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STRESS CORROSION CRACKING EVALUATION OF SEVERAL PRECIPITATION HARDENING STAINLESS STEELS

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16. ABSTRACT

The stress corrosion cracking resistance of precipitation hardening stainless steels PH 13-8 Mo, PH 14-8 Mo, 15-5 PH, PH 15-7 Mo, 17-4 PH, 17-7 PH, A-286, Almar 362, AM-350, and Unitemp 212 are presented. Three types of specimens (round tensile, flat tensile, and C-rings) were employed and were subjected to alternate immersion in a 3.5 percent salt solution. The results indicated that under these test conditions, PH 13-8 Mo, PH 14-8 Mo, 15-5 PH, 17-4 PH, A-286, Almar 362, and Unitemp 212 stainless steels are highly resistant to stress corrosion cracking in practically all forms and heat treat conditions. Alloys PH 15-7 Mo and 17-7 PH are susceptible to stress corrosion cracking in nearly all heat treat conditions except CH 900, and AM-350 is susceptible in Condition SCT 850 but resistant to stress corrosion cracking in Condition SCT 1000.

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SUMMARY

Numerous stress corrosion failures of space vehicle components fabricated from precipitation hardening stainless steels have been encountered. Most of these problems were solved by changing to a more stress corrosion resistant alloy or heat treat condition. Unfortunately only a limited amount of published data is available on the stress corrosion cracking characteristics of the precipitation hardening (PH) stainless steels. Because of this, a test program was initiated to evaluate the stress corrosion resistance of the more frequently used PH stainless steels in an accelerated test solution (alternate immersion in 3.5 percent salt solution) representative of the general service environment of space vehicles prior to launch.

The results of this investigation indicated that PH 13-8 Mo, PH 14-8 Mo, 15-5 PH, 17-4 PH, A-286, Almar 362, and Unitemp 212 stainless steels are highly resistant to stress corrosion cracking in 3.5 percent salt water in all heat treat conditions tested. PH 15-7 Mo and 17-7 PH stainless steels were susceptible to stress corrosion cracking in all conditions except 17-7 PH-CH 900, and PH 15-7 Mo is reportedly highly resistant in the CH 900 condition [1]. AM-350 stainless steel was susceptible in the SCT 850 condition but resistant in the SCT 1000 condition.

INTRODUCTION

High strength stainless steels and the so called superalloys have played an important role in the advent and growth of jet engines, missiles, supersonic aircraft and space vehicles. The precipitation hardening stainless steels are among the more important materials that have made possible the rapid growth in these fields.

The PH stainless steels combine the excellent corrosion resistance of the austenitic chromium - nickel steels with the heat hardening characteristics of the straight chromium, martensitic steels [1]. Many of the problems encountered with normal high temperature heat treatments are eliminated by the relatively low temperature aging treatment of the PH stainless steels, which are basically of two types: (1) martensitic and (2) semi-austenitic.

The PH stainless steels like the hardenable chromium stainless steels may under certain conditions of tensile stress and corrosive environment suffer stress corrosion. As with most metals, the stress corrosion cracking susceptibility normally increases with increasing hardness or strength. However, susceptibility is not governed solely by hardness or strength of the material, but in certain cases appears to be associated with the process procedure used to obtain these properties. For example, both 17-7 PH and PH 15-7 Mo stainless steels exhibit the highest resistance to stress corrosion cracking in Condition CH 900 although this condition gives the highest hardness of any of the available heat treat conditions of these two alloys [2].

EXPERIMENTAL PROCEDURES

The PH stainless steels evaluated in this investigation were PH 13-8 Mo, PH 14-8 Mo, 15-5 PH, PH 15-7 Mo, 17-4 PH, 17-7 PH, A-286, Almar 362, AM-350, and Unitemp 212 in the form of bar stock and/or sheet. Three types of specimens were required to test the material in at least two directions of grain orientation. Flat tensile specimens, loaded by constant deflection, were used for testing sheet material; round tensile specimens, stressed in direct tension, were used for testing the longitudinal direction of all bar stock and the transverse direction of two inch or greater diameter bar; and C-rings, utilizing the constant deflection method, were used for testing the transverse direction of bar stock of less than two inch diameter. In one case, (17-4 PH Condition A) flat tensile specimens were stressed in direct tension, and this is illustrated along with the other methods of loading in Figures 1, 2, and 3.

The specimens were deflected or strained the calculated amount to give the desired stress levels, wiped with acetone, and placed in the alternate immersion tester until failure or until the test was terminated (approximately six months). A detailed description of the test specimens, formulas for calculating deflection and strain, and methods of loading and testing is given in Reference 3. Mechanical properties of the alloys were measured in both directions of testing. The chosen stress level was from 25 to 100 percent of the directional yield strength except as noted for small diameter bar. Duplicate unstressed tensile specimens were exposed under identical conditions for comparative control. The tests were conducted in a ferris wheel type alternate immersion tester (Figure 4) containing a 3.5 percent solution (deionized water) of sodium chloride, with an immersion cycle of 10 minutes in solution followed by 50 minutes of drying above the solution.

RESULTS AND DISCUSSION

The compositions of the alloys evaluated in this program are listed in Table I. In some cases, the typical analysis is given because the composition of the specific material was not available. The mechanical properties and the heat treatments used to obtain the properties of the PH stainless steels are shown in Tables II and III, respectively. Listed in Table IV are the complete stress corrosion results obtained in this investigation.

