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MELLON INSTITUTE

Quarterly Scientific Progress Report

Report No. 16

for the period

February 1, 1962 - April, 30, 1962

STRESS CORROSION OF HIGH STRENGTH STEELS
AND ALLOYS; ARTIFICIAL ENVIRONMENT

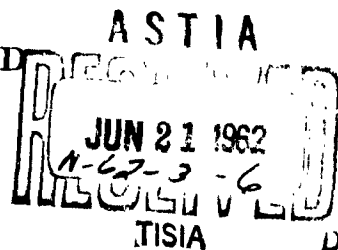
Research Project No. 389-2

Sponsored by

U. S. Army Ordnance, Frankford Arsenal

Mr. H. Rosenthal, Contract Monitor

Contract No. DA-36-034-ORD-3277RD



Approved H. L. Anthony
Dr. H. L. Anthony
Staff Adviser

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This Report Presented By The
Project Staff

C. J. Owen, Fellow
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The publication of this report does not necessarily constitute approval by the Army of the findings or conclusions contained therein.

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ABSTRACT

A brief review of the experimental procedures utilized in the stress corrosion testing program is presented for reference purposes.

During the period covered by this report, all three strength levels of Vascojet-1000 and two strength levels of D6Ac U-bend samples were subjected to stress corrosion testing in five synthetic environments. The V-1000 data indicate that the alloy is the most susceptible of all groups tested to date. No minimum strength level of inhibition is indicated by the data for this alloy. Failure during testing of the V-1000 samples was often of the multiple-crack catastrophic type rather than of the single-crack type.

The D6Ac data indicate that, of the low alloy, high strength steels tested to date, this material is the least susceptible to stress corrosion failure.

Data for stress corrosion testing of comparative heats of V-1000 and D6Ac substantiate the order of magnitude of failure observed for the foregoing.

Tables of cumulative stress corrosion test data for other alloys being tested by both the U-bend and bent beam test methods are presented for comparative reference.

I. INTRODUCTION

The project work described herein represents a portion of a grant made available by the Army to promote a general scientific advancement in the area of case materials for missiles. This specific project is concerned with the synthetic environment stress corrosion testing of specified high strength steels and alloys. The research objectives of the project were presented in Report No. 1.

Natural environmental tests on high strength steels and alloys are being conducted by Aerojet General Corporation, with actual production environments and rocket propellant environments being utilized. By prior mutual agreement, the same steel and alloy sheet material will be used for both projects and possible heat treatment variations will be circumvented by exchanging heat treated material whenever possible.

For the tests described herein, bent beam and U-bend samples were cut and machined from available sheet material and subjected to stress corrosion testing in five selected synthetic environments in the laboratory.

This report presents further information on continuing U-bend and bent beam tests for the assigned alloys, and for Rocoloy 270, 4137 Co, and Ardeform 301 missile steels.

II. EXPERIMENTAL PROCEDURES

Test Methods

A discussion of the U-bend and bent beam test methods together with an outline of the synthetic stress corrosion test environments used in performing the research are given in the July, 1960, Monthly Scientific Report, Report No. 1.

All recently-exposed (and future) samples being subjected to stress corrosion testing are being weighed prior to exposure to the test solutions to provide, whenever possible, general corrosion information.

Apparatus

Schematic drawings of bent beam sample holders, the U-bend test holders, a sample bending device for bent beam specimens, and a stress corrosion test tank were presented in Report Nos. 1 and 3.

Polyethylene containers are presently being used for the stress corrosion exposure of U-bend specimens to the various synthetic environments. Each container will adequately hold six U-bend specimens. The use of these containers will supplement the sample testing presently being conducted in epoxy-coated tanks. Bent beam specimens are being tested in heavy glass dishes and epoxy-coated metal tanks.

Construction of shelving and an aeration system (Report No. 6) together with other pertinent items has facilitated (wherever feasible) the transfer of some samples under test from the glass containers to the epoxy-coated test tanks. The completed facility is illustrated in Report No. 7.

Alloy Sample Material

The alloys being used in the study on stress corrosion include:

1. Low Alloy: Ladish D6Ac
2. Si-Modified 4300 Series: 300M.
3. Hot-Worked Die Steel: Vascojet 1000.
4. Cold-Worked PH Steel: AM355.
5. Heat-Treated PH Steel: PH15-7 Mo.
6. Titanium Alloy: B120VCA.
7. Low Alloy-Cobalt Modified: 4137 Co.
8. Low Alloy-Cobalt Modified: Rocoloy 270.
9. Stretch-Formed 17/7 Stainless Steel: Ardeform 301.
10. Low Alloy-Co and U-Modified: 4137 Co.

All of the sample material is being tested in sheet form and was procured as such.

Chemical analyses for the above listed alloys and for the comparative heats are given in their entirety in Table I in Report

No. 13. Physical properties and heat treating surveys for the alloys were presented in Report No. 12.

Sample Preparation

Sheet material of the various alloys was sheared into slightly over-size U-bend, bent beam, and tensile specimens in both the primary (direction of lowest Y.S.) and secondary directions. The specimens were then wet-ground to width, length, and thickness (if necessary). Sample thickness was maintained between 30 and 50 mils, and as close to 50 mils as possible.

After heat treatment surveys were conducted (see Report No. 12) to determine the Y.S. variation with tempering temperature for each alloy (not necessary for AM355), the specimens were heat treated to strength levels approximating 200, 220, 240 Kpsi and maximum Y.S. Heat treating of the B120VCA alloy consisted of aging in an inert atmosphere (see Report No. 12).

All the surfaces except the ends of the heat treated specimens were then polished with emery paper to remove oxide films, the final polish being administered with 240-grit emery. Care was taken to assure a uniformly square edge on the specimens. A tendency of the D6Ac, V-1000, and 300M specimens to decarburize was circumvented by carefully wet-grinding the surfaces of the heat-treated samples an additional 5 mils per surface.

Tensile and metallographic samples were also cut from the alloy sheet material for the determination of as-received and heat-treated physical properties.

Sample Testing

The U-bend specimens were bent into a V-shape with a special bending apparatus, sprung into clips (see Report No. 12), and immersed in each of the five test solutions (one-molar NaCl, Na₂SO₄, NaNO₃, NaPO₃, and Na₂S).

The bent beam specimens were precision-cut to length (± 0.005 inches) and sprung into a holder with a bending device (see Report No. 12). Immersion in the above five solutions constituted the test phase.

Status of Sample Material

The present status of the alloy sample material to date:

1. D6Ac - some bent beam and U-bend samples being tested.
2. 300M - U-bend data on 3 strength levels available;
U-bend data on comparative heat also available.
3. Vascojet 1000 - bent beam and U-bend data on 3 strength levels available; U-bend data on 3 comp. heats also available.

6.

4. AM355 - all U-bends and all bent beam samples

under test.

5. PH15-7 Mo - all U-bends and some bent beam samples

under test.

6. B120VCA - some U-bend and bent beam samples

under test.

7. 4137Co - various U-bends under test.

8. Rocoloy 270 - U-bends under test.

9. Ardeform 301 - U-bends under test.

III. EXPERIMENTAL

Sample preparation and stress corrosion testing of all alloys, both assigned materials and additional samples accepted for study, are continuing.

A. Sample Preparation

During the period of this report, three groups of U-bend samples totalling 360 specimens were prepared for coating tests.

