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The Qualification of IVD Aluminum to Replace Cadmium at the Sacramento Air Logistics Center

ABSTRACT

The qualification and substitution of an Ion Vapor Deposition (IVD) aluminum coating for cadmium plating eliminates a major source of hazardous waste at Air Force repair maintenance centers. Cadmium waste streams arise from several maintenance operations: cadmium plating, paint stripping (deposit media contaminated with cadmium), and cadmium stripping. Cadmium is a toxic metal, a known carcinogen, and on the EPA 17 hazardous materials list for reduction or removal from the workplace. Once cadmium escapes into the environment, it can find its way into the water supply or food chain. Also, electroplated cadmium has hazards associated with cyanide products in the plating bath. In September 1992, OSHA restricted the permissible exposure limits (PEL) to cadmium dust which greatly increased regulatory record keeping, medical surveillance, and cost for protection of workers below exposure limits. On the other hand, the aluminum coating and IVD coating process are environmentally clean. Aluminum is low toxicity and safe to handle, store, and dispose of with standard shop practices. Aluminum dust is nontoxic and is regulated only at the “nuisance dust” level by OSHA. To eliminate cadmium usage, McDonnell Douglas Aerospace (MDA) assisted the Sacramento Air Logistics Center (SM-ALC) qualification of IVD aluminum for the various applications that now require cadmium processing. MDA performed this program utilizing “hands-on” coordination with pertinent organizations at SM-ALC. Qualification and full implementation of IVD aluminum processing required: evaluation of process support equipment; determination of the applicability of IVD process for each cadmium-plated part: demonstration of coating feasibility; verification of coating compliance to MIL-C-83488; troubleshooting equipment and processing problems; and maintaining environmental compliance of all processing procedures and materials. As a result of this program, SM-ALC has been able to fully implement the use of IVD aluminum and close their cadmium plating line.

INTRODUCTION

In May 1993 the SM-ALC implemented a contract with the MDA component of McDonnell Douglas to assist with qualification of IVD aluminum coatings for all parts being cadmium plated. The thrust of this effort was elimination of the hazardous waste streams arising from the toxic cadmium metal, from the plating bath, and from depainting and cadmium stripping

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operations during overhaul. Sacramento had a large number of intricate parts arising from aircraft hydraulic system overhaul which required extensive masking and finish thickness control to achieve qualification.

BACKGROUND

Both the aluminum coating and the IVD process are environmentally clean. Cadmium is a toxic metal, a known carcinogen, and on the EPA 17 hazardous materials list for reduction or removal from the workplace. In September 1992, OSHA restricted the PEL to cadmium dust which greatly increased regulatory record keeping, medical surveillance, and cost for protection of workers below exposure limits. On the other hand, the aluminum coating and IVD coating process are environmentally clean. Aluminum is low toxicity and safe to handle, store, and dispose of with standard shop practices. Aluminum dust is nontoxic and is regulated only at the “nuisance dust” level by OSHA.

There are inherent advantages to the substitution of IVD aluminum for cadmium, in addition to hazardous waste reduction and safe worker exposure. IVD aluminum outperforms cadmium in preventing corrosion in acidic environments and actual service tests. Also, aluminum coatings can be used at temperatures up to 950^0F, whereas cadmium is limited to 450°F. IVD aluminum coatings can be applied to high-strength steel without fear of hydrogen embrittlement. Aluminum coatings can be used in contact with titanium without causing solid-metal embrittlement, and they can also be used in contact with fuels; cadmium is prohibited for these applications. Additionally, IVD aluminum can be used in space applications, whereas cadmium is limited because of sublimation.

The use of IVD aluminum is also well suited for aluminum-alloy details providing excellent corrosion resistance, good electrical conductivity, and elimination of fatigue debit associated with anodize coatings. MDA uses IVD aluminum to protect literally hundreds of aluminum-alloy parts on the F-l5, F/A-l8, and AV-8B aircraft. The soft, ductile aluminum coating is used on fatigue critical aluminum-alloy structure, replacing hard, brittle anodize coatings; it provides excellent sacrificial corrosion resistance and does not reduce fatigue properties. IVD aluminum is highly conductive and remains so in service when treated with a standard chromate conversion coating. IVD aluminum coated fuel and pneumatic line fittings provide a conductive path across bonding joints dissipating static electrical charges generated by fluid or air flow. IVD aluminum replaces electroplated tin to provide a low-resistance path at the interface with other components for electromagnetic interference capability (EMIC).

