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SYNTHETIC SEA WATER - AN IMPROVED STRESS CORROSION TEST MEDIUM FOR ALUMINUM ALLOYS

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16. ABSTRACT

A major problem in evaluating the stress corrosion cracking resistance of aluminum alloys by alternate immersion in 3.5 percent salt (NaCl) water is excessive pitting corrosion. Several methods were examined to eliminate this problem and to find an improved accelerated test medium. These included the addition of chromate inhibitors, surface treatment of specimens, and immersion in synthetic sea water. The results indicate that alternate immersion in synthetic sea water is a very promising stress corrosion test medium. Neither chromate inhibitors nor surface treatment (anodize and alodine) of the aluminum specimens improved the performance of alternate immersion in 3.5 percent salt water sufficiently to be classified as an effective stress corrosion test method.

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SYNTHETIC SEA WATER - AN IMPROVED STRESS CORROSION TEST MEDIUM FOR ALUMINUM ALLOYS

SUMMARY

Alternate immersion in a 3.5 percent sodium chloride (NaCl) solution, referred to hereafter as salt water, is undoubtedly the most widely used accelerated test medium in the United States for evaluating the stress corrosion cracking (SCC) resistance of metal alloys, especially aluminum alloys. The major problem is that this solution when made with high purity salt and distilled or deionized water causes excessive pitting corrosion of the aluminum alloys containing copper and this interferes with SCC evaluation. An investigation was undertaken to find an improved accelerated SCC test medium for aluminum alloys.

The results of this investigation indicate that alternate immersion in synthetic sea water is superior to alternate immersion in salt water as a SCC test medium for aluminum alloys. Although low concentrations of chromates reduce the corrosiveness of salt water, this inhibited solution is not an effective SCC test medium. Neither anodize nor alodine surface treatment of the specimens significantly improves the performance of alternate immersion in salt water for SCC testing aluminum alloys.

INTRODUCTION

There is little doubt that the phenomenon previously called "season cracking" because of its resemblance to cracks in seasoned wood, then stress corrosion, and finally stress corrosion cracking was observed as far back as the bronze age. However, it was not until the latter part of the nineteenth century that sufficient consciousness to cracking problems (brass cartridge cases) caused any real concern and it was not until much later that any concerted effort was made to investigate and combat SCC of metals. (1)

One of the primary steps necessary to investigate the SCC of metals was the development of a suitable test method. After investigating several test methods, the Aluminum Company of America, one of the early leaders in this field, chose alternate immersion in 3.5 percent salt water as the preferable SCC test medium for aluminum alloys. (2) Because of the large volume of water involved, Alcoa used New Kensington, Pennsylvania tap water for making their salt water whereas most other investigators have used distilled or deionized water. Unfortunately salt solutions made with distilled or deionized water are more corrosive to aluminum than those made with New Kensington tap water, and other investigators have encountered rather severe pitting of aluminum alloys, particularly those alloys containing copper. Any media that causes pronounced localized attack of the specimen is undesirable because the tensile stresses at the tip of the pits would be difficult if not impossible to calculate, and the net section stress would normally be greater than the original applied load. Under certain conditions it is conceivable that the use of very corrosive media may result in rating the resistance of alloys to pitting corrosion instead of to SCC.

EXPERIMENTAL PROCEDURE

A large number of high strength aluminum alloys were used to evaluate the test media. The alloys employed were 2014-T6; 2017-T4; 2219-T37, -T62, -T87; 2021-T8E31; 2024-T351, -T4, -T6, -T851; 7001-T75; 7039-T64; 7075-T6, -T73; and 7079-T6 (see Table I for composition). Round tensile specimens stressed in uniaxial tension were used exclusively. This was possible because all material was two inches or thicker plate except for a two inch diameter 2017-T4 bar, and a 7001-T75 forging.

The tensile specimens were strained with the aid of a stressing fixture (Figure 1) to the desired stress levels, wiped with methanol, and placed in the test media until failure or until the test was terminated (normally 90 days). Prior to exposure the stressing jigs were coated with a strippable coating (Mascoat No. 2) to prevent galvanic corrosion of the specimens. Calculated strain was based on mechanical properties (Table II) measured in the load direction, mainly short transverse. All tests were conducted in a ferris wheel type alternate immersion tester (Figure 2) with an immersion cycle of 10 minutes in the test media followed by 50 minutes of drying above the media. A detailed description of the specimen, formulas for calculating the strain, and method of loading and testing are given in Reference 3. Salt water was prepared with high purity (USP or equivalent) NaCl and deionized water (50,000 ohms minimum resistance) with the pH adjusted to 6.8 to 7.2 with reagent grade hydrochloric acid or sodium hydroxide. Synthetic sea water which contains other salts besides NaCl (see Table I) was prepared according to ASTM D1141-52, without heavy metals.

RESULTS AND DISCUSSION

The initial investigation to improve the performance of 3.5 percent salt water as an accelerated SCC test medium involved additions of corrosion inhibitors. Low concentrations (50 to 100 ppm) of chromates were found to be effective in reducing the pitting action of salt water on aluminum. However chromates reduced the SCC of aluminum alloys to such a degree that salt water inhibited with chromates could not be classed as an accelerated SCC test medium.

