1/2" x 12" x 1/8"	1.5 - 2.5 mils ATP	TT-C-490 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
	Chemical Stripping	**	ST	18	5-1/2" x 12" x 1/8"	1.5 - 2.5 mils ATP	TT-C-490 Type I	1 - 1.5 mils DFT MIL-P-53030	2.0 - 2.5 mils DFT MIL-P-64159 Type II
				172					

***** The same set of panels will be used for all three tests

** Details of test method will be provided prior to stripping demo

Pre-treatments:

TT-C-490 Type I - Zinc Phosphate
MIL-A-8625 Type I - Chromic acid anodize
ACT b952/p60 - Zinc Phosphate
CRO4 Conversion Coat

Acronym Key

ATP - anchor tooth profile
DFT - dry film thickness

U.S. Marine Corps Experimental Coating Data Sheet

Equipment Classification	**Trial Location**	**Application Start Date**
USMC Number	**Manufacturer**	
Equipment Nomenclature	**Batch Numbers**	
National Stock Number (NSN)		
TAM Number		
Owning Unit		
MSC Phone Number		
Surface Preparation ○ Abrasive Blast ○ None ○ Sweep Blast ○ Hydro-Blast ○ Hand Tool/Sand		

Manufacturer's Suggested System

Coating Name	Coating Type	Nozzle Size	Number of Coats	Required WFT (mils)	Required DFT (mils)
		Total			

Coating System Applied

Coating Name	Coating Type	Date Applied	Nozzle Size	WFT (mils)	DFT (mils)
			Total		

Coating Notes

U.S. Marine Corps Experimental Coating Data Sheet

Equipment Nomenclature	USMC Number	Coating System Applied

Environmental Conditions

Conditions / Coating	Ambient Temperature	Surface Temperature	Dew Point	Relative Humidity

Application Summary

Post Application Summary

Chemical Agent Resistance Test Procedure

The chemical agent resistance test was performed in accordance with the requirements of MIL-DTL-64159. The procedure was updated in a joint effort between ARL and the Edgewood Chemical and Biological Center (ECBC) at Aberdeen Proving Ground, and incorporates advances in instrumentation since the procedure developed for the original CARC topcoat specifications.

Panel preparation. Spray steel panels, zinc phosphate pretreated according to TT-C-490, type 1 with epoxy primer conforming to MIL-P-53022 or MIL-P-53030 to a dry film thickness between 0.0009 and 0.0011 inch. Air dry 2 hours and spray the coating to be tested to a dry film thickness between 0.0018 and 0.0022 inch. Air dry the panels for 7 days.

Test conditions. Because the desorption rate of agents from paint is temperature dependent, all agent tests will be conducted at 25° C. Extremely toxic materials are used in this testing. Agent HD, a vesicant agent, is also a known carcinogen. Agent GD is a toxic nerve agent, exposure to which is difficult to treat. Consequently, all work will be performed in an approved fume hood, and appropriate measures to protect individuals at risk of exposure must be taken.

Test apparatus. The test apparatus used for both HD and GD testing consists of a temperature controlled Plexiglas box (approximately 0.5 m x 0.5 m x 1 m) containing five separate test cells. Four of these cells are used to test sample CARC panels; the fifth is used to test a control panel, all five tests to be run simultaneously. The test cells are machined from aluminum and consist of two parts that are clamped together to hold the test panels in place. A gastight seal is maintained by means of O-rings. Agent desorbed from the test panels is entrained by dry nitrogen that passes through a Miller-Nelson HCS401 temperature-humidity-flow controller, with final temperature controlled by a YSI Model 72 proportional temperature controller. The nitrogen passes through an external chamber fitted with a bleed valve before entering the test cells. Determine the agent recovered in micrograms.

Test Procedure. Place a 5 cm^2 circular template on the area of the test panel to be contaminated with agent. Use a grease pencil to mark a circle around the template; the grease mark serves to keep the agent from spreading out of the designated area. Place 50 microliters of agent (HD or GD) on the test area using a microliter syringe. Place a glass cover slip (microscope slide) over the test area to minimize evaporation of the agent. After 30 minutes remove the cover slip, rinse the agent from the panel with isopropanol and allow to air dry for approximately 45 seconds. Place the panel in the test cell, which has been maintained at 25° C, with the coated area positioned such that the nitrogen stream will pass across the contaminated area. Nitrogen is used instead of air to eliminate the possibility of reaction of the desorbed agent over the time of the test, which is 22 hours. Pass the nitrogen through an impinger containing the appropriate solvent, n-decane for HD and iso-octane (2,2,4-trimethylpentane) for GD. The flow of nitrogen across each sample shall be 200 mL/min, maintained by mass flow controllers. Terminate the test at the end of 22 hours.

