EVALUATION AND CONTROL OF ENVIRONMENTAL CORROSION FOR ALUMINUM AND STEEL ALLOYS

by

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Because of the extreme demands placed on corrosion protective systems for aerospace application, extensive evaluation of a variety of protective coatings and sealants is required. For steel alloys zinc-rich coatings have been found to be most effective. For aluminum alloys chromate pigmented systems have proven most useful. Evaluation and control of stress corrosion is also required to insure the structural and functional integrity of aerospace components. Based on a comprehensive test program coupled with experience associated with a variety of practical applications over the past several years, techniques and procedures for control of stress corrosion have been developed. The most effective method for control of stress corrosion is the selection of materials which are inherently resistant to stress corrosion failure under the anticipated environmental conditions.

- LOW SAFETY FACTORS
- EXTREMELY HIGH RELIABILITY
- REDUNDANCY
- HIGH QUALITY CONTROL STANDARDS
- UNIQUE ENVIRONMENTAL CONDITIONS
- REUSEABILITY

Figure 1. Aerospace requirements for corrosion control.

- STORAGE
- STANDBY FOR LAUNCH
- AERODYNAMIC HEATING
- QUENCH IN SEAWATER
- SEAWATER IMMERSION
- CLEANING
- REFURBISHMENT

Figure 2. Shuttle SRB environmental cycle.

- SYSTEMS FOR STEEL
  - SAND BLAST
  - RED-LEAD EPOXY PAINT SYSTEM
  - ZINC-RICH EPOXY PAINT SYSTEM PROTECTION AT BARE AREAS.
  - 500°F TEMPERATURE (SHORT TIME)
- SYSTEM FOR ALUMINUM
  - CONVERSION COAT
  - CHROMATE PIGMENTED EPOXY PAINT SYSTEM
  - 300°F TEMPERATURE (SHORT TIME)
  - HIGH GLOSS FOR EASY REFURBISHMENT.

Figure 3. Corrosion protection systems.

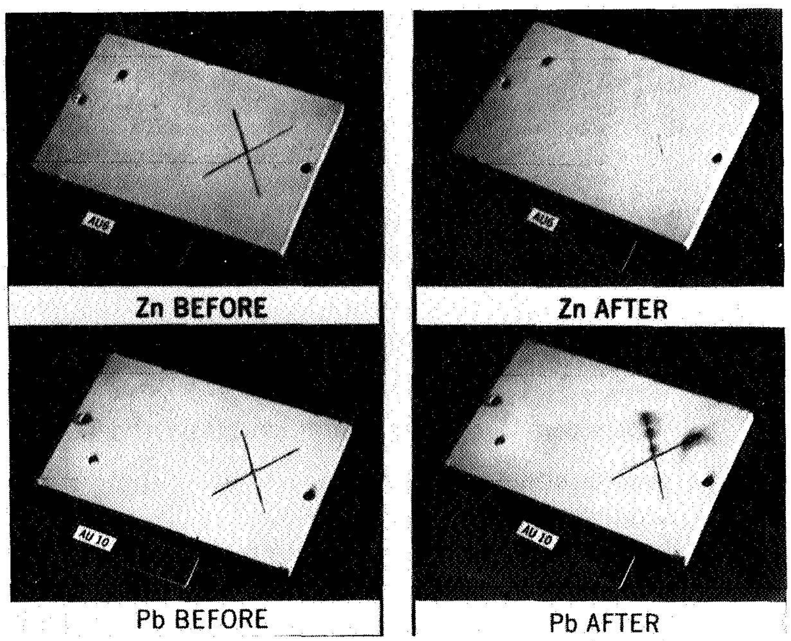


Figure 4. Membrane corrosion testing.