The samples included:

1. 120 Vascojet 1000 samples; tempered at 975°F;
longitudinal (primary) direction.
2. 120 4137 Co samples; tempered at 550°F; longitudinal
(primary) direction.
3. 120 4137 Co samples; tempered at 550°F; transverse
(secondary) direction.

The edges of all samples were rounded and the samples numbered before heat treatment. Heat treatment procedures followed those set forth for these alloys in Report No. 12. After heat treatment, the first two groups of samples were bent into the V-shape and the third group of samples was left in the flat shape to be bent after coating. All samples except the controls were shipped to Aberdeen Proving

Ground for coating with the following interrelated coating variables being taken into consideration:

<u>Variable</u>	<u>Level</u>
Pretreatment	1. None 2. Zinc phosphate 3. Wash primer
Organic Primer Coating	1. Mil P 11414 (a lacquer primer) 2. TTP 664 (an enamel primer) 3. Mil P 8585 (a vinyl primer) 4. Mil P 52192 ORD (an epoxy primer)
Test Site and Type	1. Mellon Institute (synthetic environment; 1M NaCl soln.) 2. Kure Beach* (natural environment; marine atmosphere)

After coating (by Aberdeen's research facility under Dr. Pickett and supervised by Mr. M. H. Sandler), the samples will be returned to Mellon Institute for distribution (between this project and U. S. Steel Applied Research) and stress corrosion testing.

* A cooperative test with U. S. Steel Applied Research Laboratory; Dr. E. H. Phelps and A. W. Loginow will supervise the procedures.

B. Stress Corrosion Testing

The cumulative results to date of the various bent beam and U-bend stress corrosion tests are presented in Tables I through XXIX on the final pages of this report. There have been relatively few additional changes in status of the material since the last report was issued and a summation of results would essentially be identical to the discussion presented in Report No. 15. Reference is therefore made to this last report for the purpose of obtaining a discussion of the results.

During this report period, a number of Vascojet 1000 and D6Ac U-bend samples were subjected to synthetic environment stress corrosion testing. A more detailed discussion of the results to date for these alloys is provided below.

1. Vascojet 1000 U-bends. All U-bend stress corrosion test samples from the low (~200 Kpsi Y.S.), intermediate (~240 Kpsi, Y.S.), and high strength (~255 Kpsi Y.S.) groups were subjected to testing in the five synthetic environments. The samples were taken from the Primary Heat and three Comparative Heat sheet specimens of V-1000. The Primary Heat samples included both the primary (longitudinal) and secondary (transverse) directions, while, for the Comparative Heats, only the primary direction was utilized for sample testing.

The cumulative stress corrosion test data for the Primary Heat, low, intermediate, and high strength levels, are given in Tables XXX, XXXI, and XXXII. With the exception of the sulfide environment in which no failures have been recorded to date, the failure time for the low strength samples was of the order of days (hours in the phosphate). For the intermediate and high strength samples, the failure time was of the order of minutes (hours and days for the nitrate environment).

The general order of susceptibility, in decreasing rate of effect, for the Vascojet-1000 specimens was: phosphate; chloride; sulfate; nitrate; and sulfide. The first three were of the same order of magnitude and may be considered equally detrimental in effect.

Sample failure of the Vascojet-1000 specimens was somewhat different than the other types of materials tested. Usually U-bend sample failure resulted from propagation of a single crack to failure. The V-1000 samples often, but not always, shattered into as many as eight pieces. This shattering effect was most noticeable for those samples immersed in phosphate, chloride, and sometimes in the sulfate but did not occur in the nitrate solution. Multiple failure of this type occurred in both the plastically-deformed (at the apex of the U-bend) and the highly stressed areas of the sample simultaneously.

TABLE XXX

CUMULATIVE VASCOJET-1000 U-BEND STRESS CORROSION TESTS

Low Strength (Y.S.) Samples

Primary Heat

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset) Kpsi	Kpsi					
NaCl	Primary	196	231	6	6	6	7.23	4 to 10.4
	Secondary	207	245	6	6	6	6.08	5.4 to 9.15
NaNO ₃	Primary	196	231	6	5 to 52 days	5	--	--
	Secondary	207	245	6	6	6	17.0	16 to 22
Na ₂ S	Primary	196	231	6	none to 52 days	none	--	--
	Secondary	207	245	6	none to 53 days	none	--	--
Na ₂ SO ₄	Primary	196	231	6	6	6	18.0	15 to 27
	Secondary	207	245	5	4 to 53 days	4	--	--
NaPO ₃	Primary	196	231	6	6	6	2.08 hrs	1 hr to 3 hrs
	Secondary	207	245	6	6	6	2.16 hrs	1.5 hrs to 3 hrs

Note: The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the longitudinal direction for this alloy.

These specimens were preheated at 1450°F for 30 min., austenitized at 1900°F for 40 min., air-quenched, and tempered for 2 + 2 + 2 hrs. at 1100°F, an air quench following each temper.

TABLE XXXI

CUMULATIVE VASCOJET-1000 U-BEND STRESS CORROSION TESTS

Intermediate Strength (Y. S.) Samples

Primary Heat

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days	
		(.2% Offset) Kpsi							
NaCl	Primary	237		305	6	6	3.8 min	3 min	to 5.8 min
	Secondary	246		309	6	6	4.9 min	2 min	to 6.8 min
NaNO ₃	Primary	237		305	5	5	20.4 hrs	5 hrs	to 42 hrs
	Secondary	246		309	6	6	17.5 hrs	7 1/2 hrs	to 29 1/2 hrs
Na ₂ S	Primary	237		305	6	none to 55 days	--	--	--
	Secondary	246		309	6	none to 55 days	--	--	--
Na ₂ SO ₄	Primary	237		305	6	6	9.8 min	2.8 min	to 28 min
	Secondary	246		309	6	6	8.08 min	4 min	to 12 min
NaPO ₃	Primary	237		305	6	6	4.8 min	4 min	to 5.5 min
	Secondary	246		309	6	6	3 min	2 min	to 4 min

Note: The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the longitudinal direction for this alloy.

These specimens were preheated at 1450°F for 30 min., austenitized at 1900°F for 40 min., air-quenched, and tempered for 2 + 2 + 2 hrs. at 850°F, an air quench following each temper.

TABLE XXXII

CUMULATIVE VASCOJET-1000 U-BEND STRESS CORROSION TESTS

High Strength (Y. S.) Samples

Primary Heat

Test Solution	Direction of Specimen	Y.S.		No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days	
		(.2% Offset) Kpsi	Tensile Strength Kpsi					
NaCl	Primary	256	323	6	6	12.8 min	5.5 min	to 26 min
	Secondary	260	327	6	6	11.6 min	7 min	to 17 min
NaNO ₃	Primary	256	323	6	6	5.6	4.5	to 5.4
	Secondary	260	327	6	6	3.5	.3	to 4.5
Na ₂ S	Primary	256	323	6	none to 61 days	--	--	--
	Secondary	260	327	6	none to 61 days	--	--	--
Na ₂ SO ₄	Primary	256	323	6	6	10.3 min	5 min	to 22 min
	Secondary	260	327	6	6	10.4 min	7 min	to 19 min
NaPO ₃	Primary	256	323	6	6	4.8 min	2.5 min	to 7 min
	Secondary	260	327	6	6	6.1 min	2 min	to 10.5 min

Note: The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the longitudinal direction for this alloy.

These specimens were preheated at 1450°F for 30 min., austenitized at 1900°F for 40 min., air-quenched, and tempered for 2 + 2 + 2 hrs. at 975°F, an air quench following each temper.