Analysis. Transfer the contents of each impinger to a 25-mL volumetric flask. Rinse the impinger twice with the same solvent and add the rinse to the flask. Bring the volume up to the mark with solvent and mix well. Transfer a 1-mL portion to a GC vial for analysis. Perform the analysis on a Finnigan-MAT GQC ion-trap mass spectrometer equipped with a 25 m MS-5 capillary column, using helium as the carrier gas. Standardize the mass spectrometer by serial dilutions of an agent solution in the appropriate solvent, analyzed in the same conditions. The instrument conditions are as follows: introduce the samples from an AST 2000 autosampler, volume of 1 microliter, onto the GC column in splitless mode; injector temperature of 280° C. Temperature program the column from an initial temperature of 50° C to 120° C at a rate of 10°/min; followed by an increase of 25° C/min to a final temperature of 200° C. Acquire mass spectra in electron impact mode over the mass range of 50-150 for HD and 50-200 for GD. Under these conditions, HD has a retention time of 8.15 minutes. Integrate the peak areas of the relevant portion of the reconstructed ion chromatograms for the ion at m/z 109. Under the cited conditions GD elutes as a pair of completely resolved diastereomeric enantiomers with retention times of 9.56 and 10.04 minutes. Integrate the peak areas of the relevant portion of the reconstructed ion chromatograms for the ion at m/z 99. Construct the standard response curve for HD and GD using the integrated area on the y-axis and concentration (µg/mL) on the x-axis. Use the linear regression analysis function of an Excel spreadsheet, which will calculate the slope, intercept, and correlation coefficient of the standard response curve. The slope and intercept of the standard response curve are used to calculate concentration of agent (HD or GD) in the impinger solutions. Calculate the total amount of agent (in micrograms) that outgassed from the CARC panel by multiplying the concentration of agent in the impinger solution (micrograms per milliliter read from the standard curve) by the volume of the impinger solution (25 mL).

Appendix C: Additional Product Testing for non-JTP Applications

TECHNICAL INFORMATION

WATERBORNE CARC MIL-C-64159 (proposed), Type 2 (Non-Siliceous)
POLYURETHANE CAMOUFLAGE COATING GREEN 383, 34094
F93G502/V93V502

SHERWIN WILLIAMS — CHEMICAL COATINGS

PRODUCT DESCRIPTION

F93G502 is a two component camouflage topcoat. The components when properly mixed and reduced with deionized water may be sprayed applied to properly prepared surfaces. This coating meets the performance properties of MIL-C-46168D and MIL-C-53039A. This product is on test at the US Army Research Lab in Aberdeen Proving Ground, MD for inclusion on the Experimental Products Program for non-silaceous waterborne CARC.

CHARACTERISTICS

Color: Green 383
Fed. Std. 595B # 34094

Admix ratio by volume: 2:1:0.75
F93G502/V93V502/deionized water

Component A (F93G502)

Non volatiles, weight:	50.0 ± 2.0%
Non volatiles, volume:	35.0 ± 1.0%
VOC:	130g/l or 1.1#/gal minus water

Component B (V93V502)

Non volatiles, weight:	75.0%+/-1.0%
Non volatiles, volume:	69.3%+/-1.0%
VOC:	266/l or 2.2#/gal

Admixed Constants:

VOC:	1.50 lb./gallon or 180 g/l max.
Volume solids:	36% admixed 2:1:0.75
Viscosity:	13-18 sec #3 Zahn (admixed 2:1:0.75)

Theoretical Coverage:
577 sq.ft./gallon @ 1.0 mil dry
no application loss

Gloss:	1.0 max. 60° 3.5 max. 85° Gloss at 2.0 mils dry, spray.
HMIS Codes:	H 2 F 1 R 0 PP 1
Flash Point	200°F
Pot Life:	4 hours

Cure Data: This product's cure depends on temperature and humidity. Cure rate at 70°F and 50% R.H.

Set to touch	60 minutes
Dry hard:	6 hours
Dry through:	8 hours

APPLICATION

Component A should be shaken 5 minutes on Red Devil type shaker before opening. Mix Component B into Component A using a mechanical mixer. Mix for 3 minutes. The viscosity of the admixed components will increase significantly. Reduce to spray viscosity by adding deionized water. Mix by volume, 2 parts A, 1 part B, and 0.75 parts deionized water.

Substrate Preparation:
Substrate should be clean, free of grease, dirt, rust or other contaminants that may cause adhesion problems.
Recommended primer is MIL-P-53022.
Allow primer to dry 2 hours. Then apply topcoat.
Follow surface cleaning and priming As described in MIL-C-53072B.

Equipment:
Conventional Spray:
Use 45-60 pounds atomization air with a .070 fluid tip.

HVLP:
Use 65 pounds atomizing air (10 at cap) 5-10 pounds fluid with a .070" fluid tip.

