Audit Report

OFFICE OF THE INSPECTOR GENERAL

CORROSION PREVENTION FOR WHEELED VEHICLE SYSTEMS

Report No. 93-156

August 13, 1993

Department of Defense

Acronyms

AMC	U.S. Army Materiel Command
BRDEC	U.S. Army Belvoir Research, Development and Engineering Center
CARC	Chemical Agent Resistant Coating
CPC	Corrosion Prevention Controls
DODI	Department of Defense Instruction
HEMTT	Heavy Expanded Mobility Tactical Truck
HMMWV	High Mobility Multipurpose Wheeled Vehicle
ILS	Integrated Logistics Support
LCC	Life-Cycle Costs
TACOM	U.S. Army Tank-Automotive Command

INSPECTOR GENERAL
DEPARTMENT OF DEFENSE
400 ARMY NAVY DRIVE
ARLINGTON, VIRGINIA 22202-2884

August 13, 1993

MEMORANDUM FOR INSPECTOR GENERAL, DEPARTMENT OF THE ARMY

SUBJECT: Audit Report on Corrosion Prevention for Wheeled Vehicle Systems (Report No. 93-156)

We are providing this final report for your information and use. The report discusses the Army's procedures for acquiring corrosion prevention and chemical agent resistant coatings for wheeled vehicle systems. Comments on the draft were not received as of the report date from the Program Executive Officer, Combat Support; Commander, U.S. Army Tank-Automotive Command; and the Commander, U.S. Army Materiel Command.

DoD Directive 7650.3 requires that all audit recommendations be resolved promptly. Therefore, we request that the Program Executive Officer, Combat Support; Commander, U.S. Army Tank-Automotive Command; and the Commander, U.S. Army Materiel Command provide comments on the findings and recommendations by October 12, 1993. The Directive also requires that comments indicate concurrence or nonconcurrence with the findings and each recommendation addressed to you. If you concur, describe the corrective actions taken or planned, the completion dates for actions already taken, and the estimated dates for completion of planned actions. If you nonconcur, state your specific reasons for each nonconcurrence. If appropriate, you may propose alternative methods for accomplishing the desired improvements.

We did not quantify any monetary benefits; Appendix D lists other potential benefits of our audit. Recommendations are subject to resolution in accordance with DoD Directive 7650.3 in the event of nonconcurrence or failure to comment. We also ask that your comments indicate concurrence or nonconcurrence with the internal control weaknesses highlighted in Part I.

We appreciate the courtesies extended to our audit staff. If you have questions on this audit, please contact Mr. James L. Koloshey, Program Director, at (703) 614-6225 (DSN 224-6225) or Mr. Verne F. Petz, Project Manager, at (703) 693-0388 (DSN 223-0388). Appendix F lists the planned distribution of this report.

Robert J. Lieberman
Assistant Inspector General
for Auditing

Office of the Inspector General, DoD

Report No. 93-156 August 13, 1993
Project No. 2AG-0013

AUDIT REPORT ON CORROSION PREVENTION FOR WHEELED VEHICLE SYSTEMS

EXECUTIVE SUMMARY

Introduction. The Program Executive Officer, Combat Support, and the Commander, U.S. Army Tank-Automotive Command, are responsible for procuring and remanufacturing wheeled vehicle systems, respectively. The U.S. Army Belvoir Research, Development and Engineering Center in Virginia has responsibility for protective coatings and finishes used on wheeled vehicle systems.

Objective. The audit objective was to evaluate the effectiveness and efficiency of the Army's procedures for acquiring corrosion prevention and chemical agent resistant coatings for wheeled vehicle systems. To accomplish this objective, we reviewed corrosion controls and painting processes. The audit also included a review of the adequacy of internal controls related to the audit objective.

Audit Results. The procedures used by the Army to obtain corrosion prevention for the acquisition and remanufacture of wheeled vehicle systems need improvement.

o Wheeled vehicle systems had extensive corrosion damage early in their life cycles. Consequently, repair costs were increased, useful life was reduced, and readiness was adversely affected (Finding A).

o High Mobility Multipurpose Wheeled Vehicles have extensive deterioration of their Chemical Agent Resistant Coating (CARC) paint. As a result, CARC paint is not providing the resistance to chemical agents and corrosion as intended (Finding B).

Internal Controls. The audit identified internal control weaknesses as defined by Public Law 97-255, Office of Management and Budget Circular A-123, and DoD Directive 5010.38. Procedures for acquiring corrosion prevention (Finding A) were inadequate.

Potential Benefits of Audit. The principal benefits that will be realized from implementing the audit recommendations are reduced unquantifiable operational and maintenance costs, increased useful life of wheeled vehicle systems, and enhanced operational readiness. These potential benefits are detailed in Appendix D.

Summary of Recommendations. We recommended that the Program Executive Officer, Combat Support, use state-of-the-art corrosion prevention technology for all future acquisitions of wheeled vehicle systems and prepare adequate life-cycle-cost estimates that accurately reflect corrosion-related maintenance and repair costs to wheeled vehicle systems. We recommended that the Commander, U.S. Army Tank-Automotive Command, incorporate state-of-the-art corrosion prevention control technology in all extended service programs and new acquisitions of wheeled vehicle systems. We also recommended that the Commander, U.S. Army Materiel Command, satisfy the requirement for chemical protection by developing another paint with better adhesion qualities.

Management Comments. The Army did not provide written comments to the draft of this report issued May 19, 1993. Management comments were due on July 19, 1993. We request that the Program Executive Officer, Combat Support; Commander, U.S. Army Tank-Automotive Command; and the Commander, U.S. Army Materiel Command comment on the findings and recommendations by October 12, 1993.

