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MCDONNELL AIRCRAFT CO ST LOUIS MO  
ION VAPOR DEPOSITION PROCESSING OF ARMAMENT PARTS. (U)  
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Department of the Army  
U.S. Army Armament R&D Command  
Attn: Edgardo Silvestre  
Code DRDAR-SCM-P  
Dover, New Jersey 07801

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| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                     | READ INSTRUCTIONS<br>BEFORE COMPLETING FORM                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|---------------------------------------------------------------------------------------------|
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| 18. SUPPLEMENTARY NOTES<br>"THE VIEW, OPINIONS, AND/OR FINDINGS CONTAINED IN THIS REPORT ARE THOSE OF THE AUTHOR(S) AND SHOULD NOT BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION, POLICY OR DECISION, UNLESS SO DESIGNATED BY OTHER DOCUMENTATION".                                                                                                                                                                                                                                                                                                                                                                                                                   |                                     |                                                                                             |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>Hydrogen Embrittlement<br>Ion Vapor Deposited (IVD) Aluminum Coating<br>Aluminum Coating<br>Aluminum Coated Armament Details<br>Non-toxic Aluminum Coatings                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                     |                                                                                             |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>Over 3,000 armament components are currently electroplated with cadmium. All DoD organizations are committed to replace toxic cadmium wherever feasible. There is an equal need to alleviate the potential for hydrogen embrittlement failures. All electroplate processes introduce hydrogen. IVD aluminum coating per MIL-C-83488 has been identified by MIL-STD-1568 as an acceptable alternate to cadmium on steel stating its non-toxic and corrosion prevention characteristics. The object of the program is to establish IVD aluminum as a viable coating for armament hardware/parts. |                                     |                                                                                             |

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**FOREWORD**

This report describes the work accomplished by the McDonnell Aircraft Company (MCAIR), McDonnell Douglas Corporation, St. Louis, Missouri on ARRADCOM Contract DAAK10-81-R-0352, "Ion Vapor Deposition Processing of Armament Parts". The program was administered under the direction of the Army Research and Development Command by Edgardo Silvestre. The contract period was 1 October 1981 to 30 June 1982. The program was conducted by the Material and Process Development Department at MCAIR, St. Louis, and was managed by E. R. Fannin with J. J. Reilly as Principal Investigator. J. C. Marzaloes and M. B. Munsell of the MCAIR Physics Laboratory were major contributors to the program.

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### **1. INTRODUCTION**

Cadmium electroplating has been the favored method for protecting steel on aircraft structure for many years. Obvious problems with its use were minimal prior to the use of high strength steel and aluminum alloys. Cadmium electroplating on high strength steel often caused hydrogen embrittlement, and cadmium plated fasteners installed in high strength aluminum alloys helped promote exfoliation corrosion in the countersinks. More recently it has received further disfavor because it was found to cause solid metal embrittlement of titanium structure and because of its toxicity and harmful effects on the environment.

McDonnell Aircraft Company (MCAIR) started looking for a viable alternate for cadmium in the early 1960's. After extensive paper studies, aluminum coatings were selected as the best substitute. Being the least dissimilar to aluminum alloy structure, it is ideally compatible. Furthermore, aluminum is anodic to steel and provides galvanic protection as does cadmium.

It was quickly found that available processes for applying aluminum coatings such as metal spraying, electroplating, cladding, hot dipping and others had severe limitations such as thickness control, adhesion, size and shape of product that could be coated, and effect on substrate properties.

During this same period, we had selected vacuum deposited cadmium as the coating for solving the problem of hydrogen embrittlement of high strength steel. Our production experience with the vacuum coating process was very favorable. For this reason, we started looking at vacuum coating processes for aluminum. This included physical vapor deposition, ion vapor deposition, and chemical vapor deposition. Ion vapor deposition (IVD) provided the best adhesion and most uniform coating thickness and with other considerations was selected for further development.

Production equipment is now available for plating aluminum by the IVD process. It is recognized by a number of military, industrial and company specifications and is used for a broad range of applications on a growing number of programs (see Attachment A).

IVD aluminum is the baseline corrosion protection system for the U.S. Army Copperhead Cannon Launch Guided Projectile. MCAIR extensively uses IVD aluminum on the F-15, F-18 and AV-8B aircraft programs. We use it on high strength aluminum alloys, mild steels, including high strength steel landing gear details as well as on steel and titanium fasteners installed in aluminum structure.

Over 3,000 armament components are currently electroplated with cadmium. All DoD organizations are committed to replace toxic cadmium wherever feasible. There is an equal need to alleviate the potential for hydrogen embrittlement failures. All electroplate processes introduce hydrogen.

The U.S. Army Armament Research and Development Command (ARRADCOM) awarded MCAIR contract #DAAK10-81-R-0352, on 21 September 1981 to evaluate and establish IVD aluminum as a viable coating for armament hardware/parts. This is the final report as required by the contract.

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### **2. PROGRAM AND SCHEDULE**

Schedule program tasks entailed:

- o Coating of a maximum of 17 types of weapon hardware with IVD aluminum. The ARRADCOM supplied hardware would be IVD aluminum coated by MCAIR.
- o Coating of (10) 3" x 4" 4340 steel panels and (10) 3" x 4" aluminum alloy panels with IVD aluminum. MCAIR will supply and coat the panels. MCAIR will supply ARRADCOM with a like number of uncoated steel panels for ARRADCOM to electroplate with cadmium. These panels will be used for comparative testing with the IVD aluminum coated panels.
- o MCAIR will judge the feasibility of IVD aluminum coatings for each of the finished details, document processing parameters including pre-cleaning and post-coating processing and record coating thickness. This information will be furnished to ARRADCOM.
- o MCAIR will perform adhesion and corrosion resistance testing on representative details coated with each run of details supplied to ARRADCOM.
- o Cost analysis of IVD aluminum processing for each of the ARRADCOM supplied details will be furnished by MCAIR.

Non-scheduled program tasks included:

- o Request by ARRADCOM through the University of Notre Dame for MCAIR to IVD aluminum coat 8 alloy steel test panels. Notre Dame will evaluate the effect of coating parameters on corrosion resistance, coating structure and adhesion in support of the ARRADCOM contract (see Attachment B).
- o Request by ARRADCOM that MCAIR furnish additional alloy steel test panels coated with IVD aluminum, and also panels electroplated with cadmium. ARRADCOM will evaluate the relative corrosion resistance characteristics of the 2 platings.
- o MCAIR offered to obtain budgetary coating quotes from outside plating-houses for several of the ARRADCOM furnished details. ARRADCOM accepted the offer.
- o A visit by MCAIR to ARRADCOM to discuss the program. MCAIR offered to IVD aluminum coat additional ARRADCOM prototype parts after the conclusion of the reference contract for applications deemed feasible by ARRADCOM.

### **3. SIGNIFICANT RESULTS**

- o The following ARRADCOM furnished details were coated with IVD aluminum and returned to ARRADCOM:

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BARREL FIXTURED

10 Couplings  
15 Lockrings  
15 Springs  
15 Piston Washers  
12 Fector Gear Washers

RACK FIXTURED

14 Key Washers  
2 Bolts  
2 Handles  
1 Nut  
6 Pins  
2 Racks  
2 Sleeves  
15 Springs  
2 Struts  
6 Stress Rupture Specimens

- o ARRADCOM requested the specific fixturing for the aforementioned details. MCAIR deviated with the 14 key washers which cannot be barrel fixtured. Photographs of the coated details were furnished (see Attachment C).
- o The following MCAIR furnished details (scheduled items) were coated with IVD aluminum and were sent to ARRADCOM along with 10 bare alloy steel panels:

(10) 2" x 4" Alloy Steel Panels  
(10) 2" x 4" Aluminum Alloy Panels

- o The coating parameters for the ARRADCOM and MCAIR furnished details (see Attachment D) were sent to ARRADCOM.
- o The recommended fixturing, approximate coating costs and throughput numbers (see Attachment E) for the ARRADCOM furnished details were also submitted.
- o The 8 panels furnished by the University of Notre Dame were coated with IVD aluminum and were returned to Notre Dame (see Attachment F).
- o Forty-eight additional 2" x 4" alloy steel panels (non-scheduled items) requested by ARRADCOM were furnished by MCAIR. The panels were coated as follows:

(12) panels - IVD aluminum; MIL-C-83488, Class I, Type II  
(12) panels - IVD aluminum; MIL-C-83488, Class 2, Type II  
(12) panels - Electroplated Cadmium; QQ-P-416, Class 1, Type II  
(12) panels - Electroplated Cadmium; QQ-P-416, Class 2, Type II

(see Attachment G)

- o IVD aluminum coating adhesion and corrosion resistance properties test data performed on representative details coated with each run of details supplied to ARRADCOM is attached (see Attachment H).
- o Budgetary quotes for coating typical ARRADCOM details from 2 contractors with IVD aluminum coaters are attached (see Attachment I).

