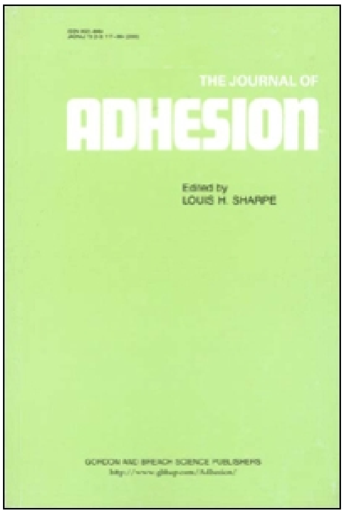

The Journal of Adhesion
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453635

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J. Dean Minford[a]
[a] Alcoa Research Laboratories, Alcoa Center, PA, U.S.A.

To cite this Article Minford, J. Dean(1985) 'Comparative Aluminium Joint Evaluations in Varying Saltwater Exposure Conditions', The Journal of Adhesion, 18: 1, 19 — 24
To link to this Article: DOI: 10.1080/00218468508074934
URL: http://dx.doi.org/10.1080/00218468508074934

J. Adhesion, 1985, Vol. 18, pp. 19–24
0021–8464/85/1801–0019 $18.50/0

Comparative Aluminium Joint Evaluations in Varying Saltwater Exposure Conditions†

J. DEAN MINFORD‡
Alcoa Research Laboratories, Alcoa Center, PA 15069, U.S.A.

(*Received February 13, 1984*)

INTRODUCTION

The compatibility of aluminium in the presence of a wide variety of nonmetallic materials and corrosive saltwater has been the subject of study at our laboratories for many years. These studies have provided guides for evaluating the durability of aluminium bonded joints since an adhesive is only another form of nonmetallic material. A widely accepted standard test has been ASTM B117 which provides continuous joint exposure to a 5% sodium chloride salt fog. Publications in recent years,[1–9] have cited test conditions where the exposure to saltwater has been intermittent rather than continuous. This was consistent with our observation in earlier years of investigating joint durability that continuous immersion in 3–1/2% sodium chloride solution was the most innocuous of exposures and less aggressive than immersion in deionized or distilled waters. Since 1978, our publications have included exposure results obtained by daily exposures to continuous salt fog for 16 hours followed by drying under ambient lab temperatures for 8 hours. We had also used an immersion of aluminium structures in 3–1/2% salt-

†Presented at the Seventh Annual Meeting of The Adhesion Society, Jacksonville, Florida, U.S.A., February 13–15, 1984.
‡Now Consultant, 1 Harleston Green, Hilton Head Island, SC 29928, U.S.A.

water for 10 minutes of each hour for stress corrosion evaluations. Most recently, the author has been seeking the most economical way for customers to evaluate the corrosion resistance of aluminium joints without the need for any special test equipment. A discriminating procedure has been simply to immerse test joints in 3–1/2% saltwater overnight and dry out in ambient air during the work day. It was the purpose of this investigation to determine the relative aggressiveness of some of these procedures.

EXPERIMENTAL

The test specimens conformed to those described in ASTM D1002–72 except the lap depth was 25.4 mm (1.0 in.) and the joints were fabricated separately from 25.4 mm × 101.6 mm (1 in. × 4 in.) sheet coupons. The alloy was 6009-T4 in 1.27 mm (0.050 in.) thickness and the mill finish surface condition. A one-part, heat-cured epoxy adhesive modified to bond to oily or poorly prepared surfaces was employed. A one hour cure at 204C (400F) was used to assure good surface wetting and full curing.

Three sets of test conditions were selected for comparison:

(1) ASTM B117 consisting of continuous exposure at 35C (95F) to a fog generated with a 5% sodium chloride solution.

(2) Alcoa Alternate Immersion Procedure based on immersion for 10 minutes of each hour in 3–1/2% sodium chloride solution. Hereafter referred to in the text as the A.I. (10 min./hr.) procedure.

(3) The author's modification of the alternate immersion procedure consisting of overnight immersion in 3–1/2% sodium chloride and an 8 hour drying out under ambient temperature conditions. Hereafter referred to in text as A.I. (daily cycle).

Test joints were removed from each exposure condition after 10, 20, 30, 40, 50 and 60 days and failed in a tensile tester and the results compared.