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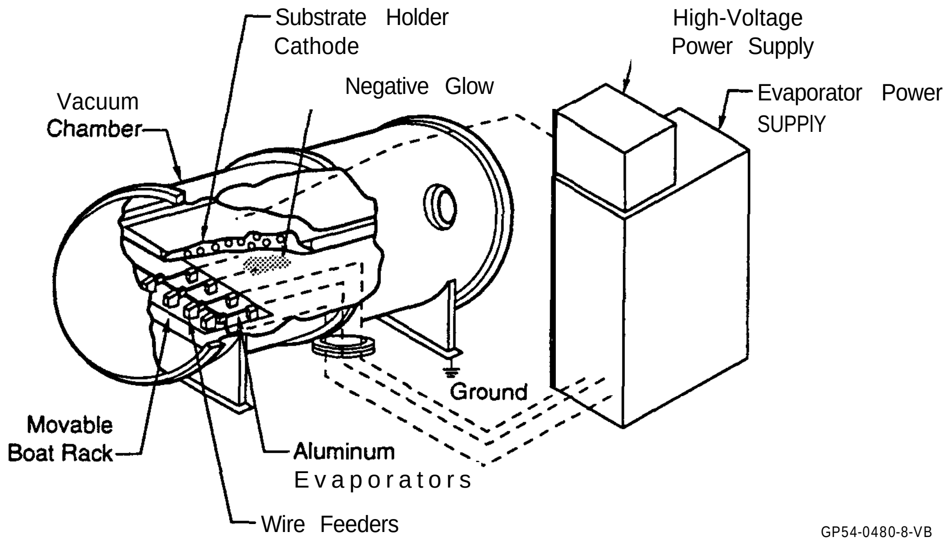

Figure 1. Schematic of an Ion Vapor Deposition System

The IVD aluminum coating is applied in production coating equipment called Ivadizers®. The basic equipment consists of steel vacuum chamber, a pumping system, fixturing to hold the parts, an evaporator power supply, and a high-voltage power supply (Figure 1).

The IVD processing sequence consists of pumping the vacuum chamber down to about 9×10^{-5} Torr. The chamber is then backfilled with argon gas to about 1.0×10^{-2} Torr, and a high negative potential is applied between the parts being coated and the evaporation source. The argon gas becomes ionized and creates a glow discharge around the parts. The positively-charged gas ions bombard the negatively-charged surface of the parts and performs a final cleaning, which contributes to good coating adhesion.

Following glow-discharge cleaning, aluminum wire is evaporated by being continuously fed into resistance-heated crucibles. As the aluminum vapor passes through the glow discharge, a portion of it becomes ionized. This, in addition to collision with the ionized argon gas, accelerates the aluminum vapor towards the part surface, resulting in excellent coating adhesion and uniformity.

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The coating requirements for IVD aluminum are specified in MIL-C-83488, the tri-service specification for pure aluminum coatings. After coating, the parts are chromate-treated in accordance with MIL-C-5541. This provides additional protection against corrosion, forms a good base for paint adhesion, and is a common treatment for aluminum-alloy and cadmium-plated surfaces. In virtually all applications, IVD aluminum can replace cadmium of equal thickness. It can also be applied thicker than cadmium where part tolerance permits; this results in additional corrosion resistance.

SACRAMENTO OBJECTIVES

The primary objective of this program was to assist SM-ALC qualification of IVD aluminum coating for the various applications that now require cadmium processing. A secondary objective was to implement the use of IVD aluminum coating on selective aluminum-alloy parts. These objectives were accomplished by completing the following five tasks:

- Review and evaluate the need for additional process support equipment to improve IVD processing efficiency and cost effectiveness.
- Establish prototype testing requirements for conversion from cadmium plating to IVD aluminum coating.
- Establish Quality Assurance guideline for evaluation of the coating and substrates.
- Demonstrate to SM-ALC personnel the feasibility of applying IVD aluminum to all parts that are now processed with cadmium.
- Verify the environmental compliance associated with the elimination of cadmium processing.

Each of these major tasks had three or more subtasks to better define the requirements to be completed. This paper will list the subtask requirements but will discuss only selected subtasks. The reader is encouraged to contact the writer for additional discussions concerning any subtask or for the complete **Ion Vapor Deposition Aluminum Qualification Tests** report.