Surface treatment was evaluated to determine the effectiveness of alodine and anodize in reducing pitting corrosion of aluminum alloys in salt water and at the same time not interferring with SCC evaluation of the alloy. As may be seen in Table III, anodize was more effective than alodine in reducing pitting corrosion of the aluminum-copper alloy 2024 in salt water based on losses in mechanical properties. However, as had been found with corrosion inhibitors, protective surface treatment does not appear promising as a method of improving SCC testing of aluminum by alternate immersion in salt water. Alodine treatment showed no improvement over bare specimens and the performance of the anodized specimens was too erratic (Table IV), especially the longitudinal and long transverse specimens, to be considered a part of an acceptable SCC test method. It was speculated that stressing a specimen that had been previously treated might damage the coating, and if so the surface treatment would have to be applied after the specimens were loaded. However, application of the surface treatment before and after stressing the specimens showed no relative difference in performance (Table V).

In addition to corrosion inhibitors and protective surface treatments, alternate immersion in sea water was investigated. Substitution of sea water for 3.5 percent salt water appeared logical because it more closely represented service conditions in or near the ocean. Synthetic sea water was used for standardization of solution because the composition of natural sea water varies as a result of contamination and dilution with fresh water. In addition, it is more convenient to prepare synthetic sea water than to maintain a supply of fresh sea water. One of the advantages attendant to choosing sea water is that sea water does not pit corrode aluminum to the extent that salt water does. As may be seen in Table VI and Figure 3, alternate immersion in sea water caused considerably less damage to aluminum alloys than did alternate immersion in salt water. For example, loss in tensile strength of unstressed 2024-T351 specimens ranged from 35 percent in 15 days to 90 percent in 90 days in salt water, but the loss was only 15 percent in 90 days in sea water. The loss in tensile strength of many of the test alloys was greater than 25 percent after 15 days and most alloys had lost over 25 percent after 30 days of exposure in salt water. The loss in tensile strength did not exceed 20 percent even after 90 days of exposure to sea water for any of the alloys except 2014-T6.

An acceptable SCC test medium must meet the following requirements:

1. Cause failure of susceptible material in a reasonable time period.

2. Give reproducible results, allowing rank ordering of SCC resistant materials.

3. Not cause corrosion sufficiently severe to interfere with SCC evaluation of the test materials.

Synthetic sea water seemed to fulfill all three requirements. Failure of susceptible alloys occured within 30 days and usually within 10 day, and reproducibility of results were as good as those obtained in salt water (Table

VII). The performance of low, intermediate, and high SCC resistant aluminum alloys were readily distinguishable with sea water test medium. Alloys such as 2014-T6, 2219-T37, 2024-T351, 7075-T6, etc., were shown to possess low (< 10 ksi) resistance to SCC in the short transverse (ST) grain direction; whereas 2219-T87, 2024-T851, 7075-T73, and a few others exhibited high resistance in sea water. The long transverse (LT) specimens of 2014-T6, 2219-T37, 2024-T4, etc., exhibited an intermediate resistance to SCC in this medium. No failures were encountered in sea water with those alloys previously shown to have high resistance to SCC such as 2219-T87, 2024-T851, and 7075-T73; whereas, numerous failures occurred after long periods of exposure (20-90 days) in salt water because of severe pitting. In most cases, the results obtained in sea water agree with those obtained in salt water. Where the results appear not to agree, it is most likely caused by severe pitting encountered in salt water. At the time of crack initiation in a specimen containing a deep pit, the average stress of the net section at the site of the pit is higher than the applied load. This gives an apparent SCC threshold which is lower than that based on the applied load. In cases where the pits are very numerous, SCC may be delayed or even prevented because the intensity of corrosion in any single path decreases as the number of corroded points or localized paths increase. In addition, it has been demonstrated that the greater the number of notches or pits and the closer they approach each other, the less the stress concentration at the base of any individual notch.[4] Thus extreme care should be exercised in the interpretation of SCC data obtained after long periods of exposure to alternate immersion in salt water, seacoast atmospheres, or any media that causes pronounced pitting of the test specimens.

It should be emphasized that the results of this investigation do not necessarily discredit the present SCC rating of aluminum alloys. Even though alternate immersion in salt water has been the main accelerated test medium used to evaluate aluminum, properly conducted tests take into account the effect of pitting. In addition the results have been correlated with environmental tests (seacoast and industrial atmospheres) and service experience. When pitting is encountered as with the copper bearing aluminum alloys exposed to alternate immersion in salt water, detailed examination (light and/or electron microscopy) of the specimens is necessary to determine the type of fracture and the effect of pitting corrosion.

CONCLUSIONS

The results of this investigation indicate that:

1. Alternate immersion in synthetic sea water (ASTM D1141-52) is a very promising test medium for SCC evaluation of aluminum alloys.

2. Alternate immersion in 3.5 percent salt water causes severe pitting of aluminum alloys, particularly the Al-Cu series, and examination (light and/or electron microscopy) of failed specimens of these alloys may be necessary to ascertain the type of failure and the effect of pitting corrosion.

3. Low concentrations (50 to 100 ppm) of chromates reduce the corrosiveness of salt water, but the inhibited salt water is not an effective SCC test medium for aluminum alloys.

4. Neither anodize or alodine surface treatments appear promising as methods of improving alternate immersion in salt water for SCC testing aluminum alloys.

5. Synthetic sea water is a more definitive medium for use in classifying the SCC resistance of aluminum alloys than is salt water.