Armco's* martensitic PH stainless steels (PH 13-8 Mo, 15-5 PH, and 17-4 PH) were found to possess a higher degree of stress corrosion resistance than their semi-austenitic type (PH 15-7 Mo, and 17-7 PH). No failures were encountered in the three martensitic stainless steels in most forms and heat treat conditions tested at loads up to 100 percent of their yield strengths. The only stress corrosion failure occurred in 17-4 PH-H 900 bar stock stressed in the transverse grain direction to 100 percent of the yield strength. This agrees with information published by Armco[2], which states that, for maximum resistance to stress corrosion cracking, 17-4 PH should be hardened at the highest temperature that will yield required properties, but not less that 1000°F. However, the results obtained with Condition-A material does not agree with Armco's information that the structure of 17-4 PH Condition A is untempered martensite having poor resistance to stress corrosion cracking. No stress corrosion failures were encountered with either sheet or bar stock of 17-4 PH Condition A at stress loads up to 100 percent yield strength exposed to both alternate immersion in salt water and salt spray.

The semi-austenitic type PH 15-7 Mo and 17-7 PH suffered stress corrosion cracking in all conditions of heat treat except the CH 900. The only condition in which 17-7 PH steel was found to possess a high resistance to stress corrosion cracking was the cold rolled and hardened CH 900. Both PH 14-8 Mo and PH 15-7 Mo are, reportedly, resistant to stress corrosion cracking in Condition CH 900 [1,2]. This is somewhat surprising because the highest mechanical properties obtainable from these three semi-austenitic stainless steels are produced by Condition CH 900. The test results indicated that the transverse grain direction of both sheet and bar of PH 15-7 Mo and 17-7 PH was more susceptible to stress corrosion cracking than the longitudinal direction. In addition, both alloys were more susceptible to stress corrosion cracking when hardened at 950°F than 1100°F (lower mechanical properties). It was reported that PH 15-7 Mo is more resistant to stress corrosion than 17-7 PH and the TH condition is more resistant than the RH[1]. The

*Armco Steel Corporation

results of this investigation did not substantiate these findings. From a stress corrosion standpoint, the semi-austenitic PH 14-8 Mo was similar to the martensitic stainless steels in that this alloy was highly resistant to stress corrosion cracking in all heat treat conditions tested.

Of the remaining precipitation hardening stainless steels tested, A-286, Almar 362, and Unitemp 212 were highly resistant to stress corrosion cracking in all test tempers or conditions. Alloy AM-350 was found to be resistant to stress corrosion cracking in the SCT 1000 condition but susceptible in the higher strength SCT 850 condition. As with alloys PH 15-7 Mo and 17-7 PH, alloy AM-350 was more susceptible to stress corrosion cracking in the transverse grain direction than in the longitudinal direction.

CONCLUSIONS AND RECOMMENDATION

The results obtained with this accelerated test indicated that:

1. The precipitation hardening PH 13-8 Mo, PH 14-8 Mo, 15-5 PH, 17-4 PH, A-286, Almar 362, and Unitemp 212 stainless steels are highly resistant to stress corrosion cracking.

2. Alloys PH 15-7 Mo and 17-7 PH were susceptible to stress corrosion cracking in all heat treat conditions tested except CH 900, and AM-350 was resistant in Condition SCT 1000 but susceptible in Condition SCT 850.

3. Precipitation hardening stainless steels appear to be less resistant to stress corrosion cracking in the transverse direction of grain orientation than in the longitudinal direction.

4. The stress corrosion cracking susceptibility of the precipitation hardening stainless steels generally increased with increasing hardness or strength, but in certain cases appears to be associated with the process procedure used to obtain these properties. Alloy 17-7 PH stainless steel exhibited the highest resistance to stress corrosion cracking in Condition CH 900 and this condition gave the highest hardness and strength of any of the conditions tested.

The stress corrosion cracking resistance should be determined for the precipitation hardening stainless steels in all recommended process and heat treat conditions because of the effect of these conditions on the resistance to stress corrosion cracking.

REFERENCES

1. E. E. Denhard, Jr. "Stress Corrosion Cracking of High Strength Stainless Steels," Stress Corrosion Cracking in Aircraft Structural Materials, AGARD Conference Proceedings No. 18, 1967.

2. Armco Product Data S-6a (17-4 PH), S-21a (15-5 PH), S25 (PH 14-8 Mo), S-30 (17-7 PH), S-33b (PH 13-8 Mo), S-37 (PH 15-7 Mo), Armco Steel Corporation