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This report was prepared by the Acquisition Management Directorate, Office of the Assistant Inspector General for Auditing, Department of Defense. Copies of the report can be obtained from the Secondary Reports Distribution Unit, Audit Planning and Technical Support Directorate, at (703) 614-6303 (DSN 224-6303).

Part I - Introduction

Background

DoD Instruction (DoDI) 5000.1, part 1, states, "Critical parameters that are design cost drivers or have a significant impact on readiness, capability, and life-cycle costs (LCCs) must be identified early and managed intensively." In addition, DoDI 5000.2, part 7, states that

> An effective integrated logistics support effort shall be established within each program office. Integrated logistics support (ILS) shall be managed as a disciplined, unified, interactive approach to the management and technical activities necessary to:
>
> 1. Developing support requirements that are related consistently to readiness objectives, to design, and to each other;
>
> 2. Effectively integrating support considerations into the system and equipment design;
>
> 3. Identifying the most cost-effective approach to supporting the system when it is fielded.

The primary goal of the integrated logistics support program is to achieve system readiness objectives at an affordable LCC. The resources needed to achieve the readiness objective must receive equal emphasis with the resources required to achieve schedule or performance objectives. LCC analysis helps to achieve these objectives by evaluating the cost implications of various design and logistic support alternatives.

Early in the acquisition cycle, the LCC analysis concentrates on quantifying the cost of implications of selected design alternatives, which provide the desired level of performance. ILS activities at this stage focus on designing supportability characteristics into the system and evaluating the cost of ownership and support requirements. Frequently, these supportability characteristics require the expenditure of higher development and acquisition costs in return for lower operation and maintenance costs.

Objectives

The overall audit objective was to evaluate the adequacy of ILS for wheeled vehicle systems. After initial research, we focused on determining whether corrosion prevention was adequately addressed during the acquisition process for wheeled vehicle systems. In addition, we were to determine whether the use of Chemical Agent Resistant Coating (CARC) paint was meeting its intended purpose or if it was increasing the difficulty of maintaining wheeled vehicle systems.

Scope

This performance audit was conducted from February 1992 to November 1992 in accordance with auditing standards issued by the Comptroller General of the United States, as implemented by the Inspector General, Department of Defense, and accordingly included such tests of internal controls as were deemed necessary. We reviewed data dated from April 1985 through August 1992. We also interviewed personnel involved in the acquisition, maintenance, and repair related to Corrosion Prevention Controls (CPCs) and in the handling and acquisition of CARC paint. A complete list of organizations visited during the audit is in Appendix E.

Internal Controls

We reviewed internal controls applicable to the wheeled vehicle systems. In assessing internal controls, we evaluated management plans, written policies and procedures, and management-initiated reviews. The audit disclosed internal control weakness as defined by Public Law 97-255, Office of Management and Budget Circular A-123, and DoD Directive 5010.38.

Internal controls were not in place to ensure the procurement of wheeled vehicles with proper corrosion prevention incorporated into their designs (Finding A). Implementation of Recommendations A.1.a., A.1.b., and A.2. will correct the weakness. Implementation of these recommendations will provide a means for determining the cost-effectiveness of various corrosion prevention controls and will ensure that state-of-the-art corrosion control technology is used in future procurements and remanufacture of wheeled vehicle systems.

Prior Audits and Other Reviews

The Department of Defense, Office of the Inspector General; Service Audit Agencies; and the General Accounting Office have not specifically reviewed corrosion prevention for wheeled vehicle systems within the last 5 years.

Part II - Findings and Recommendations

Finding A. Corrosion

Wheeled vehicle systems acquired by the U.S. Army showed extensive corrosion early in their life cycles. This condition occurred because the Army procured the vehicles without requiring state-of-the-art corrosion-prevention technology to be used during vehicle production. As a result, maintenance and repair costs were increased, useful life was reduced, and operational readiness was adversely impacted.

Background

Definition. Corrosion is the unintended destruction or deterioration of a material due to reaction with the environment. Corrosion prevention is important due to its impact on cost, equipment operational safety, and conservation of valuable raw materials. Corrosion of metals increases maintenance requirements and reduces the useful life of military vehicles.

Army Policy. In calendar year 1985, the Army Materiel Command (AMC) directed all major subcommands, including the U.S. Army Tank-Automotive Command (TACOM), to use state-of-the-art corrosion-prevention technology in original equipment design.

Army Regulation 750-59, "Army Corrosion Prevention and Control (CPC) Program," dated September 1988, established policy and procedures for all Army systems and equipment. The CPC program goals were to be achieved by using the latest corrosion control technology in the original equipment design, manufacturing, maintenance, supply, and storage processes. These factors were to be considered for all acquisitions including nondevelopmental items. The objective was to minimize corrosion by the selection of appropriate surface treatments, materials, and system design. Regulation 750-59 also directed AMC to establish a CPC Program Office to administer the Army CPC Program. The Corrosion and Materials Branch (now the Materials Engineering Office) was designated as the focal point for corrosion prevention and control.

The Program Executive Officer, Combat Support, is responsible for the procurement of wheeled vehicle systems including vehicles for the Extended Service Programs. TACOM, a subcommand of AMC, is responsible for the procurement of certain trailers and material-handling equipment such as forklifts. Trailers uniquely associated with a wheeled vehicle system are usually procured by the Program Executive Officer.

