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STRESS CORROSION CRACKING OF ALUMINUM AND STEEL IN DIMETHYL DICHLOROVINYL PHOSPHATE

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16. Abstract

The stress corrosion cracking (SCC) susceptibility of aluminum alloys 2024-T351 and 7075-T651 and 18 nickel maraging steel was evaluated in dilute solutions of dimethyl-dichlorovinyl phosphate (DDVP), distilled water, and 3.5 percent sodium chloride solution. Round tensile specimens stressed to 50 and 75 percent of the respective yield strengths were partially immersed in the test solutions. The results indicate that under these test conditions the stress corrosion cracking susceptibility of 2024-T351 and 7075-T651 aluminum and 18 Ni maraging steel are similar in distilled water and dilute solutions (0.001 to 0.1 percent) of DDVP. Although DDVP could not be considered to contribute to SCC at these concentrations, the test results do verify the susceptibility of the three alloys to SCC in aqueous solutions.

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STRESS CORROSION CRACKING OF ALUMINUM AND STEEL IN DIMETHYL DICHLOROVINYL PHOSPHATE

SUMMARY

A few investigators (1,2) have evaluated the corrosiveness of dilute solutions of the relatively new organic phosphorus compound dimethyl-dichlorovinyl phosphate (DDVP)* with regard to aircraft materials, but no stress corrosion data have been reported. Because of the possible use of this compound for disinsection (removal of insect) of commercial aircraft making international flights, the stress corrosion cracking (SCC) susceptibility of aircraft structural materials in dilute solutions of DDVP was evaluated and compared to that in distilled water and 3.5 percent sodium chloride (NaCl) solution.

The results of this investigation indicated that there is no significant difference in the SCC susceptibility of 2024-T351 and 7075-T651 aluminum and 18 Ni maraging steel in dilute solutions (0.001 to 0.1 percent) of DDVP than in distilled water. These alloys were found to be more susceptible to SCC in 3.5 percent sodium chloride solution than in DDVP.

* Also known as Dichlorvos

INTRODUCTION

The World Health Organization has recommended to member states an automatic, in-flight, disinsection system or aerosol disinsection on the ground upon arrival to replace the existing in-flight "bug bomb" method of insect control for pressurized aircraft on international flights. The recommended automatic in-flight, disinsection is based on design parameters recommended by the United States Public Health Service which provides for the dispersion of DDVP.

There are many factors to be considered in the use of the proposed system, such as; feasibility, entomological aspects, toxicity to humans, and acceptability to crew and passengers. Another important consideration is the effect of the disinsectant on the service life of the aircraft. A few investigators (1, 2) have evaluated the corrosiveness of DDVP on the structural components, but no stress corrosion data have been generated. At the request of the Federal Aviation Administration, Aeronautical Center, an investigation was undertaken to generate SCC data.

EXPERIMENTAL PROCEDURES

Aluminum alloys 2024-T351 and 7075-T651 were tested because these are the two most prevalent structural metals in commercial aircraft, and 18 nickel maraging steel was tested to represent typical steel components and fasteners. Round tensile specimens were taken from the short transverse grain direction (thickness) of 50.8 to 76.2 mm (2 to 3 in) thick plate of the aluminum alloys and from the long transverse direction (width) of 6.35 mm (1/4 in) thick plate of the maraging steel.

All the aluminum specimens were etched for 30 seconds in a 5 percent solution of sodium hydroxide, desmutted in concentrated (70 percent) nitric acid and rinsed in water. The maraging steel specimens were wet-grit blasted with "fast-cut" (quartz) No. 325 abrasive to remove surface oxides, rinsed in water, and dipped in alcohol to facilitate drying. The specimens were placed in stressing assemblies and stressed in direct tension by pressing the sides of the assemblies toward the center until the desired strain in the specimens, as measured with an extensometer, was obtained. A stressing fixture was used so that both sides were depressed an equal distance to insure a simple, uniaxial stress in the specimens. The stressing fixture and stressing assemblies with specimens in place are shown in Figure 1. A more detailed description of the test specimen and method of loading is given in Ref. 3.