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

TABLE I. CHEMICAL COMPOSITION OF PRECIPITATION HARDENING STAINLESS STEEL

Alloy	Source & Heat No.	Form	C	Mn	P	S	Si	Cr	Ni	Mo	Al	N	Cu	Cb	Ta	Ti
								Composition Wt %								
PH 13-8 Mo	Armco Steel Corp.**	Bar	.05*	.10*	.010*	.008*	.10*	13.00	8.0	2.25	1.2	.01*				
PH 14-8 Mo Air Melt	Armco Steel Corp. 33024	Sheet	.033	.39	.007	.005	.38	14.61	8.14	2.27	1.23					
PH 14-8 Mo Vacuum Melt	Armco Steel Corp. 5432	Sheet	.032	.05	.003	.004	.05	15.05	8.32	2.21	1.22	.004				
15-5 PH	Armco Steel Corp.**	Bar	.07*	1.00*	.04*	.03*	1.00*	15.00	5.00				3.50	Cb + Ta .30		
PH 15-7 Mo	Armco Steel Corp. 44570	Bar	0.74	.70	.018	.009	.50	15.17	7.33	2.22	1.20					
PH 15-7 Mo	Armco Steel Corp. 850395	Sheet	.070	.66	.018	.012	.38	15.27	7.27	2.21	1.16					
17-4 PH	Armco Steel Corp. 64091	Sheet	.035	.28	.017	.010	.54	15.97	4.37				3.28	.25	.02	
17-4 PH	Armco Steel Corp.**	Bar	.07*	1.00*	.04*	.03*	1.00*	17.00	4.00				4.0	Cb + Ta .30		
17-7 PH	Armco Steel Corp. 850268	Sheet	.069	.50	.012	.015	.41	16.94	7.26		1.18					
17-7 PH	Armco Steel Corp. 63742	Bar	.067	.65	.014	.010	.28	16.83	7.29		1.23					
A-286	**	Bar	.05	1.35			.50	15.00	26.00	1.25	0.2					2.0
AM-350	Allegheny Ludlum 29721**	Sheet	.08	.80			.25	16.50	4.30	2.75		.10				
Almar 362	Allegheny Ludlum A65500	Bar	.029	.35	.017	.018	.20	14.73	6.60	.095	.011		.12			.77
Unitemp 212	Universal Cyclops KH 3765	Bar	.06		<.01	.01		15.94	24.99		<.02		<.01	.57		4.10

* Maximum Allowable

** Typical Analysis or Composition

TABLE II. MECHANICAL PROPERTIES OF PRECIPITATION HARDENING STAINLESS STEEL

Alloy	Form	Heat Treatment	Grain Direction	Tensile Strength (ksi)	Yield Strength (ksi)	Percent Elongation
PH 13-8 Mo	Bar	H 950	Trans.	226	211	16
	Bar		Long.	231	217	15
	Bar	H 1000	Trans.	219	210	14
	Bar		Long.	222	212	10
PH 14-8 Mo Air Melt	Sheet	SRH 950	Trans.	216	194	3
	Sheet		Long.	218	198	10
	Sheet	SRH 1050	Trans.	221	205	5
	Sheet		Long.	218	202	3
PH 14-8 Mo Vacuum Melt	Sheet	SRH 950	Trans.	247	231	5
	Sheet		Long.	242	225	6
	Sheet	SRH 1050	Trans.	241	223	4
	Sheet		Long.	238	230	5
PH 15-5 Mo	Bar	H 900	Long.	189	173	11
	Bar	H 925	Long.	187	163	11
	Bar	H 1025	Long.	164	156	9
15-7 PH	Sheet	RH 950	Trans.	240	225	5
	Sheet		Long.	236	221	7
	Sheet	RH 1050	Trans.	227	220	6
	Sheet		Long.	224	217	7
	Sheet	RH 1075	Trans.	205	201	6
	Sheet		Long.	207	202	6
	Bar	RH 950	Trans.	203	197	3
	Bar		Long.	233	201	18
	Bar	RH 1075	Trans.	202	186	5
	Bar		Long.	203	184	19
17-7 PH	Sheet	H 900	Trans.	215	207	4
	Sheet		Long.	213	206	8
	Bar	Annealed	Trans.	156	124	10
	Bar		Long.	155	151	16
	Bar	H 900	Trans.	200	184	8
	Bar		Long.	198	186	18

TABLE II. MECHANICAL PROPERTIES OF PRECIPITATION HARDENING STAINLESS STEELS (Continued)

Alloy	Form	Heat Treatment	Grain Direction	Tensile Strength (ksi)	Yield Strength (ksi)	Percent Elongation
17-7 PH	Sheet	CH 900*	Trans.	243	228	9
	Sheet		Long	235	228	5
	Sheet	RH 950	Trans.	234	233	6
	Sheet		Long.	230	220	5
	Sheet	RH 1050	Trans.	219	214	5
	Sheet		Long.	217	212	6
	Sheet	RH 1100	Trans.	198	193	6
	Sheet		Long.	193	190	7
	Sheet	TH 1050	Trans.	216	209	7
	Sheet		Long.	213	205	8
	Sheet	TH 1100	Trans.	192	185	7
	Sheet		Long.	190	181	8
	Bar	RH 950	Trans.	187	186	5
	Bar		Long.	184	176	4
	Bar	RH 1050	Trans.	176	171	4
	Bar		Long.	174	170	4
	Bar	RH 1100	Trans.	158	154	4
	Bar		Long.	155	152	5
	Bar	TH 1050	Trans.	173	167	5
	Bar		Long.	170	160	6
	Bar	TH 1100	Trans.	154	148	6
	Bar		Long.	152	145	6
A-286	Bar	No Cold Work	Long	147	95	30
	Bar	>40% Cold Work	Long	203	188	13
AM-350	Sheet	SCT 850	Trans.	210	187	11
	Sheet		Long.	208	189	11
	Sheet	SCT 1000	Trans.	177	164	10
	Sheet		Long.	178	162	12
Almar 362	Bar	1000°F, 3 Hrs.	Long.	167	161	16
Unitemp 212	Bar	Double Aged	Long.	187	135	25
	Bar	Single Aged	Long.	185	136	23

* The tensile and yield strengths are approximately 10 percent below published typical properties.