Air Assisted Airless:
Not recommended due to the coarse nature of the pigmentation.

Clean Up:
Flush line with clean water. Then use MIL-T-81772, Type 1 thinner for final equipment and line wash.

Special Instructions:
Disposal:
Do not dispose of in sealed drums.

"Disposal" caution - This Waterborne polyurethane should not be disposed of in a sealed container due to carbon dioxide generation. Allow unused material to cure in a vented container and dispose of according to state, federal or local regulations for hazardous material.

Note:
Product Data Sheets are periodically updated to reflect new information relating to the product. It is important that the customer obtain the most recent Product Data Sheet for the product being used. The information, rating and opinions stated above pertain to the material currently offered and represent the results of tests believed to be reliable. However, due to variations in customer handling and methods of application which are not know or under our control, The Sherwin-Williams Company cannot make any warranties or guarantees as to the end results.

Chicago-AWSTC
MW-8/18/00

MATERIAL SAFETY DATA SHEET

F93G00502
01 00X

MANUFACTURER'S NAME
THE SHERWIN-WILLIAMS COMPANY
101 Prospect Avenue N.W.
Cleveland, OH 44115

EMERGENCY TELEPHONE NO.
(216) 566-2917

DATE OF PREPARATION
12-APR-00

INFORMATION TELEPHONE NO.
(216) 566-2902

Section I -- PRODUCT IDENTIFICATION

PRODUCT NUMBER

F93G00502

HMIS CODES	
Health	2*
Flammability	0
Reactivity	0

PRODUCT NAME
WB CARC GN 383#34094,T II
PRODUCT CLASS
-

Section II -- HAZARDOUS INGREDIENTS

INGREDIENT CAS No.	% by WT	ACGIH TLV	OSHA PEL	UNITS	V.P.
1-Methyl-2-Pyrrolidone 872-50-4	3	Not Established			1.00
Chromium Oxide 1308-38-9	8	0.5	0.5	MG/M3	0.00
Cobalt-Chrome Oxide. 68187-49-5	14	0.5	0.5	MG/M3	0.00
Chromium III (as Cr)	9.29	0.50		MG/M3	

Section III -- PHYSICAL DATA

PRODUCT WEIGHT	11.02 lb/gal	1320 g/l
SPECIFIC GRAVITY	1.33	
BOILING POINT	212 - 396 F	100 - 202 C
MELTING POINT	Not Available	
VOLATILE VOLUME	65 %	
EVAPORATION RATE	Slower than ether	
VAPOR DENSITY	Heavier than air	
SOLUBILITY IN WATER	N.A.	
VOLATILE ORGANIC COMPOUNDS	(VOC Theoretical)	
1.08 lb/gal 130 g/l	Less Federally Exempt Solvents	
0.43 lb/gal 52 g/l	Emitted VOC	

Section IV -- FIRE AND EXPLOSION HAZARD DATA

FLASH POINT	LEL	UEL
>200 F PMCC	N.A.	N.A.

FLAMMABILITY CLASSIFICATION
Not Applicable

Continued on page 2

EXTINGUISHING MEDIA
Carbon Dioxide, Dry Chemical, Alcohol Foam
UNUSUAL FIRE AND EXPLOSION HAZARDS
Closed containers may explode (due to the build-up of pressure) when exposed to extreme heat.
SPECIAL FIRE FIGHTING PROCEDURES
Full protective equipment including self-contained breathing apparatus should be used. Water spray may be ineffective. If water is used, fog nozzles are preferable. Water may be used to cool closed containers to prevent pressure build-up and possible autoignition or explosion when exposed to extreme heat.

Section V -- HEALTH HAZARD DATA

ROUTES OF EXPOSURE
Exposure may be by INHALATION and/or SKIN or EYE contact, depending on conditions of use. To minimize exposure, follow recommendations for proper use, ventilation, and personal protective equipment.
ACUTE Health Hazards
EFFECTS OF OVEREXPOSURE
Irritation of eyes, skin and upper respiratory system. In a confined area vapors in high concentration may cause headache, nausea or dizziness.
SIGNS AND SYMPTOMS OF OVEREXPOSURE
Redness and itching or burning sensation may indicate eye or excessive skin exposure.
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE
None generally recognized.
EMERGENCY AND FIRST AID PROCEDURES

If INHALED:	If affected, remove from exposure. Restore breathing. Keep warm and quiet.
If on SKIN:	Wash affected area thoroughly with soap and water. Remove contaminated clothing and launder before re-use.
If in EYES:	Flush eyes with large amounts of water for 15 minutes. Get medical attention.
If SWALLOWED:	Get medical attention.