Before exposure, the mechanical properties of the alloys were measured in the direction of testing. After loading, the specimens to be exposed were wiped with acetone and placed in one liter beakers. Three specimens loaded to 50 percent of the yield strength, three specimens loaded to 75 percent, and three unstressed control specimens were placed in each beaker (Figure 2). Solutions of 0.001, 0.01, and 0.1 percent DDVP and 3.5 percent NaCl were prepared. The distilled water used in this investigation contained less than 0.5 ppm ionizable chlorides, had a pH of 6.4 and a specific resistance of 130,000 ohm-cm. There were no measurable chlorides (less than 0.6 percent) in any of the DDVP solutions and the pH and specific resistance of the 0.001 and 0.01 percent solutions were similar to those of the distilled water. The 0.1 percent solution showed a difference in both the pH value (5.0) and specific resistance (78,000 ohm-cm). None of the solutions showed any change in excess of 0.5 pH during exposure. Sufficient volume (approximately 200 ml) of each solution was added to the beakers so that the specimens were half submerged. The beakers were not covered and distilled water was added daily to compensate for loss by evaporation. To remove a specimen from test, the solution was brought to the original level in the beaker with distilled water, the specimen or specimens were removed and the solution was returned to the original level by the addition of the specific test solution. Thus, the volume of solution was not the same at the beginning and end of the test except when no specimens were removed. The solutions that were added were pre-prepared at the beginning of the test so that they would have the same storage time as the test solutions. The test duration was 42 days (approximately 1000 hours) except for prior failures. Daily visual inspections were made and cracked specimens were removed, rinsed and air dried. Metallographic examination of selected specimens was made with a Scanning Electron Microscope (SEM) to verify and record the mode of failure. After the test was terminated, the solutions were sent to the Technical Development Laboratories, Center for Disease Control (Mr. J. A. Jensen) for analysis.

RESULTS AND DISCUSSION

The results of the analysis of the DDVP solutions after exposure are shown in Appendix I. Pronounced decomposition of the DDVP occurred as was indicated in the previously referenced reports. Chloride contamination of the solutions as indicated by the analysis is not surprising because the tests were conducted in open beakers in laboratory exhaust hoods with no specific precautions taken to prevent chloride contamination. It is assumed that chloride contamination of DDVP disinsectant will occur in service also.

The stress corrosion results obtained in this investigation are listed in Table I. The aluminum alloys were stressed well above their SCC threshold to assure failure in distilled water for comparison with the specimens in the DDVP solution. Specimens of both aluminum alloys failed in all five test solutions, and failure of the maraging steel specimens was encountered in distilled water, 0.1 percent DDVP, and the 3.5 percent salt solution. There was no significant difference in the rate of failure in the distilled water and the DDVP solutions but the time to failure in the salt solution was considerably shorter than in the other test media. The mode of failure in all three solutions was similar and typical of brittle SCC as indicated by the SEM fractographs in Figures 3 through 7.

CONCLUSIONS

The results obtained in this investigation indicated that the stress corrosion cracking susceptibility of 2024-T351 and 7075-T651 aluminum and 18 nickel maraging steel is not accelerated by exposure to low concentrations up to 0.1 percent DDVP. That is, SCC susceptibility was found to be no worse in DDVP than in pure distilled water and better (longer life and less degradation of tensile strength) than in a 3.5 percent salt solution.

REFERENCES

1. Blair, Austin, "Aircraft Disinsectant Corrosion Testing Program," The Boeing Company Report D6-25246-TN, March, 1970.

2. Eastern Engineering Report E-501, September 1969, "Corrosive and Toxicological Properties of DDVP Decomposition Products."

3. Humphries, T. S.: "Procedures for Externally Loading and Corrosion Testing Stress Corrosion Specimens," NASA TM X-53483, June, 1966.