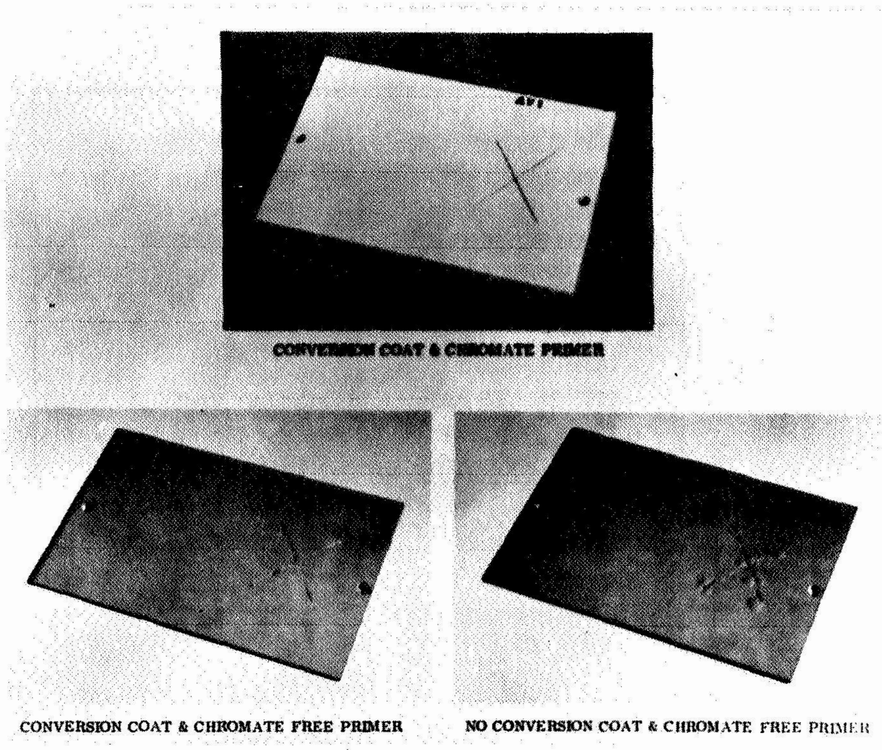


Figure 5. Effect of surface treatment and primer coatings on corrosion protection of aluminum.

- STRUCTURAL JOINTS
  - POLYSULFIDE – 300°F
  - SILICONE – 500°F REQUIRES SPECIAL PRIMER
- ZINC CHROMATE PUTTY
  - 500°F TEMPERATURE LIMIT
  - ALLOWS PARTS TO BE REMOVED
  - PERMITS ELECTRICAL BONDING
- CHROMATE INHIBITED GREASE
  - 250°F TEMPERATURE LIMIT
  - ALLOWS LEAK CHECKS TO BE MADE
  - EASY REMOVAL AND REPLACEMENT
- KRYTOX 240AC GREASE
  - COMPATIBLE WITH HYDRAZINE
  - ALLOWS LEAK CHECKS TO BE MADE
- CALCIUM GREASE (PRELIMINARY EVALUATION)
  - EXCELLENT CORROSION RESISTANCE
  - RESISTANT TO WATER IMMERSION

Figure 6. Sealants.

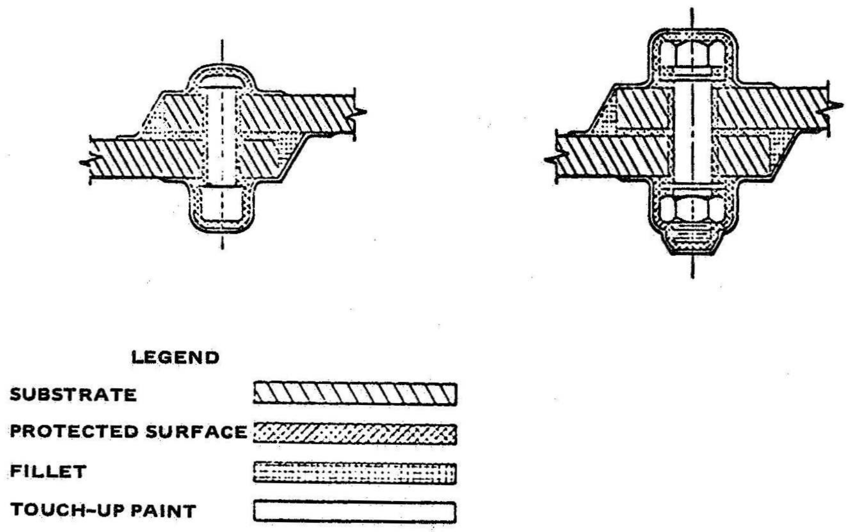


Figure 7. Typical sealed structural joints.