Evaluation of Wheeled Vehicle Systems

We evaluated wheeled vehicle systems including 5-ton trucks (M-900 series), 7.2- and 40-ton cranes, flatbeds, forklifts, Heavy Expanded Mobility Tactical Trucks (HEMTT), High Mobility Multipurpose Wheeled Vehicles (HMMWV), and tankers at 17 field sites (Appendix A) to determine the extent of corrosion damage to wheeled vehicle systems. We performed physical inspections of 275 vehicles from the Army (143 vehicles), Marine Corps (45 vehicles), Army Reserve (16 vehicles), and Army National Guard (71 vehicles). The inspection sites were selected to represent varied climatic and environmental conditions representing northern, southern, western high desert, and eastern coastal locations. The vehicles inspected at each site were randomly selected to realistically represent the condition of the entire fleet of vehicles at each location. All inspected vehicles had deterioration resulting from corrosion, ranging from surface corrosion to major structural deterioration. Table 1 summarizes the results of our review of corrosion.

Table 1. Corrosion Data

Vehicle Type	No. of Vehicles Inspected	No. of Sites Visited	Average No. of Corroded Parts Per Vehicle	Average Age of Vehicles (In years)
HMMWV	121	7	48	4.7
5-Ton	57	11	55	5.7
HEMTT	9	3	151	3.1
Crane	3	3	27	1.3
Flatbed	62	6	25	9.2
Tankers	11	4	25	6.3
Forklifts	12	8	24	4.6
Totals	275		51	5.9

The parts we found to be corroded varied among the various vehicle classes. Generally, most damage occurred either at or around screws, bolts, and fasteners; bumpers and tie-down supports; outer body surfaces; passenger compartments; body frames and supporting suspension parts; and engine compartments. No metallic section of any vehicle class was found to be immune from corrosion. The vehicles examined were not, as far as we could determine, abused or used outside of their intended operating environments. We noted that vehicles exposed to marine and tropic environments did show a greater degree of deterioration. Appendix B provides a detailed summary of major components inspected and found to be corroded.

Reasons for Corrosion

The deteriorated condition of the wheeled vehicles shown in Table 1. developed because of inadequate corrosion controls in the original equipment design and manufacturing process. These controls include applying appropriate protective coatings, selecting the proper materials, and incorporating appropriate system design. Appendix C (Photographs 1, 2, and 3) depicts damage to wheeled vehicle systems that was due, in part, to the failure to apply the corrosion-preventative techniques.

Protective Coatings. These coatings can be grouped as metallic and organic coatings.

Metallic. These coatings consist of metals or alloys applied to the surface of another metal item. The coatings can be applied by electrolytic deposition (electroplating), metallic bonding (cladding), or chemical or vapor deposition. Immersion of the item into a bath of molten zinc (hot-dipped galvanization) is the most effective method and is widely used by industry leaders in the manufacturing process. Hot-dipped galvanization enhances structural integrity and is economical to apply, costing between $200 to $400 per unit. None of the vehicle classes we reviewed included hot-dipped galvanization in the manufacturing process.

Organic. These coatings include all paints, lacquers, enamels, varnishes, primers, and temporary corrosion-inhibiting greases, waxes, and oils. Primers used by industry leaders are applied by electrodeposition (E-coat), whereby the object being coated is immersed in a liquid. E-coating does not provide the same protection as hot-dipped galvanization. As far as can be determined, no vehicle inspected had been E-coated.

Material Selection. Proper selection procedures should result in materials that exhibit corrosion resistance to the operating environment and are compatible with adjacent materials. Non-compatible metals may corrode due to galvanic effects when they are in contact with each other within a corrosive environment. For example, we found extensive corrosion on and around ferrous metal fasteners that should have been constructed of either corrosion-resistant or compatible materials.

System Design. Proper design of a vehicle body or structure can inhibit corrosion by avoiding design features that trap debris and moisture. Potential corrosion sites should be avoided wherever possible by eliminating crevices, ensuring that proper drain holes are included, and specifying sealing materials where crevices are unavoidable. We found extensive rust at the bottom of door frames and at truck vertical support stakes. Properly sized and located drain holes would have helped reduce corrosion in these instances.

Contractual Specifications

Performance. Wheeled vehicles are acquired as Nondevelopmental Items; therefore, contracting procedures emphasize performance specifications rather than design specifications. Performance specifications state that the item will perform at a certain level for a stated period. For example, the corrosion control specification for the 1989 HMMWV contract, DAAE07-89-C-0998, requires:

> The vehicle shall be capable of operating for a total service life of fifteen (15) years which can include varying or extended periods in a corrosion environment involving high humidity, salt spray, road de-icing agents, gravel impingement, and atmospheric contamination. During the 15 year service life, there shall be no corrosion past stage 1. . . . Such capability shall be achieved by a combination of design features (as found in but not limited to the TACOM Design Guidelines for Prevention of Corrosion in Combat and Tactical Vehicles), material selection (i.e. composites), production techniques, process controls, inspection and documentation. No action beyond normal washing, periodic inspection, repair of damaged areas shall be necessary to keep the corrosion prevention in effect. Damaged areas are defined to mean any fault that is not a result of a deficiency in design, material and/or manufacturing.

Design. Design specifications specifically state processes or techniques to be used in the manufacturing process. For example, the Family of Medium Tactical Vehicles contract states, under Protective Coatings, "For corrosion susceptible areas such as cab body, cargo bed and sides, frame rails and sheet metal components, MIL-P-53084, GM9984070 or GM9980417, E-coat primer shall replace the primers specified in MIL-STD-193 [Military Standard]."

Relative Merits. We recognize that every opportunity should be taken to state requirements in performance specifications. Unnecessarily specifying how a requirement will be met restricts the range of products that may be considered. For corrosion prevention, however, the use of a performance specification has not resulted in the use of state-of-the-art corrosion techniques. Moreover, enforcing claims under previous corrosion warranties defined by performance specifications has been extremely difficult. In these situations, contractors have consistently argued that the warranty applies only when the vehicle is rendered inoperative by the corrosion.