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| TITLE: 10M VAPOR DEPOSITION PROCESSING<br>OF ARMAMENT PARTS - ARRAADCOM<br>P.O. DAAK10-81-R-0353 |                                                | DATE<br>PAGE OF<br>PREP. BY<br>PERT. NO. |     | LEGEND:<br>SCHEM. ACTUAL<br>▽ SCHEDULED EVENT<br>◇ RESCHEDULED EVENT |     | APPROVAL<br>APP. APP. APP. APP. |     |     |     |     |      |
|--------------------------------------------------------------------------------------------------|------------------------------------------------|------------------------------------------|-----|----------------------------------------------------------------------|-----|---------------------------------|-----|-----|-----|-----|------|
| PROGRAM<br>SCHEDULE                                                                              |                                                | 1981                                     |     | 1982                                                                 |     |                                 |     |     |     |     |      |
|                                                                                                  |                                                | Sept                                     | Oct | Nov                                                                  | Dec | Jan                             | Feb | Mar | Apr | May | June |
| 1                                                                                                | Contract Award                                 | ▲                                        |     |                                                                      |     |                                 |     |     |     |     |      |
| 2                                                                                                |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 3                                                                                                | Cost ARRAADCOM Furnished Details               |                                          | ▲   |                                                                      |     |                                 |     |     |     |     |      |
| 4                                                                                                |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 5                                                                                                | Cost MCALR Furnished Details                   |                                          |     | ▲                                                                    |     |                                 |     |     |     |     |      |
| 6                                                                                                |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 7                                                                                                | Submit First Progress Report                   |                                          |     |                                                                      | ▲   |                                 |     |     |     |     |      |
| 8                                                                                                |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 9                                                                                                | Ship Coated Details; Applicable Documentation  |                                          |     |                                                                      |     | ▲                               |     |     |     |     |      |
| 10                                                                                               |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 11                                                                                               | Cost and Ship Any Additional Details Submitted |                                          |     |                                                                      |     |                                 | ▲   |     |     |     |      |
| 12                                                                                               | by ARRAADCOM                                   |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 13                                                                                               |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 14                                                                                               | Submit Second Progress Report                  |                                          |     |                                                                      |     |                                 |     | ▲   |     |     |      |
| 15                                                                                               |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 16                                                                                               | Cost and Ship Any Additional Details Submitted |                                          |     |                                                                      |     |                                 |     |     | ▲   |     |      |
| 17                                                                                               | by ARRAADCOM                                   |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 18                                                                                               |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 19                                                                                               | Submit Pre-Publication Copy of Final Report    |                                          |     |                                                                      |     |                                 |     |     |     | ▲   |      |
| 20                                                                                               |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
| 21                                                                                               | Submit Final Report                            |                                          |     |                                                                      |     |                                 |     |     |     |     | ▲    |
| 22                                                                                               |                                                |                                          |     |                                                                      |     |                                 |     |     |     |     |      |
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DATE 08-01-2001 BY 1045

After Co. Award

Calendar

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## **MCDONNELL AIRCRAFT COMPANY**

### **4. CONCLUSION**

MCAIR has completed all scheduled and non-scheduled items of the reference contract. IVD aluminum coating is a feasible corrosion protection system for all of the details coated during the contract period. The adhesion and corrosion resistance requirements of MIL-C-83488 were easily met. In fact, Attachment G shows the corrosion resistance characteristics of the IVD aluminum coating on all of the test specimens to be far in excess of the requirement. Most of the specimens are still in the test and some have exceeded 5,000 hours. Additional advantages of using IVD aluminum coating on armament hardware are:

- o An absence of hydrogen embrittlement caused by the process
- o A useful service temperature of 925°F
- o Compatibility of aluminum with fuel
- o The non-toxic properties of both the process and the coating

This program, sponsored by ARRADCOM, to evaluate the use of IVD aluminum coatings contributes to the United States Department of Defense effort to minimize the use of cadmium. The various federal specifications for cadmium deposition require the use of acceptable alternate processes where feasible. An excerpt from MIL-STD-1568 which recognizes IVD aluminum as an acceptable alternate to cadmium on steel is attached (see Attachment J).

The coating quotes received from outside contractors and reported herein could most likely be negotiated downward with normal procurement practices. For this program, no such special effort was made. Also, quotes would undoubtedly be lowered as orders were placed on a recurring production basis. Our experience in production has shown the processing costs for IVD aluminum to be comparable to vacuum cadmium but slightly greater than electroplated cadmium. However, if clean-up costs are separately factored, then the IVD process becomes even more cost efficient.

MCAIR will continue to work with ARRADCOM on feasible applications for IVD aluminum coating. The scope of this work can range from coordinating the coating of prototype details to advising the optimization of coating parameters and fixturing to minimize coating costs.

15 August 1982

IVD ALUMINUM ACCEPTANCE

o **MILITARY SPECIFICATIONS**

- MIL-STD-1516 - Coatings for Aircraft and Missiles
- MIL-S-5002 - Surface Treatments and Metallic Coatings for Metallic Surfaces of Weapons Systems
- MIL-C-83488 - Coating, Aluminum, Ion Vapor Deposited
- MIL-STD-1515 - Fastener Systems for Aerospace Applications
- MIL-STD-1568 - Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems
- MIL-S-24149B - Studs, Arc Welding and Arc Shields (Ferrules); General Specifications for

o **INDUSTRY-WIDE SPECIFICATIONS**

- ASTM - Aluminum Coatings
- AMS 2427 - Aluminum Plating - Ion Vapor Deposition
- AS 1650 - Procurement Specification, Coupling, Fuel, Rigid, Threaded Type

o **COMPANY ISSUED SPECIFICATIONS**

- McDonnell Aircraft
- Douglas Aircraft
- Pratt & Whitney
- Raytheon
- Boeing
- Martin-Marietta
- Bell
- Northrop
- FMC
- Airbus Consortium
- Bendix
- General Electric

o **PROGRAMS USING IVDIZER**

AIRCRAFT

F-4 757  
F-15 767  
F-18 SAAB 340  
AV-8B A-300  
DC-9 DC-10

MISSILES

Harpoon  
Patriot  
MX

PROJECTILES

Copperhead (Army)  
5" SAL GP (Navy)  
8" SAL ER GP (Navy)

MISC.

MARK 34 Launcher  
Space Shuttle  
Trident Submarine  
Centrifuge  
A129 Helicopter  
Multiple Launch  
Rocket System  
Mark 75 Gun

**MCDONNELL AIRCRAFT COMPANY**

**UNIVERSITY OF NOTRE DAME  
DEPARTMENT OF METALLURGICAL ENGINEERING  
AND MATERIALS SCIENCE**

BOX E  
NOTRE DAME INDIANA 46556  
AREA 219  
PHONE 219-239-5330

January 15, 1982

Mr. Greg B. Smith  
2033 Quiet Stream  
Maryland Heights, MD 63043

Dear Mr. Smith:

Enclosed are four 2 x 2 x 1/16 inch samples each of Type 4340 steel which have been heat-treated to HRC50 and 55. As part of a U.S. Army ARRADCOM sponsored project (monitored by Dr. W. Ebihara of ARRADCOM) concerned with adhesion and corrosion resistance of ion vapor deposited steels, we need to have the steel samples ion vapor deposited with aluminum.