RESULTS

The results have been summarized in Table I and plotted in Figure one.

Comparative corrosion evaluations with three corrosive saltwater procedures

Exposure condition	Spec. no's.	Exposure time (hrs.)	Final Joint Strength MPa	Final Joint Strength psi	% Change[1] due to exposure	Failure observations
None	1	0	7.72	1120	0	100% thin cohesive
None	2	0	7.72	1120	0	100% thin cohesive
ASTM B117[2]	1	240	8.13	1180	+5	100% thin cohesive
ASTM B117	2	240	7.58	1100	−2	100% thin cohesive
A.I.[3] (10 min./hr.)	1	240	7.25	1140	+2	100% thin cohesive
A.I. (10 min./hr.)	2	240	8.13	1180	+5	100% thin cohesive
A.I. (daily cylce)	1	240	8.09	1174	+18	100% thin cohesive
A.I. (daily cycle)	2	240	8.54	1240	+11	100% thin cohesive
ASTM B117	3	480	8.41	1220	+9	100% thin cohesive
ASTM B117	4	480	8.20	1190	+6	100% thin cohesive
A.I. (10 min./hr.)	3	480	3.24	470	−58	75% adhesive, 20% surface corr.
A.I. (10 min./hr.)	4	480	5.86	850	−24	50% adhesive, 10% surface corr.
A.I. (daily cycle)	3	480	8.54	1240	+11	100% thin cohesive
A.I. (daily cycle)	4	480	8.13	1180	+5	100% thin cohesive
ASTM B117	5	720	7.85	1140	+2	100% thin cohesive
ASTM B117	6	720	7.51	1090	−3	100% thin cohesive
A.I. (10 min./hr.)	5	720	0.07	10	−99	100% adhesive, 100% surface corr.
A.I. (10 min./hr.)	6	720	6.20	900	−20	60% adhesive, 15% surface corr.
A.I. (daily cycle)	5	720	6.41	930	−17	80% thin cohesive, 20% surface corr.
A.I. (daily cycle)	6	720	6.13	890	−21	70% thin cohesive, 30% surface corr.
ASTM B117	7	960	9.65	1400	+25	100% thin cohesive
ASTM B117	8	960	8.47	1230	+10	95% thin cohesive, 5% adhesive
A.I. (10 min./hr.)	7	960	0	0	−100	100% surface corrosion
A.I. (10 min./hr.)	8	960	0	0	−100	95% surface corrosion
A.I. (10 min./hr.)	9	960	5.96	865	−23	70% thin cohesive, 30% surface corr.
A.I. (daily cycle)	7	960	6.34	920	−18	80% thin cohesive, 20% surface corr.
A.I. (daily cycle)	8	960	0	0	−100	100% surface corrosion
ASTM B117	9	1200	9.23	1340	+20	100% thin cohesive
ASTM B117	10	1200	8.96	1300	+16	100% thin cohesive
A.I. (10 min./hr.)	10	1200	2.24	325	−71	20% thin cohesive, 80% surface corr.
A.I. (10 min./hr.)	11	1200	0	0	−100	100% surface corr.
A.I. (daily cycle)	9	1200	0	0	−100	100% adhesive, 80% surface corr.
A.I. (daily cycle)	10	1200	1.72	250	−78	10% thin cohesive, 90% surface corr.
ASTM B117	11	1440	7.03	1020	−9	75% thin cohesive, 25% adhesive
ASTM B117	12	1440	8.27	1200	+7	80% thin cohesive, 5% surface corr.
A.I. (10 min./hr.)	12	1440	0.28	40	−96	100% adhesive, 80% surface corr.
A.I. (daily cycle)	11	1440	0	0	−100	100% adhesive, 100% surface corr.
A.I. (daily cycle)	12	1440	5.72	830	−26	80% thin cohesive, 20% surface corr.

[1]Based on average strength shown by unexposed control joints.
[2]Continuous immersion in salt fog.