Life-Cycle-Cost Analysis

TACOM did not perform adequate life-cycle-cost analysis to support the acquisition of wheeled vehicle systems. Our review of maintenance data, correspondence, and discussions with cognizant TACOM personnel showed that no established reporting system adequately collected all corrosion-related cost data. Also, for the data that were available, adequate analysis for corrosion costs was not performed or reported by TACOM to the various Program Managers for the wheeled vehicle systems that we reviewed. An adequate life-cycle-cost estimate and trade-off analysis is required by DoDI 5000.1 at each milestone in the acquisition process and should have been accomplished for the vehicle systems that we reviewed.

Effects of Corrosion

Failure to provide adequate corrosion prevention to wheeled vehicle systems has led to increased maintenance and repair costs, reduced useful life of those vehicles, and adversely impacted operational readiness.

Maintenance and Repair Costs. Corrosion-related problems cost the Army an estimated $2.0 billion to $2.5 billion annually for Army-managed weapon systems, according to TACOM. We could not determine what part of these costs applied to wheeled vehicle systems; however, to ascertain the approximate cost to repair vehicles that had deterioration due to corrosion, we obtained the following cost estimates to repair HMMWVs and 5-ton trucks:

HMMWVs. Cost estimates to repair corrosion damage were obtained from the Maintenance Directorate, Marine Corps Logistics Base - Atlantic, for four HMMWVs. The initial unit procurement costs of these vehicles were calculated to be $36,000. Two examples were selected by the Marine Corps.

Vehicle Number 050787. This vehicle was built in June 1988 and had 55.6 miles on the odometer, having never been issued to an operational unit. The estimated cost of $3,109 to repair included repairs to floor pans, transmission cooling lines, the cargo bed, body and frame bolts, rocker panels, the fly wheel, tie rods, the A-frame assembly, and other vehicle components.

Vehicle Number 529764. This vehicle was returned from an operational unit and represented a moderate degree of deterioration due to corrosion. The estimated cost of $18,019 to repair required the complete disassembly of the vehicle and the engine compartment, spot blasting, and complete repainting.

Five-Ton Trucks. Estimates to repair corrosion damage were obtained from the Maintenance Directorate, Marine Corps Logistics Base - Pacific, for three 5-ton trucks and from the Maintenance Directorate, Marine Corps Logistics Base - Atlantic, for two 5-ton trucks. The average initial unit procurement costs of these trucks were calculated to be $82,000. The Pacific Base estimates include vehicles with light, moderate, and extensive corrosion. The estimates to repair the damage were $1,770; $12,697; and $33,923, respectively. The Atlantic Base estimates represent what the Depot considered to be vehicles with light and extensive corrosion. The estimates to repair the corrosion-damaged vehicles were $14,060 and $47,418, respectively.

Useful Life and Readiness. Corrosion not only causes increased repair costs but also shortens the useful life of wheeled vehicle systems and decreases readiness. Although we could not quantify the precise impact on operational readiness, vehicles that require corrosion repairs are not available to their components for as long as 2 to 4 months. However, at the Atlantic Base, current HMMWV repair cycle time is 12 months. Additionally, vehicles with relatively low unit costs, such as the HMMWVs ($36,000 per unit), with extensive corrosion can breach the threshold of economic repair which is 65 percent of the unit replacement cost. An example of this is a 5-year-old HMMWV (Vehicle No. 529882) at the Marine Corps Logistics Base - Atlantic. In this case, procurement of a new vehicle was considered to be more economical than repairing the corroded vehicle. Such vehicles were not representative of the wheeled vehicle fleet.

Conclusion

We recognize that the goals of the acquisition community have stressed cost and schedule performance; thus, low unit cost and high unit output have been emphasized by program offices. This philosophy has resulted in supportability considerations to generally receive less emphasis. As a result, state-of-the-art corrosion prevention technology was not incorporated into the design of the vehicles inspected because the procurement unit cost of the wheeled vehicle systems would have increased. However, this acquisition philosophy has caused the life-cycle ownership cost to increase because vehicles did not last as long as expected or they required extensive repairs to corroded parts.

To meet the challenges of future military requirements, state-of-the-art corrosion prevention technology should be required in design specifications of initial vehicle production. This requirement would maximize vehicle life, minimize corrosion-related repair costs, and meet the intended objective of DoDI 5000.2.

Recommendations, Management Comments, and Audit Response

1. We recommend that the Program Executive Officer, Combat Support:

a. Incorporate state-of-the-art corrosion-prevention technology for all future acquisitions and extended service programs for wheeled vehicle systems. Design specifications should be used in contractual documents.

b. Prepare life-cycle-cost estimates that show the costs of corrosion-related maintenance and repair cost alternatives applicable to all future wheeled vehicle system acquisitions and extended service programs.

2. We recommend that the Commander, U.S. Army Tank-Automotive Command, incorporate state-of-the-art corrosion-prevention technology for all future acquisitions and extended service programs for certain trailers and material-handling equipment such as forklifts. Design specifications should be used in contractual documents.

Management Comments. The Army's Program Executive Officer, Combat Support, did not provide written comments to Recommendation 1.

The Commander, U.S. Army Tank-Automotive Command, did not provide written comments to Recommendation 2.

Audit Response. We request that the Army's Program Executive Officer, Combat Support, provide comments to Recommendation 1. and the Commander, U.S. Army Tank-Automotive Command, provide comments to Recommendation 2. of this final report.

Finding B. Chemical Agent Resistant Coating

HMMWVs have experienced extensive deterioration of their CARC paint. Fifty-nine percent of the 121 vehicles we inspected had peeling, chipping, or cracking CARC paint on body surfaces. The paint failures were caused by the inelastic physical properties of CARC paint and improper application of the paint. As a result, CARC paint is not meeting its intended objectives of providing resistance to both chemical warfare agents and corrosion. Moreover, there are potentially serious environmental consequences to the use of this paint.