TABLE III. HEAT TREATMENTS*

1. PH 13-8 Mo, 15-5 PH, and 17-4 PH

   H 900 - 900F, 1 hour, A.C.
   H 925, H950, H1025 - heat at indicated temperature for 4 hours

2. PH 14-8 Mo - SRH 950 and SRH 1050
   Austenite conditioning: 1700F, 1 hour, A.C.
   Transformation cooling: Minus 100F, 8 hours
   Precipitation hardening at indicated temperature for 1 hour

3. PH 15-7 Mo

   a. Condition RH 950 (heat treated per Boeing specification BAC 5619)
      Austenite conditioning: 1725, 10 min. per 0.1 inch section thickness (10 minutes minimum)
      Transformation cooling: Minus 100F, 8 hours
      Precititation hardening: 950F, 1 hour

   b. Condition RH 1075 (Heat Treated per NAR specification MA0111-009)
      Austenite conditioning: 1750, 10 minutes plus 1 minute for each 0.01 inch section thickness, A.C.
      Transformation cooling: Minus 100F, 4 hours
      Precipitation hardening: 1075F, 1 hour

4. 17-7 PH

   a. Condition CH 900 (material cold reduced to Condition C)
      Heated at 900F for one hour

   b. Condition RH 950, RH 1050, and RH 1100
      Austenite conditioning: 1750F, 10 minutes, A.C.
      Transformation cooling: Minus 100F, 8 hours
      Precipitation hardening at indicated temperature for one hour

   c. Condition TH 1050 and TH 1100
      Austenite conditioning: 1400F, 1.5 hour
      Transformation cooling: Within 1 hour to 60F, 1/2 hour
      Precipitation hardening at indicated temperature for 1.5 hour

TABLE III. HEAT TREATMENTS* (Continued)

5. A-286

   a. A-286

      Solution treated 1800F, 2 hours, W.Q., aged 1325F, 16 hours, by vendor

   b. A-286 with cold work

      Solution treated 1800F, 2 hours, W.Q., cold worked 40 percent minimum, aged 1200F, 16 hours, by vendor

6. Almar 362

   Aged 1000F, 3 hours

7. AM 350 - SCT 850 and SCT 1000
   LTA 1710F, 5 minutes, A.C., minus 100F, 3 hours, temper at indicated temperature for 3 hours.

8. Unitemp 212

   a. Double aged - Solution treated 1850F, 2 hours, aged 1425F, 2 hours, A.C., 1250F, 16 hours

   b. Single aged - Solution treated by vendor, aged 1325F, 16 hours, by MSFC

* All material received in the solution treated or annealed condition and heat treated by MSFC except as noted.

TABLE IV. STRESS CORROSION CRACKING TEST RESULTS(1)

Material Form	Heat Treat Condition	Stress Direction	Applied ksi	Stress % YS	Failure Ratio	Days to Failure	% Loss in T.S.
			PH 13-8 Mo Stainless Steel				
Bar Stock (10" Dia.)	H 950	Long.	163	75	0/2	--	N
			196	90	0/2	--	N
		Trans.	158	75	0/2	--	N
			190	90	0/2	--	N
	H 1000	Long.	159	75	0/2	--	N
			191	90	0/2	--	N
		Trans.	158	75	0/3	--	N
			190	90	0/3	--	N
			15-5 PH Stainless Steel				
Bar Stock (2 " Dia.)	H900	Long.	130	75	0/3	--	N
			173	100	0/3	--	N
	H 925	Long	0	0	--	--	N
			123	75	0/3	--	N
			163	100	0/3	--	N
	H 1025	Long	0	0	--	--	N
			117	75	0/3	--	N
			156	100	0/3	--	N
			17-4 PH Stainless Steel				
Sheet (.062")	Condition A (Solution Treated - Annealed)	Long	110	75	0/6(2)	--	N
			148	100	0/6(2)	--	N
			110	75	0/6(2)	--	N
		Trans.	110	75	0/6(2)	--	N
			148	100	0/6(2)	--	N
		Long.	110	75	0/3(3)	--	N
			148	100	0/3(3)	--	N
		Trans.	110	75	0/5(3)	--	N
			148	100	0/3(3)	--	N
Bar Stock (2.5" Dia.)	Condition A (Solution Treated - Annealed)	Long.	0	0	--	--	N
			113	75	0/9(4)	--	N
			151	100	0/9(4)	--	N
		Trans.	0	0	--	--	N
			93	75	0/9(4)	--	N
			124	100	0/9(4)	--	N
Sheet (.062")	H 900	Long.	0	0	--	--	N
			155	75	0/3	--	N
			206	100	0/3	--	N
		Trans.	0	0	--	--	N
			156	75	0/3	--	N
			207	100	0/3	--	N

TABLE IV. STRESS CORROSION CRACKING TEST RESULTS(1) (Continued)