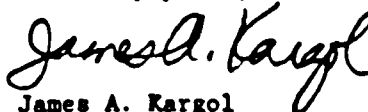
We are interested in studying the corrosion resistance with electro-chemical techniques, and the adhesion and coating structure with surface wave ultrasonic techniques. To make the study, we need one sample of each hardness steel deposited with a 0.001 inch thick aluminum coating according to your standard manufacturing practice. We request that the coated steel not be shot peened nor chromate rinsed.

Our goal is to compare the standard Al-coating to three alternative Al-coatings of equivalent thickness which are deposited by modified practice such that the coating structures differ. For example, we may wish to study the effects of Al-crystal size and shape, or coating porosity which may vary with coating deposition rate or other factors.

I cannot be more specific regarding my request because I am not familiar enough with the ion vapor deposition process. Therefore, I request that you call me at 219-239-5891 so that we may discuss possible changes to the deposition process.

Thank you for your willingness to provide us with your coating service. Our project could not be carried out without your cooperation.

Sincerely yours,



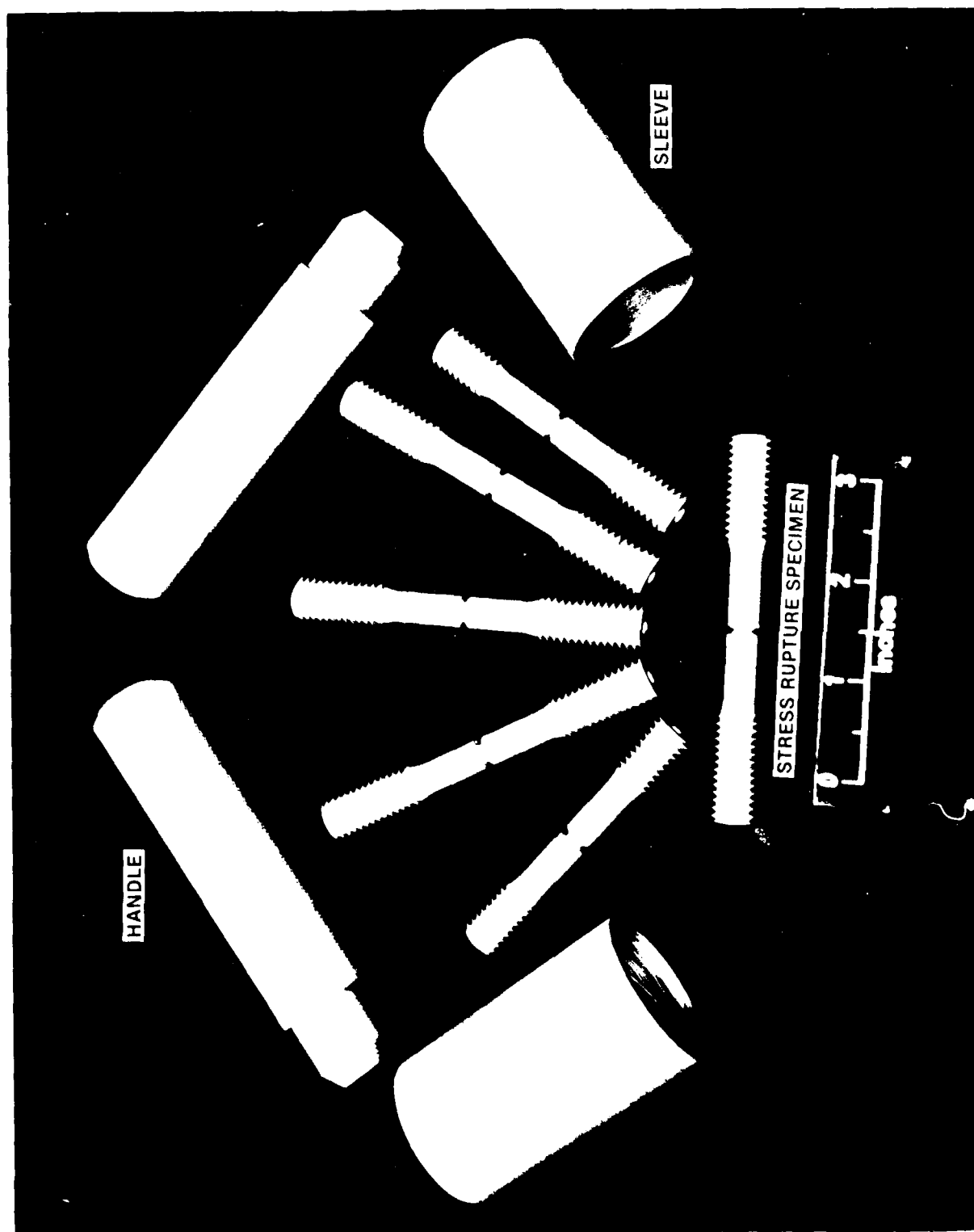
James A. Kargol  
Assistant Professor

JAK/jp  
Enc.