APPENDIX I

NASA STRESS CORROSION TESTS - DICHLORVOS VS AIRCRAFT METALS

Chemical Analysis of Test Solutions for DDVP and Chlorides (1)

No.	Material	Dichlorvos Before Test %	Dichlorvos Before Test PPM	Dichlorvos After Test %	Dichlorvos After Test PPM	Chlorides Before Test %	Chlorides Before Test PPM	Chlorides After Test %	Chlorides After Test PPM
1	2024-T351	.001	10	<.00001	<.1	$2.2X10^{-8}$	$2.2X10^{-4}$	.0013	13
2	H-11 Steel	.001	10	<.00001	<.1	$2.2X10^{-8}$	$2.2X10^{-4}$	.002	20
3	7075-T651	.001	10	<.00001	<.1	$2.2X10^{-8}$	$2.2X10^{-4}$	.0011	11
4	2024-T351	.01	100	.0003	3.0	$2.2X10^{-7}$	$2.2X10^{-3}$	.0013	13
5	7075-T651	.01	100	.0018	18	$2.2X10^{-7}$	$2.2X10^{-3}$	.0012	12
6	H-11 Steel	.01	100	.00002	.2	$2.2X10^{-7}$	$2.2X10^{-3}$	.0024	24
7	2024 2/	.1	1000	.01	100	$2.2X10^{-6}$	$2.2X10^{-2}$	.0018	18

1. These data were supplied by the Center for Disease Control
2. 32 Days (all others 43 days)

CHLORIDES - ORIGIN AND QUANTITIES

The DDVP had 22 ppm of chlorides before dilution with water. Total conversion of DDVP freeing the chlorides would contribute 3.2 ppm (2) for the .001% (1) solutions, 32 ppm, and 320 ppm for the .01% and .1% solutions, respectively.

CHLORIDES

No.	Solution (%)	In DDVP (ppm)	Total Conversion (ppm)	Total (ppm)	Found (ppm)
1	.001	.00022	3.2	3.20022	13
4	.01	.0022	32.0	32.0022	13
7	.1	.022	320.0	320.0	18

(1) 10 ppm DDVP

(2) Mol. wt. Cl = 35.5

Mol. wt. DDVP = 221

Calculation solution 1: $10 \times 2 \times 35.5 \div 221 = 3.2$ ppm

NOTE: More chloride was found in Nos. 1 - 3 than the DDVP could generate; it is likely that contamination occurred.