Of all the types of high strength alloy material tested to date, the Vascojet-1000 was the most susceptible to stress corrosion failure. Unlike the 4137 Co, for example, there seems to be no threshold yield strength level below which stress corrosion failure is negligible for the V-1000.

The cumulative stress corrosion test results for the three Comparative Heats, shown in Tablex XXXIII, XXXIV, and XXXV, confirm the order of magnitude of failure of the Primary Heat samples.

2. D6Ac U-bends. Only the low (~ 200 Kpsi Y.S.) and intermediate strength level (~ 220 Kpsi Y.S.) samples of this alloy have been subjected to U-bend stress corrosion testing. The high strength (~ 250 Kpsi Y.S.) samples would not take the degree of bending required in the formation of the U-bend samples, a breakage rate exceeding 50% having been encountered.

The cumulative U-bend stress corrosion test data for the Primary Heat of D6Ac, both primary (transverse) and secondary (longitudinal) directions, are presented in Tables XXXVI and XXXVII. Of the low alloy (less than about 10% alloys, remainder iron), high strength materials tested to date, the D6Ac seems to be the least prone to stress corrosion failure. This comparative group of alloys would include the Vascojet-1000, 300M, and 4137 Co. It is also apparently somewhat less ductile and it may be that a sacrifice in ductility

TABLE XXXIII

CUMULATIVE VASCOJET-1000 U-BEND STRESS CORROSION TESTS

Low Strength (Y. S.) Samples

Comparative Heats

Test Solution	Direction of Specimen	Comparative Heat No.	Y. S.		No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days	
			(.2% Offset)	Kpsi					
NaCl	Primary	1	195		6	6	9.3	6.9 to 18.05	
	Primary	2	195		6	6	7.1	5.5 to 9.19	
	Primary	3	195		6	6	4.6	17 hrs. to 3.17	
NaNO ₃	Primary	1	195		5	5	18.2	17 to 20	
	Primary	2	195		5	5	18.4	17 to 20	
	Primary	3	195		5	5	15.0	11 to 18	
Na ₂ S	Primary	1	195		-	-	--	--	
	Primary	2	195		-	-	--	--	
	Primary	3	195		-	-	--	--	
Na ₂ SO ₄	Primary	1	195		5	5	9	8 to 10	
	Primary	2	195		5	5	8.4	6 to 10	
	Primary	3	195		6	6	3.7	2.10 to 4.8	
NaPO ₃	Primary	1	195		4	4	2 hrs	1.25 hrs to 2.25 hrs	
	Primary	2	195		5	5	4 days	2 hrs to 6 days	
	Primary	3	195		5	5	2.6 hrs	2.25 hrs to 3.5 hrs	

Note: The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the longitudinal direction for this alloy.

These specimens were preheated at 1450°F for 30 min., austenitized at 1900°F for 40 min., air-quenched, and tempered for 2 + 2 + 2 hrs. at 1100°F, an air quench following each temper.

TABLE XXXIV

CUMULATIVE VASCOJET-1000 U-BEND STRESS CORROSION TESTS

Intermediate Strength (Y.S.) Samples

Comparative Heats

Test Solution	Direction of Specimen	Comparative Heat No.	Y.S.		No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days	
			Comparative	(.2% Offset)					
				Kpsi					
NaCl	Primary	1		235	6	6	4 min	3 min	to 5.2 min
	Primary	2		235	6	6	6.3 min	5 min	to 7.5 min
	Primary	3		235	6	6	2.8 min	2 min	to 5 min
NaNO ₃	Primary	1		235	3	3	8.3 hrs	5 1/2 hrs	to 11 1/2 hrs
	Primary	2		235	6	6	24.8 hrs	12 1/2 hrs	to 41 1/2 hrs
	Primary	3		235	6	6	12.3 hrs	6 hrs	to 12 1/2 hrs
Na ₂ S	Primary	1		235	-	-	--	--	--
	Primary	2		235	-	-	--	--	--
	Primary	3		235	-	-	--	--	--
Na ₂ SO ₄	Primary	1		235	6	6	3.4 min	2.5 min	to 4.8 min
	Primary	2		235	6	6	17.3 min	4.5 min	to 40 min
	Primary	3		235	6	6	3.58 min	2 min	to 6 min
NaPO ₃	Primary	1		235	6	6	3.6 min	2.5 min	to 5.5 min
	Primary	2		235	6	6	4.08 min	3 min	to 5.8 min
	Primary	3		235	6	6	3.16 min	2 min	to 4 min

Note: The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the longitudinal direction for this alloy.

These specimens were preheated at 1450°F for 30 min., austenitized at 1900°F for 40 min., air-quenched, and tempered for 2 + 2 + 2 hrs. at 850°F, an air quench following each temper.

TABLE XXXV

CUMULATIVE VASCOJET-1000 U-BEND STRESS CORROSION TESTS

High Strength (Y.S.) Samples

Comparative Heats

Test Solution	Direction of Specimen	Comparative Heat No.	Y.S. (.2% Offset) Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	1	255	6	6	9.1 min	6 min to 14.5 min
	Primary	2	255	6	6	18.2 min	10 min to 29 min
	Primary	3	255	6	6	8.7 min	5 min to 13.5 min
NaNO ₃	Primary	1	255	6	6	6.5	0.3 to 4.5
	Primary	2	255	6	6	8.4	5.6 to 14.5
	Primary	3	255	6	6	5.3	1.8 to 14.5
Na ₂ S	Primary	1	255	-	-	--	--
	Primary	2	255	-	-	--	--
	Primary	3	255	-	-	--	--
Na ₂ SO ₄	Primary	1	255	6	6	9.9 min	7.0 to 15 min
	Primary	2	255	6	6	21 min	12.5 to 32 min
	Primary	3	255	6	6	10.3 min	4.5 min to 1.5 min
NaPO ₃	Primary	1	255	6	6	7.5 min	6.5 to 9.0 min
	Primary	2	255	6	6	15.8 min	11.5 min to 87 min
	Primary	3	255	6	6	6.3 min	4.5 min to 14 min

Note: The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the longitudinal direction for this alloy.

These specimens were preheated at 1450°F for 30 min., austenitized at 1900°F for 40 min., air-quenched, and tempered for 2 + 2 + 2 hrs. at 975°F, an air quench following each temper.

TABLE XXXVI

CUMULATIVE D6Ac U-BEND STRESS CORROSION TESTS

Low Strength (Y.S.) Samples

Primary Heat

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset) Kpsi	(.2% Offset) Kpsi					
NaCl	Primary	185	197	6	6	none to 47 days	--	--
	Secondary	197	208	6	6	none to 46 days	--	--
NaNO ₃	Primary	185	197	6	6	none to 45 days	--	--
	Secondary	197	208	5	5	none to 45 days	--	--
Na ₂ S	Primary	185	197	6	6	none to 45 days	--	--
	Secondary	197	208	6	6	none to 45 days	--	--
Na ₂ SO ₄	Primary	185	197	6	6	none to 46 days	--	--
	Secondary	197	208	6	6	none to 45 days	--	--
NaPO ₃	Primary	185	197	5	5	1 to 45 days	--	--
	Secondary	197	208	6	6	1 to 45 days	--	--

Note: The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the transverse direction for this alloy.

These specimens were austenitized at 1550°F for 20 min., oil-quenched, and tempered for 2 + 1 hrs. at 1050°F, an air quench following each temper.