Material Form	Heat Treat Condition	Stress Direction	Applied ksi	Stress % YS	Failure Ratio	Days to Failure	% Loss In T.S.
Bar Stock (2.5" Dia.)	H 900	Long.	0	0	--	--	N
			140	75	0/3	--	N
			186	100	0/3	--	N
		Trans.	0	0	--	--	N
			146	75	0/6	--	N
			195	100	2/6	50,90	N
	H 925	Trans.	0	0	--	--	N
			152	75	0/3	--	N
			202	100	0/3	--	N
Bar Stock (2.5" Dia.)	H 1025	Trans.	0	0	--	--	N
			130	75	0/3	--	N
			174	100	0/3	--	N
		PH 14-8 Mo Stainless Steel					
Sheet (.058" Thick)	SRH 950 Vacuum Melt	Long.	0	0	--	--	6
			182	75	0/3	--	16
			243	100	0/3	--	6
		Trans.	0	0	--	--	17
			185	75	0/3	--	21
			247	100	0/3	--	N
	SRH 1050 Vacuum Melt	Long.	0	0	--	--	14
			173	75	0/3	--	14
			231	100	0/3	--	N
		Trans.	0	0	--	--	21
			185	75	0/3	--	17
			246	100	0/3	--	7
	SRH 950 Air Melt	Long.	0	0	--	--	N
			163	75	0/3	-	19
			218	100	0/3	--	15
		Trans.	0	0	--	--	7
			161	75	0/3	--	10
			216	100	0/3	--	N
	SRH 1050 Air Melt	Long.	0	0	--	--	N
			161	75	0/3	--	13
			218	100	0/3	--	N
		Trans.	0	0	--	--	N
			166	75	0/3	--	18
			221	100	0/3	--	N

TABLE IV. STRESS CORROSION CRACKING TEST RESULTS (1) (Continued)

Material Form	Heat Treat Condition	Stress Direction	Applied Stress ksi	% YS	Failure Ratio	Days to Failure	% Loss In T.S.
			PH 15-7 Mo Stainless Steel				
Sheet (.062" Thick)	RH 900	Long.	0	0	--	--	N
			55	25	0/3	--	N
			110	50	0/3	--	N
			165	75	0/6	--	N
			220	100	3/5	3(2),156	-
		Trans.	0	0	--	--	N
			56	25	0/3	--	N
			112	50	0/3	--	N
			168	75	3/3	3(2),52	-
			224	100	3/3	3(2),4	-
	RH 1075	Long.	0	0	--	--	N
			54	25	0/3	--	N
			108	50	0/3	--	8
			151	75	3/3	10,17(2)	-
			202	100	3/3	5,17(2)	-
		Trans.	0	0	--	--	N
			55	25	0/3	--	N
			110	50	3/3	47,58,100	-
			151	75	3/3	6,17(2)	-
			201	100	3/3	4,5(2)	-
Bar Stock (2.5" Dia.)	RH 950	Long.	0	0	--	--	N
			50	25	0/3	--	8
			101	50	3/3	40,48,70	-
			151	75	3/3	1(2),2	-
			201	100	3/3	1(3)	-
		Trans.	0	0	--	--	10
			56	25	2/3	1,40	N
			112	50	3/3	1 (2),4	-
			150	75	2/2	1 (2)	-
Bar Stock (2.5" Dia.)	RH 1075	Long.	0	0	--	--	N
			46	25	0/3	--	18
			92	50	0/3	--	12
			139	75	3/3	5,6(2)	-
			185	100	3/3	5,15,23	-
		Trans.	0	0	--	--	53
			45	25	2/3	29,34	N
			91	50	3/3	4(3)	-
			136	75	2/2	6(2)	-
			17-7 PH Stainless Steel				
Sheet (.050" Thick)	CH 900	Long.	114	50	0/3	--	N
			171	75	0/3	--	N
			205	90	0/3	--	N
		Trans.	114	50	0/3	--	N
			171	75	0/3	--	N
			205	90	0/3	--	N

TABLE IV. STRESS CORROSION CRACKING TEST RESULTS[1] (Continued)

Material Form	Heat Treat Condition	Stress Direction	Applied ksi	Stress % YS	Failure Ratio	Days to Failure	% Loss In T.S.
Sheet (.062" Thick)	RH 950	Long.	0	0	--	--	N
			100	43	0/3	--	N
			140	61	0/3	--	N
			180	80	4/9	1,165(3)	N
		Trans.	0	0	--	--	N
			100	45	0/3	--	N
			140	64	1/3	71	N
			180	81	6/6	1 to 117	-
	RH 1050	Long.	0	0	--	--	N
			140	65	0/3	--	N
			180	84	2/6	165(2)	N
		Trans.	0	0	--	--	N
			140	65	0/3	--	N
			180	84	5/6	1,51,165(3)	N
Sheet (.062" Thick)	RH 1100	Long.	180	95	0/3	--	N
		Trans.	180	93	0/3	--	N
	TH 1050	Long.	0	0	--	--	N
			140	66	0/3	--	N
			180	87	1/6	165	N
		Trans.	0	0	--	--	N
			140	67	0/3	--	N
			180	88	2/6	165(2)	N
	TH 1100	Long.	180	99	0/3	--	N
		Trans.	180	97	0/3	--	N
Bar Stock (2.5" Dia.)	RH 950	Long	0	0	--	--	N
			50	24	2/3	1,22	N
			100	48	3/3	1(2),4	-
			140	70	3/3	1,5(2)	-
		Trans.	0	0	--	--	23
			50	25	3/3	1(3)	-
			100	50	2/2	1(2)	-
			140	70	3/3	1(3)	-
	RH 1050	Long.	0	0	--	--	N
			50	26	0/3	--	N
			100	52	0/3	--	N
			140	73	2/3	13,29	N
		Trans.	0	0	--	--	11
			50	27	1/3	22	24
			100	55	3/3	1(2),4	-
			140	77	3/3	1(3)	-