CHRONIC Health Hazards
Cobalt and cobalt compounds are classified by IARC as possibly carcinogenic to humans (group 2B) based on experimental animal data, however, there is inadequate evidence in humans for its carcinogenicity.
Chromium III is considered the active species in cancer induction, but Chromium III compounds do not cross the cell wall. However, there is some evidence that Chromium III compounds of respirable particle size may be taken up by the cells in the lung.

Section VI -- REACTIVITY DATA

STABILITY -- Stable
CONDITIONS TO AVOID
None known.
INCOMPATIBILITY
None known.
HAZARDOUS DECOMPOSITION PRODUCTS
By fire: Carbon Dioxide, Carbon Monoxide, Oxides of Nitrogen, possibility of Hydrogen Cyanide, Qxides of Metals in Section II
HAZARDOUS POLYMERIZATION
Will not occur

Continued on page 3

Section VII -- SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Remove all sources of ignition. Ventilate and remove with inert absorbent.

WASTE DISPOSAL METHOD

Waste from this product may be hazardous as defined under the Resource Conservation and Recovery Act (RCRA) 40 CFR 261.

Waste must be tested for extractability to determine the applicable EPA hazardous waste numbers.

Incinerate in approved facility. Do not incinerate closed container. Dispose of in accordance with Federal, State, and Local regulations regarding pollution.

Section VIII -- PROTECTION INFORMATION

PRECAUTIONS TO BE TAKEN IN USE

Use only with adequate ventilation. Avoid breathing vapor and spray mist. Avoid contact with skin and eyes. Wash hands after using.

This coating may contain materials classified as nuisance particulates (listed "as Dust" in Section II) which may be present at hazardous levels only during sanding or abrading of the dried film. If no specific dusts are listed in Section II, the applicable limits for nuisance dusts are ACGIH TLV 10 mg./m3 (total dust), 3 mg./m3 (respirable fraction), OSHA PEL 15 mg./m3 (total dust), 5 mg./m3 (respirable fraction).

VENTILATION

Local exhaust preferable. General exhaust acceptable if the exposure to materials in Section II is maintained below applicable exposure limits. Refer to OSHA Standards 1910.94, 1910.107, 1910.108.

RESPIRATORY PROTECTION

If personal exposure cannot be controlled below applicable limits by ventilation, wear a properly fitted organic vapor/particulate respirator approved by NIOSH/MSHA for protection against materials in Section II.

When sanding, wirebrushing, abrading, burning or welding the dried film, wear a particulate respirator approved by NIOSH/MSHA for protection against non-volatile materials in Section II.

PROTECTIVE GLOVES

Wear gloves which are recommended by glove supplier for protection against materials in Section II.

EYE PROTECTION

Wear safety spectacles with unperforated sideshields.

Section IX -- PRECAUTIONS

DOL STORAGE CATEGORY

3B

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Keep container closed when not in use. Transfer only to approved containers with complete and appropriate labeling. Do not take internally. Keep out of the reach of children.

Section X -- OTHER REGULATORY INFORMATION

SARA 313 (40 CFR 372.65C) SUPPLIER NOTIFICATION

CAS No.	CHEMICAL/COMPOUND	% by WT	% Element
872-50-4	1-Methyl-2-Pyrrolidone	3	
	Chromium Compound.	21	9.3

Continued on page 4

Cobalt Compound.	14	1.6
Zinc Compound.	14	1.9

CALIFORNIA PROPOSITION 65

WARNING: This product contains chemicals known to the State of California to cause cancer.

TSCA CERTIFICATION

All chemicals in this product are listed, or are exempt from listing, on the TSCA Inventory.

The above information pertains to this product as currently formulated, and is based on the information available at this time. Addition of reducers or other additives to this product may substantially alter the composition and hazards of the product. Since conditions of use are outside our control, we make no warranties, express or implied, and assume no liability in connection with any use of this information.

MATERIAL SAFETY DATA SHEET

V93V00502
01 00

MANUFACTURER'S NAME
THE SHERWIN-WILLIAMS COMPANY
101 Prospect Avenue N.W.
Cleveland, OH 44115

EMERGENCY TELEPHONE NO.
(216) 566-2917

DATE OF PREPARATION
13-APR-00

INFORMATION TELEPHONE NO.
(216) 566-2902

Section I -- PRODUCT IDENTIFICATION

PRODUCT NUMBER

V93V00502

HMIS CODES	
Health	3*
Flammability	2
Reactivity	1

PRODUCT NAME
WATERBORNE CARC CATALYST
PRODUCT CLASS
-

Section II -- HAZARDOUS INGREDIENTS

INGREDIENT CAS No.	% by WT	ACGIH TLV	OSHA PEL	UNITS	V.P.
Oxo-Hexyl Acetate. 88230-35-7	25	Not Established			0.70
Hexamethylene Diisocyanate (max.) 822-06-0	0.2	0.005		PPM	0.05
Hexamethylene Diisocyanate Polymer 28182-81-2	75	Not Established			0.00

Section III -- PHYSICAL DATA

PRODUCT WEIGHT	8.87 lb/gal	1063 g/l
SPECIFIC GRAVITY	1.07	
BOILING POINT	327 - 349 F	163 - 176 C
MELTING POINT	Not Available	
VOLATILE VOLUME	30 %	
EVAPORATION RATE	Slower than ether	
VAPOR DENSITY	Heavier than air	
SOLUBILITY IN WATER	N.A.	