TABLE XXXVII

CUMULATIVE D6Ac U-BEND STRESS CORROSION SAMPLES

Intermediate Strength (Y.S.) Samples

Primary Heat

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time		Failure Time Range, days
		(.2% Offset) Kpsi	Strength Kpsi				to Failure, days	days	
NaCl	Primary	206	218	6	none to 47 days	6	none to 47 days	--	--
	Secondary	223	229	6	1 to 47 days	6	1 to 47 days	--	--
NaNO ₃	Primary	206	218	6	none to 45 days	6	none to 45 days	--	--
	Secondary	223	229	4	none to 45 days	4	none to 45 days	--	--
Na ₂ S	Primary	206	218	6	none to 45 days	6	none to 45 days	--	--
	Secondary	223	229	4	1 to 45 days	4	1 to 45 days	--	--
Na ₂ SO ₄	Primary	206	218	6	none to 46 days	6	none to 46 days	--	--
	Secondary	223	229	6	1 to 45 days	6	1 to 45 days	--	--
NaPO ₃	Primary	206	218	6	6	6	23.6 min	15 to 29.5 min	
	Secondary	223	229	4	4	4	17.6 min	15 to 21 min	

Note: The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the transverse direction for this alloy.

These specimens were austenitized at 1550°F for 20 min., oil-quenched, and tempered for 2 + 1 hrs. at 825°F, an air quench following each temper.

is necessary to obtain a minimum of stress corrosion susceptibility for yield strength levels in excess of 200 Kpsi.

The test data for the Comparative Heat of D6Ac alloy, low and intermediate strength levels, are shown in Table XXXVIII and confirm the relative non-susceptibility of the Primary Heat alloy material.

TABLE XXXVIII
CUMULATIVE D6Ac U-BEND STRESS CORROSION TESTS

Comparative Heat

Low and Intermediate Strength (Y.S.) Levels

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Secondary	~ 200	~ 210	6	none to 47 days	--	--
	Secondary	~ 225	~ 230	6	none to 47 days	--	--
NaNO ₃	Secondary	~ 200	~ 210	6	none to 46 days	--	--
	Secondary	~ 225	~ 230	5	none to 46 days	--	--
Na ₂ S	Secondary	~ 200	~ 210	-	--	--	--
	Secondary	~ 225	~ 230	-	--	--	--
Na ₂ SO ₄	Secondary	~ 200	~ 210	6	none to 46 days	--	--
	Secondary	~ 225	~ 239	5	none to 46 days	--	--
NaPO ₃	Secondary	~ 200	~ 210	6	none to 46 days	--	--
	Secondary	~ 225	~ 230	6	5 to 46 days	--	--

Note: The outer surface of the specimen is stressed beyond its Y.S.
Primary direction is the transverse direction for this alloy.
These specimens were austenitized at 1550°F for 20 min., oil-quenched, and tempered for 2 + 1 hrs. at 1050°F (low strength) and 840°F (intermed. strength), an air quench following each temper.

IV. FUTURE WORK

The cumulative stress corrosion test data to date will be presented in the Final Report, Report No. 17, together with test data on the coated specimens and the results of the surface decarburization study.

C. J. Owen:grr


FELLOW

R: 6-6-62

T: 6-7-62

TABLE I
CUMULATIVE D6Ac STRESS CORROSION BENT BEAM TESTS

Intermediate Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Applied Stress* Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	206	154	6	none to 136 days	--	--
	Secondary	223	--	--	--	--	--
NaNO ₃	Primary	206	154	6	none to 136 days	--	--
	Secondary	223	--	--	--	--	--
Na ₂ S	Primary	206	--	--	--	--	--
	Secondary	223	--	--	--	--	--
Na ₂ SO ₄	Primary	206	154	6	none to 136 days	--	--
	Secondary	223	--	--	--	--	--
NaPO ₃	Primary	206	154	6	none to 136 days	--	--
	Secondary	223	--	--	--	--	--

* Samples stressed to 75% of Y.S. in holder.

Specimens were austenitized at 1550°F for 20 min., oil quenched, and tempered at 840°F for 2 + 1 hrs., with an air quench after each temper.

TABLE II
CUMULATIVE VASCOJET-1000 BENT BEAM TESTS

Low Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Applied Stress* Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	207	155	6	6	29.7	24.5 to 36.5
	Secondary	--	--	-	-	--	--
NaNO ₃	Primary	207	155	5	4 to 160 days	--	--
	Secondary	--	--	-	-	--	--
Na ₂ S	Primary	207	155	6	none to 159 days	--	--
	Secondary	--	--	-	-	--	--
Na ₂ SO ₄	Primary	207	155	6	5 to 159 days	--	--
	Secondary	--	--	-	-	--	--
NaPO ₃	Primary	207	155	6	2 to 159 days	--	--
	Secondary	--	--	-	-	--	--

* Samples stressed to 75% of their Y.S. in holders; all 4-inch samples.

Note: These samples were austenitized at 1900°F for 40 min., oil quenched, and tempered for 2 + 2 + 2 hrs. at 1100°F with an air quench after each temper.

Primary direction is the direction of lowest Y.S. (transverse for this alloy).

TABLE III
CUMULATIVE VASCOJET-1000 BENT BEAM TESTS

Intermediate Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Applied Stress* Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days	
		(.2% Offset)	Kpsi						
NaCl	Primary	246		184	6	6	0.5	3 hrs	to 1 day
	Secondary	--		--	-	-	--	--	--
NaNO ₃	Primary	246		184	6	6	3.9	2.5 to 5.5	
	Secondary	--		--	-	-	--	--	--
Na ₂ S	Primary	246		184	6	none to 145 days	--	--	--
	Secondary	--		--	-	-	--	--	--
Na ₂ SO ₄	Primary	246		184	6	6	1.5	0.5 to 3.5	
	Secondary	--		--	-	-	--	--	--
NaPO ₃	Primary	246		184	6	6	0.5	4 hrs	to 1 day
	Secondary	--		--	-	-	--	--	--

* Samples stressed to 75% of their Y.S. in holders; all 4-inch samples.

Note: These samples were austenitized at 1900°F for 40 min., oil quenched, and tempered for 2 + 2 + 2 hrs. at 850°F with an air quench after each temper.

Primary direction is the direction of lowest Y.S. (transverse for this alloy).

TABLE IV

CUMULATIVE VASCOJET-1000 BENT BEAM TESTS

High Strength (Y. S.) Samples

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Applied Stress* Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	260	195	6	6	2.2 hrs	1.1 hrs to 2.7 hrs
	Secondary	256	192	6	6	0.6	1 hr to 0.5 days
	Secondary**	256	192	6	6	0.3	2 hrs to 0.5 days
NaNO ₃	Primary	260	195	6	6	4.1 hrs	2.7 to 6.7 hrs
	Secondary	256	192	6	6	19.0	8.5 to 25.5
	Secondary**	256	192	6	6	22.3	8.5 to 28.5
Na ₂ S	Primary	260	195	-	-	--	--
	Secondary	256	192	-	-	--	--
Na ₂ SO ₄	Primary	260	195	6	6	7.4	5.2 to 9.6
	Secondary	256	192	6	6	1.4	0.5 to 3
NaPO ₃	Primary	260	195	6	6	45.3 min	33 min to 51 min
	Secondary	256	192	6	6	3.3 hrs	1.6 hrs to 5 hrs

* Samples stressed to 75% of their Y.S. in holders.