MDA employed a “hands-on” strategy at the SM-ALC to implement the usage of IVD aluminum. “Hands-on” coordination with responsible departments had been used successfully to implement the usage of the IVD aluminum process at MDA, when it was a new process.

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TASK 1 - Process Support Equipment Evaluation

The need for additional process support equipment to improve IVD aluminum processing efficiency and cost effectiveness was completed by (1) designing and providing sketches of masking devices, special coater hooks and fixtures for local fabrication or purchase, (2) providing vendor information and support data for support equipment to be purchased, and (3) reviewing the need for additional precleaning and post cleaning equipment and providing purchase descriptions as required.

Hooks are used to suspend parts from the heavy, wire-mesh grid (screen) on the stationary parts-hanging rack. They provide the necessary electrical contact between the part and screen to maintain the parts at the proper negative potential during glow-discharge cleaning and coating as shown schematically in Figure 2. Figure 3 shows parts fixtured to the parts-rack for IVD aluminum coating at SM-ALC. The parts are positioned at or near the optimum part-to-evaporator (part-to-boat) spacing for best coating uniformity consistent with highest coating efficiency. Best coating uniformity occurs when parts are positioned nominally 10 inches above the boats.

The hooks are designed with a small radius to easily fit within the diamond pattern of the screen. This generally requires fabrication from wire stock l/8 to 3/16 inch in diameter. A “J” shaped hook with the end slightly grounded to dull the point is the best configuration. This configuration allows coating to wrap-around and under the hook leaving only a small point contact area on the part that is void of coating. Since most parts are subsequently turned over and recoated to achieve the desired coating uniformity, hook contact areas are usually coated over. IVD aluminum coating buildup is easily stripped from hooks with a sodium hydroxide/water solution. The use of stainless-steel hook material requires only stripping, rinsing, and drying before reuse.

The variety and complexity of parts being processed with IVD aluminum at SM-ALC requires various lengths of the standard “J” hook. “J” hooks were fabricated with lengths varying from 5 to 15 inches in 2-inch increments and with the diameter of the J-section varying from l/2 inch to 5 inches. Small diameter "J" hooks are used to fixture parts with small IDs to the parts-rack. The 3-, 4-, and 5-inch diameter larger hooks allow long cylindrical parts to be hung quickly by laying the cylindrical parts in the “J” section of the hooks. For better thickness uniformity, most cylindrical parts are turned 180 degrees to coat the cylinders again. At the turnover of the parts, the cylinders are shifted slightly laterally to assure complete coating coverage.

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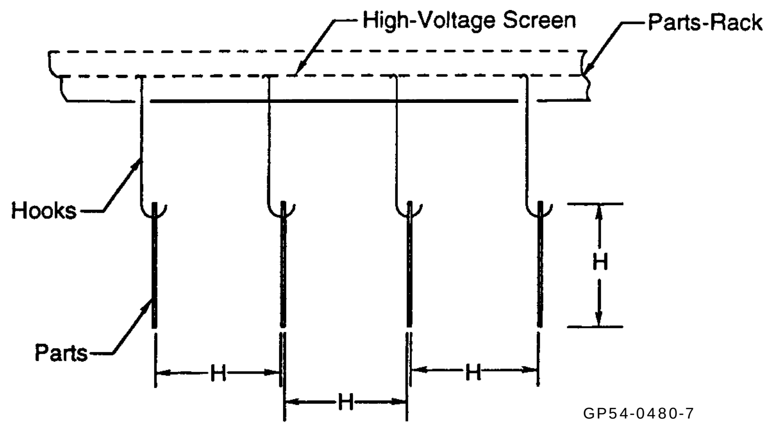

Figure 2. Hooks Suspend Parts From the High-Voltage Screen on the Standard Parts-Rack