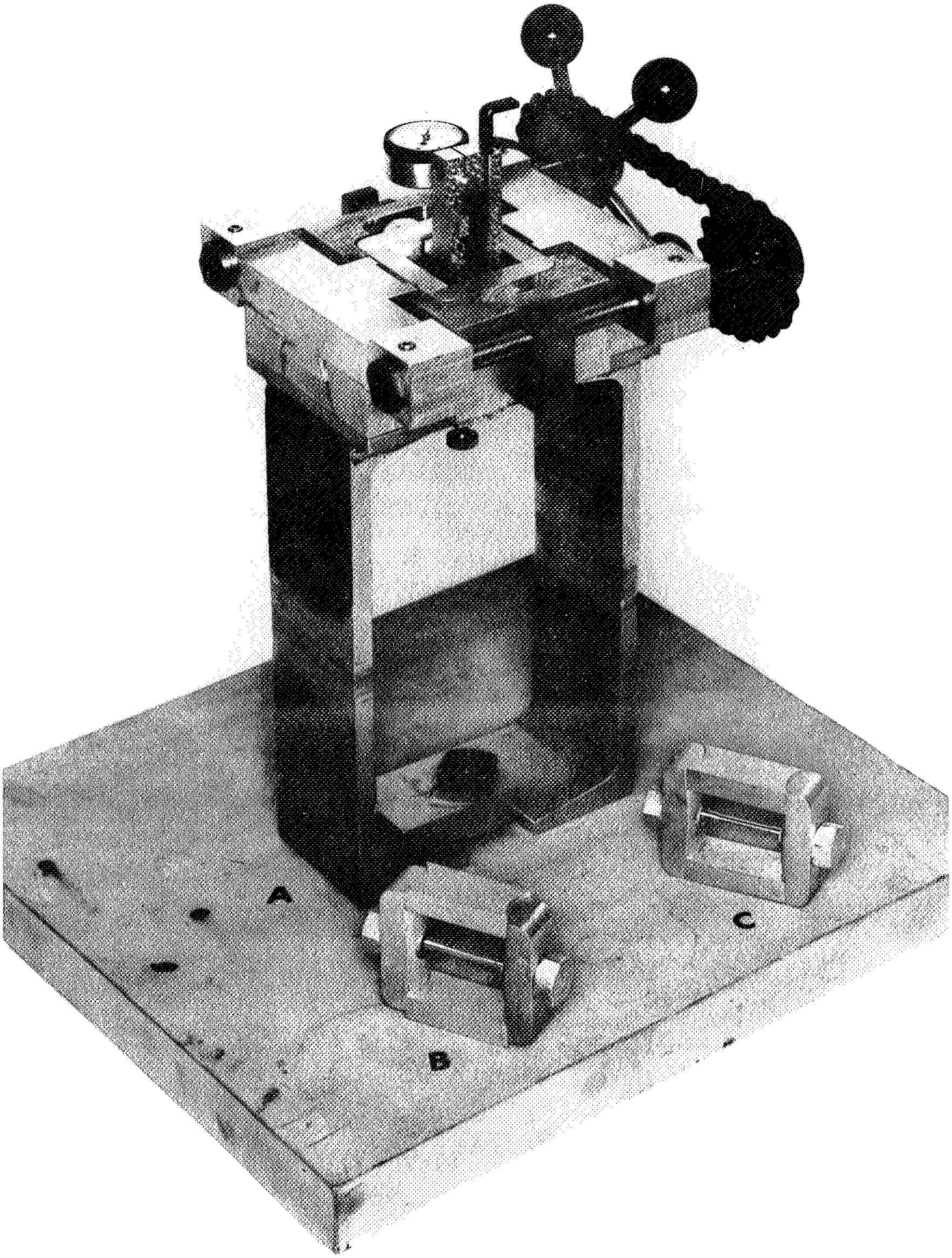

Figure 1 - Fixture and Assemblies for Stressing Round Tensile Specimens

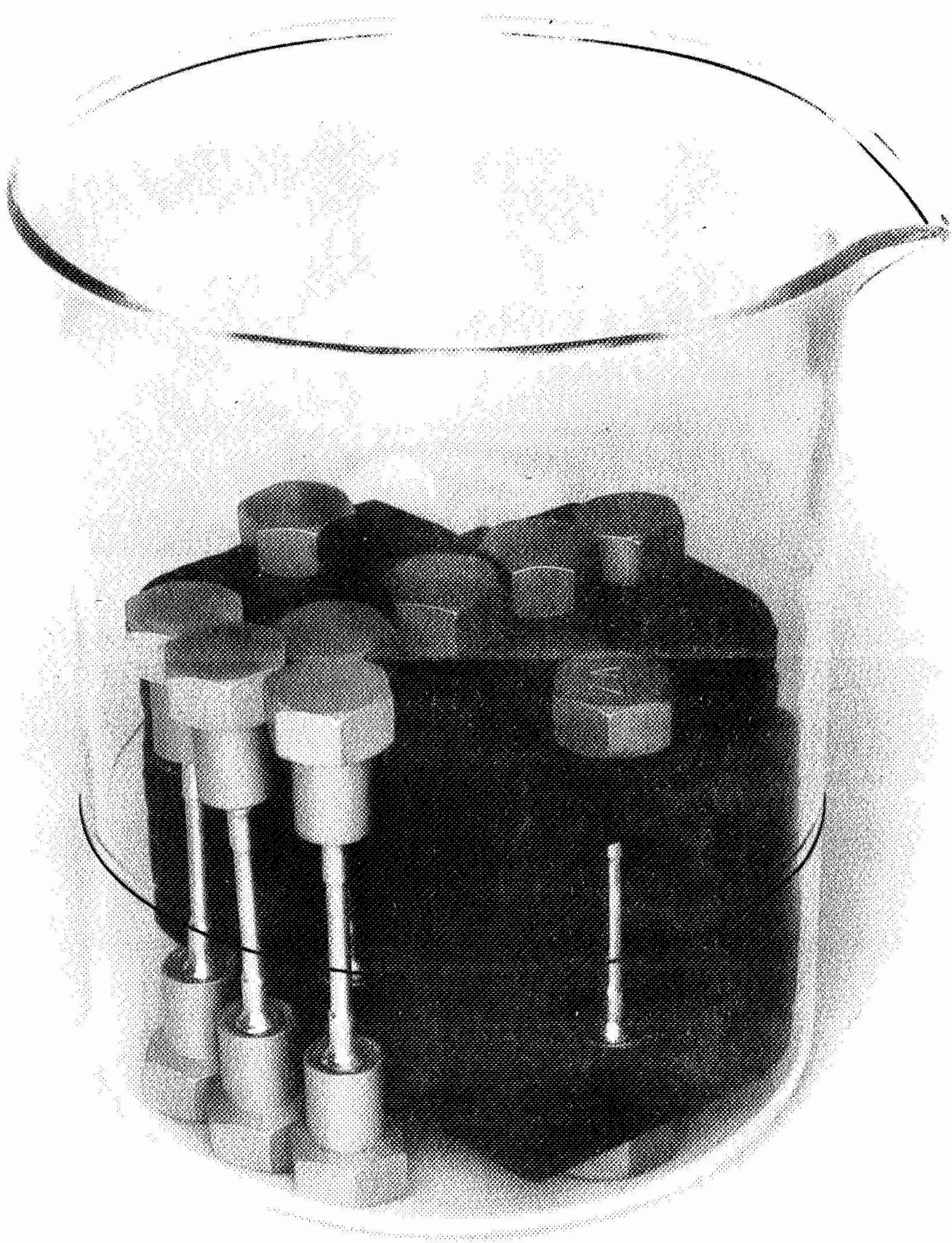