Background

The CARC paint system consists of surface cleaning and pretreatment, epoxy primers, epoxy interior topcoat, and a polyurethane exterior topcoat. A major benefit from using this paint is resistance to chemical penetration of the paint film by chemical warfare agents. Also, this system results in easier decontamination and a much more rapid return of equipment to service. Other potential benefits are a longer than normal service life of the paint and better resistance to corrosion. Equally important, CARC paint also provides camouflage protection, resembling living foliage when viewed in a spectroscope.

The Department of the Army required CARC paint, beginning in FY 1985, for all combat, combat-support, tactical wheeled vehicles, aircraft, and essential ground-support equipment. The Materials, Fuels and Lubricants Directorate at the Belvoir Research, Development and Engineering Center (BRDEC) of AMC was given responsibility for protective coatings on tactical and ground-support equipment. These responsibilities include research and development, specification preparation, and management of associated Qualified Products Lists. Nearly all vehicles are painted by their original manufacturers and later repainted in the field at major rework facilities, such as Army and Marine Corps Depots, or touched up at smaller, unit-level organizations.

Evaluation of HMMWVs

We conducted inspections of HMMWVs at six Army and Marine Corps sites and several National Guard sites to determine the extent of the deterioration of CARC paint in a variety of environments. The results of our inspections are included in Table 2.

Table 2. CARC Inspection Results

Component	Activity	HMMWVs Inspected	HMMWVs With Deteriorated Paint
Army	Fort Bragg	17	4
Army	Fort Sill	13	9
Army	Fort Knox	9	3
Army	Fort Drum	11	11
Marine Corps	MCLB-Atlantic	2	2
Marine Corps	Camp Lejeune	40	30
Wisc. Nat'l Guard	Various	29	13
Total		121	72

Percentage Affected (72/121) = 59.5%.

Specific Areas of Deterioration. Vehicles inspected had CARC paint in various states of deterioration. CARC paint had noticeably lifted from the bodies of the vehicles. In many cases, the metal was exposed in high-abrasion areas, such as quarter panels, bumpers, and cargo beds. Additionally, there were areas where the paint was cracked and peeling but not yet detached. Moisture accumulation in these crevices would result in additional peeling of the paint (Appendix C: Photographs 4 and 6 show CARC deterioration).

Other Observations. We also observed 10 vehicles at the Marine Corps Logistics Base - Atlantic that had severe paint deterioration. Even though these vehicles were not in our sample selection, they illustrate a severe failure of CARC paint. These vehicles, under the control of Defense Logistics Agency while in storage since 1988, were never used since the time the Marine Corps received them from the manufacturer (Appendix C: Photograph 5). Additionally, we observed CARC deterioration on other vehicle classes, such as 5-ton trucks and HEMTTs, although the deterioration was not as severe or as widespread as the deterioration on the HMMWVs.

Reasons for CARC Paint Failures

Discussions with BRDEC and the Corrosion Center at TACOM revealed that the failures of CARC paint are due to the physical properties and improper application of the paint.

Physical Properties. The expansion and contraction rate of an organic coating must approximate the expansion and contraction rate of the material it is applied to in order to prevent cracking, chipping, or peeling. CARC paint hardens after application and is extremely inelastic; therefore, when exposed to temperature extremes, CARC paint can become separated from the material to which it is applied. Metals typically expand and contract much faster than CARC paint.

This problem may cause paint failures in hot climates where rainstorms can rapidly reduce the temperature of the painted surfaces.

Application. One main disadvantage of CARC paint is its sensitivity to surface preparation. For the paint to adhere to the surface, stringent quality control must be adhered to during the cleaning, pretreatment, and application processes. While this degree of control can be achieved under environments such as a production line, this control is especially difficult to achieve in the field. Additionally, CARC paint applied too thickly to surfaces will not adhere properly.

Lack of CARC Paint Effectiveness

Protection From Chemical Agents. We spoke with cognizant Army and Marine Corps personnel to determine whether CARC paint provided chemical protection and simplified vehicle decontamination. They indicated that, when properly applied, CARC paint resisted penetration of chemical agents and aided initial decontamination; however, chipped and peeled CARC paint on contaminated wheeled vehicles can cause additional problems during decontamination. Chemical agents that penetrate scratches, cracks, or other paint defects can diffuse underneath the CARC paint. Once penetrated, the paint must be stripped for decontamination.

Other Sources of Contamination. A further decontamination problem is the tendency of chemical warfare agents to accumulate in engine components, interior cargo areas, and passenger compartments. The agents can also be trapped by the filters, lubricants, dirt, fabrics, tires, petroleum-based undercoatings, and other absorbent items. From these sources, chemical agents slowly leak out or evaporate, creating hazards for exposed personnel.

Environmental Effects

Certain negative environmental effects to the application and disposal of CARC paint exist. These effects are the volatile organic compounds from the paint as it dries and the hazardous waste generated by repainting the vehicles.

Volatile Organic Compounds. Volatile Organic Compounds are the atmospheric vapor emissions given off by the organic solvents that suspend the pigments, driers, and other ingredients of the coating. The amount of solvents in CARC paint is relatively high because of the military requirements for camouflage and decontamination.

Hazardous-Waste. The ongoing repainting of vehicles with CARC paint deterioration has increased the amount of hazardous waste such as residues from solvents and particulant matter.

Recommendation, Management Comments, and Audit Response

We recommend that the Commander, U.S. Army Materiel Command, satisfy the requirement for chemical protection by developing another paint with better adhesion qualities than Chemical Agent Resistant Coating paint for the protection of wheeled vehicle systems.

Management Comments. The Commander, U.S. Army Materiel Command, did not provide written comments to the recommendation.