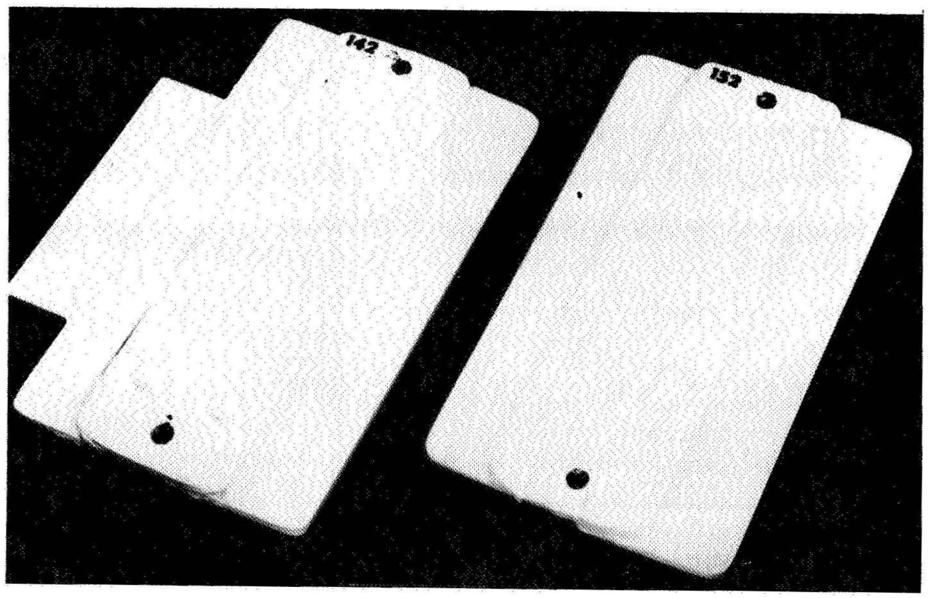


Figure 8. Sealant No. 1 — PR 1422 after 57 days exposure (ocean and beach), typical of polysulfide sealant samples.

- PRIMARY FACTORS INVOLVED
  - HIGH RELIABILITY
  - LOW SAFETY FACTORS
  - ENVIRONMENTAL CONDITIONS
- CONDITIONS FOR STRESS CORROSION
  - SUSCEPTIBLE MATERIAL
  - SUSTAINED TENSILE STRESS
  - CORROSIVE ENVIRONMENT
  - TIME

Figure 9. Control of stress corrosion.