Figure 2 - Exposure Method

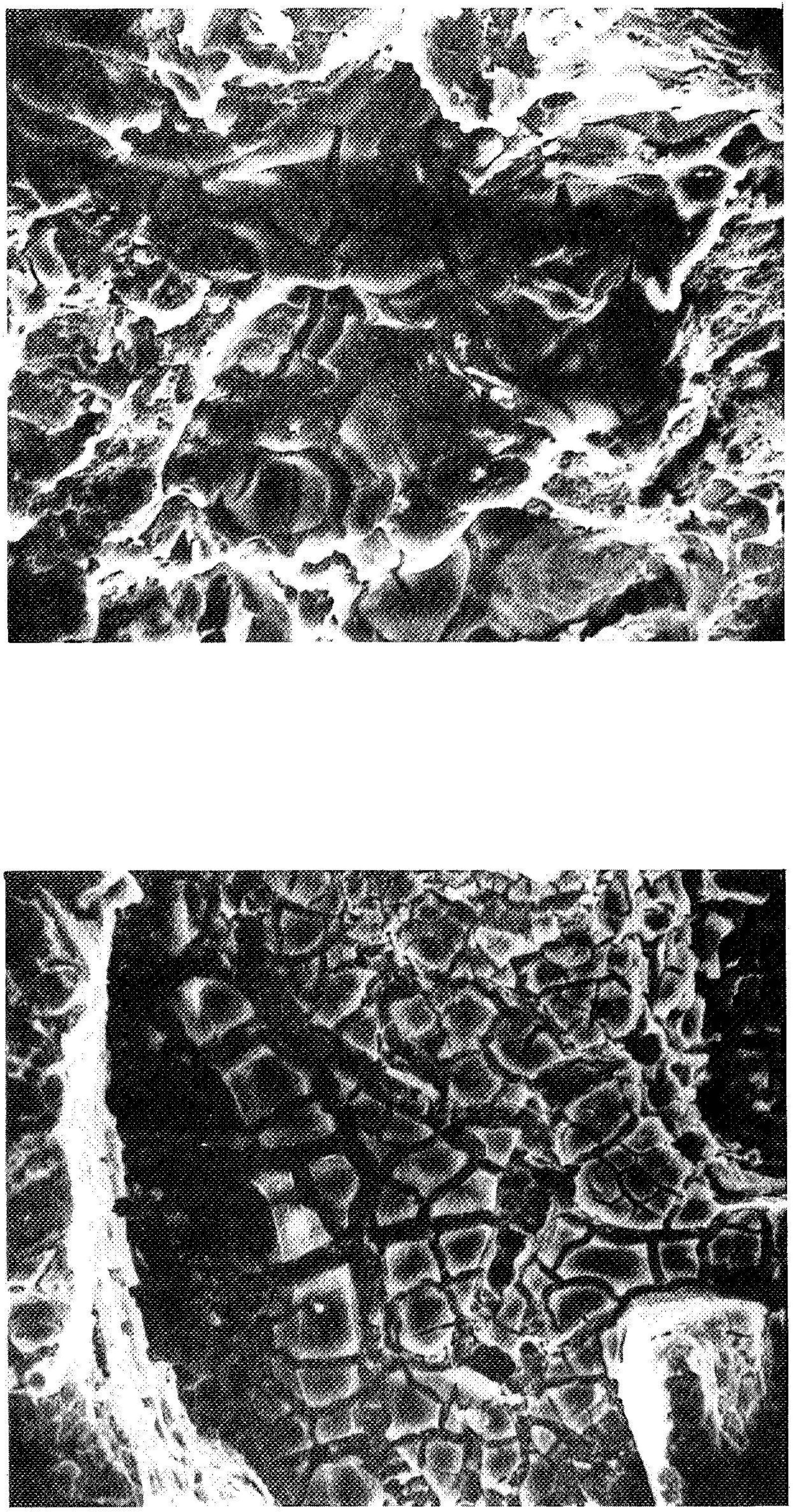

Figure 3 - SEM Fractograph (1000X) of 2024-T351 (Top) and 7075-T651 (Bottom) Exposed in Distilled Water