Based on the results obtained in this investigation, alternate immersion in synthetic sea water per ASTM D1141-52 (without heavy metals) should be considered as the medium for SCC testing of aluminum alloys. It is hoped that other investigators will evaluate alternate immersion in sea water as a SCC test medium for aluminum alloys. Working with the aluminum association -ASTM Joint Task Group (G01.06.91) to develop a procedure for SCC testing 7XXX aluminum alloys, Marshall Space Flight Center made an informal recommendation to include synthetic sea water in the evaluation of SCC test methods and supplied some test data that had been generated here.

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TABLE I
CHEMICAL COMPOSITION OF ALLOYS
Weight Percent

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
2014	0.85	1.0	4.40	0.40	0.50	0.10	0.25	0.15
2017	0.80	1.0	4.00	0.70	0.50	0.10	0.25	-
2219	0.40	0.40	6.10	0.25	-	-	-	0.15
2021*	0.07	0.18	6.24	0.28	-	-	-	0.06
2024	0.50	0.50	4.40	0.60	1.50	0.10	0.25	-
7001	0.35	0.40	2.10	0.20	3.00	0.29	7.40	0.20
7039	0.30	0.40	0.10	0.25	2.80	0.20	4.00	0.10
7075	0.50	0.70	1.60	0.30	2.50	0.29	5.60	0.20
7079	0.30	0.40	0.60	0.20	3.30	0.18	4.30	0.10

* Also contains 0.10 V, 0.15 Cd, 0.15 Zr.

CHEMICAL COMPOSITION OF SYNTHETIC SEA WATER
WEIGHT PERCENT

$NaCl$	2.453	$NaHCO_3$	0.0201
$MgCl_2$	0.520	KBr	0.0101
Na_2SO_4	0.409	H_3BO_3	0.0027
$CaCl_2$	0.116	$SrCl_2$	0.0025
KCl	0.0695	NaF	0.0003

TABLE II
SHORT TRANSVERSE MECHANICAL PROPERTIES*

Alloy	Tensile Strength MN/m^2	(ksi)	Yield Strength MN/m^2	(ksi)	Percent Elongation
2014-T6	423	(61.3)	368	(53.3)	2.5
2017-T4 (Bar)	414	(60.0)	246	(35.6)	14.5
2219-T37	390	(55.8)	276	(40.0)	8.0
2219-T62	402	(58.3)	287	(41.6)	6.0
2219-T87	474	(68.8)	397	(57.6)	-
2021-T8E31	465	(67.5)	426	(61.8)	4.0
2024-T351	399	(57.8)	314	(45.5)	4.0
2024-T4	382	(55.4)	334	(48.5)	3.0
2024-T42	366	(53.1)	276	(40.0)	5.0
2024-T6	436	(63.3)	400	(58.0)	2.0
2024-T851	422	(61.2)	382	(55.4)	3.0
7001-T75 (Forging)	520	(75.4)	452	(65.6)	6.0
7039-T64	412	(59.7)	350	(50.7)	5.0
7075-T6	534	(77.5)	456	(66.1)	4.0
7075-T73	452	(65.5)	401	(58.2)	3.0
7079-T6	496	(72.0)	400	(58.1)	7.0

* Average of 3 Specimens

TABLE III
EFFECT OF SURFACE TREATMENT ON THE LOSS IN
TENSILE STRENGTH OF UNSTRESSED 2024 SPECIMENS [1]

Surface Treatment[2]	Stress Direction	Diameter mm (in.)	Percent Loss In Tensile Strength 15 Days	30 Days	60 Days	90 Days
		2024-T4				
None	LT	3.2 (1/8)	36	45	69	72
Alodine			17	36	54	61
Anodize			7	13	9	14
None		6.4 (1/4)	22	24	34	35
Alodine			13	21	34	33
Anodize			N	6	7	10
None	LO	3.2 (1/8)	26	30	58	53
Alodine			22	40	50	65
Anodize			5	5	5	N
None		6.4 (1/4)	8	19	24	29
Alodine			N	18	21	29
Anodize			N	N	5	7
		2024-T6				
None	ST	3.2 (1/8)	34	55	78	86
Alodine			31	44	69	84
Anodize			5	7	5	18
None		6.4 (1/4)	24	30	48	60
Alodine			14	24	49	56
Anodize			-	15	11	16
None	LT	3.2 (1/8)	11	17	38	51
Alodine			N	12	35	32
Anodize			N	N	N	5
None		6.4 (1/4)	10	12	24	25

TABLE III
EFFECT OF SURFACE TREATMENT ON THE LOSS IN TENSILE STRENGTH OF UNSTRESSED 2024 SPECIMENS [1]
(CONTINUED)

Surface Treatment[2]	Stress Direction	Diameter mm (in.)	Percent Loss In Tensile Strength 15 Days	30 Days	60 Days	90 Days
		2024-T6				
Alodine	LT	6.4 (1/4)	9	13	18	30
Anodize			8	5	9	9
None	LO	3.2 (1/8)	15	27	50	66
Alodine			15	26	49	33
Anodize			6	N	5	5
None		6.4 (1/4)	10	9	19	23
Alodine			N	9	18	21
Anodize			5	N	5	N

ST-short transverse; LT-long transverse; LO-longitudinal; N-negligible (<5).