VOLATILE ORGANIC COMPOUNDS (VOC Theoretical)
2.21 lb/gal 265 g/l Less Federally Exempt Solvents
2.21 lb/gal 265 g/l Emitted VOC

Section IV -- FIRE AND EXPLOSION HAZARD DATA

FLASH POINT	LEL	UEL
138 F PMCC	1.0	8.0

FLAMMABILITY CLASSIFICATION
Combustible, Flash above 99 and below 200 F
EXTINGUISHING MEDIA
Carbon Dioxide, Dry Chemical, Foam

Continued on page 2

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UNUSUAL FIRE AND EXPLOSION HAZARDS

Keep containers tightly closed. Isolate from heat, electrical equipment, sparks, and open flame. Closed containers may explode when exposed to extreme heat. Application to hot surfaces requires special precautions. During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms may not be immediately apparent. Obtain medical attention.

SPECIAL FIRE FIGHTING PROCEDURES

Full protective equipment including self-contained breathing apparatus should be used. Water spray may be ineffective. If water is used, fog nozzles are preferable. Water may be used to cool closed containers to prevent pressure build-up and possible autoignition or explosion when exposed to extreme heat.

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Section V -- HEALTH HAZARD DATA

ROUTES OF EXPOSURE

Exposure may be by INHALATION and/or SKIN or EYE contact, depending on conditions of use. To minimize exposure, follow recommendations for proper use, ventilation, and personal protective equipment.

ACUTE Health Hazards

EFFECTS OF OVEREXPOSURE

Irritation of eyes, skin and respiratory system. May cause nervous system depression. Extreme overexposure may result in unconsciousness and possibly death.

SIGNS AND SYMPTOMS OF OVEREXPOSURE

Headache, dizziness, nausea, and loss of coordination are indications of excessive exposure to vapors or spray mists.

Redness and itching or burning sensation may indicate eye or excessive skin exposure.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE

None generally recognized.

EMERGENCY AND FIRST AID PROCEDURES

If INHALED:	If affected, remove from exposure. Restore breathing. Keep warm and quiet.
If on SKIN:	Wash affected area thoroughly with soap and water. Remove contaminated clothing and launder before re-use.
If in EYES:	Flush eyes with large amounts of water for 15 minutes. Get medical attention.
If SWALLOWED:	Get medical attention.

CHRONIC Health Hazards

No ingredient in this product is an IARC, NTP or OSHA listed carcinogen.

Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage.

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Section VI -- REACTIVITY DATA

STABILITY -- Stable

CONDITIONS TO AVOID

None known.

INCOMPATIBILITY

None known.

HAZARDOUS DECOMPOSITION PRODUCTS

By fire: Carbon Dioxide, Carbon Monoxide

HAZARDOUS POLYMERIZATION

Will not occur

Continued on page 3

Section VII -- SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Remove all sources of ignition. Ventilate and remove with inert absorbent.

WASTE DISPOSAL METHOD

Waste from this product may be hazardous as defined under the Resource Conservation and Recovery Act (RCRA) 40 CFR 261.

Waste must be tested for ignitability to determine the applicable EPA hazardous waste numbers.

Incinerate in approved facility. Do not incinerate closed container. Dispose of in accordance with Federal, State, and Local regulations regarding pollution.

Section VIII -- PROTECTION INFORMATION

PRECAUTIONS TO BE TAKEN IN USE

Use only with adequate ventilation. Avoid breathing vapor and spray mist. Avoid contact with skin and eyes. Wash hands after using.

This coating may contain materials classified as nuisance particulates (listed "as Dust" in Section II) which may be present at hazardous levels only during sanding or abrading of the dried film. If no specific dusts are listed in Section II, the applicable limits for nuisance dusts are ACGIH TLV 10 mg./m3 (total dust), 3 mg./m3 (respirable fraction), OSHA PEL 15 mg./m3 (total dust), 5 mg./m3 (respirable fraction).

VENTILATION

Local exhaust preferable. General exhaust acceptable if the exposure to materials in Section II is maintained below applicable exposure limits. Refer to OSHA Standards 1910.94, 1910.107, 1910.108.

RESPIRATORY PROTECTION

If personal exposure cannot be controlled below applicable limits by ventilation, wear a properly fitted organic vapor/particulate respirator approved by NIOSH/MSHA for protection against materials in Section II.