TABLE IV. STRESS CORROSION CRACKING TEST RESULTS(1) (Continued)

Material Form	Heat Treat Condition	Stress Direction	Applied Stress ksi	Applied Stress % YS	Failure Ratio	Days to Failure	% Loss In T.S.
	RH 1100	Long.	0	0	--	--	N
			50	32	0/3	--	N
			100	63	0/3	--	N
			140	89	1/3	39	N
Bar Stock (2.5" Dia.)	RH 1100	Trans.	0	0	--	--	N
			50	33	0/3	--	N
			100	65	1/3	48	N
			140	91	2/3	1(2)	N
	TH 1050	Long.	140	78	0/3	--	N
		Trans.	50	27	3/3	4(2),28	-
			100	55	3/3	1(2),4	-
			140	77	3/3	1(3)	-
	TH 1100	Long.	140	93	0/3	--	N
		Trans.	0	0	--	--	N
			50	33	2/3	34,37	N
			100	66	2/3	1,82	N
			140	92	3/3	4,8,11	-
		A-286 Stainless Steel					
Bar Stock (1" Dia.)	No Cold Work	Trans. (C-ring)(5)	48	50	0/3	--	-
			71	75	0/3	--	-
			95	100	0/3	--	-
	40% Min. Cold Work	Long.	0	0	--	--	N
			140	75	0/9	--	N
			170	90	0/9	--	N
			188	100	0/9	--	N
		Trans. (C-ring)(5)	94	50	0/9	--	N
			140	75	0/9	--	-
			170	90	0/9	--	-
			188	100	0/9	--	-
		Almar 362 Stainless Steel					
Bar Stock (1.75" Dia.)	Aged 1000°F, 3 Hours	Long.	0	0	--	--	N
			120	75	0/3	--	N
			161	100	0/3	--	N
		Trans. (C-ring)(5)	120	75	0/3	--	-
			161	100	0/3	--	-
		AM 350 Stainless Steel					
Sheet (.025" Thick)	SCT 850	Long.	141	75	0/3	--	N
			188	100	2/2	5,20	-
		Trans.	140	75	2/3	20,153	N
			187	100	2/2	1(2)	-

TABLE IV. STRESS CORROSION CRACKING TEST RESULTS (1) (Continued)

Material Form	Heat Treat Condition	Stress Direction	Applied ksi	Stress % YS	Failure Ratio	Days to Failure	% Loss In T.S.
	SCT 1000	Long.	122	75	0/3	--	N
			162	100	0/2	--	N
		Trans.	123	75	0/3	--	N
			164	100	0/2	--	N
		Unitemp 212 Stainless Steel					
Bar Stock (1.5" Thick)	Single-Aged	Trans. (C-ring)(5)	34	25	0/3	--	-
			70	50	0/3	--	-
			102	75	0/3	--	-
			122	90	0/3	--	-
			136	100	0/3	--	-
	Double-Aged	Trans. (C-ring) (5)	34	25	0/3	--	-
			67	50	0/3	--	-
			95	75	0/3	--	-
			121	90	0/3	--	-
			135	100	0/3	--	-

N - Negligible change in tensile properties

Note (1) Test Data

a. Specimen: Round tensile (C-ring where noted) for bar stock and flat tensile for sheet.

b. Stress method: Direct tension for round tensile and constant deflection for flat tensile and C-rings

c. Medium: Alternate immersion in 3.5 percent NaCl solution

d. Exposure time: Until failure or six months

(2) Three of the specimens were tested in the standard medium and the remaining three were exposed to 5 percent salt spray.

(3) The specimens were loaded in direct tension rather than by constant deflection

(4) Six of the specimens were tested in the standard medium and the remaining three specimens were exposed to 5 percent salt spray.

(5) Load calculations were based on longitudinal rather than transverse yield strength.