Audit Response. We request that the Commander, U.S. Army Materiel Command, provide comments to the final report.

Part III - Additional Information

Appendix A. Inspected Vehicles by Site Location

SITE	NO. VEHICLES
ARMY	
Fort Sill, OK	21
Fort Knox, KY	24
Fort Drum, NY	24
Fort Bragg, NC	30
Tooele Army Depot, UT	44
MARINE CORPS	
Marine Corps Logistics Base - Atlantic, Albany, GA	2
Marine Corps Logistics Base - Pacific, Barstow, CA	3
Camp Lejeune, NC	40
ARMY RESERVE	
Fort Jackson, SC	6
Charleston, SC	10
ARMY NATIONAL GUARD	
Wisconsin National Guard	
Fort McCoy	4
General Mitchell Field	9
Richards Street Armory	19
Camp Williams	21
Arizona National Guard	
Tucson	3
Flagstaff	4
Phoenix	11
Total Vehicles	275

Appendix B. Summarization of Major Parts Inspected and Found To Be Corroded

Table B.1. Corroded Vehicle Parts

Table B.1. summarizes the major vehicle parts the auditors inspected and found to be corroded.

VEHICLE PARTS	NO. VEHICLES AFFECTED (275 POSSIBLE)
ENGINE COMPARTMENT	
-- Heads	49
-- Injectors	53
-- Engine mounts	78
-- Valve covers	87
-- Radiator assembly	131
SUSPENSION AND STEERING	
-- Idler arms	48
-- Control arms (HMMWV only)	78
-- Tie rod	124
-- Housing, Axle	161
-- Springs	205
BODY	
-- Fenders	72
-- Bumpers	105
-- Door frames	115

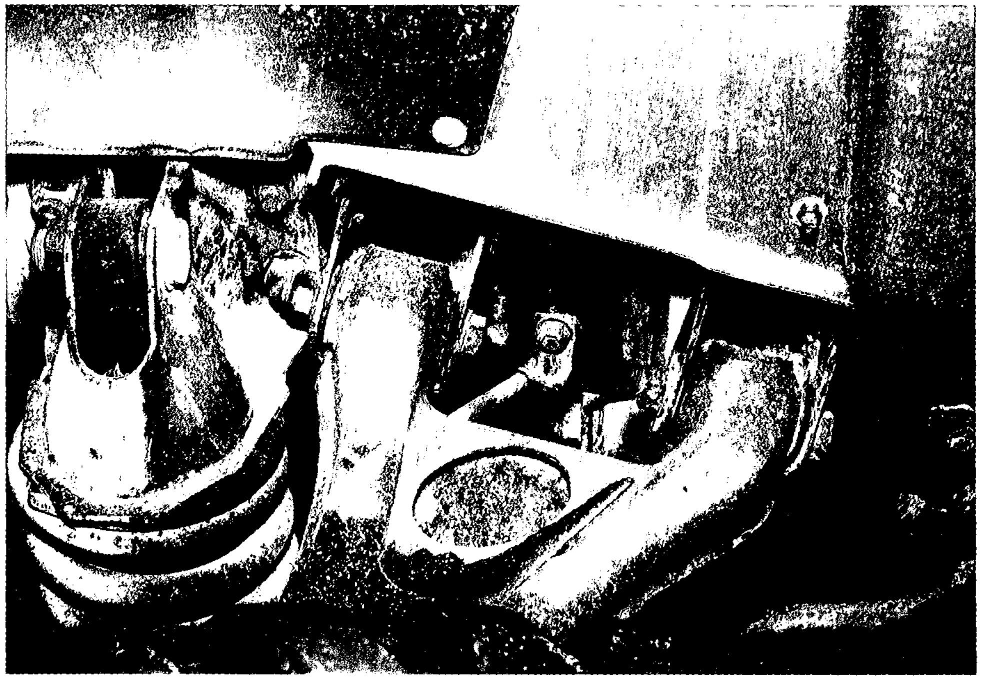
Table B.1. (Cont.)

VEHICLE PARTS	NO. VEHICLES AFFECTED (275 POSSIBLE)
BODY (Cont.)	
-- Bed	120
-- Tie downs/Lift points	209
UNDERBODY	
- Metal brake lines	35
-- Air tanks	40
-- Driveshafts	105
-- Fuel lines	106
-- Universal joints	135
OTHER	
-- Pump assembly (HEMTT and Tankers)	13
-- Forklift and Crane assemblies	22
-- Metal hydraulic and air line connections	25
-- Welded seams	73
-- Fuel tank Assemblies	135
-- Nuts, bolts, and fasteners	177
-- Frame	187