cc: W. T. Ebihara- U.S. Army ARRADCOM

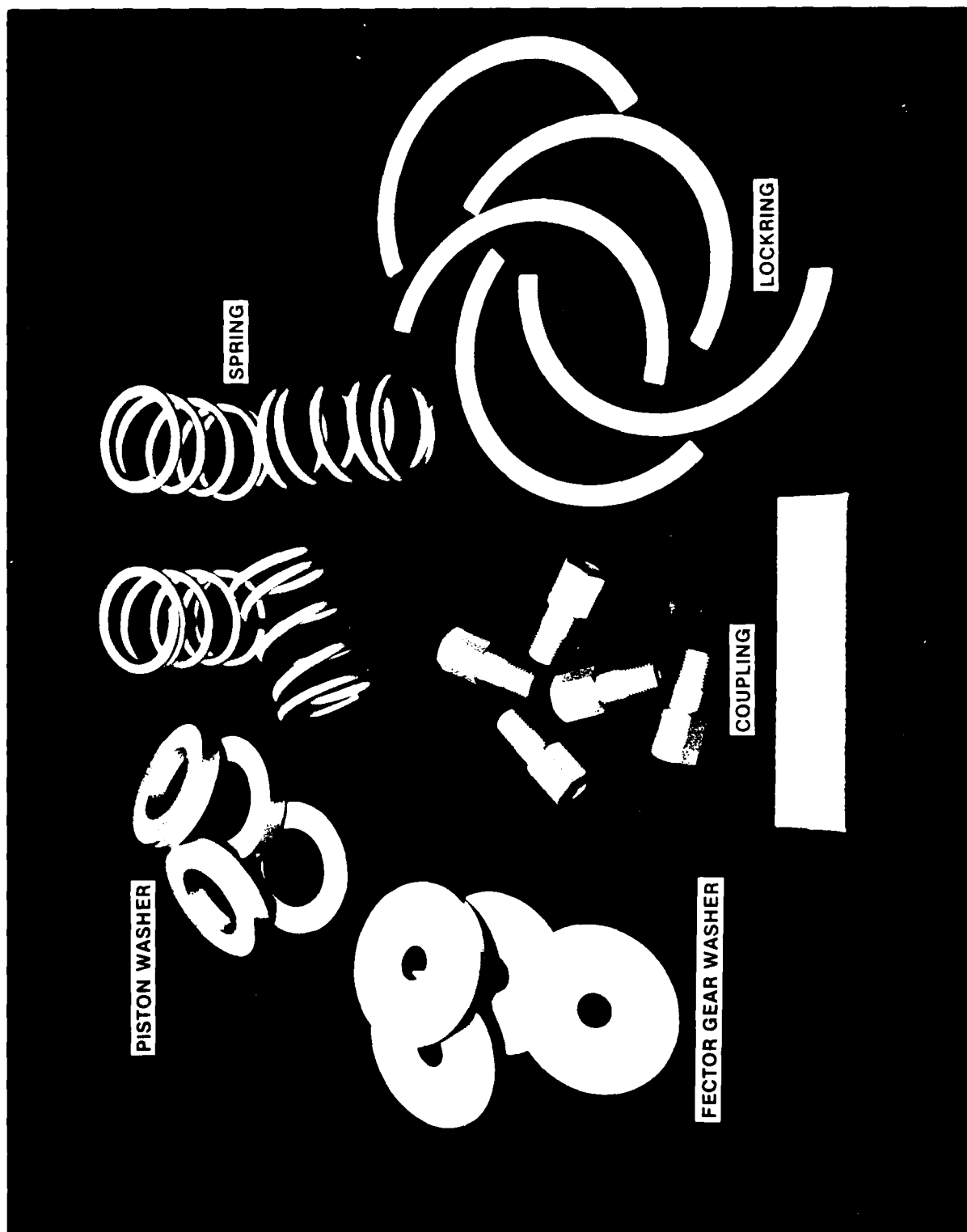
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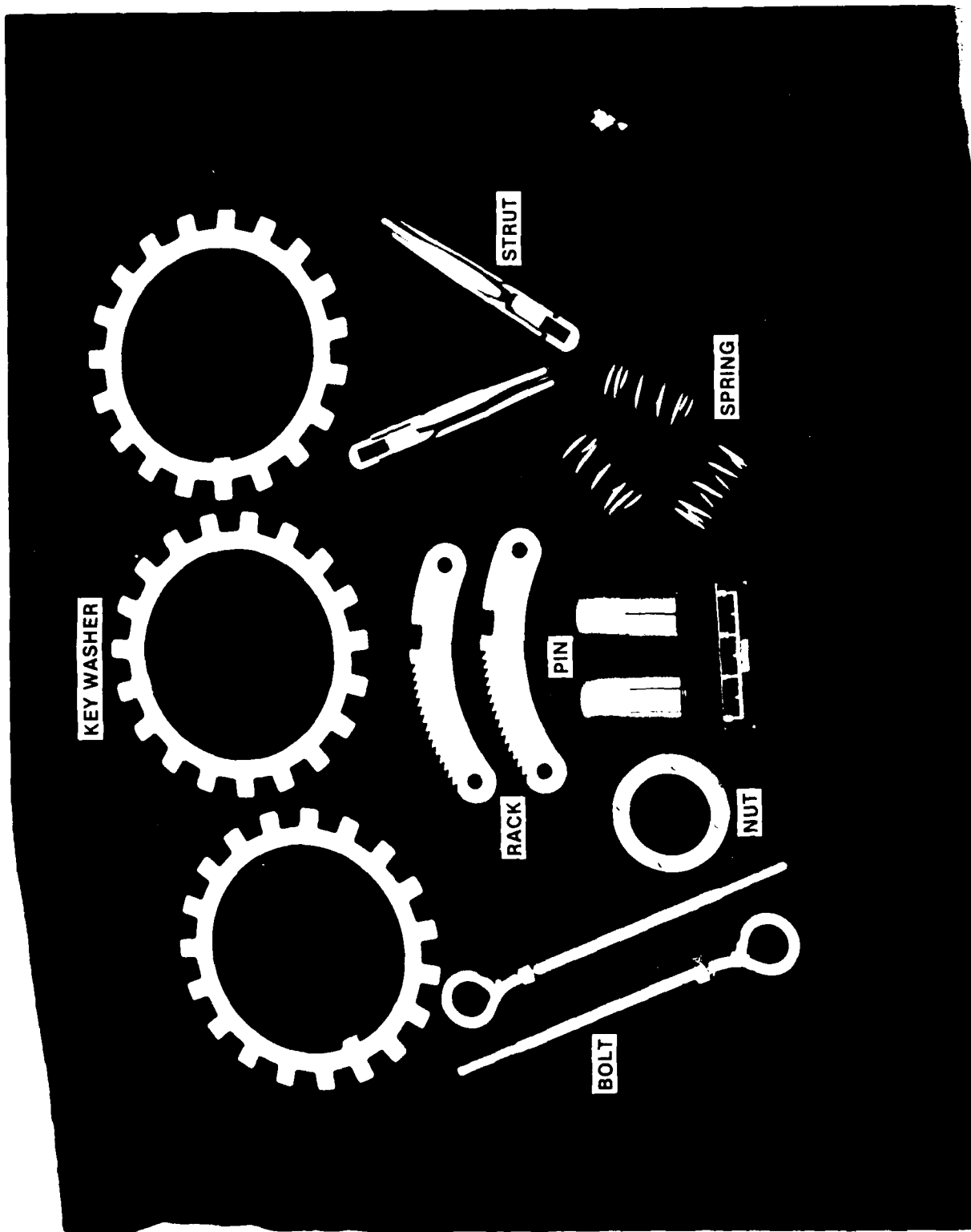
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Attachment (C)

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Attachment (C)

**MCDONNELL DOUGLAS CORPORATION**

**MCDONNELL AIRCRAFT COMPANY**

Box 516, Saint Louis, Missouri 63166 (314) 232-0232

26 January 1982  
USA-347-7385

Commander  
U.S. Army - ARRADCOM  
Dover, NJ 07801

Attention: Mr. Edgardo Silvestre, DRDAR-SCM-P, Bldg. 355

Subject: Processing Parameters for Ivdized Details

Reference: ARRADCOM Contract DAAK10-81-R-0352, "Ion Vapor Deposition  
Processing of Armament Parts"

Dear Edgardo:

The processing parameters used to IVD aluminum coat both the ARRADCOM supplied armament details and the McDonnell Aircraft supplied panels that were recently returned to your attention are shown in the enclosed table. The applicable MIL-C-83488, "Coating, Aluminum, Ion Vapor Deposited" class and type and the approximate coating thickness are also shown.

I have also enclosed several photographs of the coated details with identification.

I plan to supply cost and throughput data for each detail within the next month.

Please call me at (314) 233-8663 if you have any questions.