NOTES: (1) Round tensile specimens exposed by alternate immersion to 3.5% salt water.

(2) Treatments consisted of Alodine 1200 or sulfuric acid anodize plus hot water seal.

TABLE IV
EFFECT OF SURFACE TREATMENT ON THE STRESS CORROSION CRACKING OF 2024 ALUMINUM [1]

Surface Treatment [2]	Specimen Diameter mm (in.)	Stress Direction	Applied Load % Y.S	MN/m^2 (ksi)	Failure Ratio	Days to Failure
		2024-T4				
None	3.2 (1/8)	ST	75	245 (35)	4/4	2-5
None	6.4 (1/4)		75	245 (35)	3/3	3-4
Alodine			75	245 (35)	7/7	4-12
Anodize			75	245 (35)	7/7	4-8
None	3.2 (1/8)	LT	50	175 (25)	4/4	27-28
None			75	245 (35)	6/6	3-19
Alodine			50	175 (25)	4/4	8-38
Alodine			75	245 (35)	4/4	7-19
Anodize			50	175 (25)	1/4	24
Anodize			75	245 (35)	0/4	-
None	6.4 (1/4)		50	175 (25)	4/4	28-79
None			75	245 (35)	4/4	7-20
Alodine			50	175 (25)	4/4	42-65
Alodine			75	245 (35)	4/4	7-40
Anodize			50	175 (25)	1/4	49
Anodize			75	245 (35)	4/8	12-28
None	3.2 (1/8)	LO	50	175 (25)	4/4	34-44
None			75	279 (40)	6/8	4-38
Alodine			50	175 (25)	3/4	38-44
Alodine			75	279 (40)	4/4	9-29
Anodize			50	175 (25)	0/4	-
Anodize			75	279 (40)	1/4	12
None	6.4 (1/4)		50	175 (25)	0/4	-
None			75	279 (40)	4/4	37-57
Alodine			50	175 (25)	0/4	-

TABLE IV
EFFECT OF SURFACE TREATMENT ON THE STRESS CORROSION CRACKING OF 2024 ALUMINUM (1)
(CONTINUED)

Surface Treatment (2)	Specimen Diameter mm (in.)	Stress Direction	Applied Load % Y.S	MN/m^2 (ksi)	Failure Ratio	Days to Failure
			2024-T4			
Alodine	6.4 (1/4)	LO	75	279 (40)	4/4	47-84
Anodize			50	175 (25)	0/4	-
Anodize			75	279 (40)	0/4	-
			2024-T6			
None	3.2 (1/8)	ST	50	210 (30)	4/4	28-41
None			75	314 (45)	4/4	18-19
Alodine			50	210 (30)	4/4	28-42
Alodine			75	314 (45)	4/4	19-29
Anodize			50	210 (30)	0/4	-
Anodize			75	314 (45)	3/4	55-84
None	6.4 (1/4)		50	210 (30)	4/4	42-69
None			75	314 (45)	9/9	24-42
Alodine			50	210 (30)	4/4	49-78
Alodine			75	314 (45)	9/9	40-70
Anodize			50	210 (30)	0/4	-
Anodize			75	314 (45)	5/9	17-73
None	3.2 (1/8)	LT	50	245 (35)	2/4	55, 61
None			75	349 (50)	4/4	40-79
Alodine			50	245 (35)	2/4	83, 85
Alodine			75	349 (50)	4/4	42-89
Anodize			50	245 (35)	0/4	-
Anodize			75	349 (50)	0/4	-

TABLE IV
EFFECT OF SURFACE TREATMENT ON THE STRESS CORROSION CRACKING OF 2024 ALUMINUM (1)
(CONTINUED)

Surface Treatment (2)	Specimen Diameter mm (in.)	Stress Direction	Applied Load % Y.S	MN/m^2(ksi)	Failure Ratio	Days to Failure
			2024-T6			
None	6.4 (1/4)	LT	50	245 (35)	1/4	89
None			75	349 (50)	4/4	40-69
Alodine			50	245 (35)	0/4	-
Alodine			75	349 (50)	1/4	82
Anodize			50	245 (35)	0/4	-
Anodize			75	349 (50)	0/4	-
None	3.2 (1/8)	LO	50	210 (30)	4/4	29-57
None			75	349 (50)	4/4	20-41
Alodine			50	210 (30)	4/4	29-76
Alodine			75	349 (50)	4/4	29-42
Anodize			50	210 (30)	0/4	-
Anodize			75	349 (50)	0/4	-
None	6.4 (1/4)		50	210 (30)	0/4	-
None			75	349 (50)	0/4	-
Alodine			50	210 (30)	0/4	-
Alodine			75	349 (50)	0/4	-
Anodize			50	210 (30)	0/4	-
Anodize			75	349 (50)	0/4	-

ST-short transverse; LT-long transverse: LO-longitudinal

NOTES: (1) Round tensile specimens exposed by alternate immersion to 3.5% salt water until failure or a maximum of 90 days.

(2) Treatments consisted of Alodine 1200 or sulfuric acid anodize plus hot water seal.