When sanding or abrading the dried film, wear a dust/mist respirator approved by NIOSH/MSHA for dust which may be generated from this product, underlying paint, or the abrasive.

PROTECTIVE GLOVES

Wear gloves which are recommended by glove supplier for protection against materials in Section II.

EYE PROTECTION

Wear safety spectacles with unperforated sideshields.

Section IX -- PRECAUTIONS

DOL STORAGE CATEGORY

2

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Contents are COMBUSTIBLE. Keep away from heat and open flame.

Consult NFPA Code. Use approved Bonding and Grounding procedures.

Keep container closed when not in use. Transfer only to approved containers with complete and appropriate labeling. Do not take internally. Keep out of the reach of children.

OTHER PRECAUTIONS

Intentional misuse by deliberately concentrating and inhaling the contents can be harmful or fatal.

Continued on page 4

Section X -- OTHER REGULATORY INFORMATION

SARA 313 (40 CFR 372.65C) SUPPLIER NOTIFICATION

CAS No.	CHEMICAL/COMPOUND	% by WT	% Element

No ingredients in this product are subject to SARA 313 (40 CFR 372.65C) Supplier Notification.

TSCA CERTIFICATION

All chemicals in this product are listed, or are exempt from listing, on the TSCA Inventory.

The above information pertains to this product as currently formulated, and is based on the information available at this time. Addition of reducers or other additives to this product may substantially alter the composition and hazards of the product. Since conditions of use are outside our control, we make no warranties, express or implied, and assume no liability in connection with any use of this information.

Barstow survey sample 1

MIL-P-64159 TYPE II WRCARC FIELD TRIAL APPLICATION SURVEY

<u>Fill out the correct column, based on which coating is currently used</u>

WBCC

How would you describe the mixing of this material when compared to WBCC?

1. With respect to complexity of mix ratio:
☐ Much Easier ☒ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

2. With respect to mixing:
☐ Much Easier ☒ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

3. With respect to time:
☐ Much Slower ☐ Slower ☒ Same
☐ Quicker ☐ Much Quicker

Additional comments:

How would you describe the spray characteristics of this material when compared to WBCC?

1. With respect to spraying:
☐ Much Easier ☒ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

2. With respect to spray quality:
☐ Much Worse ☐ Worse ☐ Same
☐ Better ☒ Much Better

3. With respect to application rate:
☐ Much Slower ☐ Slower ☐ Same
☐ Quicker ☒ Much Quicker

4. With respect to wet film quality (i.e. orange peel, pinholes, sags, etc.):
☐ Much Worse ☐ Worse ☐ Same
☐ Better ☒ Much Better

Additional comments:

What is your general opinion of this material compared to WBCC?

☐ Much Worse ☐ Worse ☐ Same
☐ Better ☒ Much Better

Please use back of form to provide <u>any</u> additional comments about the material.

Solvent Based CARC

How would you describe the mixing of this material when compared to solvent based CARC?

1. With respect to complexity of mix ratio:
☐ Much Easier ☒ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

2. With respect to mixing:
☐ Much Easier ☒ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

3. With respect to time:
☐ Much Slower ☐ Slower ☐ Same
☒ Quicker ☐ Much Quicker

Additional comments:

BASED ON WATER VAPORS THINNER

How would you describe the spray characteristics of this material when compared to solvent based CARC?

1. With respect to spraying:
☒ Much Easier ☐ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

2. With respect to spray quality:
☐ Much Worse ☐ Worse ☐ Same
☐ Better ☒ Much Better

3. With respect to application rate:
☐ Much Slower ☐ Slower ☐ Same
☒ Quicker ☐ Much Quicker

4. With respect to wet film quality (i.e. orange peel, pinholes, sags, etc.):
☐ Much Worse ☐ Worse ☐ Same
☒ Better ☐ Much Better

Additional comments:

VAPORS OF THINNERS

What is your general opinion of this material compared to solvent based CARC?

☐ Much Worse ☐ Worse ☐ Same
☐ Better ☒ Much Better

Please use back of form to provide <u>any</u> additional comments about the material.

WATER VERSA THINNER

Ogden survey sample 1

MIL-P-64159 TYPE II WRCARC FIELD TRIAL APPLICATION SURVEY

Fill out the correct column, based on which coating is currently used

WBCC

How would you describe the mixing of this material when compared to WBCC?

1. With respect to complexity of mix ratio:
☐ Much Easier ☐ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

2. With respect to mixing:
☐ Much Easier ☐ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

3. With respect to time:
☐ Much Slower ☐ Slower ☐ Same
☐ Quicker ☐ Much Quicker

Additional comments:

How would you describe the spray characteristics of this material when compared to WBCC?