Very truly yours,



J. J. Reilly  
Technical Specialist  
Ivdizer Technology

JJR:gah

Enclosures

MCDONNELL DOUGLAS

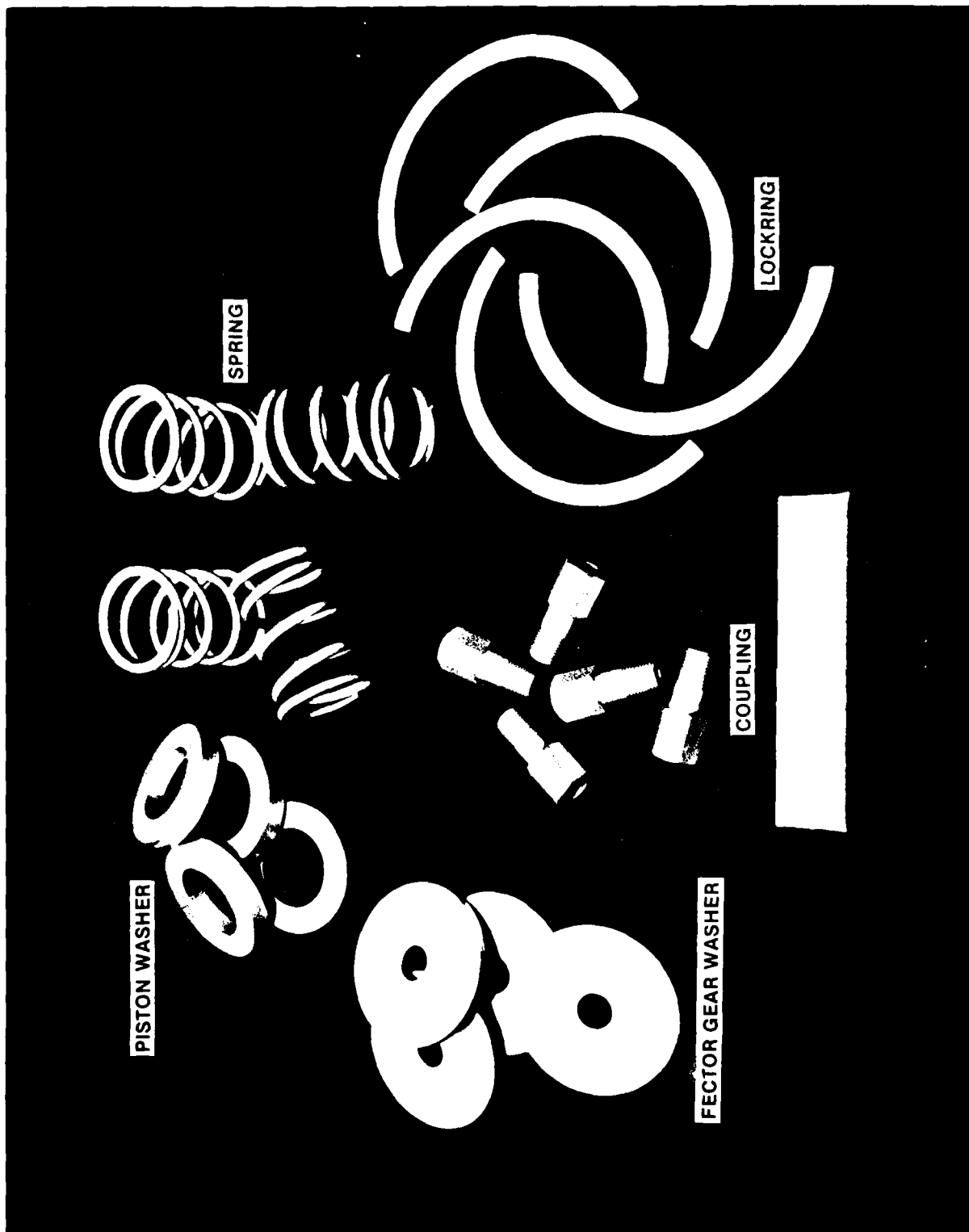


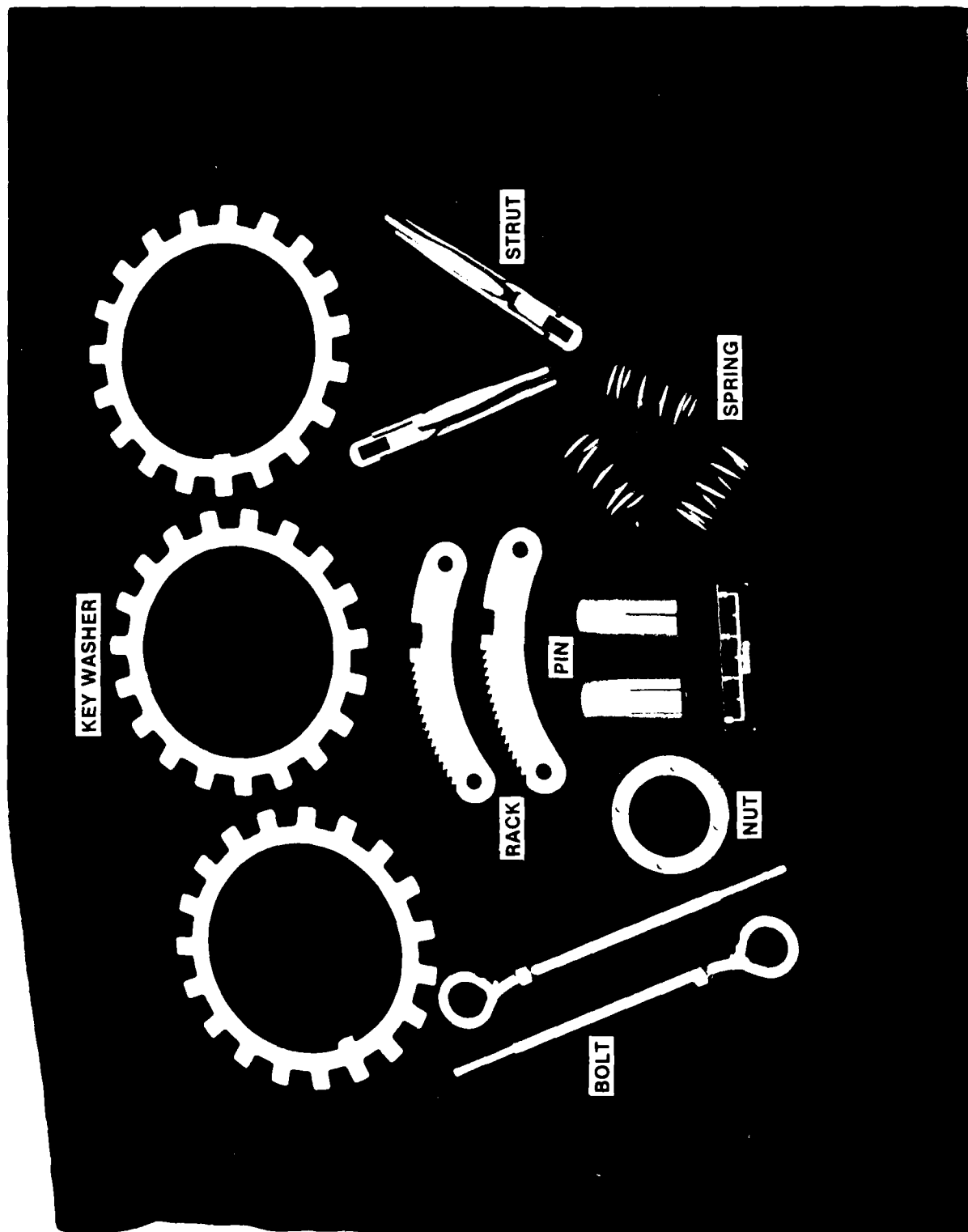


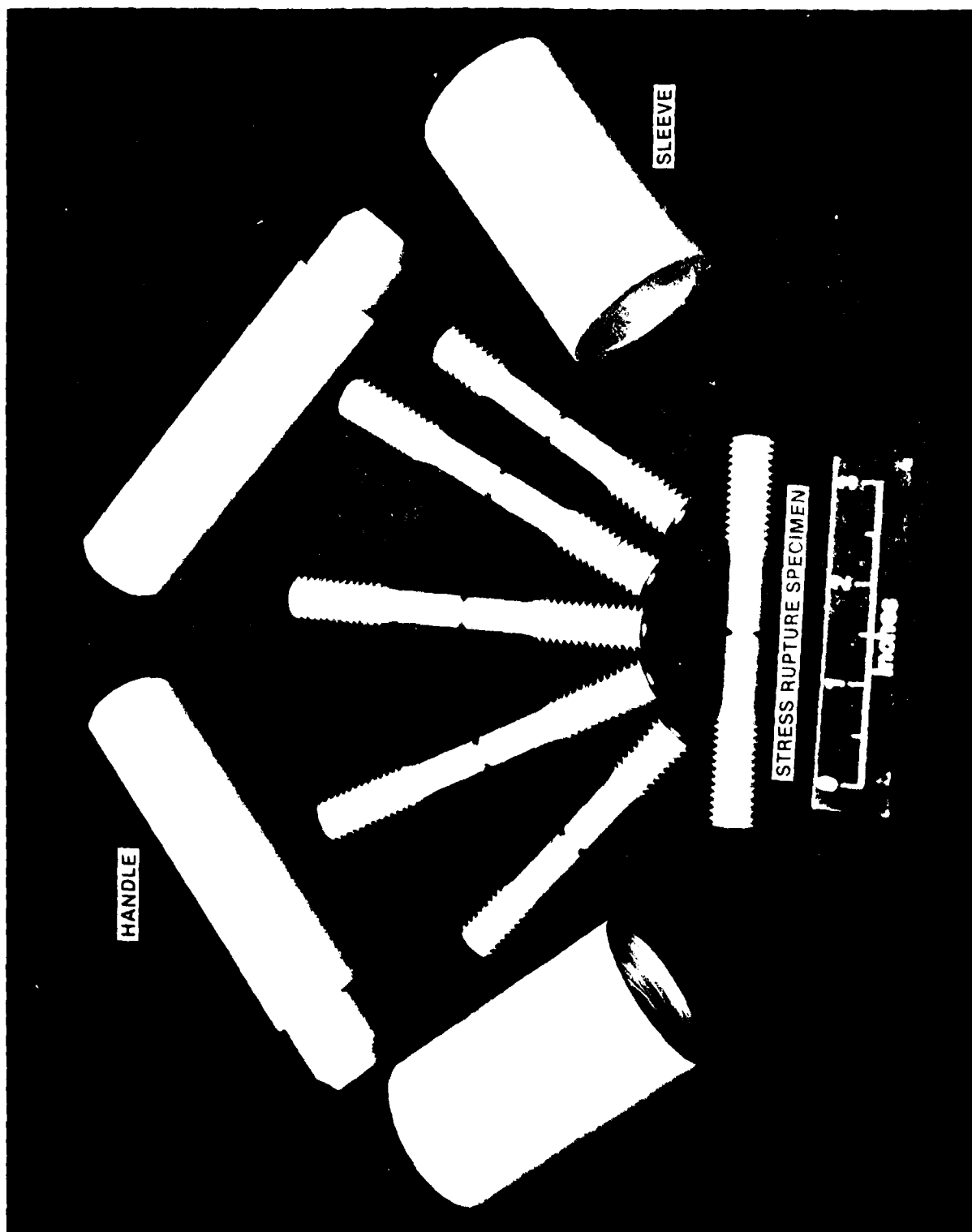
MCDONNELL AIRCRAFT COMPANY

| SPECIMEN                      | MIL-C-83488 |      | COATING THICKNESS APPROXIMATE (MILS) | GLOW DISCHARGE CLEANING PARAMETERS |                 |                 | COATING PARAMETERS |                 |                 |
|-------------------------------|-------------|------|--------------------------------------|------------------------------------|-----------------|-----------------|--------------------|-----------------|-----------------|
|                               | CLASS       | TYPE |                                      | PRESSURE (MICRONS)                 | VOLTAGE (VOLTS) | AMPERAGE (AMPS) | PRESSURE (MICRONS) | VOLTAGE (VOLTS) | AMPERAGE (AMPS) |
| <u>Rack Fixtured</u>          |             |      |                                      |                                    |                 |                 |                    |                 |                 |
| Nut                           | 2           | II   | 0.7                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Bolt                          | 2           | II   | 0.7                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Handle                        | 1           | II   | 2.0                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Key Washer                    | 1           | II   | 1.6                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Pin                           | 1           | II   | 2.0                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Rack                          | 1           | II   | 2.0                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Sleeve                        | 1           | II   | 2.0                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Spring                        | 1           | II   | 1.8                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Strut                         | 1           | II   | 2.0                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Stress Rupture                | 1           | II   | 1.7                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Steel Panel (High Voltage)    | 1           | II   | 2.0                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Steel Panel (Low Voltage)     | 1           | II   | 2.0                                  | 10                                 | 500             | 0.9             | 10                 | 750             | 0.1             |
| Aluminum Panel (High Voltage) | 1           | II   | 2.0                                  | 10                                 | 900             | 1.5             | 10                 | 1500            | 0.2             |
| Aluminum Panel (Low Voltage)  | 1           | II   | 2.0                                  | 10                                 | 500             | 0.9             | 10                 | 750             | 0.1             |
| <u>Barrel Fixtured</u>        |             |      |                                      |                                    |                 |                 |                    |                 |                 |
| Coupling                      | 2           | II   | 0.7                                  | 10                                 | 500             | 2.0             | 10                 | 1400            | 0.1             |
| Lockring                      | 2           | II   | 0.9                                  | 10                                 | 500             | 2.0             | 10                 | 1400            | 0.1             |
| Spring                        | 2           | II   | 0.8                                  | 10                                 | 500             | 2.0             | 10                 | 1400            | 0.1             |
| Piston Washer                 | 2           | II   | 0.9                                  | 10                                 | 500             | 2.0             | 10                 | 1400            | 0.1             |
| Washcoat Gear                 | 2           | II   | 0.9                                  | 10                                 | 500             | 2.0             | 10                 | 1400            | 0.1             |

MCDONNELL DOUGLAS CORPORATION







**MCDONNELL AIRCRAFT COMPANY**

Box 516, Saint Louis, Missouri 63166 (314) 232-0232

24 March 1982  
USA-347-7594



Commander  