** Seven-inch bent beam specimens; all others are four-inch.

Note: These samples were austenitized at 1900°F for 40 min., oil quenched, and tempered for 2 + 2 + 2 hrs, at 975°F with an air quench after each temper.

Primary direction is the direction of lowest Y.S. (transverse for this alloy).

TABLE V

CUMULATIVE AM355 STRESS CORROSION BENT BEAM TESTS

Primary (Lowest Y.S.) Direction

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Applied Stress* Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	224	168	4	none to 122 days	--	--
	Primary	235	176	4	none to 122 days	--	--
	Primary	274	205	4	none to 122 days	--	--
NaNO ₃	Primary	224	168	4	none to 122 days	--	--
	Primary	235	176	4	none to 122 days	--	--
	Primary	274	205	4	none to 122 days	--	--
Na ₂ S	Primary	224	168	--	--	--	--
	Primary	235	176	--	--	--	--
	Primary	274	205	--	--	--	--
Na ₂ SO ₄	Primary	224	168	4	none to 122 days	--	--
	Primary	235	176	4	none to 122 days	--	--
	Primary	274	205	4	none to 122 days	--	--
NaPO ₃	Primary	224	168	4	none to 122 days	--	--
	Primary	235	176	4	none to 122 days	--	--
	Primary	274	205	4	none to 122 days	--	--

* Samples stressed to 75% of Y.S. in holder.

Sheet material rolled to strength by vendor; three Y.S. levels are 224, 235, and 274 Kpsi. Primary direction is direction of lowest Y.S. (transverse direction for this alloy).

TABLE VI

CUMULATIVE AM355 STRESS CORROSION BENT BEAM TESTS

Test Solution	Direction* of Specimen	Applied Stress Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Secondary	180	6	none to 302 days	--	--
	Secondary	195	6	none to 286 days	--	--
	Secondary	226	6	none to 299 days	--	--
NaNO ₃	Secondary	180	6	none to 302 days	--	--
	Secondary	195	6	none to 286 days	--	--
	Secondary	226	6	none to 299 days	--	--
Na ₂ S	Secondary	180	6	none to 302 days	--	--
	Secondary	195	6	none to 286 days	--	--
	Secondary	226	6	none to 299 days	--	--
Na ₂ SO ₄	Secondary	180	6	none to 302 days	--	--
	Secondary	195	6	none to 291 days	--	--
	Secondary	226	6	none to 304 days	--	--
NaPO ₃	Secondary	180	6	none to 302 days	--	--
	Secondary	195	6	none to 291 days	--	--
	Secondary	226	6	none to 304 days	--	--

Note: These specimens were cold-rolled to strength level.

The outer surface of the specimens is stressed to 75% of its Y.S.

(250 Kpsi, 261 Kpsi, and 302 Kpsi, resp.)

Above tests considered complete as of January 2, 1962.

* Primary direction is direction of lowest Y.S. (transverse direction for this alloy).

TABLE VII

CUMULATIVE PIH5-7Mo STRESS CORROSION BENT BEAM TESTS

High Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Applied Stress* Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	296	214	4	none to 130 days	--	--
	Secondary	--	--	--	--	--	--
NaNO ₃	Primary	286	214	4	none to 130 days	--	--
	Secondary	--	--	--	--	--	--
Na ₂ S	Primary	286	214	4	none to 130 days	--	--
	Secondary	--	--	--	--	--	--
Na ₂ SO ₄	Primary	286	214	4	none to 130 days	--	--
	Secondary	--	--	--	--	--	--
NaPO ₃	Primary	286	214	4	none to 130 days	--	--
	Secondary	--	--	--	--	--	--

* Samples stressed to 75% of Y.S. in holder.

CR sheet material tempered 1 hr. at 900°F.

Primary direction is direction of lowest Y.S. (transverse direction for this alloy).

TABLE VIII

CUMULATIVE B120VCA STRESS CORROSION BENT BEAM TESTS

High Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Applied Stress* Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	--	--	--	--	--	--
	Secondary	198	148	4	none to 130 days	--	--
NaNO ₃	Primary	--	--	--	--	--	--
	Secondary	198	148	4	none to 130 days	--	--
Na ₂ S	Primary	--	--	--	--	--	--
	Secondary	198	148	4	none to 130 days	--	--
Na ₂ SO ₄	Primary	--	--	--	--	--	--
	Secondary	198	148	4	none to 130 days	--	--
NaPO ₃	Primary	--	--	--	--	--	--
	Secondary	198	148	4	none to 130 days	--	--

* Samples stressed to 75% of Y.S. in holder.

Solution-treated, as-received material was aged for 200 hrs. in argon at 900°F.

Primary direction is direction of lowest Y.S. (transverse direction for this alloy).

TABLE IX

CUMULATIVE 4137 Co STRESS CORROSION BENT BEAM TESTS*

Natural Environment	Applied Stress on Specimen** Kpsi	Direction of Specimen	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
Marine Exposure Kure Beach, N.C.	190 ⁺	Primary	3	3	8	3 to 16
	160 ⁺⁺	Primary	5	5	13	6 to 18
	130 ⁺⁺⁺	Primary	5	none to 551 days	--	--
Semi-Industrial Exposure Monroeville, Pa.	190	Primary	5	5	19	2 to 30
	160	Primary	5	5	35	18 to 45
	130	Primary	5	none to 551 days	--	--

* Cooperative testing program with U. S. Steel Applied Research Lab., Monroeville, Pa.

** All specimens stressed to 75% of Y.S.

Note: These specimens were austenitized at 1700°F for 30 min and tempered at 550, 750 and 1100°F for 2 + 1 hrs producing Y.S. of 255, 213, and 174 Kpsi, respectively.

The primary direction is direction of lowest Y.S. (transverse for this alloy).

+ 550°F Temper ++ 750°F Temper +++ 1100°F Temper

TABLE X

CUMULATIVE 4137 Co STRESS CORROSION BENT BEAM TESTS

Severe Industrial Exposure (Pittsburgh, Pennsylvania)

% of Y.S. for Test	Applied Stress on Specimen, Kpsi	Direction of Specimen	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
50	130 ⁺	Primary	6	4 to 424 days	--	--
	115 ++	Primary	5	none to 424 days	--	--
	95 +++	Primary	6	none to 424 days	--	--
75	195	Primary	6	6	47.2	30 to 65
	175	Primary	6	4 to 424 days	--	--
	140	Primary	6	none to 424 days	--	--
90	230	Primary	6	6	33.6	21 to 43
	200	Primary	5	5	143.2	88 to 203
	170	Primary	6	none to 424 days	--	--

Note: These specimens were austenitized at 1700°F for 30 min and tempered at 550, 750 and 1100°F for 2 + 1 hrs producing Y.S. of 258, 232 and 191 Kpsi, respectively.
The primary direction is direction of lowest Y.S.

+ 550°F Temper ++ 750°F Temper +++ 1100°F Temper

TABLE XI

CUMULATIVE 300M STRESS CORROSION U-BEND TESTS

Primary Heat
Low Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure,		Failure Time Range, days
		(.2% Offset) Kpsi					days		
NaCl	Primary	-	-	-	6	none to 53 days	--	--	--
	Secondary	~ 200	-	-	6	none to 89 days	--	--	--
NaNO ₃	Primary	-	-	-	6	none to 53 days	--	--	--
	Secondary	~ 200	-	-	6	none to 89 days	--	--	--
Na ₂ S	Primary	-	-	-	6	none to 89 days	--	--	--
	Secondary	~ 200	-	-	6	none to 89 days	--	--	--
Na ₂ SO ₄	Primary	-	-	-	6	none to 53 days	--	--	--
	Secondary	~ 200	-	-	6	1 to 89 days	--	--	--
NaPO ₃	Primary	-	-	-	5	5	23.8 min	20.5 to 28.5 min	
	Secondary	~ 200	-	-	6	6	3.0 hrs	1 to 12 hrs	

* Y.S. estimated; tensile results not yet available.