TABLE V

APPLICATION OF SURFACE TREATMENT BEFORE AND AFTER LOADING STRESS CORROSION SPECIMENS (1)

Surface Treatment (2)	Applied In Relation To Stressing Spec.	Stress Direction	Failure Ratio	Days To Failure
Anodized	After Stressing	ST	2/2	4, 8
Anodized	Before Stressing	ST	2/2	5, 6
Alodine	After Stressing	ST	2/2	6, 7
Alodine	Before Stressing	ST	2/2	6, 12
Anodized	After Stressing	LT	0/2	-
Anodized	Before Stressing	LT	0/2	-
Alodine	After Stressing	LT	1/2	69
Alodine	Before Stressing	LT	1/2	69

ST-short transverse; LT-long transverse

NOTES:
(1) Round tensile specimens (6.35 mm or 1/4" diameter) of 2024-T4 stressed to 75% of yield strength either before or after application of surface treatment and exposed by alternate immersion to 3.5% salt water until failure or 90 days.

(2) Treatments consisted of Alodine 1200 or sulfuric acid anodize plus hot water seal.

TABLE VI
PERCENT LOSS IN TENSILE STRENGTH OF UNSTRESSED ALUMINUM ALLOYS EXPOSED BY ALTERNATE IMMERSION IN SYNTHETIC SEA WATER AND 3.5 PERCENT SALT WATER

Alloy	Specimen Size mm (in.)	Grain Direction	Days In Test 15	30	90	Days In Test 15	30	90
			Synthetic Sea Water			3.5 Percent Salt Water		
2014-T6	3.2 (1/8)	ST	20	25	30*	40	60	-
2017-T4	6.4 (1/4)	ST	N	N	20	-	-	55
		LO	N	N	N	-	-	30
2219-T37	6.4 (1/4)	ST	N	10	15	-	-	65
2219-T62	6.4 (1/4)	ST	N	N	15	-	-	85
		LT	N	N	N	-	-	55
2219-T87	6.4 (1/4)	ST	N	N	15	-	-	70
		LT	N	N	N	-	-	50
2021-T8E51	3.2 (1/8)	ST	20	20	20	35	45	85*
	6.4 (1/4)	ST	10	10	15	15	20	-
2024-T351	3.2 (1/8)	ST	10	10	15	35	55	90
		LT	-	-	10	25	40	75
2024-T4	3.2 (1/8)	ST	5	-	-	40	70	90
		LT	10	-	10	30	45	70
2024-T4	6.4 (1/4)	ST	-	-	10	20	30	40
2024-T6	3.2 (1/8)	ST	-	10	-	40	55	95
		LT	-	-	10	20	30	60
	6.4 (1/4)	ST	-	-	5	15	30	35
2024-T851	3.2 (1/8)	ST	-	-	15	30	50	65
		LT	-	-	5	20	30	65
7049-T73	3.2 (1/8)	ST	-	-	15	-	-	35
7075-T6	3.2 (1/8)	ST	10	10	15	20	25	45
7075-T73	3.2 (1/8)	ST	15	15	15	30	30	40
	6.4 (1/4)	ST	N	N	N	15	20	30
7079-T6	3.2 (1/8)	ST	5	10	10	10	20	25

ST-short transverse, LT-long transverse, LO-longitudinal
N-negligible (<5)
*Percent loss in 60 days

TABLE VII
COMPARATIVE SCC PERFORMANCE OF ALUMINUM ALLOYS IN SYNTHETIC SEA WATER AND 3.5 PERCENT SALT WATER

Stress Direction	Specimen Diameter mm (in.)	Applied Load MN/m^2 (ksi)	Failure Ratio	Days to Failure	Specimen Diameter mm (in.)	Applied Load MN/m^2 (ksi)	Failure Ratio	Days to Failure
	Synthetic Sea Water				3.5 Percent Salt Water			
				2014-T6				
ST	3.2 (1/8)	70 (10)	9/12	3-90	3.2 (1/8)	70 (10)	3/3	3-4
LT	6.4 (1/4)	210 (30)	4/6	3-32		210 (30)	0/6	-
LO		349 (50)	6/12	3-24		349 (50)	0/10	-
				2017-T4 BAR				
ST	6.4 (1/4)	105 (15)	1/6	22	6.4 (1/4)	105 (15)	3/3	27-33
				2219-T37				
ST	6.4 (1/4)	105 (15)	5/6	5-43	3.2 (1/8)	210 (30)	3/3	1, 1, 1
LT		175 (25)	2/3	6-44		210 (30)	6/6	2-4
				2219-T62				
ST	6.4 (1/4)	279 (40)	0/6	-	3.2 (1/8)	314 (45)	2/3*	90, 90
LT		245 (35)	0/3	-		314 (45)	0/3	-

TABLE VII
COMPARATIVE SCC PERFORMANCE OF ALUMINUM ALLOYS IN SYNTHETIC SEA WATER AND 3.5 PERCENT SALT WATER
(CONTINUED)