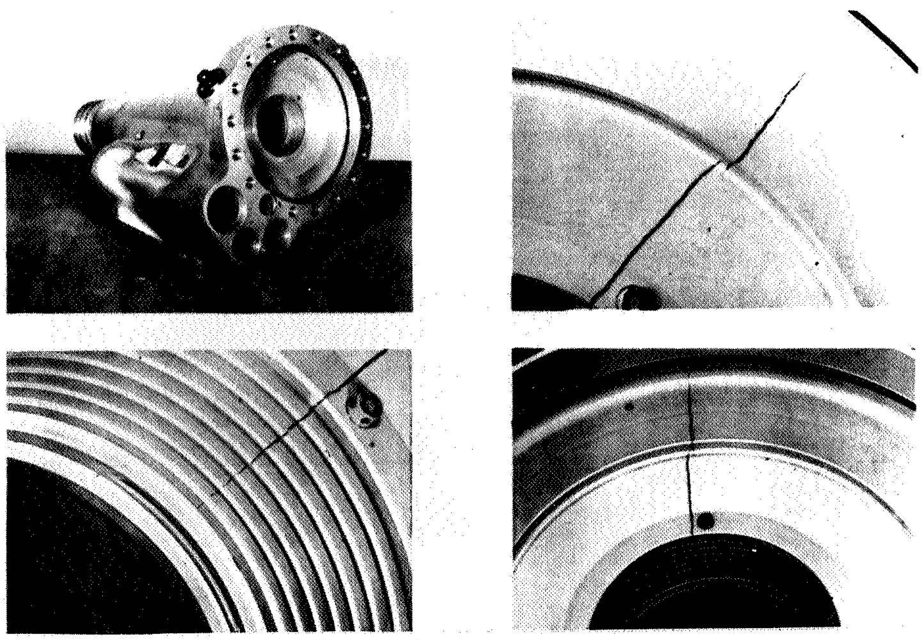
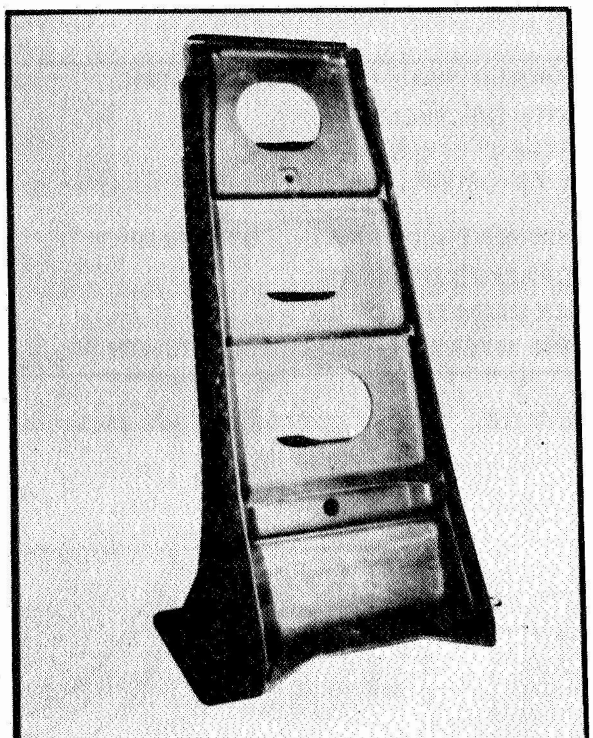
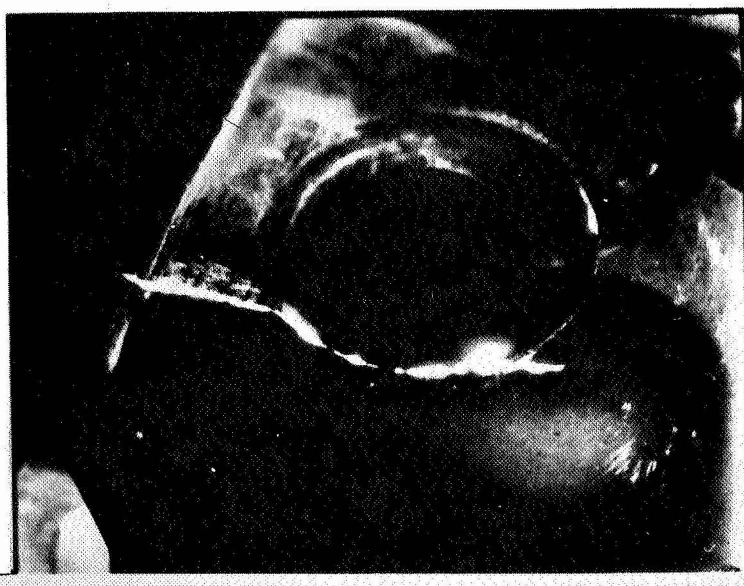


Figure 10. Typical stress corrosion failure.