Note: These specimens were austenitized at 1650° F for 20 min., oil quenched, and tempered at 1000° F for 2 + 2 hrs. with an air quench after each.
The primary direction is the direction of lowest Y.S. (transverse for this alloy).

TABLE XII

CUMULATIVE 300M STRESS CORROSION U-BEND TESTS

Primary Heat
Intermediate Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset)	Kpsi					
NaCl	Primary	-	-	-	6	4 to 53 days	--	--
	Secondary	~220	-	-	5	none to 101 days	--	--
NaNO ₃	Primary	-	-	-	6	6	12.0	4.5 to 19.5
	Secondary	~220	-	-	5	none to 101 days	--	--
Na ₂ S	Primary	-	-	-	4	none to 53 days	--	--
	Secondary	~220	-	-	5	none to 101 days	--	--
Na ₂ SO ₄	Primary	-	-	-	6	6	1.6**	4 min to 5.5 days
	Secondary	~220	-	-	5	4 to 101 days	--	--
NaPO ₃	Primary	~220	-	-	6	6	7.0 min	6 to 8.5 min
	Secondary	~220	-	-	5	5	12.0 min	9 to 19 min

* Y.S. estimated; tensile results not yet available.

** One sample lasting 28 days not averaged.

Note: These specimens were austenitized at 1650° F for 20 min., oil quenched, and tempered at 800° F for 2 + 2 hrs. with an air quench after each.

The primary direction is the direction of lowest Y.S. (transverse for this alloy).

TABLE XIII

CUMULATIVE 300M STRESS CORROSION U-BEND TESTS

Primary Heat
High Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time		Failure Time Range, days
		(.2% Offset) Kpsi	(.2% Offset) Kpsi				to Failure, days	to Failure, days	
NaCl	Primary	~ 250	-	-	6	6	9.2 min	**	1 to 30 min
	Secondary	~ 250	-	-	6	6	6.8 hrs		8 min to 27 hrs
NaNO ₃	Primary	~ 250	-	-	6	6	15.0 hrs		2 to 40 hrs
	Secondary	~ 250	-	-	6	6	31.9 hrs		12 to 59 hrs
Na ₂ S	Primary	~ 250	-	-	6	none to 101 days	--	--	--
	Secondary	~ 250	-	-	6	none to 101 days	--	--	--
Na ₂ SO ₄	Primary	~ 250	-	-	6	6	8.8 min		4 to 16 min
	Secondary	~ 250	-	-	6	6	2.8 hrs		15 min to 12 hrs
NaPO ₃	Primary	~ 250	-	-	6	6	6.7 min		5 to 8 min
	Secondary	~ 250	-	-	6	6	9.5 min		5 to 13 min

* Y.S. estimated; tensile results not yet available.

** One sample lasting 59.5 hrs. not averaged.

Note: These specimens were austenitized at 1650°F for 20 min., oil quenched, and tempered at 550°F for 2 + 2 hrs. with an air quench after each.
The primary direction is the direction of lowest Y.S. (transverse for this alloy).

TABLE XIV

CUMULATIVE 300M STRESS CORROSION U-BEND TESTS

Comparative Heat
Low, Intermediate, and High Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset) Kpsi	(.2% Offset) Kpsi					
NaCl	Secondary	250	-	-	6	6	65.5 hrs	40.5 to 93.5 hrs
	Secondary	220	-	-	6	none to 23 days	--	--
	Secondary	200	-	-	6	none to 53 days	--	--
NaNO ₃	Secondary	250	-	-	6	6	26.0 hrs	12 to 40 hrs
	Secondary	220	-	-	6	3 to 53 days	--	--
	Secondary	200	-	-	6	none to 53 days	--	--
Na ₂ S	Secondary	250	-	-	6	none to 101 days	--	--
	Secondary	220	-	-	-	-	--	--
	Secondary	200	-	-	-	-	--	--
Na ₂ SO ₄	Secondary	250	-	-	6	6	39.1 hrs	12 to 58.5 hrs
	Secondary	220	-	-	6	none to 23 days	--	--
	Secondary	200	-	-	6	none to 53 days	--	--
NaPO ₃	Secondary	250	-	-	6	6	16.2 min	12 to 20 min
	Secondary	220	-	-	6	6	18.6 min	14 min to 31 min
	Secondary	200	-	-	6	5 to 53 days	--	--

* Y.S. estimated; tensile results not yet available.

Note: These specimens were austenitized at 1650°F for 20 min., oil quenched, and tempered at 550°F for 2 + 2 hrs. with an air quench after each.
The primary direction is the direction of lowest Y.S. (transverse for this alloy).

TABLE XV
CUMULATIVE AM355 STRESS CORROSION U-BEND TESTS

Low Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset) Kpsi						
NaCl	Primary	224		277	6	2 to 144 days	--	--
	Secondary	250		261	6	none to 223 days	--	--
NaNO ₃	Primary	224		277	6	none to 144 days	--	--
	Secondary	250		261	6	none to 223 days	--	--
Na ₂ S	Primary	224		277	6	none to 144 days	--	--
	Secondary	250		261	6	none to 223 days	--	--
Na ₂ SO ₄	Primary	224		277	6	none to 144 days	--	--
	Secondary	250		261	6	none to 223 days	--	--
NaPO ₃	Primary	224		277	6	none to 144 days	--	--
	Secondary	250		261	6	none to 223 days	--	--

Note: These specimens were cold-rolled to strength.

The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is direction of lowest Y.S. (transverse direction of this alloy).

Specimen thickness - .038 inches.

TABLE XVI

CUMULATIVE AM355 STRESS CORROSION U-BEND TESTS

Intermediate Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset)	Kpsi					
NaCl	Primary	235		286	6	6	6.3	0.5 to 14.5
	Secondary	261		271	6	1 to 222 days	--	--
NaNO ₃	Primary	235		286	6	none to 222 days	--	--
	Secondary	261		271	6	none to 222 days	--	--
Na ₂ S	Primary	235		286	6	none to 222 days	--	--
	Secondary	261		271	6	none to 222 days	--	--
Na ₂ SO ₄	Primary	235		286	6	none to 222 days	--	--
	Secondary	261		271	6	none to 222 days	--	--
NaPO ₃	Primary	235		286	6	none to 222 days	--	--
	Secondary	261		271	6	none to 222 days	--	--

Note: These specimens were cold-rolled to strength level.

The outer surface of the test specimen is stressed beyond its Y.S.

Primary direction is the direction of lowest Y.S. (transverse direction for this alloy).

Specimen thickness - .0365 inches.