U.S. Army - ARRADCOM  
Dover, NJ 07801

Attention: Mr. Edgardo Silvestre, DRDAR-SCM-P, Bldg. 355

Subject: Processing Costs for Ivadized Details

Reference: ARRADCOM Contract DAAK10-81-R-0352, "Ion Vapor Deposition  
Processing of Armament Parts"

Dear Edgardo:

The reference contract requires cost analysis by McDonnell Aircraft Company (MCAIR) for IVD aluminum processing of the items furnished to MCAIR by ARRADCOM. I have enclosed a table (Enclosure 1) which lists the furnished items and shows the approximate processing cost based on production size loads.

The detail throughputs are approximate and are based on our latest barrel coater design and on our standard rack coater design. The hourly cost is a MCAIR figure. This cost differs among the various facilities that offer IVD aluminum coating services on a subcontract basis (Enclosure 2). Profit is not included in the cost per detail amount.

More realistic cost data can be obtained by asking for budgetary quotes from several of the job shop plating facilities. I will be happy to obtain this data if you so desire. Drawings of the items in question and approximate usage requirements would be beneficial. Please advise me on this matter.

Please contact me at (314) 233-8663 if you have any questions.

Very truly yours,

A handwritten signature in cursive script, appearing to read "Jim".

J. J. Reilly  
Technical Specialist  
Ivadizer Technology

JJR:gah

Enclosures

MCDONNELL DOUGLAS

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CORPORATION

ATTACHMENT (E)

**MCDONNELL AIRCRAFT COMPANY**

**THROUGHPUT AND COST DATA**

| <u>ITEM</u>        | <u>FIXTURING</u> | <u>APP. THROUGHPUT<br/>PER HOUR</u> | <u>APP. COST<br/>PER HOUR</u> | <u>APP. COST<br/>PER DETAIL</u> |
|--------------------|------------------|-------------------------------------|-------------------------------|---------------------------------|
| Coupling           | Barrel           | 3523                                | \$120                         | \$ .03                          |
| Spring             | Barrel           | 2040                                | \$120                         | \$ .06                          |
| Piston Washer      | Barrel           | 4715                                | \$120                         | \$ .03                          |
| Pector Gear Washer | Barrel           | 5333                                | \$120                         | \$ .02                          |
| Nut                | Barrel           | 800                                 | \$120                         | \$ .15                          |
| Bolt               | Rack             | 288                                 | \$125                         | \$ .43                          |
| Handle             | Rack             | 549                                 | \$125                         | \$ .23                          |
| Key Washer         | Rack             | 309                                 | \$125                         | \$ .40                          |
| Pin                | Rack             | 883                                 | \$125                         | \$ .14                          |
| Rack               | Rack             | 343                                 | \$125                         | \$ .36                          |
| Strut              | Rack             | 686                                 | \$125                         | \$ .18                          |

**MCDONNELL DOUGLAS CORPORATION**

**MCDONNELL AIRCRAFT COMPANY**

**COMPANIES OFFERING IVADIZE ALUMINUM SUBCONTRACT WORK**

Embee Plating (Subcontract Plater)  
Los Angeles, CA  
John Dahlberg (714) 546-9842  
6' x 12' Rack Coater

Michigan Chrome & Chemical (Subcontract Plater)  
Detroit, MI  
Jim Kerrigan (313) 921-3711  
6' x 12' Rack Coater

Voi-Shan (Fastener Mfg.)  
Culver City, CA  
Boyd Sellers (213) 870-5321  
4' x 6' Barrel Coater

Metals Applied (Subcontract Plater)  
Division of Cleveland Pneumatic Company  
Cleveland, OH  
Pablo Prieto (216) 241-5913  
4' x 8' Rack Coater  
6' x 12' Rack Coater

Ekco Products, Inc. (Subcontract Plater)  
Chicago, IL  
Norm Gemignani (312) 237-6000  
7' x 12' Rack Coater

McDonnell Aircraft Co.  
St. Louis, MO  
E. Fannin (314) 232-9924  
7' x 12' Rack Coater  
6' x 12' Rack Coater (2)  
4' x 7' Barrel Coater  
2' x 3' Rack/Barrel Coater

St. Charles Metal Finishing  
St. Charles, MO  
Quince Parker (314) 724-6851  
6' x 12' Rack Coater

Robert Stuart (London) Ltd  
London, England  
M.H.C. Maxwell 01-267-2414  
4' x 6' Barrel/Rack Coater

AAA Plating Co. (Subcontract Plater)  
Los Angeles, CA  
Joe Trankla (213) 979-8930  
4' x 6' Barrel/Rack Coater