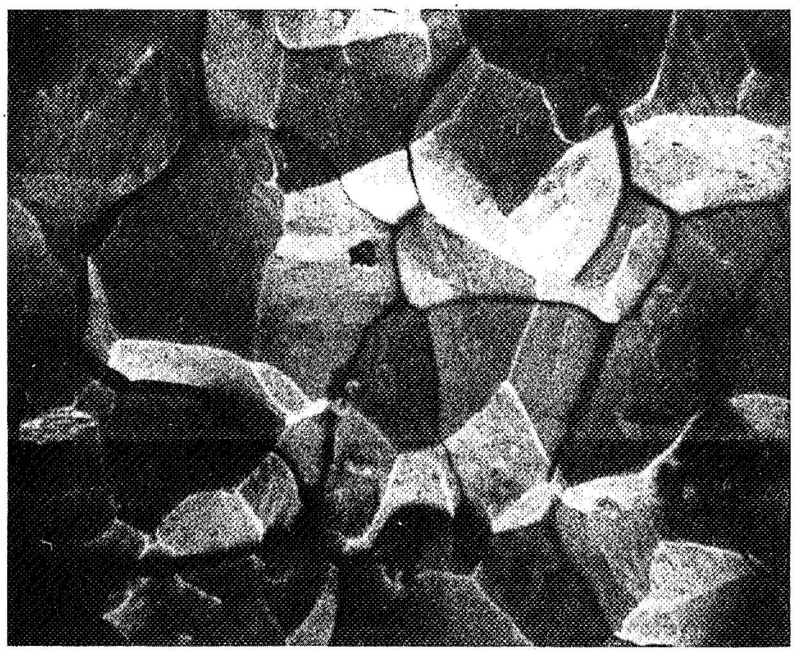

Figure 4 - SEM Fractograph (1000X) of Maraging Steel Exposed in Distilled Water

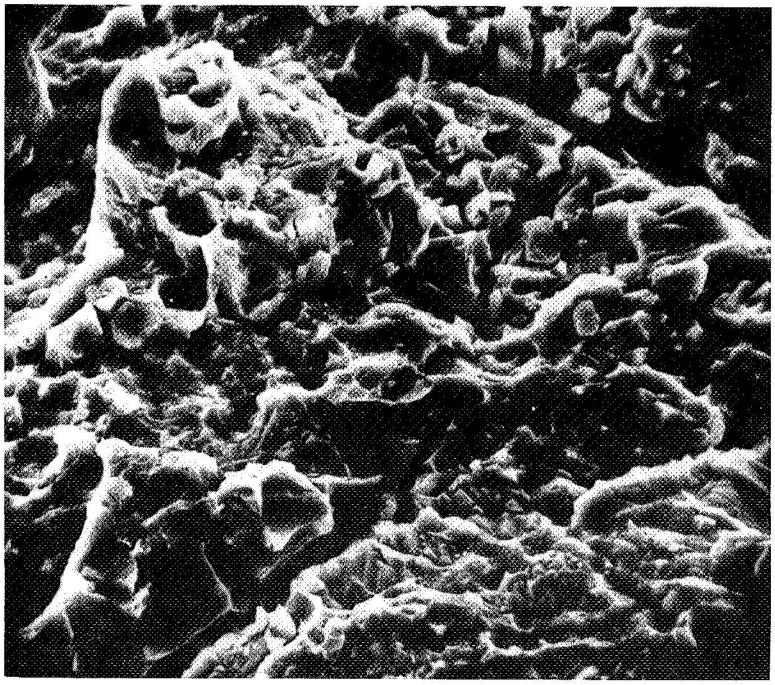

Figure 5 - SEM Fractograph (1000X) of 2024-T351 (Top) and 7075-T651 (Bottom) Exposed in .001 Percent DDVP