TABLE XVII
CUMULATIVE AM355 STRESS CORROSION U-BEND TESTS

High Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time		Failure Time Range, days
		(.2% Offset) Kpsi	(.2% Offset) Kpsi				to Failure, days	to Failure, days	
NaCl	Primary	274	307	6	6	1	6	3.25	0.5 to 8
	Secondary	302	311	6	6	to 222 days		--	--
NaNO ₃	Primary	274	307	6	6	none to 369 days		--	--
	Secondary	302	311	6	6	none to 222 days		--	--
Na ₂ S	Primary	274	307	6	6	none to 369 days		--	--
	Secondary	302	311	6	6	none to 222 days		--	--
Na ₂ SO ₄	Primary	274	307	6	6	none to 369 days		--	--
	Secondary	302	311	6	6	none to 222 days		--	--
NaPO ₃	Primary	274	307	6	6	none to 369 days		--	--
	Secondary	302	311	6	6	none to 222 days		--	--

Note: These specimens were cold-rolled to strength level.

The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is direction of lowest Y.S. (transverse direction for this alloy).

Specimen thickness - .033 inches.

TABLE XVIII

CUMULATIVE PH15-7Mo STRESS CORROSION U-BEND TESTS

Low Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset) Kpsi						
NaCl	Primary	201		238	6	none to 397 days	--	--
	Secondary	218		221	6	none to 397 days	--	--
NaNO ₃	Primary	201		238	5	none to 397 days	--	--
	Secondary	218		221	6	none to 397 days	--	--
Na ₂ S	Primary	201		238	6	none to 397 days	--	--
	Secondary	218		221	6	none to 397 days	--	--
Na ₂ SO ₄	Primary	201		238	5	none to 397 days	--	--
	Secondary	218		221	6	none to 397 days	--	--
NaPO ₃	Primary	201		238	5	none to 397 days	--	--
	Secondary	218		221	6	none to 397 days	--	--

Note: These specimens are in the cold-rolled condition, as received.

The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is direction of lowest Y.S. (transverse direction for this alloy).
Specimen thickness - 0.032 inches.

TABLE XIX

CUMULATIVE PIH5-7Mo STRESS CORROSION U-BEND TESTS

Low-Intermediate Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset)	Kpsi					
NaCl	Primary	208		214	6	none to 199 days	--	--
	Secondary	224		229	6	none to 199 days	--	--
NaNO ₃	Primary	208		214	6	none to 199 days	--	--
	Secondary	224		229	6	none to 199 days	--	--
Na ₂ S	Primary	208		214	6	none to 199 days	--	--
	Secondary	224		229	6	none to 199 days	--	--
Na ₂ SO ₄	Primary	208		214	6	none to 199 days	--	--
	Secondary	224		229	6	none to 199 days	--	--
NaPO ₃	Primary	208		214	6	none to 199 days	--	--
	Secondary	224		229	6	none to 199 days	--	--

Note: These specimens were tempered at 1125°F for 1 hr.

The outer surface of the specimens is stressed beyond its Y.S.

Primary direction is the direction of lowest Y.S. (transverse direction for this alloy).

TABLE XX

CUMULATIVE PH15-7Mo STRESS CORROSION U-BEND TESTS

High-Intermediate Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset)	Kpsi					
NaCl	Primary	244		254	6	none to 199 days	--	--
	Secondary	258		263	6	none to 199 days	--	--
NaNO ₃	Primary	244		254	6	none to 199 days	--	--
	Secondary	258		263	6	none to 199 days	--	--
Na ₂ S	Primary	244		254	6	none to 199 days	--	--
	Secondary	258		263	6	none to 199 days	--	--
Na ₂ SO ₄	Primary	244		254	6	none to 199 days	--	--
	Secondary	258		263	6	none to 199 days	--	--
NaPO ₃	Primary	244		254	6	none to 199 days	--	--
	Secondary	258		263	6	none to 199 days	--	--

Note: These specimens were tempered at 1075°F for 1 hr.

The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is direction of lowest Y.S. (transverse direction for this alloy).

TABLE XXI
CUMULATIVE PH15-7Mo STRESS CORROSION U-BEND TESTS

High Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset) Kpsi	Strength Kpsi					
NaCl	Primary	286	293	6	none to 199 days	--	--	--
	Secondary	289	290	6	none to 199 days	--	--	--
NaNO ₃	Primary	286	293	6	none to 199 days	--	--	--
	Secondary	289	290	6	none to 199 days	--	--	--
Na ₂ S	Primary	286	293	6	none to 199 days	--	--	--
	Secondary	289	290	6	none to 199 days	--	--	--
Na ₂ SO ₄	Primary	286	293	6	none to 199 days	--	--	--
	Secondary	289	290	6	none to 199 days	--	--	--
NaPO ₃	Primary	286	293	6	none to 199 days	--	--	--
	Secondary	289	290	6	none to 199 days	--	--	--

Note: These specimens were tempered at 900°F for 1 hr.
The outer surface of the specimen is stressed beyond its Y.S.
Primary direction is direction of lowest Y.S. (transverse direction for this alloy).

TABLE XXII

CUMULATIVE PH15-7Mo AND AM355 STRESS CORROSION U-BEND TESTS

Test Solution	Type of Steel	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
			(.2% Offset)	Kpsi					
Carbon tetrachloride CCl_4 (chlorinated non hydrocarbon)	PH15-7Mo	Primary	201		238	6	1 to 325 days	--	--
	PH15-7Mo	Secondary	218		221	6	none to 325 days	--	--
	AM355	Primary	274		307	6	none to 325 days	--	--
	AM355	Primary	235		286	6	none to 325 days	--	--
Pentane C_5H_{12} (non chlorinated hydrocarbon)	PH15-7Mo	Primary	201		238	6	none to 325 days	--	--
	PH15-7Mo	Secondary	218		221	6	none to 325 days	--	--
	AM355	Primary	274		307	6	none to 325 days	--	--
	AM355	Primary	235		286	6	none to 325 days	--	--
Trichloroethane $\text{C}_2\text{H}_2\text{Cl}$ (chlorinated hydrocarbon)	PH15-7Mo	Primary	201		238	5	none to 325 days	--	--
	PH15-7Mo	Secondary	218		221	6	none to 325 days	--	--
	AM355	Primary	274		307	6	none to 325 days	--	--
	AM355	Primary	235		286	6	none to 325 days	--	--

Note: These specimens were cold-rolled to strength level.

The outer surface of the specimen is stressed beyond its Y.S.

Primary direction is the direction of lowest Y.S. (transverse direction for these alloys).

TABLE XXIII
CUMULATIVE BI20VCA STRESS CORROSION U-BEND TESTS

Primary Heat
Low Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
		(.2% Offset) Kpsi	Strength Kpsi					
NaCl	Primary	139	140	4	4	none to 188 days	--	--
	Secondary	143	145	4	4	none to 480 days	--	--
NaNO ₃	Primary	139	140	4	4	none to 188 days	--	--
	Secondary	143	145	4	4	none to 480 days	--	--
Na ₂ S	Primary	139	140	4	4	none to 188 days	--	--
	Secondary	143	145	4	4	none to 188 days	--	--
Na ₂ SO ₄	Primary	139	140	4	4	none to 188 days	--	--
	Secondary	143	145	4	4	none to 188 days	--	--
NaPO ₃	Primary	139	140	4	4	none to 188 days	--	--
	Secondary	143	145	4	4	none to 480 days	--	--

Note: These specimens are in the "as received" condition.
The outer surface of the specimen is stressed beyond its Y.S.
The primary direction is direction of lowest Y.S.