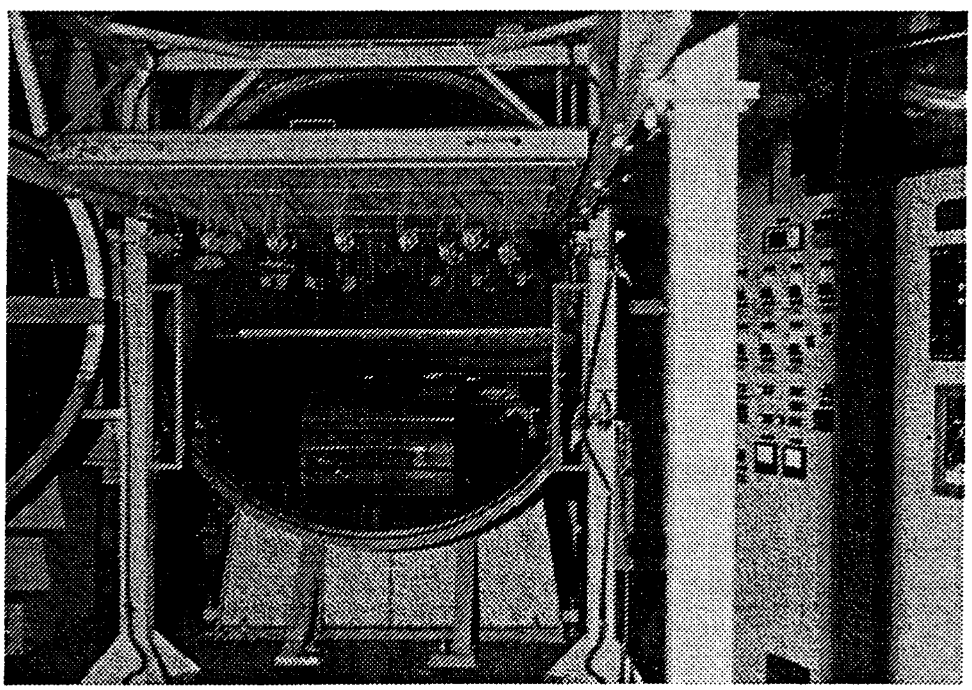

Figure 3. Suspension of Parts From Stationary Parts-Rack With "J" Hooks

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TASK 2 - Implementation of Prototype Tests

Prototype testing was used to demonstrate that parts could be converted from cadmium plating to IVD aluminum coating. Implementation of prototype tests was accomplished by (1) reviewing part drawings, parts illustrations, and production parts, (2) evaluating each part's function and operating environment to determine coating requirements, and (3) establishing guidelines for masking, fixturing, and prototype testing production parts.

During Task 2 a minimum of 87 Technical Orders (T.0.s) and 214 parts were reviewed to determine if these parts could be changed from cadmium plating to IVD aluminum coating. Prototyping establishes any masking requirements, fixturing needs, processing parameters, and coating quality to be expected on production parts. Coating quality includes coverage, uniformity, thickness, and substrate integrity, Since IVD aluminum coatings are applied in a vacuum environment, cleaning, masking and fixturing requirements are different from tank plating. Therefore, Masking Guidelines were developed for proper selection of materials and procedures to enhance cleaning and vacuum processing. Fixturing Guidelines that produced the best coating uniformity, coverage, adhesion, thickness and without damage to the substrate were developed for attaching parts onto the parts-rack. The masking and fixturing guidelines were also incorporated into the IVD Aluminum Equipment and Operating Procedures document for automation operation of the equipment. Guidelines were established for continued prototyping of parts after the conclusion of this contract. The Prototype Guidelines described the complete process for determining if IVD aluminum is applicable as a replacement coating for cadmium plating. These guidelines cover the initial examination of the part for suitability of the ND coating process, masking and fixturing requirements, establishing coating parameters from the SM-ALC Aluminum Coating Procedures document, establishment of procedure cards, and verification of coating quality.

TASK 3 - Quality Assurance

Quality Assurance (QA) guidelines were established by (1) reviewing and defining acceptance performance requirements, (2) reviewing the existing QA test procedures and equipment for adequacy, (3) developing a training implementation plan, and (4) providing operation and preventative maintenance training.

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Acceptance performance requirements were written and quality assurance testing was implemented to verify process control and coating performance satisfaction to the requirements of the IVD aluminum Mil-Spec, MIL-C-83488. In addition to appearance and coverage, coating adhesion, thickness, corrosion resistance, and hardness for aluminum alloys was closely monitor to assure quality coatings and parts. A training system plan was developed and implemented to increase IVD operator proficiency in process application and preventive maintenance personnel knowledgeability in equipment servicing. Three training classes were conducted for SM-ALC plating shop personnel stressing hands-on and individual instruction. On-site preventive maintenance training was provided again stressing hands-on and individual instruction.