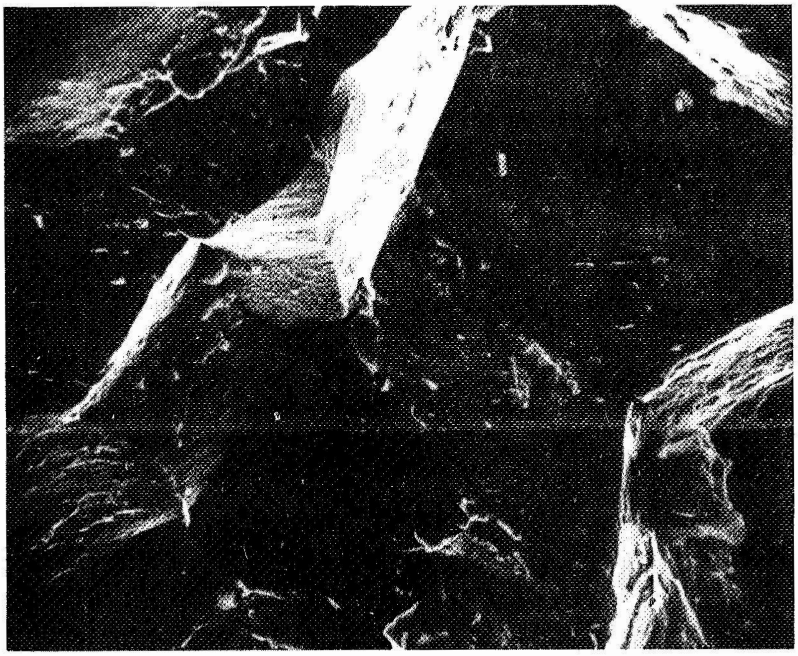

Figure 6 - SEM Fractograph (2000X) of Maraging Steel
Exposed in 0.1 Percent DDVP

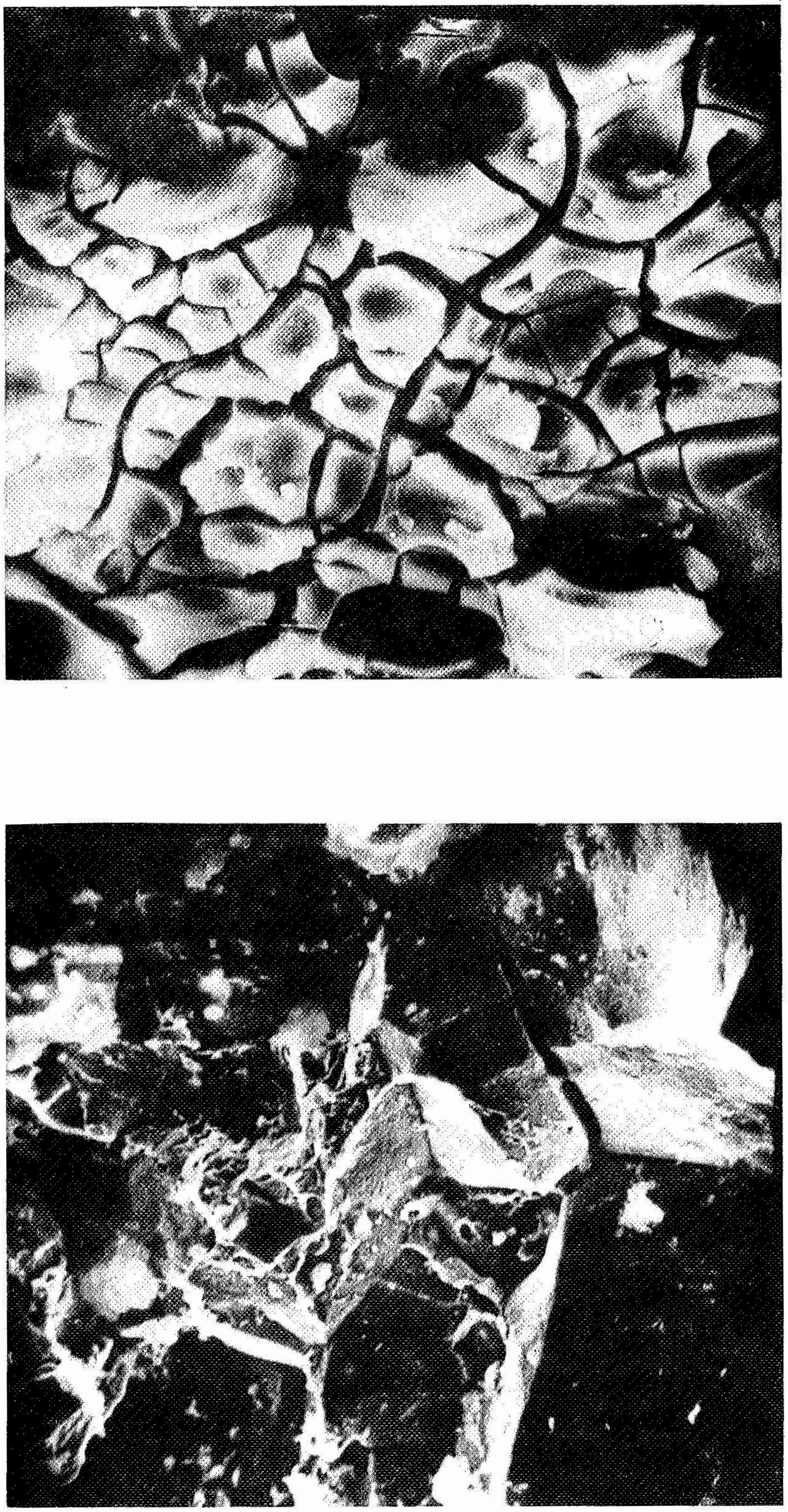

Figure 7 - SEM Fractograph (1000X) of 2024-T351 (Top) and Maraging Steel (Bottom) Exposed in 3.5 Percent Salt

TABLE I

THE PERFORMANCE OF ALUMINUM AND STEEL IN DDVP

Applied Stress (% Y.S.) (1)	Distilled Water		0.001 % DDVP		0.01% DDVP		0.1% DDVP		3.5% NaCl	
	Failure Ratio	Days to Failure	Failure Ratio	Days to Failure	Failure Ratio	Days to Failure	Failure Ratio	Days to Failure	Failure Ratio	Days to Failure
	Alloy 2024-T351 Aluminum									
50	2/3	32,41	2/3	11,32	3/3	26,32,36	3/3	27,32,32	3/3	3,3,14
75	2/3	18,22	3/3	13,18,29	1/3	19	3/3	8,11,18	2/3	18,40
	Alloy 7075-T651 Aluminum									
50	3/3	18,25,25	1/3	35	3/3	18,25,39	3/3	11,18,19	3/3	3,3,7,
75	3/3	3,11,13	2/3	3,18	2/3	3,18	3/3	3,11,19	3/3	3,3,3
	Alloy 18 Nickel Maraging Steel									
50	0/3	-	0/3	-	0/3	-	0/3	-	2/3	<42, <42
75	1/3	25	0/3	-	0/3	-	2/3	25,36	3/3	3,18,<42

Note: (1) Initial Mechanical Properties

Alloy	Tensile Str. MN/m^2(ksi)	Yield Str. MN/m^2(ksi)	% El
2024-T351	393 (57)	304 (44)	6
7075-T651	490 (71)	428 (62)	3
Maraging Steel	1600 (232)	1511 (219)	19

APPROVAL

STRESS CORROSION CRACKING OF ALUMINUM AND
STEEL IN DIMETHYL DICHLOROVINYL PHOSPHATE

By

T. S. Humphries

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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