1. With respect to spraying:
☐ Much Easier ☐ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

2. With respect to spray quality:
☐ Much Worse ☐ Worse ☐ Same
☐ Better ☐ Much Better

3. With respect to application rate:
☐ Much Slower ☐ Slower ☐ Same
☐ Quicker ☐ Much Quicker

4. With respect to wet film quality (i.e. orange peel, pinholes, sags, etc.):
☐ Much Worse ☐ Worse ☐ Same
☐ Better ☐ Much Better

Additional comments:

What is your general opinion of this material compared to WBCC?

☐ Much Worse ☐ Worse ☐ Same
☐ Better ☐ Much Better

Please use back of form to provide <u>any</u> additional comments about the material.

Solvent Based CARC

How would you describe the mixing of this material when compared to solvent based CARC?

1. With respect to complexity of mix ratio:
☐ Much Easier ☐ Easier ☐ Same
☒ More Difficult ☐ Much More Difficult

2. With respect to mixing:
☐ Much Easier ☐ Easier ☐ Same
☒ More Difficult ☐ Much More Difficult

3. With respect to time:
☐ Much Slower ☒ Slower ☐ Same
☐ Quicker ☐ Much Quicker

Additional comments:

How would you describe the spray characteristics of this material when compared to solvent based CARC?

1. With respect to spraying:
☒ Much Easier ☐ Easier ☐ Same
☐ More Difficult ☐ Much More Difficult

2. With respect to spray quality:
☐ Much Worse ☐ Worse ☐ Same
☐ Better ☒ Much Better

3. With respect to application rate:
☐ Much Slower ☐ Slower ☐ Same
☒ Quicker ☐ Much Quicker

4. With respect to wet film quality (i.e. orange peel, pinholes, sags, etc.):
☐ Much Worse ☐ Worse ☐ Same
☐ Better ☒ Much Better

Additional comments:

What is your general opinion of this material compared to solvent based CARC?

☐ Much Worse ☐ Worse ☐ Same
☐ Better ☒ Much Better

Please use back of form to provide <u>any</u> additional comments about the material.

1

Tobyhanna survey sample 1

Nov-02-00 01:14P P.02

MIL-P-64159 TYPE II WRCARC FIELD TRIAL APPLICATION SURVEY

Fill out the correct column, based on which coating is currently used

ROBERT KONAN

WBCC

How would you describe the mixing of this material when compared to WBCC?

1. With respect to complexity of mix ratio:
Much Easier / Easier / Same / More Difficult / Much More Difficult

2. With respect to mixing:
Much Easier / Easier / Same / More Difficult / Much More Difficult

3. With respect to time:
Much Slower / Slower / Same / Quicker / Much Quicker

Additional comments:

How would you describe the spray characteristics of this material when compared to WBCC?

1. With respect to spraying:
Much Easier / Easier / Same / More Difficult / Much More Difficult

2. With respect to spray quality:
Much Worse / Worse / Same / Better / Much Better

3. With respect to application rate:
Much Slower / Slower / Same / Quicker / Much Quicker

4. With respect to wet film quality (i.e. orange peel, pinholes, sags, etc.):
Much Worse / Worse / Same / Better / Much Better

Additional comments:

What is your general opinion of this material compared to WBCC?

Much Worse / Worse / Same / Better / Much Better

Please use back of form to provide any additional comments about the material.

Solvent Based CARC

How would you describe the mixing of this material when compared to solvent based CARC?

1. With respect to complexity of mix ratio:
Much Easier / ✓ Easier / Same / More Difficult / Much More Difficult

2. With respect to mixing:
✓ Much Easier / Easier / Same / More Difficult / Much More Difficult

3. With respect to time:
Much Slower / Slower / Same / ✓ Quicker / Much Quicker

Additional comments:

How would you describe the spray characteristics of this material when compared to solvent based CARC?

1. With respect to spraying:
Much Easier / ✓ Easier / Same / More Difficult / Much More Difficult

2. With respect to spray quality:
Much Worse / Worse / Same / Better / ✓ Much Better

3. With respect to application rate:
Much Slower / Slower / Same / Quicker / ✓ Much Quicker

4. With respect to wet film quality (i.e. orange peel, pinholes, sags, etc.):
Much Worse / Worse / Same / Better / ✓ Much Better

Additional comments:

What is your general opinion of this material compared to solvent based CARC?

Much Worse / Worse / Same / Better / ✓ Much Better

Please use back of form to provide any additional comments about the material.