TASK 4 - Feasibility Demonstrations

The feasibility of applying IVD aluminum to a!! parts that were processed with cadmium was demonstrated by (1) establishing production procedure cards for each part, (2) updating the SM-ALC process order and current operating procedures, (3) establishing guidelines for shop and lab personnel to verify the aluminum coating conforms to MIL-C-83488, (4) evaluating a!! current IVD aluminum process steps for improvement, (5) developing supplementary processing for specific applications, if needed, (6) recommending an alternate coating if IVD aluminum is not a suitable replacement, and (7) evaluating coater components, software, and hardware for problems.

High quality finishes result from controlled processes. At SM-ALC, IVD aluminum coatings are applied in a vacuum environment controlled at a specific low pressure by a gas-flow controller. Further control is achieved by eliminating operator variance by having a detailed written procedure for each production part that specifies any specialized cleaning, masking needs/techniques, fixturing directions for part orientation and spacing, and coating parameters. These procedures are recorded in a simple Procedure Card format for operators to review prior to processing the part. Procedure Card use ensures common processing of each individual production part regardless of coater operator or processing frequency.

SM-ALC also requested the Procedure Card information on each part be installed into a computer database file in Ashton-Tate dBASE III Plus. SM-ALC created the initial database, screen, and report files for the Procedure Cards. During this contract, MDA wrote and combined five dBASE III Plus computer programs to produce a menu driven program which easily searches the computer Procedure Card database for a specific part. A!! of the information in the database for a specific part can be viewed at the computer terminal or printed. The database can be searched by the ND operator and does not require prior knowledge about computer operation or

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dBASE III Plus. A step-by-step search procedure was written to assist the operator in how to turn on the computer; call up the main Procedure Card Menu; and then proceed to view (or print) the procedure for a specific part number, part name, control number, or a!! of the Procedure Cards in the database; and then turn off the computer.

The full implementation of IVD aluminum at SM-ALC was successfully demonstrated by IVD aluminum coating virtually a!! parts that were previously cadmium plated and then verifying the coating conformed to the quality assurance requirements of MIL-C-83488. All 214 parts prototyped were coated successfully and released for production coating. Guidelines were developed and utilized by shop personnel to verify that coating quality conformed to MIL-C-83488. New step-by-step coating and equipment operating procedures are in use for proper and efficient use of the IVD coating equipment and application of the process. These are major training aids for new or rotated IVD plating shop personnel to quickly “climb the learning curve” for an efficient coating operation.

TASK 5 - Environmental Compliance

Environmental compliance processing associated with the elimination of cadmium processing was accomplished by reviewing the following with SM-ALC laboratory, shop, and environmental management personnel (1) the MDA IVD aluminum environmental compliance program, (2) the environmental compliance of supplementary processing developed during Phase II of the contract C87-101602, The Substitution of IVD Aluminum For Cadmium.

Several presentation were made to SM-ALC lab, shop, and environmental personnel on selected environmental and chrome elimination activities being studied or implemented at MDA as well as the IVD program at SM-ALC. The presentations were:

- Ozone Depleting Substance (ODS) Elimination Effort
- Determination of the Effectiveness of Non-chromated Conversion Coatings For Use With IVD Aluminum Coatings
- Processing Aluminum-Alloy and Alloy-Steel Detail Parts With Nonhazardous Materials
- IVD Aluminum Qualification Tests at SM-ALC.

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During this contract, no parts containing cavities, where the IVD aluminum could be thin or nonexistent, were identified that needed supplemental processing. However, the functional performance and environmental compliance of supplementary coatings from past studies was updated for future use, if needed.

The qualification of IVD aluminum coating at SM-ALC has demonstrated the IVD aluminum coating process as an across-the-board replacement for the cadmium plating process. Elimination of cadmium processing at SM-ALC reduces hazardous waste production arising from both the cadmium metal and from the cadmium-plating bath as we!! as potentially harmful worker exposure to cadmium.

Conclusions

The environmentally compliant IVD aluminum process is a qualified, demonstrated across-the-board replacement for toxic cadmium processing at the SM-ALC. Full qualification and implementation of IVD aluminum has allowed closure of the cadmium plating line, thereby eliminating the cadmium plate waste stream and its associated problems. The development and use of IVD aluminum production Procedure Cards for individual parts and verification of the applied coating to the performance requirements of MIL-C-83488 ensures consistent, high-quality IVD coatings that meet or exceed the functional capability of cadmium. Establishment of a Procedure Card computer database and search capabilities; specific prototyping, coating quality assurance, and equipment operating guidelines/procedures; and detailed orientation instructions have provided SM-ALC with procedural and operational skills to continue the current efficient application of the IVD aluminum coating process into the future.

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