S-1B-8 REAR FIN SPAR FORGING



FLORESCENT DYE INDICATION SHOWING CRACK LOCATION

Figure 11. Typical stress corrosion failure.

- ENVIRONMENTALLY INDUCED CRACKING
  - SMOOTH SPECIMEN
  - DIFFERENT STRESS LEVELS
  - TIME TO FAILURE VERSUS STRESS (THRESHOLD STRESS)
- ENVIRONMENTALLY ENHANCED FLAW GROWTH
  - PRECRACKED SPECIMEN
  - CRACK GROWTH
  - STRESS INTENSITY – NO CRACK GROWTH (K_{ISCC})

Figure 12. Stress corrosion test methods.

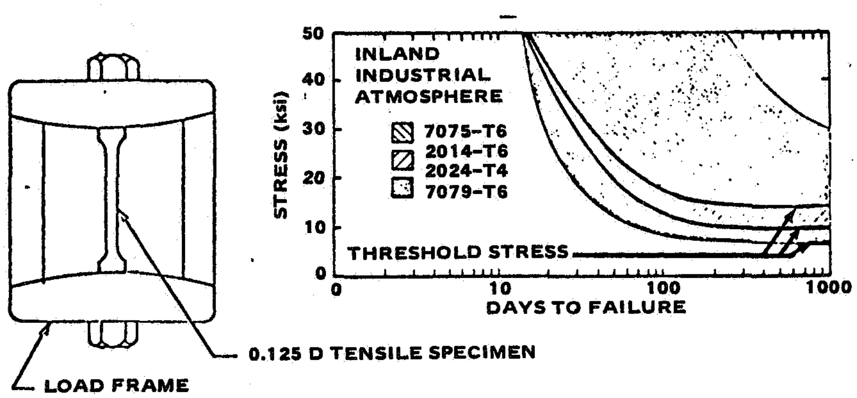


Figure 13. Smooth specimen test.

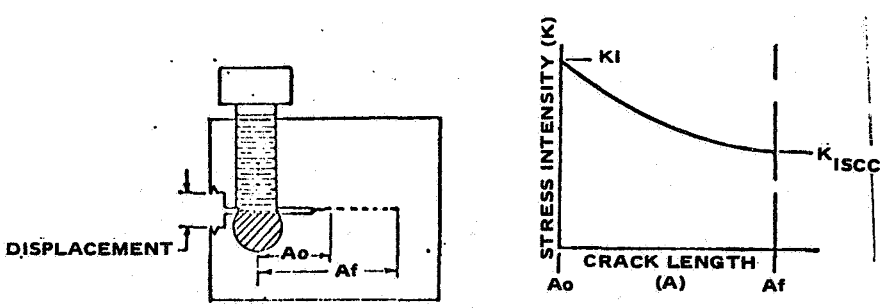


Figure 14. Precracked specimen test.

- SELECTION OF RESISTANT MATERIALS
  - MSFC-SPEC-522
  - CONTROL OF HEAT TREATMENT
  - CONTROL OF FABRICATION PROCESS
- CONTROL OF STRESSES
  - STRESS RELIEVE
  - ELIMINATION OF INTERFERENCE FITS
  - SHOT OR ROD PEENING
- CONTROL OF ENVIRONMENT
  - PROTECTIVE COATINGS
  - ELIMINATION OF MOISTURE
  - INHIBITORS

Figure 15. Methods for controlling stress corrosion.

HIGH RESISTANCE	LOW RESISTANCE
1000 SERIES	2011-T3
2011-T8	2014
2024*-T6, T8	2017
2219-T6, T8	2023-T3, T4
3000 SERIES	7001
4032-T6	7039
5000 SERIES	7075-T6
6000 SERIES	7079-T6
7076-T73	7178-T6
7475-T73	7475-T6

* LIMITATION ON SPECIFIC FORMS

Figure 16. Stress corrosion resistance of aluminum alloys.