Appendix G: Laboratory Data

U.S. Marine Corps Experimental Coating Data Sheet

Equipment Classification
Vehicle

Trial Location
MCLB Barstow, CA

Application Start Date
5/10/2000

USMC Number
544220

Manufacturer
Sherwin Williams

Equipment Nomenclature
M-1043 HMMWV

National Stock Number (NSN)

TAM Number

Owning Unit
I MEF, Camp Pendelton

MSC Phone Number
DSN 365-9157

Surface Preparation
- (●) Abrasive Blast
- ( ) Other
- ( ) Sweep Blast
- ( ) None
- ( ) Hydro-Blast
- ( ) Hand Tool/Sand

Batch Numbers

DOD-P-15328D
Manufacturer - General Coatings, Inc.
Batch 2563

MIL-P-53030A
Manufacturer - Deft Chemical Coatings

Part A: Base - 44-W-7, 40968, DOM 11/99
Part B: Catalyst- 44-W-7, 40969, DOM 11/99

MIL-DTL-64159 Ty II 383 Grn (34094)
Manufacturer - Sherwin-Williams

Part A: Polyol - F93G502, no batch #, DOM 4/27/00
Part B: Isocyanate - V93V502, OX0410, DOM 2/10/00

Manufacturer's Suggested System

Coating Name	Coating Type	Nozzle Size	Number of Coats	Required WFT (mils)	Required DFT (mils)
DOD-P-15328	Wash Primer		1		0.3-0.6
MIL-P-53030	Epoxy		1	4-5	1.5-2.0
MIL-DTL-64159 TY II	Urethane		1	6	2
		Total	3	10-11	3.8-4.6

Coating System Applied

Coating Name	Coating Type	Date Applied	Nozzle Size	WFT (mils)	DFT (mils)
DOD-P-15328D	Wash Primer				
MIL-C-53030A	Epoxy	5/5/00			4.6
MIL-DTL-64159 TY II	Urethane	5/10/00	94/94P	5	
			Total		5.8

Coating Notes

Steel hard back and aluminum body panels were blasted to bare metal, fiberglass hood area was only scuff sanded with any substrate defects fixed.

Equipment
Fluid Tip - 94
Air Cap - 94P
Gun – Binks HVLP Mach 1

Pot Pressure – 15 psi
Cap Pressure – 12-13 psi

U.S. Marine Corps Experimental Coating Data Sheet

Equipment Nomenclature	USMC Number	Coating System Applied
M-1043 HMMWV	544220	MIL-DTL-64159 TY II (SERDP CARC) for ESTCP Dem/Val

Environmental Conditions

Coating \ Conditions	Ambient Temperature (°F)	Surface Temperature (°F)	Dew Point (°F)	Relative Humidity (%)
DOD-P-15328D				
MIL-C-53030A				
MIL-DTL-64159 TY II	78	77	35	21.7

Application Summary

<u>05/10/00</u>

All component A material was placed on a shaker for 5 minutes.
Mixed two batches of paint initially.

1st Batch
0832 – Poured 2 gallons of component A into a 5 gallon can.
0833 – Poured 1 gallon of component B into the same 5 gallon can.
0834 – Begin Mixing A and B using a Squirrel™ mixer. SW suggested leaving the mixer in the center of the can rather than moving it around within the can.
0837 – Stopped mixing A and B.

2nd Batch
0837 – Poured 2 gallons of component A into a 5 gallon can.
0837 – Poured 1 gallon of component B into the same 5 gallon can.
0838 – Begin Mixing A and B using a Squirrel™ mixer.
0841 – Stopped mixing A and B.
0842 – Stopped to get a measurement cup for water.
0845 – Added 3 quarts of water to 1st batch of paint and 2 quarts to the 2nd batch. Began mixing 1st batch.
0848 – Stopped mixing the 1st batch. Started mixing the 2nd batch.
0850 – Added 1 more quart of water to the 2nd batch of paint.
0850 – Zahn #3 cup viscosity measurement of 1st batch of paint – 15.7 seconds @ 69°F.
0852 – Stopped mixing 2nd batch.
0853 – Zahn #3 cup viscosity measurement of 2nd batch of paint – 14.1 seconds @ 69°F.

After panels were painted, and some paint problems were worked out, coating of the vehicles began...

1230 – Zahn #3 cup viscosity measurement of 1st batch of paint – 14.0 seconds @ 72°F.
1245 – Painters began an air blow down of USMC vehicle ID # 544220 (HMMWV #1).
1250 – Environmental conditions taken (see chart above)
1253 – Blow down completed.
1300 – Painters began to set up equipment and prep for spraying.
1310 – Setup and prep completed.
1312 – A scrap panel was sprayed to ensure there were no problems or defects with the applied film. No problems were observed.
1315 – Began spraying the vehicle.
1329 – Completed spraying the vehicle.
1330 – WFT readings were taken to verify adequate coverage. Desired WFT was achieved.
1330 – Environmental conditions as follows: AT 78, ST 65, DP 31, RH 18.5.

Total paint (MIL-DTL-64159) used was ~2.5 Gal
Total application time was ~14 Min