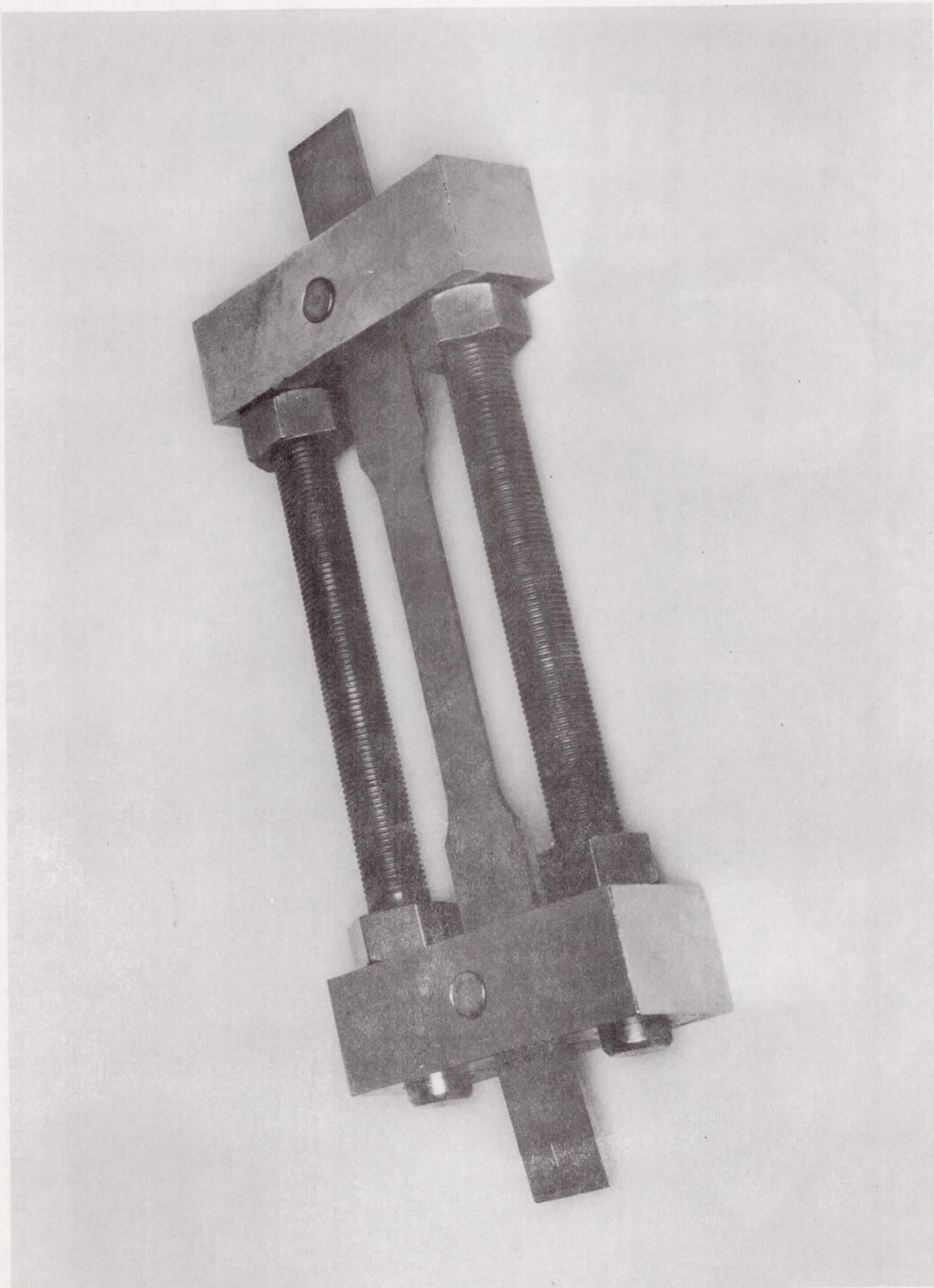

FIGURE 1 - FLAT TENSILE SPECIMEN STRESSED IN DIRECT TENSION

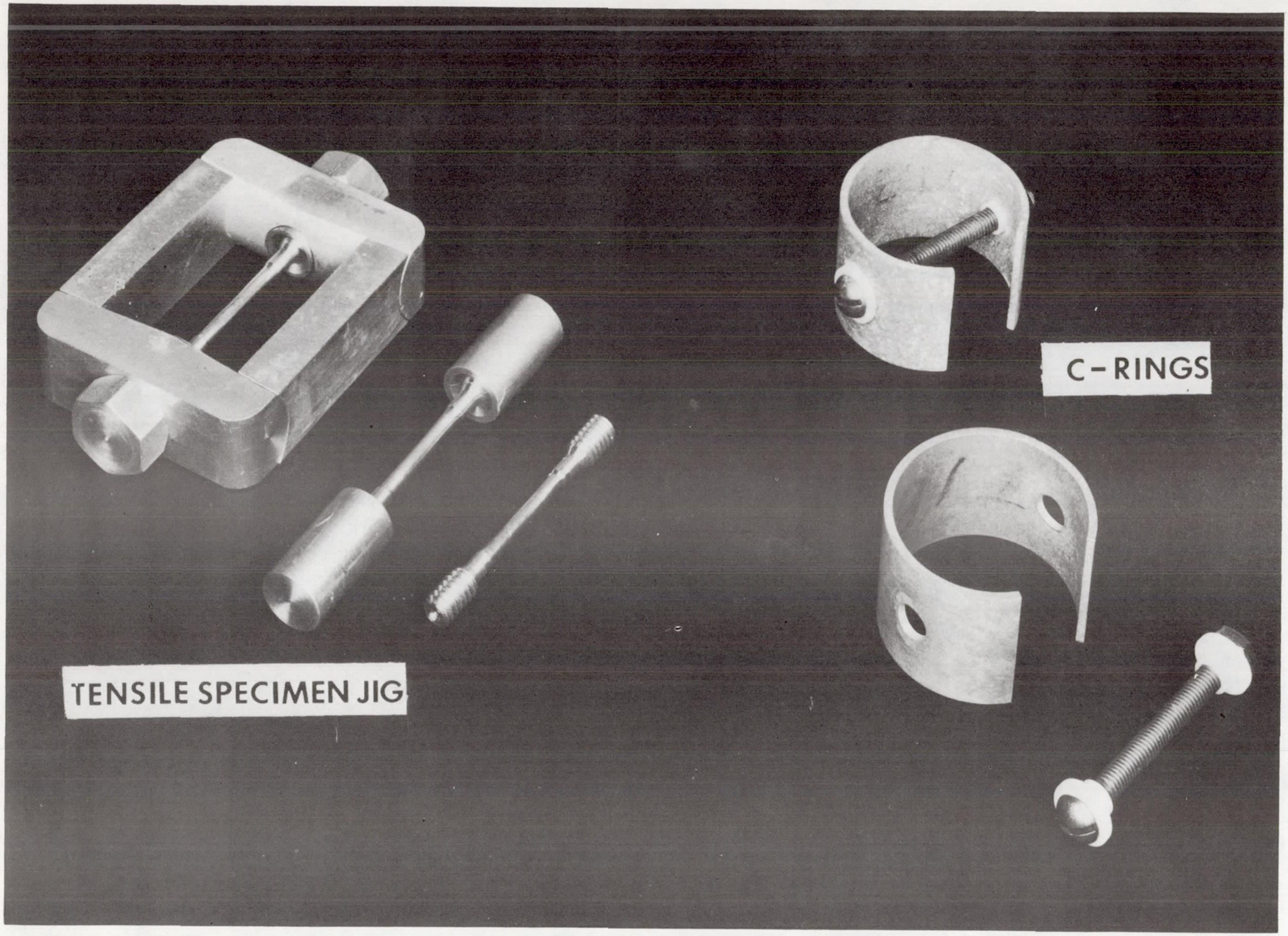