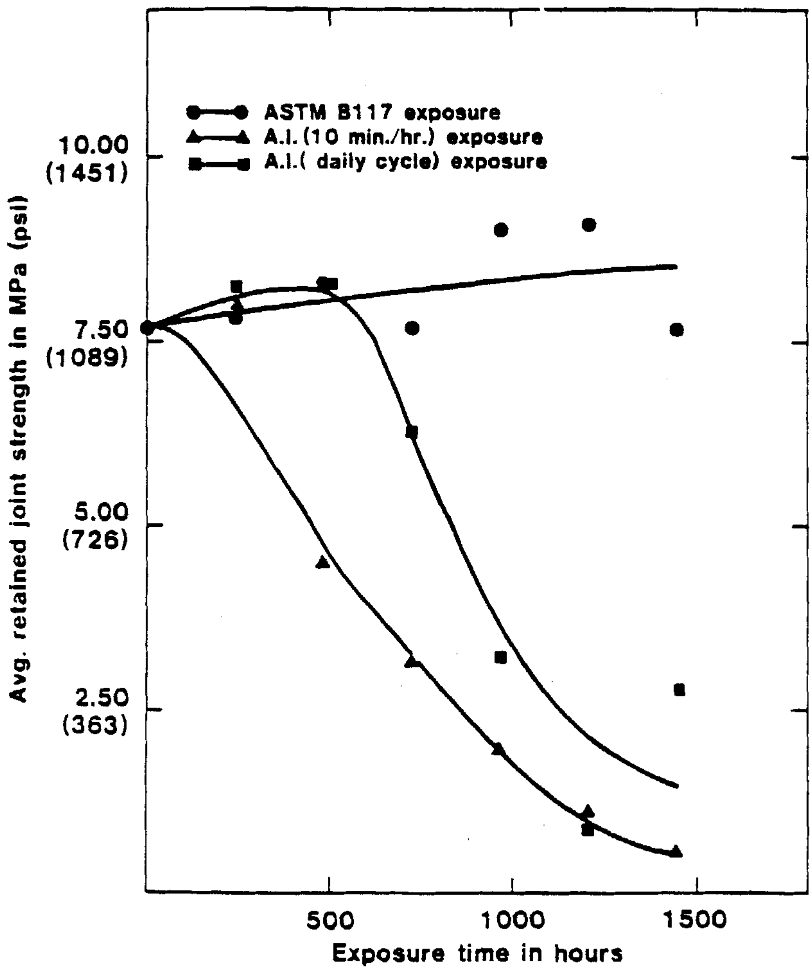

FIGURE 1 Joint Durability Results in Various Saltwater Exposure Conditions.

ASTM B117 (5% continuous salt fog)

No evidence of any corrosion was observed on the adherend interfacial surface during the first 50 days (1200 hrs.) of exposure. Even after 60 days (1440 hrs.) only a tiny spot of apparent corrosion had been initiated but no decline in joint strength was found.

A.I. (10 min./hr.) exposure

Significant undercutting corrosion from the edge of the joints was observed in as short an exposure time as 20 days (480 hrs.). Once initiated, the corrosion proceeded rapidly across the interfacial area so that total joint failures were observed in as short a time as 30 days (720 hrs.). Apparently identically fabricated joints can show significant differences in the induction time necessary for undercutting corrosion to be initiated since some joints in this aggressive exposure did not totally fail even after 50 days (1200 hrs.).

A.I. (daily cycle) exposure

Reducing the number of wet/dry soak cycles per day from 24 to 1 increased the induction time to observe corrosion in the joint from 20 days (480 hrs.) to 30 days (720 hrs.), respectively. Once initiated, however, the corrosion progression was equally rapid so that total joint failures were still observed in the daily cycle, low-cost type test procedure within only 40 days (960 hrs.).

CONCLUSIONS

Although it is common practice to judge the sensitivity of a bonded joint to corrosive saltwater conditions by its ability to resist visual corrosion in 500 or 1,000 hours of ASTM B117 exposure, the results of this investigation showed such a criterion could be passed by aluminium joints with no special surface preparation. Exposure to wet/dry saltwater cyclying conditions, however, could distinguish a much greater sensitivity to corrosive saltwater within a period of less than 500 hrs. Increasing the frequency of cycling tended to accelerate the testing and decrease the induction time to observe edge corrosion initiation. A low-cost wet/dry cyclic procedure was also shown which could distinguish corrosive saltwater sensitivity in less than 1,000 hrs.

Acknowledgement

The author wishes to thank The Aluminium Company of America for their permission to use these data and their most helpful cooperation in compiling this paper.

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