III. DESCRIPTION OF CARC

A. What is CARC?

The US military relies on paint to achieve a variety of visual and mechanical effects, ranging from camouflage to unit identification to the protection of metal surfaces. CARC-painted surfaces resist the absorption of chemical warfare agents, making decontamination much easier to accomplish. Chemical agent resistant coatings—CARC—make up the largest category of paints applied to the US military's inventory of equipment. CARC's ability to conceal and protect improves the survivability of tracked and wheeled vehicles, artillery pieces and missile launchers, rotary and fixed-wing aircraft, and support equipment such as communications vans, water purification units, generators, and forklifts.

The Army developed the first chemical agent resistant coatings in 1974. The Army made the decision in 1983 to require all combat, combat support, tactical wheeled vehicles, aircraft, and essential ground support equipment (i.e., tactical equipment) be painted with CARC.[1] This decision initiated the development of the CARC protocol as it exists today. As a result of stringent health and environmental regulations, lead and hexavalent chromium were removed from CARC and the levels of solvents or volatile organic compounds (VOCs) were reduced. These actions occurred before the Gulf War.[2]

CARC is essentially a low gloss version of automotive-grade polyurethane paint. These coatings provide the standard characteristics of any protective finish: corrosion resistance, durability, identification marking, etc. However, CARC formulations provide some unique properties that distinguish them from typical commercially-available paints.

Chemical agent resistant coatings all have a very matte finish, or extremely low gloss, to minimize visual detection due to glare or reflection from the sun or other bright light sources.

Because chemical warfare agents are unable to penetrate the coating, a standard military decontaminating solution, such as decontaminating solution number two (DS2), can readily neutralize surface chemical contaminants on CARC-painted vehicles.[3] CARC's resistance to a variety of chemicals and solvents, and its ability to withstand weathering—including exposure to sunlight—has made CARC the paint of choice for outdoor use in a military-operational environment.

While all colors of CARC are chemically similar, the pigmentation additives in CARC formulations have unique properties and characteristics that make them particularly suitable for military operations. For example, the base green color—referred to as Green 383—used in the common three-color woodland pattern employed throughout the military, uses two types of pigments with reflectance properties in the near-infrared region of the spectrum. The combination of these pigments mimics the reflectance properties of chlorophyll present in living foliage, such as tree leaves and grasses, and thus minimizes detection of woodland-scheme CARC-painted equipment by near-infrared detectors. Another color, Tan 686, was reformulated with higher reflectance pigmentation to reduce the amount of solar heat vehicles would absorb, which was a serious concern during Operation Desert Shield. A subsequent color change, designated Tan 686A, increased the reflectance properties of the coating. Initial supplies of CARC available in the early stages of Operation Desert Shield were Tan 686. As new batches of CARC were manufactured to meet the supply needs, Tan 686A became the standard.[4] See Tab C for a discussion of CARC formulations.

B. Technical Specifications

All color variations of CARC must meet stringent military specifications. The typical formulation of these finishes consists of three primary groups of raw materials: the resin or binder system, the pigment package, and the solvents.

As a means of standardizing the paint formulations manufactured by various suppliers, the military uses a system of military specifications (MIL SPEC). The military specification lists all the requirements of the paint, including composition, color and spectral reflectance properties, and label markings. In addition, the military maintains a list of approved suppliers called the qualified products list (QPL) as another control measure to ensure the consistency, quality, and performance of its paints. The military procures CARC only from suppliers on the qualified products list. The Army Research Laboratory has rigorously tested the products of the manufacturers listed on the QPL for conformance to all specifications of performance and composition.[5] See Tab C for a detailed discussion of the military specifications and qualified products list for CARC.

C. Health Considerations

1. Identification of Compounds of Concern

Because polyurethane paint has been commercially available for years, documentation exists about the hazards and toxicity of this category of paints. While it is well known that the isocyanates found in polyurethane paints pose the most significant health risks, solvents in the paints, thinners, and cleaning products are also known to pose a secondary health risk, if absorbed in sufficient quantity.[6]

Most of the components of CARC are not unique; almost any polyurethane paint contains them. Hexamethylene diisocyanate (HDI) is the only isocyanate found in CARC.[7] Inhalation of airborne droplets containing HDI released during spray paint applications is a

well-documented hazard.[8] Direct skin contact to wet CARC is another avenue of exposure that causes irritation of the skin and mucus membranes, and possible absorption of solvents.[9]

Dry CARC poses no known health threat unless disturbed by sanding, grinding, extreme heat, or other conditions that could produce CARC dust, fumes, or vapors. Welding or cutting CARC painted surfaces results in the airborne release of HDI, carbon monoxide, and other toxic materials.[10]

Solvent exposure may occur as a result of contact with any solvent-based paint, including CARC, due to the high volatility (the ability to vaporize readily) of most solvents. Solvent exposure can occur during the surface preparation phase, however, in the Kuwait Theater of Operations, minimal surface preparation occurred.[11]

Solvents are released from CARC during the drying and curing process. These solvents are readily absorbed through the skin and through the respiratory tract.[12,13] Thinners are often added to the paint solution to achieve the correct spray paint viscosity. As the thinners evaporate, excessive solvent concentrations may occur, especially in areas with minimal airflow or ventilation.[14]

Exposure to solvents also occurred during the Gulf War when a variety of solvents were used to clean painting equipment and tools. Some of the solvents used for this purpose were locally procured, and therefore, the identity of all the solvents used in theater is not known.[15]

Tab D presents a listing of the solvents found in some of the paints and thinners most likely used during the CARC painting operations in the Gulf theater. This tab includes information on permissible exposure limits, lower explosive (flammable) limits in air (LEL), concentrations which are immediately dangerous to life or health (IDLH), odor characteristics, health effects, and target organs.