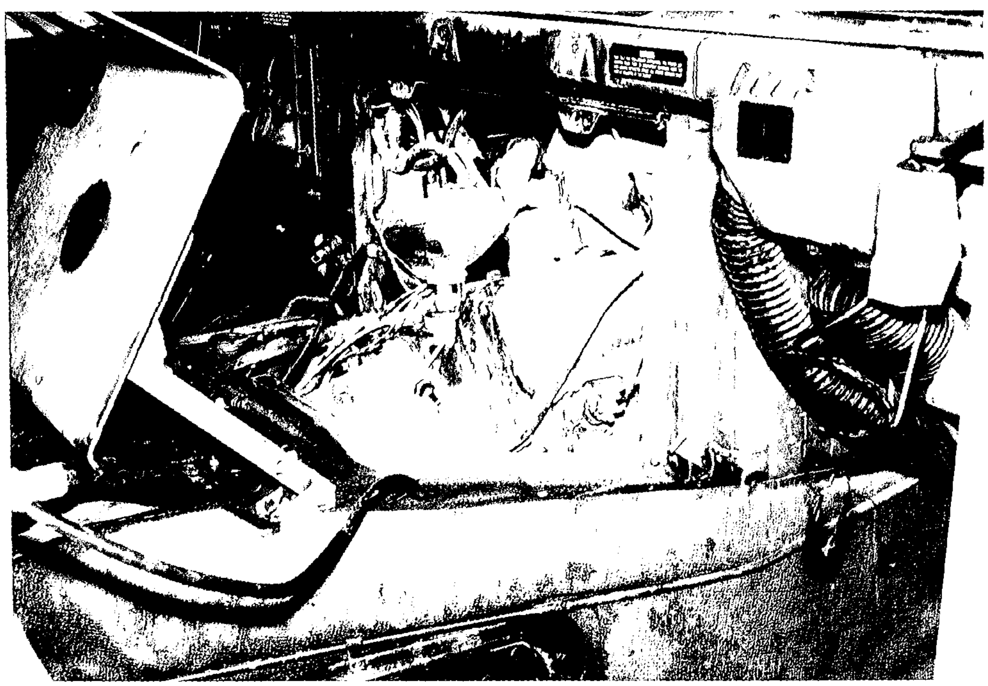
Appendix C. Photographic Examples

These six photographs depict damage to wheeled vehicle systems:

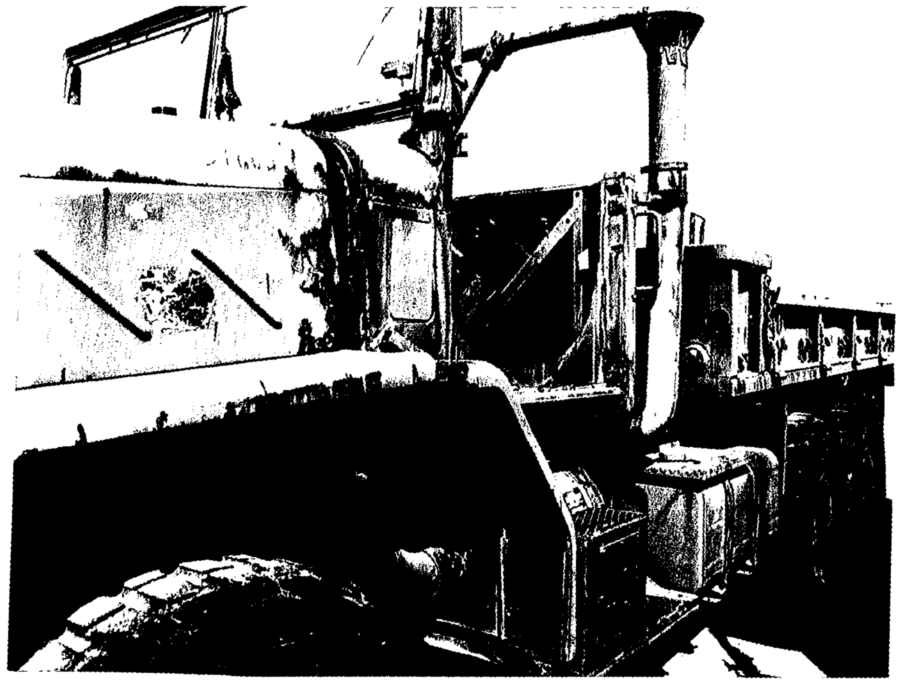
Photograph 1.	Corrosion of suspension and fasteners (Marine Corps HMMWV)
Photograph 2.	Corrosion of engine (Marine Corps HMMWV)
Photograph 3.	Corrosion (Marine Corps 5-ton Truck)
Photograph 4.	Corrosion of fasteners and peeling of paint (Marine Corps HMMWV)
Photograph 5.	Peeling of CARC paint (Marine Corps HMMWV)
Photograph 6.	Peeling of CARC paint (Army Reserve Command HMMWV)