TABLE XXIV

CUMULATIVE BL20VCA(HT1)* STRESS CORROSION U-BEND TESTS

Low Strength (Y.S.) Samples

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	141	143	4	none to 188 days	--	--
	Secondary	144	148	4	none to 188 days	--	--
NaNO ₃	Primary	141	143	4	none to 188 days	--	--
	Secondary	144	148	4	none to 188 days	--	--
Na ₂ S	Primary	141	143	4	none to 188 days	--	--
	Secondary	144	148	4	none to 188 days	--	--
Na ₂ SO ₄	Primary	141	143	4	none to 188 days	--	--
	Secondary	144	148	4	none to 188 days	--	--
NaPO ₃	Primary	141	143	4	none to 188 days	--	--
	Secondary	144	148	4	none to 188 days	--	--

*HT1 refers to comparative heat number 1.

Note: These specimens were taken in the "as received" condition.
 The outer surface of the specimen is stressed beyond its Y.S.
 The primary direction is direction of lowest Y.S.

TABLE XXV

CUMULATIVE 4137 Co STRESS CORROSION U-BEND TESTS

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	Primary	258	285	6	6	4.3	0.5 to 11.5
	Primary	232	260	6	6	126.0	38 to 224
	Primary	191	198	6	6	446.0	367 to 532
NaNO ₃	Primary	258	285	6	6	1.2	0.5 to 1.5
	Primary	232	260	6	6	33.8	29.5 to 39.5
	Primary	191	198	6	6	122.6	26 to 292
Na ₂ S	Primary	258	285	5	2 to 454 days	--	--
	Primary	232	260	6	1 to 454 days	--	--
	Primary	191	198	6	none to 454 days	--	--
Na ₂ SO ₄	Primary	258	285	6	6	0.9	10 min to 2.5 days
	Primary	232	260	5	5	451	420 to 501
	Primary	191	198	6	5 to 588 days	--	--
NaPO ₃	Primary	258	285	6	6	4.5 min *	3 to 6 min
	Primary	232	260	6	6	0.3 days **	34 min to 5 days
	Primary	191	198	6	6	1.5 days **	0.5 to 27 days

* One specimen lasting 5 days not averaged.

** One specimen lasting 27 days not averaged.

Note: These specimens were austenitized at 1700°F for 30 min and tempered at 550, 750 and 1100°F, respectively for 2 + 1 hrs.

The outer surface of the specimen is stressed beyond its Y.S.

The primary direction is direction of lowest Y.S.

TABLE XXVI

CUMULATIVE 4137 Co STRESS CORROSION U-BEND TESTS

Test Solution	Direction of Specimen	Y.S. (.2% Offset) Kpsi	Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
Dry Air (desiccator)	Primary	258	285	3	none to 455 days	--	--
	Primary	232	260	3	none to 455 days	--	--
	Primary	191	198	3	none to 455 days	--	--
Humid Air (satur. with water vapor)	Primary	258	285	4	4	6.4	4 to 11.5
	Primary	232	260	4	4	54.5	3 to 143
	Primary	191	198	4	none to 447 days	--	--
Laboratory (exposed directly to lab. environ.)	Primary	258	285	4	none to 447 days	--	--
	Primary	232	260	4	none to 447 days	--	--
	Primary	191	198	4	none to 447 days	--	--

Note: These specimens were austenitized at 1700°F for 30 min and tempered at 550, 750 and 1100°F, respectively for 2 + 1 hrs.

The outer surface of the specimen is stressed beyond its Y.S.

The primary direction is direction of lowest Y.S.

TABLE XXVII
CUMULATIVE ARDEFORM 301 STRESS CORROSION U-BEND TESTS

(Sample 1)

Test Solution	Direction of Specimen	Test Surface in Tension	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time		Failure Time Range, days
			(.2% Offset)	Kpsi				to Failure, days	to Failure, days	
NaCl	Long.	Outside (convex)	183		229	4	4	1.25		0.5 to 2.0
	Long.	Inside (concave)	183		229	4	3 to 280 days	--		--
	Trans.	Outside	--		--	6	none to 280 days	--		--
NaNO ₃	Long.	Outside	183		229	4	none to 280 days	--		--
	Long.	Inside	183		229	4	none to 280 days	--		--
	Trans.	Outside	--		--	6	none to 280 days	--		--
Na ₂ S	Long.	Outside	183		229	4	none to 280 days	--		--
	Long.	Inside	183		229	4	none to 280 days	--		--
	Trans.	Outside	--		--	6	none to 280 days	--		--
Na ₂ SO ₄	Long.	Outside	183		229	4	none to 280 days	--		--
	Long.	Inside	183		229	4	none to 280 days	--		--
	Trans.	Outside	--		--	6	none to 280 days	--		--
Na ₃ PO ₃	Long.	Outside	183		229	4	none to 278 days	--		--
	Long.	Inside	183		229	4	none to 278 days	--		--
	Trans.	Outside	--		--	6	none to 278 days	--		--

Note: These specimens are in the "as received" condition.
The outer surface of the specimen is stressed beyond its Y. S.

TABLE XXVIII

CUMULATIVE ARDEFORM 301 STRESS CORROSION U-BEND TESTS

(Sample 2)

Test; Solution	Direction of Specimen	Test Surface in Tension	Y.S.		Tensile Strength Kpsi	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
			Kpsi	(.2% Offset)					
NaCl	Long.	Outside (convex)	209		235	6	2 to 339 days	--	--
	Long.	Inside (concave)	209		235	4	3 to 339 days	--	--
	Trans.	Outside	--		--	5	none to 339 days	--	--
NaNO ₃	Long.	Outside	209		235	5	none to 339 days	--	--
	Long.	Inside	209		235	4	none to 339 days	--	--
	Trans.	Outside	--		--	5	none to 339 days	--	--
Na ₂ S	Long.	Outside	209		235	4	none to 339 days	--	--
	Long.	Outside	209		235	-	none to 339 days	--	--
	Trans.	Outside	--		--	5	none to 339 days	--	--
Na ₂ SO ₄	Long.	Outside	209		235	4	none to 339 days	--	--
	Long.	Inside	209		235	3	none to 339 days	--	--
	Trans.	Outside	--		--	5	none to 339 days	--	--
NaPO ₃	Long.	Outside	209		235	4	none to 339 days	--	--
	Long.	Inside	209		235	4	none to 339 days	--	--
	Trans.	Outside	--		--	5	none to 339 days	--	--

Note: These specimens are in the "as received" condition.
The outer surface of the specimen is stressed beyond the Y.S.

TABLE XXIX
CUMULATIVE U-MODIFIED 4137 Co U-BEND TESTS

High Strength (Y. S.) Samples

Test Solution	Sample Designation	Direction of Specimen	Tempering Temp., °F	No. of Specimens	Failures to Date	Average Time to Failure, days	Failure Time Range, days
NaCl	MV-38	Secondary	400	2	none to 235 days	--	--
	MV-38	Secondary	500	2	none to 235 days	--	--
	MV-38	Secondary	600	2	none to 235 days	--	--
NaCl	MV-40	Secondary	400	2	none to 235 days	--	--
	MV-40	Secondary	500	2	none to 235 days	--	--
	MV-40	Secondary	600	2	1 to 235 days	one failed at 208 days	--
NaCl	MV-41	Secondary	400	2	none to 235 days	--	--
	MV-41	Secondary	500	2	none to 235 days	--	--
	MV-41	Secondary	600	2	none to 235 days	--	--

Note: These samples were austenitized at 1700°F for 30 min., oil quenched, and tempered at 400, 500, and 600°F for 2 + 1 hours, an air quench following each temper.

The outer surface of the specimen is stressed beyond its Y. S.

The primary direction is the direction of lowest Y. S. (transverse for this alloy).

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