Martin Marietta Aerospace (Missile Mfg.)  
Orlando, FL  
George Bean (305) 352-4018  
6' x 12' Rack Coater

Northrop Corporation (Aircraft Mfg.)  
Los Angeles, CA  
Tom Thomas (213) 970-3497  
6' x 12' Rack Coater (3)

Blanc Aero  
Paris, France  
J. Ordines 307-00-11  
4' x 6' Barrel Coater

Tokyo Rashi Co.  
Kanagawa, Japan  
Yukio Arimi 0466 (23) 2131  
4' x 6' Barrel Coater

Turbine Support (Engine Overhaul)  
Manchester, CN  
Roy F. Cannon (512) 333-6010  
6' x 12' Rack Coater

SPS Technologies  
Jenkintown, PA  
Ken Kulju (215) 572-3309  
4' x 6' Barrel Coater

Cametoid Platers (Subcontract Plater)  
Ontario, Canada  
D. G. Newman (416) 683-6450  
4' x 6' Barrel Coater  
6' x 12' Rack Coater

**MCDONNELL DOUGLAS CORPORATION**

**MCDONNELL AIRCRAFT COMPANY**

Box 516, Saint Louis, Missouri 63166 (314) 232-0232

17 March 1982  
UND-347-7571

Mr. James A. Kargol  
Assistant Professor  
Dept. of Metallurgical Engineering  
and Materials Science  
University of Notre Dame  
Box E  
Notre Dame, IN 46556

Subject: Return of Panels for Evaluation for ARRADCOM

Dear Jim:

The 8 test panels that you submitted have been coated with IVD aluminum and were returned to you under separate cover. Per our agreement, the test panels were processed as follows:

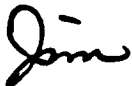
- o 2 at 10 micron coating pressure and 3.1 gram/minute wire feed rate.
- o 2 at 18 micron coating pressure and 3.1 gram/minute wire feed rate.
- o 2 at 10 micron coating pressure and 6.0 gram/minute wire feed rate.
- o 2 at 18 micron coating pressure and 6.0 gram/minute wire feed rate.

The coating is approximately 0.001" and 1 panel from each of the 4 processing parameter sets was burnished with glass beads and chromated. The other panel from each set was left as-coated.

The 10 micron coating pressure and 3.1 gram/minute wire feed rate are the normal processing parameters. Details are also normally burnished and chromated after coating. Chromating enhances corrosion protection and provides a base for subsequent processing like a paint topcoat. We burnish the details with glass beads at 40 PSI. This step also enhances corrosion protection, checks the adhesion of the coating and improves appearance.

Please call either Greg Smith at (314) 233-8658 or myself at (314) 233-8663 if we can be of any assistance.

Best regards,



J. J. Reilly  
Technical Specialist-Ivadizer Technology

JJR:gah

MCDONNELL DOUGLAS

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ATTACHMENT (F)



**MCDONNELL AIRCRAFT COMPANY**

19 April 1982  
USA-347-7572

Box 516 Saint Louis, Missouri 63166 (314) 232-0232

Commander  
U.S. Army - ARRADCOM  
Dover, NJ 07801

Attention: Mr. Edgardo Silvestre, DRDAR-SCM-P, Bldg. 355

Subject: Shipment of Test Coupons

Reference: ARRADCOM Contract DAAK10-81-R-0352, "Ion Vapor Deposition  
Processing of Armament Parts"

Dear Edgardo:

The 24 additional alloy steel parts that you requested have been coated with IVD aluminum and are being sent to you under separate cover. The coating is Class 1, Type II on 12 panels, and Class 2, Type II on the other 12 panels.

The processing parameters used to IVD aluminum coat the panels are shown in the enclosed table.

I am also sending you the 24 cadmium plated coupons that you requested in the same shipment. Twelve of the panels are plated per QQ-P-416, Class 1, Type II, and the other 12 per QQ-P-416, Class 2, Type II.

Since you intend to compare the corrosion resistance characteristics of aluminum and cadmium, you may be interested in the conclusions we have reached after extensive testing:

- o Cadmium protects steel better than aluminum in neutral salt fog environments.
- o Aluminum protects steel better than cadmium in acidic salt fog environments.
- o Aluminum protects steel better than cadmium in most outdoor environments.
- o Aluminum on steel fasteners protects aluminum alloy structure better than cadmium on steel fasteners regardless of the environment.

Please call me at (314) 233-8663 if you have any questions.

Best regards,



J. J. Reilly  
Technical Specialist  
Ivadizer Technology

JJR:gah

**MCDONNELL DOUGLAS**

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ATTACHMENT (G)

**MCDONNELL AIRCRAFT COMPANY**

USA-367-7572  
Enclosure

| SPECIMEN                          | MIL-C-83488 |      | COATING THICKNESS APPROXIMATE (MILS) | GLOW DISCHARGE CLEANING PARAMETERS |                 |                 | COATING PARAMETERS |                 |                 |
|-----------------------------------|-------------|------|--------------------------------------|------------------------------------|-----------------|-----------------|--------------------|-----------------|-----------------|
|                                   | CLASS       | TYPE |                                      | PRESSURE (MICRONS)                 | VOLTAGE (VOLTS) | AMPERAGE (AMPS) | PRESSURE (MICRONS) | VOLTAGE (VOLTS) | AMPERAGE (AMPS) |
| <u>Back Plated</u><br>(12) Panels | 1           | II   | 1.5                                  | 10                                 | 500             | 2.0             | 10                 | 1200            | .15             |
| (12) Panels                       | 2           | II   | 0.7                                  | 10                                 | 500             | 2.0             | 10                 | 1200            | .15             |

**MCDONNELL DOUGLAS CORPORATION**

**MCDONNELL AIRCRAFT COMPANY**

**COATING ADHESION AND CORROSION RESISTANCE DATA**

| MCAIR<br>RUN NUMBER | COATING<br>ADHESION<br>(BEND-TO-BREAK) | REPRESENTATIVE<br>TEST SPECIMEN<br>(ALLOY STEEL) | COATING<br>CLASS/TYPE | SALT FOG DURATION (HOURS)  |                    |                  |
|---------------------|----------------------------------------|--------------------------------------------------|-----------------------|----------------------------|--------------------|------------------|
|                     |                                        |                                                  |                       | MIL-C-83488<br>REQUIREMENT | ACTUAL<br>DURATION | STILL IN<br>TEST |
| 2269                | Passed                                 | 2" Diameter Washer                               | Class 2, Type II      | 504                        | 1584               | 5688             |
| 2270                | Passed                                 | 2" Diameter Washer                               | Class 2, Type II      | 504                        |                    | 5688             |
| 2280                | Passed                                 | 4" x 6" Panel                                    | Class 2, Type II      | 504                        |                    | 4800             |
| 2306                | Passed                                 | 2" x 4" Panel                                    | Class 1, Type II      | 672                        |                    | 4800             |
| 2308                | Passed                                 | 2" x 4" Panel                                    | Class 1, Type II      | 672                        |                    | 4800             |
| 602                 | Passed                                 | 1" x 4" Panel                                    | Class 1, Type II      | 672                        |                    | 3048             |
| 603                 | Passed                                 | 1" x 4" Panel                                    | Class 2, Type II      | 504                        |                    | 2808             |
| 595                 | Passed                                 | 1" x 3" Panel                                    | Class 1, Type II      | 672                        |                    |                  |
| 596                 | Passed                                 | 1" x 3" Panel                                    | Class 1, Type II      | 672                        |                    |                  |
| 598                 | Passed                                 | 1" x 3" Panel                                    | Class 1, Type II      | 672                        |                    |                  |
| 600                 | Passed                                 | 1" x 3" Panel                                    | Class 1, Type II      | 672                        |                    |                  |
| 601                 | Passed                                 | 1" x 3" Panel                                    | Class 1, Type II      | 672                        |                    | 2808             |
| 617                 | Passed                                 | 1" x 6" Panel                                    | Class 1, Type II      | 672                        |                    | 2684             |
| 618                 | Passed                                 | 1" x 6" Panel                                    | Class 2, Type II      | 504                        |                    | 2684             |
| 2397                | Passed                                 | 1" x 4" Panel                                    | Class 2, Type II      | 504                        |                    | 2636             |
| 2398                | Passed                                 | 1" x 4" Panel                                    | Class 1, Type II      | 672                        |                    | 2636             |
| 2407                | Passed                                 | 1" x 4" Panel                                    | Class 2, Type II      | 504                        |                    | 2160             |
| 2409                | Passed                                 | 1" x 4" Panel                                    | Class 1, Type II      | 672                        |                    | 2160             |

**MCDONNELL DOUGLAS CORPORATION**

Attachment (H)

**MCDONNELL AIRCRAFT COMPANY**



Highland Avenue  
Jenkintown  
Pennsylvania 19046  
215-572-3000  
TWX: 510-665-1718  
Telex: 83-4254

**QUOTATION**

**MCDONNELL DOUGLAS AIRCRAFT CO.**  
Box 516  
St. Louis, Missouri 63166

Attn: J. J. Reilly, Tech. Spec.