Stress Direction	Specimen Diameter mm (in.)	Applied Load MN/m^2 (ksi)	Failure Ratio	Days to Failure	Specimen Diameter mm (in.)	Applied Load MN/m^2 (ksi)	Failure Ratio	Days to Failure
		Synthetic Sea Water				3.5 Percent Salt Water		
				2219-T87				
ST	6.4 (1/4)	279 (40)	0/6	-	3.2 (1/8)	293 (42)	3/6*	24-90
LT		314 (45)	0/6	-		314 (45)	1/5*	77
LO			0/3	-			2/5*	52-55
				2021-T8E31				
ST	3.2 (1/8)	210 (30)	0/3	-	3.2 (1/8)	210 (30)	3/3	35-54
		279 (40)	2/3	14, 29		279 (40)	3/3	20-22
		314 (45)	1/3	40		314 (45)	3/3	8-36
				2024-T351				
ST	3.2 (1/8)	70 (10)	4/6	13-44	3.2 (1/8)	140 (20)	3/3	1-3
LO		279 (40)	0/3	-		279 (40)	3/3*	66, 66, 66
				2024-T42				
LT	3.2 (1/8)	140 (20)	2/3	10, 14	3.2 (1/8)	245 (35)	4/4	7-19
LO		245 (35)	3/6	13-73		279 (40)	4/4*	31-38

TABLE VII
COMPARATIVE SCC PERFORMANCE OF ALUMINUM ALLOYS IN SYNTHETIC SEA WATER AND 3.5 PERCENT SALT WATER
(CONTINUED)

Stress Direction	Specimen Diameter mm (in.)	Applied Load MN/m^2 (ksi)	Failure Ratio	Days to Failure	Specimen Diameter mm (in.)	Applied Load MN/m^2 (ksi)	Failure Ratio	Days to Failure
	Synthetic Sea Water				3.5 Percent Salt Water			
				2024-T6				
ST	3.2 (1/8)	314 (45)	3/3	1-31	3.2 (1/8)	314 (45)	4/4	3-14
LT		349 (50)	0/3	-		349 (50)	8/9*	3-48
LO			0/6	-			10/10*	20-79
				2024-T851				
ST	3.2 (1/8)	314 (45)	0/6	-	3.2 (1/8)	314 (45)	9/9*	12-78
LT		349 (50)	0/6	-		349 (50)	2/6*	86, 88
LO			0/6	-			0/3	-
				7001-T75 FORGING				
ST	3.2 (1/8)	175 (25)	0/3	-	3.2 (1/8)	175 (25)	2/3	25, 45
		210 (30)	0/3	-		210 (30)	3/3	34-73
LT		419 (60)	0/3	-		419 (60)	3/3	38-45

TABLE VII
COMPARATIVE SCC PERFORMANCE OF ALUMINUM ALLOYS IN SYNTHETIC SEA WATER AND 3.5 PERCENT SALT WATER
(CONTINUED)

Stress Direction	Specimen Diameter mm (in.)	Applied Load MN/m^2 (ksi)	Failure Ratio	Days to Failure	Specimen Diameter mm (in.)	Applied Load MN/m^2 (ksi)	Failure Ratio	Days to Failure
		Synthetic Sea Water				3.5 Percent Salt Water		
				7039-T64				
ST	3.2 (1/8)	140 (20)	0/3	-	3.2 (1/8)	140 (20)	0/3	-
		210 (30)	3/3	19-35		210 (30)	3/3	34-88
	6.4 (1/4)	140 (20)	2/3	29, 82	6.4 (1/4)	140 (20)	0/3	-
		210 (30)	3/3	29-82		210 (30)	3/3	32-39
				7075-T6				
ST	3.2 (1/8)	105 (15)	5/5	3-13	3.2 (1/8)	105 (15)	5/5	2-15
LT		314 (45)	5/6	9-79		349 (50)	2/2	55, 86
LO		349 (50)	0/3	-		349 (50)	0/2	-
				7075-T73				
ST	3.2 (1/8)	314 (45)	0/3	-	3.2 (1/8)	314 (45)	6/6	5-54
				7079-T6				
ST	3.2 (1/8)	140 (20)	2/3	5, 5	3.2 (1/8)	140 (20)	2/3	5, 8
		210 (30)	3/3	2, 2, 2		210 (30)	3/3	2, 2, 2

ST-short transverse; LT-long transverse; LO-longitudinal
* Many of the specimens probably failed from tensile overload resulting from excessive pitting.

