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AN OVERVIEW OF THE ARMY CORROSION CONTROL PROGRAM

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Corrosion control is of vital importance to the U.S. Army and in particular the Development and Readiness Command (DARCOM) because it continues to be a major problem that degrades Army readiness.

The Development and Readiness Command performs its mission in response to Army needs and concepts developed by the Training and Doctrine Command, the User Representative, or in response to the needs of the field commands (FORSCOM, 8th Army Korea, USAEUR). DARCOM's mission is support in the areas of: research, development, and acquisition of the Army's materiel, the readiness of that materiel once it is in the hands of troops, and the readiness of war reserves and certain stocks.

Within DARCOM, the R&D commands provide research, concept development, and initial acquisition in their appropriate commodity area. The Test and Evaluation Command oversees all development testing for the Army. The corresponding Readiness Commands provide for supply, maintenance, and follow-on procurement of end-items in their respective commodity area. The actual care, preservation, storage, and overhaul is performed at the appropriate depot(s). If a program requires intensive management, a project manager is designated and assigned to any of the Research or Readiness Commands or to HQ, DARCOM. Table 1 lists the DARCOM Major Subordinate Commands.

As the lead laboratory for Materials Technology, the Army Materials and Mechanics Research Center (AMMRC) was tasked by HQ, DARCOM to develop a DARCOM Corrosion Control Program. In cooperation with the Product Assurance Directorate, HQ, DARCOM, a Materiel Deterioration Prevention and Control (MADPAC) Program was established. DARCOM Regulation 702-24, dated 16 October 1979, prescribes policy, procedures, and responsibilities for the program which is aimed specifically at the reduction of deterioration of Army materiel. The MADPAC Program is centrally managed by the Director of Product Assurance, HQ, DARCOM, with the assistance of AMMRC. Advice concerning the program is proffered by the Central Steering Committee which is composed of members from the subordinate commands, selected offices from HQ, DARCOM, AMMRC, and Army Materiel Systems Analysis Activity (AMSAA).

TABLE 1. DARCOM MAJOR SUBORDINATE COMMANDS

ARRADCOM	Armaments R&D Command
AVRADCOM	Aviation R&D Command
CORADCOM	Communications R&D Command
ERADCOM	Electronics R&D Command
MERADCOM	Mobility Engineering R&D Command
NARADCOM	Natick R&D Command
TARADCOM	Tank Automotive R&D Command
ARRCOM	Armaments Readiness Command
TSARCOM	Troop Support Aviation Readiness Command
CERCOM	Communications and Electronics Readiness Command
DESCOM	Depot System Command
MICOM	Missile Command
TECOM	Test and Evaluation Command
TARCOM	Tank Automotive Readiness Command

The Major Subordinate Commands are required to establish (1) a corrosion control program which covers all systems and equipment within their mission responsibility, and (2) a corrosion control action office activity for administering the program.

Program Managers are required to establish a corrosion control plan and appoint a point-of-contact for liaison with the appropriate Subordinate Command Action Office. The depots also are required to establish a corrosion control plan and appoint a point-of-contact for liaison with the appropriate Readiness Command.

The Army Materiel System Analysis Activity is required to gather corrosion data on technical equipment in the field, through field liaison visits to Army materiel users.

In addition to serving DARCOM as Lead Laboratory for corrosion and corrosion control technology, AMMRC provides management assistance to the Director of Product Assurance by reviewing, analyzing, monitoring, and coordinating the Corrosion Control Program.

Objectives of the program include: Insure maximum use of State-of-the-Art technology in the prevention of deterioration; Provide for deterioration prevention reviews encompassing the areas of design, material selection, manufacturing processes, technical documentation, product assurance, field and depot maintainability operations, feedback data, and training requirements; Insure that all applicable contracts for Army systems and associated equipment contain requirements for a deterioration prevention program. Highlights of the program include the conduct of a Triennial inspection of DARCOM facilities, the establishment of a Materiel Deterioration Information Center, the dissemination of lessons learned, the coordination of training programs, the updating of military specifications, standards, and handbooks, and the promotion of technology effort.

The theme of the 1978 Tri-Service Corrosion Conference, hosted by the Army Materials and Mechanics Research Center, was "The National Cost of Corrosion". Dr. Elio Passaglia, National Bureau of Standards, in his Keynote Address, presented data from a report to the Congress by the NBS on "Economic Effects of Metallic Corrosion in the U.S." which showed that the total costs of corrosion in the U.S. are $\sim$ \$70 billion/year with $\sim$ \$10 billion/year being avoidable, if economically best practices were used throughout the economy, but lessening the remaining costs requires advances in technology. Both basic research and applied research investigations of corrosion and corrosion control are underway.

The prime sponsor of studies of basic mechanisms of corrosion is the Army Research Office (ARO). Generally, these fundamental studies are conducted by noted researchers at academic institutions in this country. Institutions investigating corrosion fundamentals include: Arizona State University, New York University, Rensselaer Polytechnic Institute , North Carolina State University, American University, Georgia Institute of Technology, Massachusetts Institute of Technology, University of Minnesota, and Portland State University.

Direct chemical attack of structural and coating metals by hostile substances remains a formidable problem. Basic research investigations sponsored by ARO are being made to clarify the mechanisms underlying the initiation of cracking under fretting-corrosion-fatigue in steels. Fretting, and its ramifications have had serious consequences in engine and rotating Army aircraft structural components. Investigations are underway to study fundamental mechanisms of erosion of materials in hot flowing media and to study mechanisms of protection of materials in environments encountered in gun tubes, gas turbines, and propulsion components in missiles.