Thank you for your inquiry. We are pleased to quote as follows

| SPS QUOTE DATE | SPS QUOTE NO               | YOUR REFERENCE | INQUIRY DATE | TERMS          |
|----------------|----------------------------|----------------|--------------|----------------|
| 6-10-82        | BD257                      | LTR            | OF 5-13-82   | 1/2% 10 Net 30 |
| QUANTITY       | DESCRIPTION                |                | PRICE        | DELIVERY       |
|                | SEE ATTACHED LIST OF ITEMS |                | AS NOTED     | AS NOTED       |
|                | QUOTATION FIRM FOR 30 DAYS |                |              |                |

F O B

**JENKINTOWN, PA.**

SPS TECHNOLOGIES, AREA REPRESENTATIVE

**D. FIELD**

SPS TECHNOLOGIES, INC.

*Robert P. Decembrino*

**ROBERT P. DECEMBRINO, SLS. REP**  
**AEROSPACE FASTENER SALES**

258 J RE 887

**MCDONNELL DOUGLAS CORPORATION**

**MCDONNELL AIRCRAFT COMPANY**

6-10-82

MCDONNELL DOUGLAS CORPORATION

ST. LOUIS, MISSOURI

Page 1

| QUANTITY                                | DESCRIPTION                  | PRICE        | DELIVERY         |
|-----------------------------------------|------------------------------|--------------|------------------|
| 10,000                                  | 10903625 WASHER PISTON ROD   | 21.27/C      | TO BE NEGOTIATED |
| 20,000                                  | "                            | 20.89/C      |                  |
| 10,000                                  | 10891983 SPRING VALVE HANDLE | 38.35/C      |                  |
| 20,000                                  | "                            | 37.95/C      |                  |
| 10,000                                  | 8430285 LOCKING RING         | 17.60/C      |                  |
| 20,000                                  | "                            | 17.21/C      |                  |
| 10,000                                  | 10913585 HANDLE              | 50.87/C      |                  |
| 20,000                                  | "                            | 50.47/C      |                  |
| 10,000                                  | 12000541 COUPLING            | 38.35/C      |                  |
| 20,000                                  | "                            | 37.95/C      |                  |
| 10,000                                  | 12010424 STRUT               | 50.87/C      |                  |
| 20,000                                  | "                            | 50.47/C      |                  |
| 10,000                                  | 6222781 RACK                 | 21.27/C      |                  |
| 20,000                                  | "                            | 20.89/C      |                  |
| 10,000                                  | 10908460 WASHER KEY          | NO QUOTE     |                  |
| 20,000                                  | "                            | AT THIS TIME |                  |
| NOTE: QUOTING IVD ALUMINUM COATING ONLY |                              |              |                  |
| QUOTATION FIRM FOR 30 DAYS              |                              |              |                  |

**MCDONNELL DOUGLAS CORPORATION**

**MCDONNELL AIRCRAFT COMPANY**

MC DONNELL AIRCRAFT COMPANY

Customer

Box 516

Saint Louis, Missouri 63166

Attn: J. Reilly

*Emile Mating*

2436 South Hathaway Road

Santa Ana, California 92705

(714) 746-9842

(214) 589-6051

| This is a Quotation              |             |                          | Terms Net 10th Day |             |
|----------------------------------|-------------|--------------------------|--------------------|-------------|
| Part Number                      | Description | Price                    | Quantity           | Unit Price  |
| 10903625                         | Washer      | I.V.D.                   |                    | \$ .15 Each |
| 10891983                         | Spring      | I.V.D.                   |                    | \$ .23 Each |
| 8430289                          | Ring        | I.V.D.                   |                    | \$ .25 Each |
| 10913585                         | Handle      | I.V.D.                   |                    | \$ .85 Each |
| 12000541                         | Coupling    | I.V.D.                   |                    | \$ .20 Each |
| 12010424                         | Strut       | I.V.D.                   |                    | \$1.25 Each |
| 6222781                          | Rack        | I.V.D.                   |                    | \$ .90 Each |
| 10908460                         | Washer      | I.V.D.                   |                    | \$1.50 Each |
|                                  |             | Minimum Charge: \$175.00 |                    |             |
|                                  |             | F.O.B.                   |                    |             |
|                                  |             | Santa Ana, California    |                    |             |
| THIS QUOTATION GOOD FOR 100 DAYS |             |                          |                    |             |

*This quotation is subject to Embair's approval to process in accordance with the referenced specifications*

Signature

*James P. Rantall*

Title

Sales Manager

Date

May 28, 1982

**MCDONNELL DOUGLAS CORPORATION**

**MCDONNELL AIRCRAFT COMPANY**

MIL-STD-1568A(USAF)  
24 October 1979  
SUPERSEDING  
MIL-STD-1568(USAF)  
18 November 1975

**MILITARY STANDARD**

**MATERIALS AND PROCESSES FOR  
CORROSION PREVENTION AND CONTROL IN  
AEROSPACE WEAPONS SYSTEMS**



*See Paragraph 5.6.1.3.*

**FSC MFFP**

**MCDONNELL DOUGLAS CORPORATION**

**ATTACHMENT (J)**

5.5.3 Marking pencils. Ordinary lead pencils containing graphite shall not be used to mark metal parts. Nongraphitic marking pencils covered by MIL-P-83953 shall be used.

5.5.4 Cleaning after assembly. All closed compartments shall be cleaned after assembly to remove debris such as metal chips, broken fasteners, and dust. Particular attention shall be given to insure that drain holes are not blocked.

5.5.5 Protection of parts during storage and shipment. All parts and assemblies shall be given adequate protection to prevent corrosion and physical damage during temporary or long term storage and shipment.

## 5.6 Inorganic finishes.

5.6.1 Detail requirements. Cleaning, surface treatments and inorganic finishes for metallic surfaces of aerospace weapons systems parts shall be in accordance with MIL-S-5002. Those parts or surfaces of parts located in corrosion susceptible areas or which form exterior surfaces of the system shall require chemical finishing to provide maximum corrosion resistance.

5.6.1.1 Aluminum. All nonclad parts made from 7000 series aluminum alloys shall be sulfuric acid anodized in accordance with MIL-A-8625, Type II. They may be chromic acid anodized, MIL-A-8625, Type I, provided the anodized 7000 series test specimens meet the weight and corrosion resistance requirements of MIL-A-8625, Type II. All nonclad parts made from 2000 series aluminum alloys shall be anodized in accordance with MIL-A-8625, Type I or II. Clad 2000 and 7000 series aluminum alloys may be anodized in accordance with MIL-C-5541 as a minimum corrosion preventative coating.

5.6.1.2 Cadmium coatings. Cadmium coatings for all steel parts including fasteners shall have a minimum thickness of 0.0003 inch (0.008 mm) and shall be subsequently treated with a chromate conversion coating. High strength steels having an ultimate tensile strength of 180,000 psi (1230 MPa) and above shall be coated with the titanium-cadmium process in accordance with MIL-STD-1500, the vacuum deposition process in accordance with MIL-C-8837, or a similar non-embrittling process.

5.6.1.3 Aluminum coatings. Aluminum coating per MIL-C-83488 or equivalent shall be considered acceptable alternative coatings to cadmium. Decreased toxicity and decreased environmental contamination are obtained by using aluminum coatings.



**DATE**  
**ILME**