HIGH RESISTANCE		MODERATE OR LOW RESISTANCE	
300 SERIES		400 SERIES	
21-6-9		AM350	SCT850
A-286		AM355	SCT850
AM-350	SCT 1000	PH 13-8 Mo	H950
AM-355	SCT 1000	15-5 PH	H900
PH 13-8 Mo	H1000	17-4 PH	H900
15-5PH	H1000	PH 15-7 Mo	RH950, TH1050
17-4PH	H1000	17-7 PH	RH950, TH1050
PH 15-7 Mo	CH900		
17-7PH	CH900		

Figure 17. Stress corrosion resistance of stainless steel alloys.

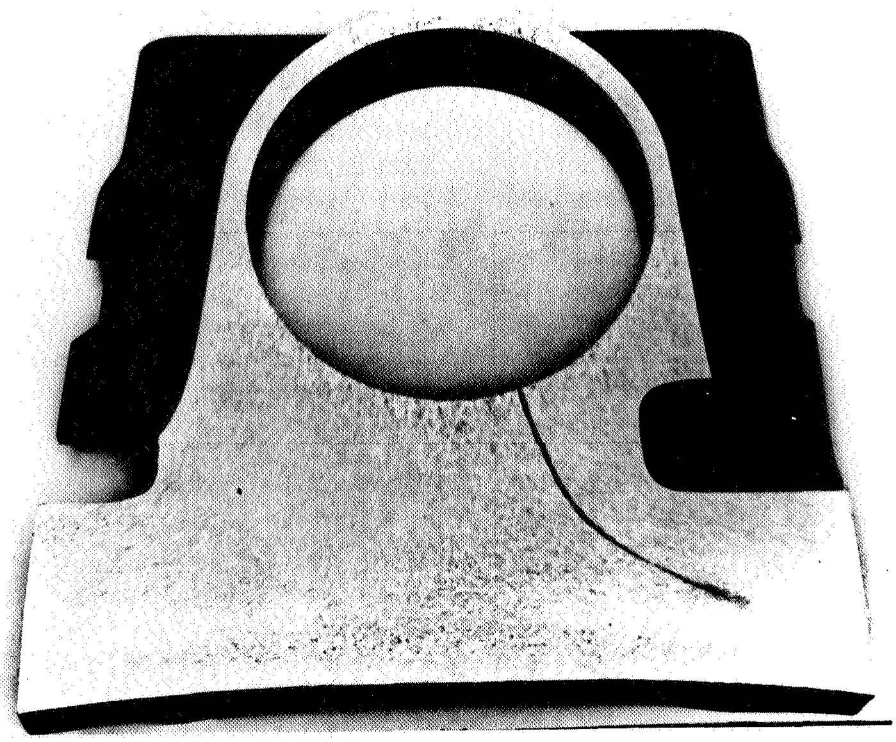


Figure 18. Stress corrosion showing dependence on grain direction.

- STRENGTH LEVEL – 160 TO 200 ksi
- THRESHOLD STRESS – 90 ksi
- K_{ISCC} 16 ksi $\sqrt{in.}$
  - INITIAL FLAW SIZE – 0.050 DEEP X 0.100 LONG
  - STRESS REQUIRED FOR FLAW GROWTH – 24 ksi
- PROCEDURE FOR CONTROL
  - MEASURE ASSEMBLY STRESS
  - NDE
  - SURFACE PAINTED AND JOINTS SEALED
  - PAINT STRIPPED AND SURFACE REINSPECTED AFTER EACH FLIGHT

Figure 19. D6AC steel (SRB motor case).

- CORROSION CONTROL
  - SINC-RICH COATING – STEEL
  - CONVERSION COAT + CHROMATE COATING - ALUMINUM
  - SEALANTS – FAYING SURFACES
- STRESS CORROSION
  - EXTENSIVE TESTING AND EVALUATION
  - SELECT MATERIALS WITH INHERENT STRESS CORROSION RESISTANCE.

Figure 20. Summary.