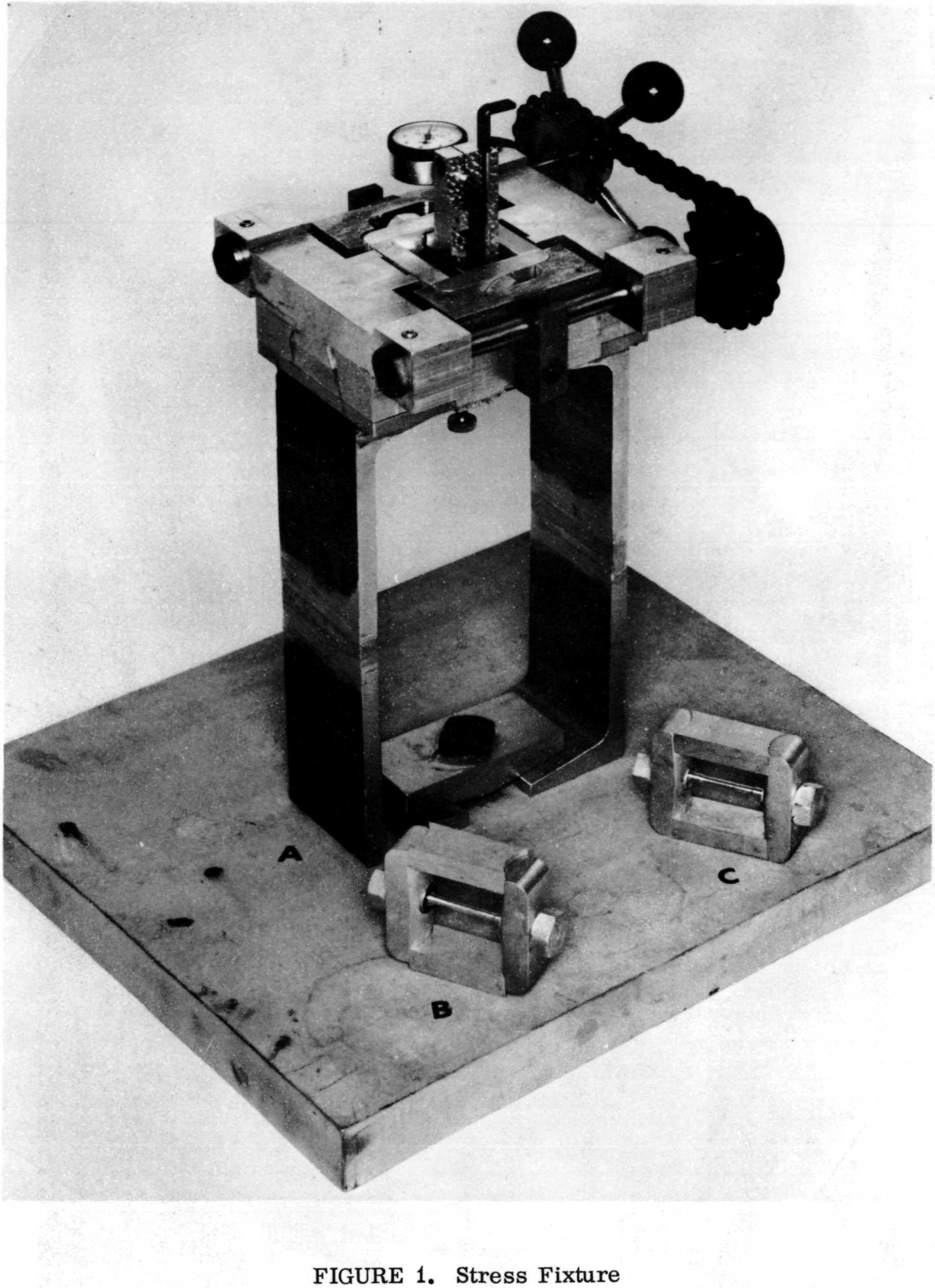

FIGURE 1. Stress Fixture

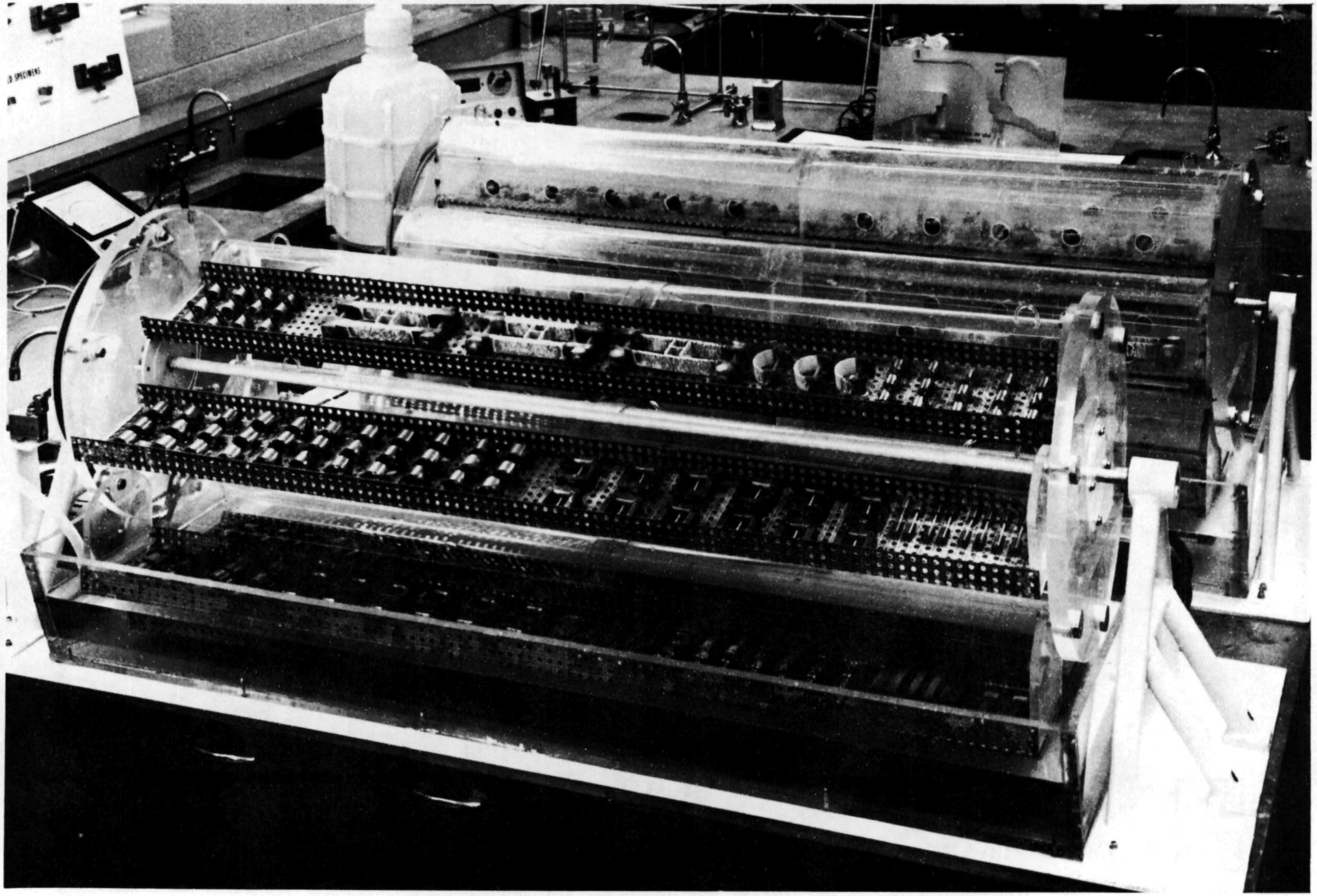

FIGURE 2. Alternate Immersion Tester

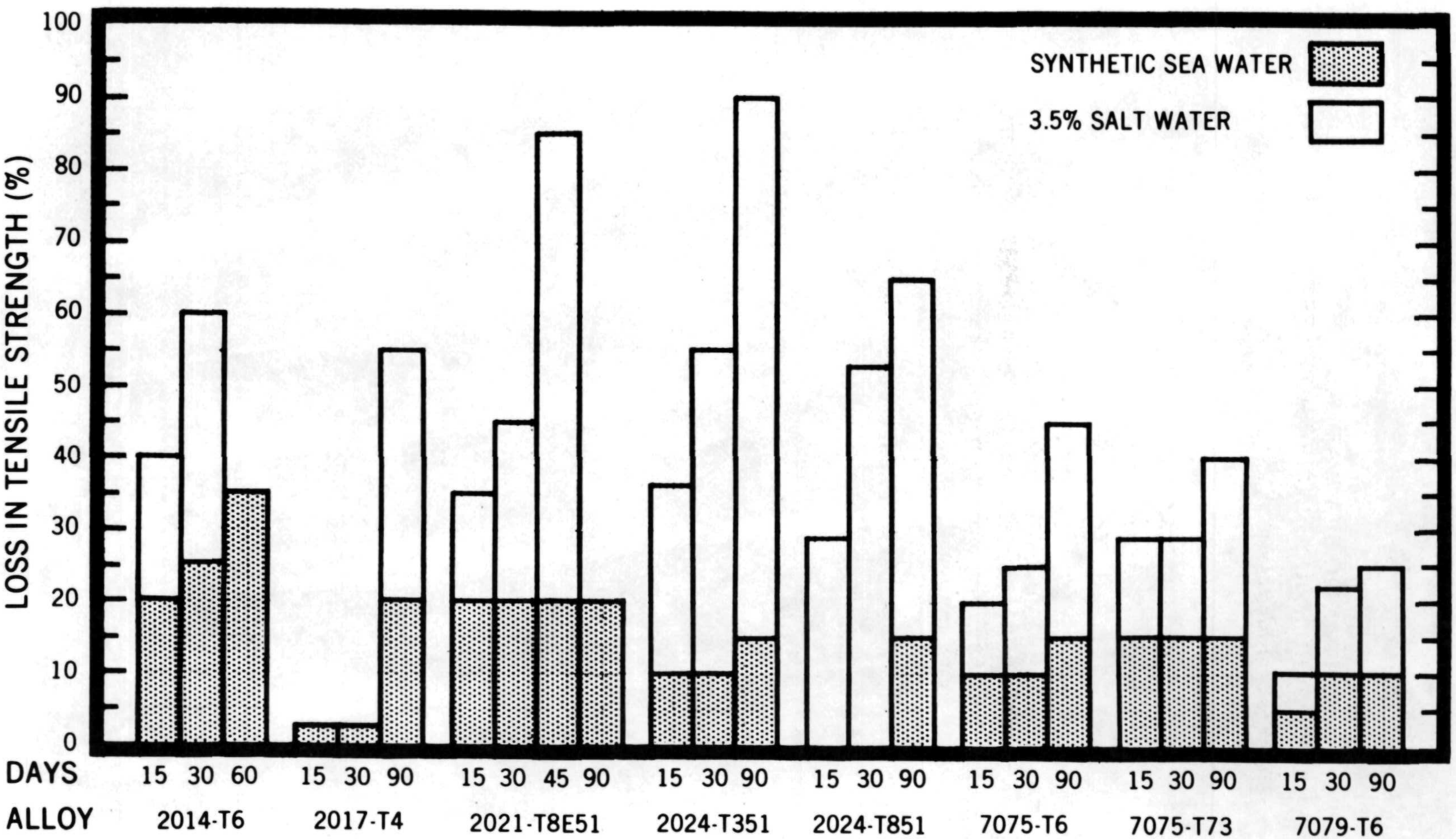

FIGURE 3. Loss in Tensile Properties of Unstressed SCC Specimens Exposed by Alternate Immersion in Sea Water and Salt Water

APPROVAL

SYNTHETIC SEA WATER AN IMPROVED STRESS CORROSION TEST MEDIUM FOR ALUMINUM ALLOYS

By

T. S. Humphries
E. E. Nelson

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 determine to be unclassified.

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

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