Photograph 1



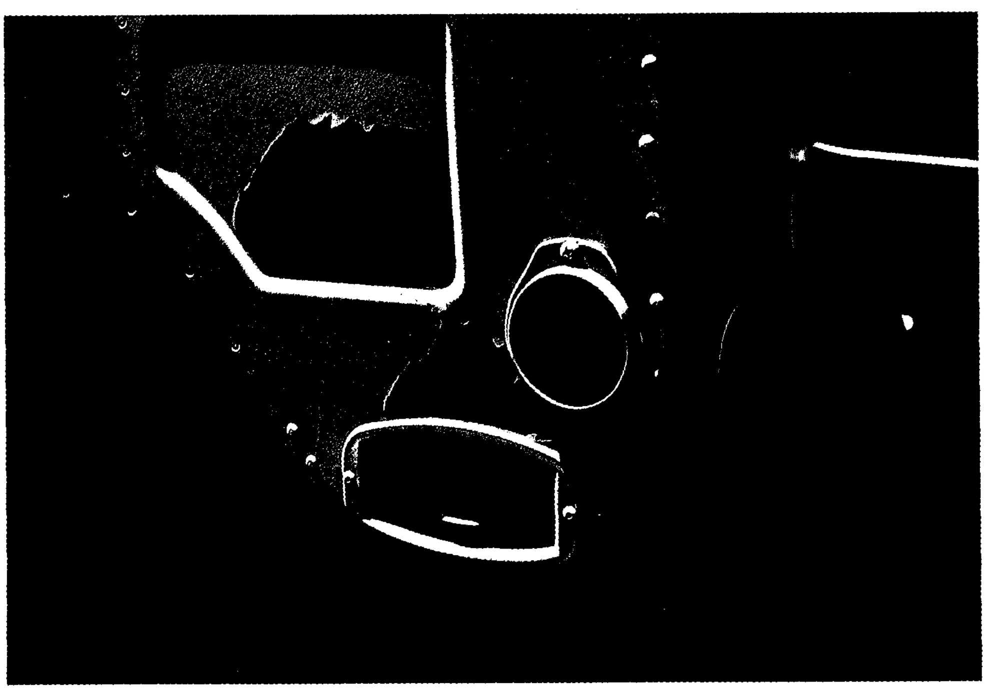
Photograph 2



Photograph 3

Photograph 4

Photograph 5



Photograph 6

Appendix D. Summary of Potential Benefits Resulting From Audit

Recommendation Reference	Description of Benefit	Amount and/or Type of Benefit
A.1.a.	Economy and Efficiency and Internal Controls. Will ensure that the most cost-effective acquisition strategy is used.	Undeterminable Monetary Benefit. Due to the lack of available data.
A.1.b.	Economy and Efficiency and Internal Controls. Will ensure adequate data for future decisions.	Nonmonetary.
A.2.	Economy and Efficiency and Internal Controls. Will ensure that the wheeled vehicle fleet will be brought to the highest possible readiness state.	Undeterminable Monetary Benefit. Due to the lack of available data.
B.	Program Results. Will ensure a safer paint coating to accomplish the necessary mission specifications.	Nonmonetary.

Appendix E. Organizations Visited or Contacted

Office of the Secretary of Defense

Under Secretary of Defense for Acquisition, Washington, DC
Comptroller of the Department of Defense, Washington, DC

Department of the Army

Assistant Secretary of the Army (Financial Management), Washington, DC
U.S. Army Forces Command, Fort McPherson, GA
- XVIII Airborne Corps, Fort Bragg, NC
- 120th Army Maintenance Support Activity, Fort Bragg, NC
- 10th Mountain Division, Fort Drum, NY

U.S. Army Materiel Command, Alexandria, VA
- U.S. Army Tank-Automotive Command, Warren, MI
- U.S. Army Materiel Technology Laboratory, Watertown, MA
- U.S. Army Belvoir Research, Development and Engineering Center, Fort Belvoir, VA
- Tooele Army Depot, Tooele, UT

U.S. Army Training and Doctrine Command, Fort Monroe, VA
- U.S. Army Armor Center and Fort Knox, Fort Knox, KY
- U.S. Army Engineering Command and Fort Leonard Wood, Fort Leonard Wood, MO
- U.S. Army Field Artillery Center and Fort Sill, Fort Sill, OK

U.S. Army Reserve Command, Fort McPherson, GA
- Headquarters, 120TH U.S. Army Reserve, Fort Jackson, SC
- 121st Army Maintenance Support Activity, Charleston, SC
- 941st Transportation Company, Charleston, SC

Headquarters, National Guard Bureau
- Arizona National Guard
- Silver Lake Maintenance Division, Tucson, AZ
- Navajo Maintenance Depot, Flagstaff, AZ
  - 259th Combined Support Maintenance Shop, Phoenix, AZ
- Wisconsin National Guard
  - U.S. Property Fiscal Office, Camp Williams, WI
  - 32nd Military Police Brigade, Richards Street Armory, Milwaukee, WI
  - 105th Maintenance Division, General Mitchell Airfield, Milwaukee, WI
  - Mobilization and Training Equipment Site, Fort McCoy, WI
- South Carolina Army National Guard, Charleston, SC

Department of the Navy

Assistant Secretary of the Navy (Financial Management), Norfolk Naval Base, VA
Naval Fleet Training Center, San Diego, CA
U.S. Marine Corps Research, Development and Acquisition Command, Quantico, VA
Fleet Marine Force Atlantic, Norfolk, VA
U.S. Marine Corps Base Camp Lejeune, Jacksonville, NC
U.S. Marine Corps Air Station, Cherry Point, NC
Marine Corps Logistics Base - Atlantic, Albany, GA
Marine Corps Logistics Base - Pacific, Barstow, CA

Department of the Air Force

Assistant Secretary of the Air Force (Financial Management and Comptroller), Washington, DC
Air Force Air Logistics Command, Robins Air Force Base, GA

Other Government Organizations

Defense Logistics Agency, Alexandria, VA
Defense Contract Administration Services Management Area Office, Milwaukee, WI
General Services Administration Paints and Chemicals Commodity Center, Auburn, WA

Non-Government Organizations

Oshkosh Truck Corporation, Oshkosh, WI
National Defense Center for Environmental Excellence, Johnstown, PA

Appendix F. Report Distribution

Office of the Secretary of Defense

Comptroller of the Department of Defense
Assistant Secretary of Defense (Production and Logistics)

Department of the Army

Secretary of the Army
Inspector General, Department of the Army
Commander, U.S. Army Materiel Command
U.S. Army Program Executive Office, Combat Support
Commander, U.S. Army Tank-Automotive Command
U.S. Army Belvoir Research, Development, and Engineering Center

Department of the Navy

Secretary of the Navy
Commandant of the Marine Corps
Assistant Secretary of the Navy (Financial Management)
Commander, U.S. Marine Corps Research, Development and Acquisition Command

Department of the Air Force

Secretary of the Air Force
Assistant Secretary of the Air Force (Financial Management and Comptroller)

Defense Agency

Director, Defense Logistics Agency

Non-DoD Federal Organizations

Office of Management and Budget
U.S. General Accounting Office, National Security International Affairs Division, Technical Information Center

Chairman and Ranking Minority Member of Each of the Following Congressional Committees and Subcommittees:

- Senate Committee on Appropriations
- Senate Subcommittee on Defense, Committee on Appropriations
- Senate Committee on Armed Services
- Senate Committee on Governmental Affairs
- House Committee on Appropriations
- House Subcommittee on Defense, Committee on Appropriations
- House Committee on Armed Services
- House Committee on Government Operations
- House Subcommittee on Legislation and National Security, Committee on Government Operations

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