The role of sulfur in the corrosion of superalloys is also being elucidated through investigations of the mechanism of migration of sulfur through single crystal and polycrystalline oxides, including NiO, CoO, Al_2O_3, Cr_2O_3, and Fe_2O_3. An improved understanding of this phenomenon will result in better materials for the hot section of aircraft engines.

An activity of practical interest concerns the chemical interaction of fiber reinforcements with aluminum alloy matrixes. This new class of lightweight, high strength materials exhibit high potential for many aircraft and bridging applications. Principles governing the corrosion behavior of aluminum-graphite and aluminum-alumina fiber composites exposed to aqueous and atmospheric service are being investigated. The ability of ion implantation to form self-healing coatings for inhibition of localized corrosion is being investigated for applications in armaments.

Another phenomena of practical interest which requires greater understanding involves the complex behavior of stress corrosion cracking. Several studies are underway to upgrade fundamental knowledge through investigations of mechanisms of stress corrosion cracking of aluminum alloys.

Employing an electrochemical scanning potential technique, a probe has been developed which measures the likelihood of corrosion of metal surfaces, adhesion of protective coatings, and differences in materials processing which can leas to susceptible corrosion sites. This development has potential application involving detection of flaws in protective coatings on high density penetrators, propensity for corrosion of shell casings, and monitoring of protective coatings on stored missile components. Basic and applied research investigations are conducted in-house within AMMRC and the several Army laboratories at ARRADCOM, MICON, and MERADCOM, because of expertise and experience with particular materiel.

Within the general corrosion area, in house studies are continuing, utilizing both long-time surveillance and short-time electrochemical methods, to minimize corrosion of equipment and materials of construction employed in the processing of ammunition.

Oxidation-sulfidation corrosion modes are of deep concern to designers of aircraft engines. Protective coatings for the upgraded performance of gas turbine alloys are being developed in-house.

Erosion-corrosion is a failure mechanism which can appear in Army-relevant material such as cannon tubes, gas turbine engines, rocket nozzles, and ammunition processing equipment. Solid particles entrained in a high velocity, viscous reactive media are among the conditions contributing to combined mechanical and chemical attack. Studies are underway, in-house, to identify the extent of chemical reaction between propellant gases and gun steels under gun chamber conditions of temperature and pressure. Efforts are also being made to determine the erosion constituents as well as the factors affecting the surface cracking phenomenon. Concomitantly, the parameters governing the erosive effects of high temperature, high pressure, and high gas velocity on gun steels are being investigated.

Stress Corrosion Cracking (SCC) failure attracts attention because of its catastrophic nature. In addition to the several ARO studies described earlier, efforts are being made to upgrade the SCC resistance during the development of new Al-Zn-Mg-Li wrought and Al-Zn-Mg-Cu powder metallurgy materials through composition and thermomechanical treatments. SCC effects of humidity and up-to-150°F temperatures on commercial grades of aluminum alloys are also being determined.

High strength steels are of continuing importance to the Army. Unfortunately, these steels are highly susceptible to stress corrosion. Effects of humidity, temperature, impurities, surface treatments, and hydrogen diffusion characteristics are being investigated. Realistic missile storage parameters are being established. Also, efforts are continuing to devise an accelerated test method for evaluating SCC characteristics of armor steels.

Stress corrosion cracking characteristics are also an important consideration in the improvement of uranium alloys for armor-piercing ammunition penetrators. Effects of hydrogen, humidity, strain rate, thermal treatments, and residual stress are being studied. Protecting the surface of susceptible alloys with a compatible coating is another approach employed to elleviate the problem of corrosion-induced failure.

In-house investigations are underway to develop materials and processing techniques for protecting a variety of materials, including aluminum, cast magnesium, uranium alloys, superalloys, gun steels, magnesium-aluminum oxide, and aluminum graphite composites against the harmful effects of a wide range of environments. Metallic, intermetallic, and nonmetallic coating systems are being developed. Lead and hexavalent chromate replacement in organic and semiorganic primer paints are being studied because of toxicity and pollution effects. Army applications for these coating systems include mobility equipment, vehicle armor, aircraft structures, gas turbine turbine engines, munition processing equipment, and high velocity armor penetrators. Evaluation of experimental and commercial coatings in natural environments is also continuing. The Clean Air Act requires the development of an entirely new range of low solvent content organic coatings (paints) to replace the presently required and used coatings.

Efforts underway have concentrated on waterborne coatings and polymers. Low solvent content coatings are being developed to replace the high volume specifications which presently include camouflage coatings, anti-corrosive primers, chemical agent resistant coatings, and pre-treatments. The water soluble alkyds appear the most promising for basic primer and camouflage use. Waterborne polyurethane, catalyzed resins, and modified polyurethane resins appear to be most suitable for applications involving severe environmental exposure, including chemical agents. The utilization of waterborne epoxy and epoxy esters, high solids alkyds, polyurethane, and epoxies are also being explored.

In summary, a new Army, centrally managed, Corrosion Control Program has been established within the Development and Readiness Command under Product Assurance Regulation. Management support by the Army Materials and Mechanics Research Center, provides close linkage between logistics and research and development. The research and development program spans the range from projects involving protective coatings, corrosion of metal matrix composites, and hot gas erosion, to those having a longer range outlook, including kinetics of materials interaction with their environments, and the identification and quantification of transient reactions and species in the degradation and reactivity of surfaces and interfaces.

Their major emphasis is the elucidation of the basic mechanisms of corrosive attack and protection, and the development of economical, new, and improved solutions for defeating the destructive effects of corrosion in Army materiel.