2. Possible Health Effects of Hexamethylene Diisocyanate and Solvents

Exposure to isocyanates and solvents without proper protection can be harmful. Isocyanate exposure, including exposure to the HDI found in CARC, can cause three types of health effects:

- Almost all persons exposed to relatively high concentrations of isocyanates will develop irritation to skin and the respiratory tract;
- A small proportion of persons who are chronically exposed can become sensitized and develop asthma;
- A small proportion of persons who are chronically exposed can develop hypersensitivity pneumonitis.

At high concentrations, isocyanates can cause non-specific irritation of the mucous membranes and respiratory tract in some individuals, even after relatively short-term (minutes to hours) exposures.[16] At high concentrations, HDI causes shortness of breath, chest pain, chest tightness and cough and is extremely irritating to the eyes, nose, and throat, causing watery eyes and burning sensations.[17,18] At high enough concentrations, nearly all exposed persons will exhibit some or all of these short-term symptoms, but when the exposure stops, the symptoms will generally resolve rapidly.[19]

A small proportion of individuals exposed to HDI over a period of months to years may develop asthma.[20] This occurs sometimes even at relatively low concentrations over time.[21] Sensitization to isocyanates after exposures of shorter duration (days or weeks) is unlikely.[22,23,24] However, once a person is sensitized to isocyanates, an exposure to levels as low as the parts-per-billion range can cause the onset of episodes of wheezing, shortness of breath, chest tightness, and coughing.[25,26,27] Sensitized persons may suffer progressive worsening of respiratory symptoms with recurrent exposures.[28] When exposures stop, the asthma may resolve; on the other hand, it may be persistent and may be triggered by other factors, such as tobacco smoke, cold air, or exercise.[29,30] The general, worldwide population diagnosed with asthma ranges from 5 to 10%.[31]

Hypersensitivity pneumonitis, though uncommon, is another known effect of chronic exposure to isocyanates. The symptoms of hypersensitivity pneumonitis can be severe, and, in most cases, abnormalities will appear on chest X-ray and pulmonary function tests. Symptoms, which usually occur about three to eight hours after exposure, include repeated bouts of fever, muscle aches, headaches, malaise, shortness of breath, dry cough, and chest tightness. Removal from exposure is usually mandatory. Sometimes the condition persists, even when no longer exposed to isocyanates. In such cases, medications such as steroids may be necessary.[32,33,34]

Some solvents found in CARC are readily absorbed through the respiratory tract and skin.[35,36] Exposure to high concentrations of solvents can lead to non-specific central nervous system effects, ranging from headaches or dizziness, to more serious effects, including staggering gait, nausea, vomiting, or loss of consciousness.[37,38] At high levels, solvent vapors can also cause irritation of the eyes, skin, mucous membranes, and respiratory tract. If exposures are brief (for example, an eight-hour shift), these irritant and

central nervous system effects are generally transient and resolve rapidly after cessation of exposure.[39,40] Nevertheless, chronic, long-term exposure to solvents can cause skin rashes, usually leading to an irritant dermatitis, characterized by dryness, scaling, and cracking of the skin, especially of the hands.[41]

Long-term exposure to solvents has been associated with increased rates of chronic central nervous system symptoms, such as fatigue, irritability, depression, headaches, poor concentration, and forgetfulness.[42] These chronic effects generally occur only after several years of heavy exposure (many experts estimate a threshold to be about ten years of relatively heavy exposure).[43] Some solvents can cause peripheral neuropathy, which means damage to the nerves in the arms and legs.[44] CARC does not contain the solvent compounds that are most closely associated with this type of nerve damage.

Workers occasionally develop liver or kidney disease after either long-term exposure or a massive single over-exposure to some solvents. Generally, chlorinated solvents cause these effects. CARC does not contain chlorinated solvents. A few solvents, such as benzene, are known or suspected to be human or animal carcinogens (cancer-causing agents),[45] but CARC has been specifically formulated to eliminate these types of solvents.

D. Occupational Safety and Health Guidance

Tab E provides a detailed discussion of safety and health requirements for CARC painting operations, including Occupational Safety and Health Administration (OSHA) and National Institute of Occupational Safety and Health (NIOSH) requirements, as well as military guidance for conducting CARC paint operations. The tab also includes a discussion of material safety data sheets and the hazard communication program. A direct comparison of the exposures during the Gulf War to existing standards is theoretical since no workplace sampling or measurements were taken during the war. These standards are discussed in detail in Tab E and in the applicable cited references, but the most important aspect of this discussion is that there were no measurements taken during the Gulf War for direct comparison. Obviously, this has hampered retrospective efforts to evaluate the frequency, intensity, and duration of exposures, and their subsequent medical or health effects.

Nevertheless, two conclusions can be drawn. First, current Army and federal occupational and safety directives require the use of personal protective equipment, including respiratory protection, during polyurethane (CARC) spray painting operations. Second, based on experience and professional judgment of the health and safety professionals monitoring the CARC painting operations in-theater, unprotected personnel who were spray painting CARC in the conditions documented in the Gulf were exposed to potentially hazardous conditions.

| First Page | Prev Page | Next Page |