FIGURE 2 - ROUND TENSILE AND C-RING TYPE STRESS CORROSION TEST SPECIMENS

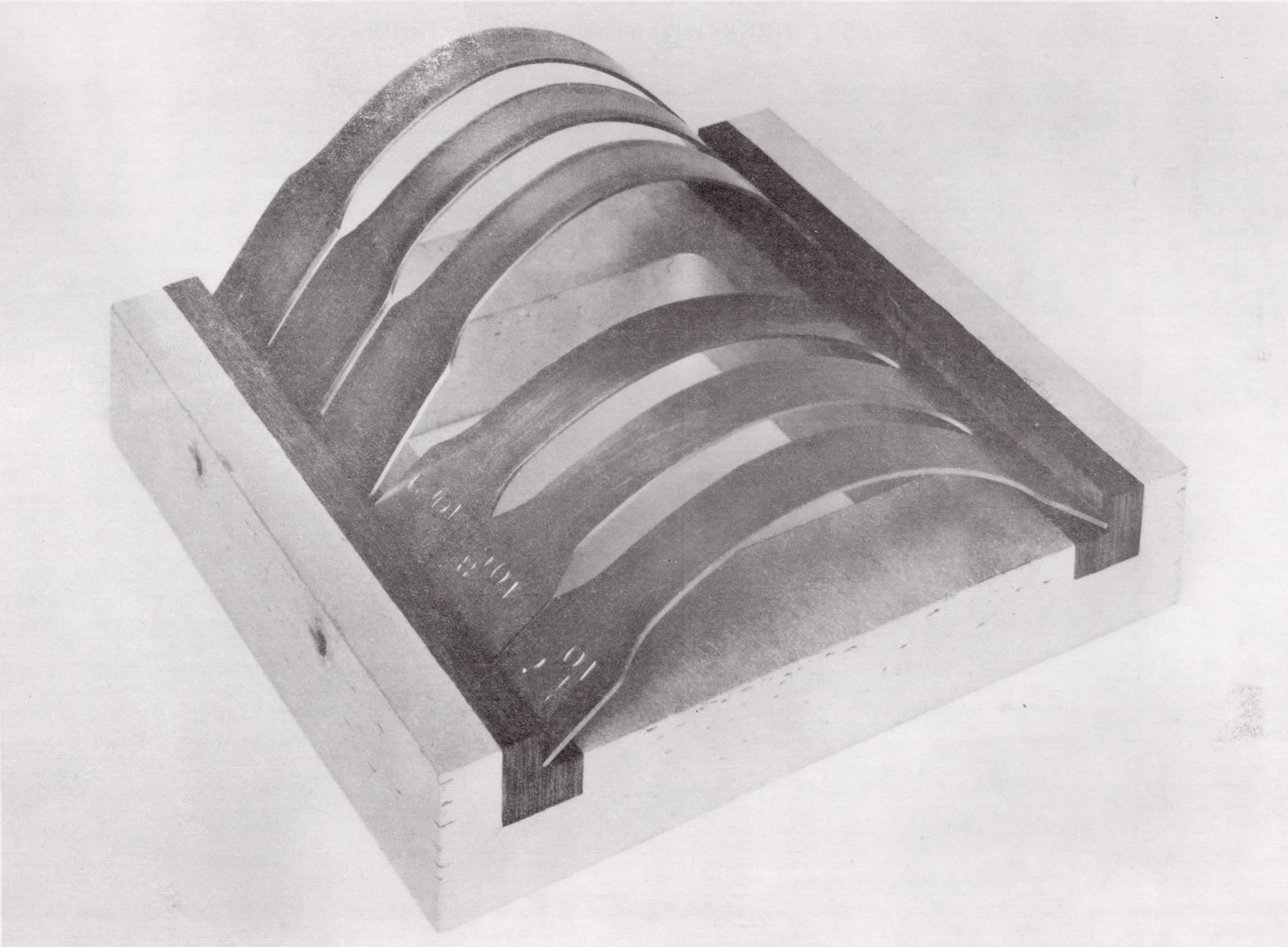

FIGURE 3 - FLAT TENSILE SPECIMENS LOADED IN A CONSTANT SPAN FIXTURE

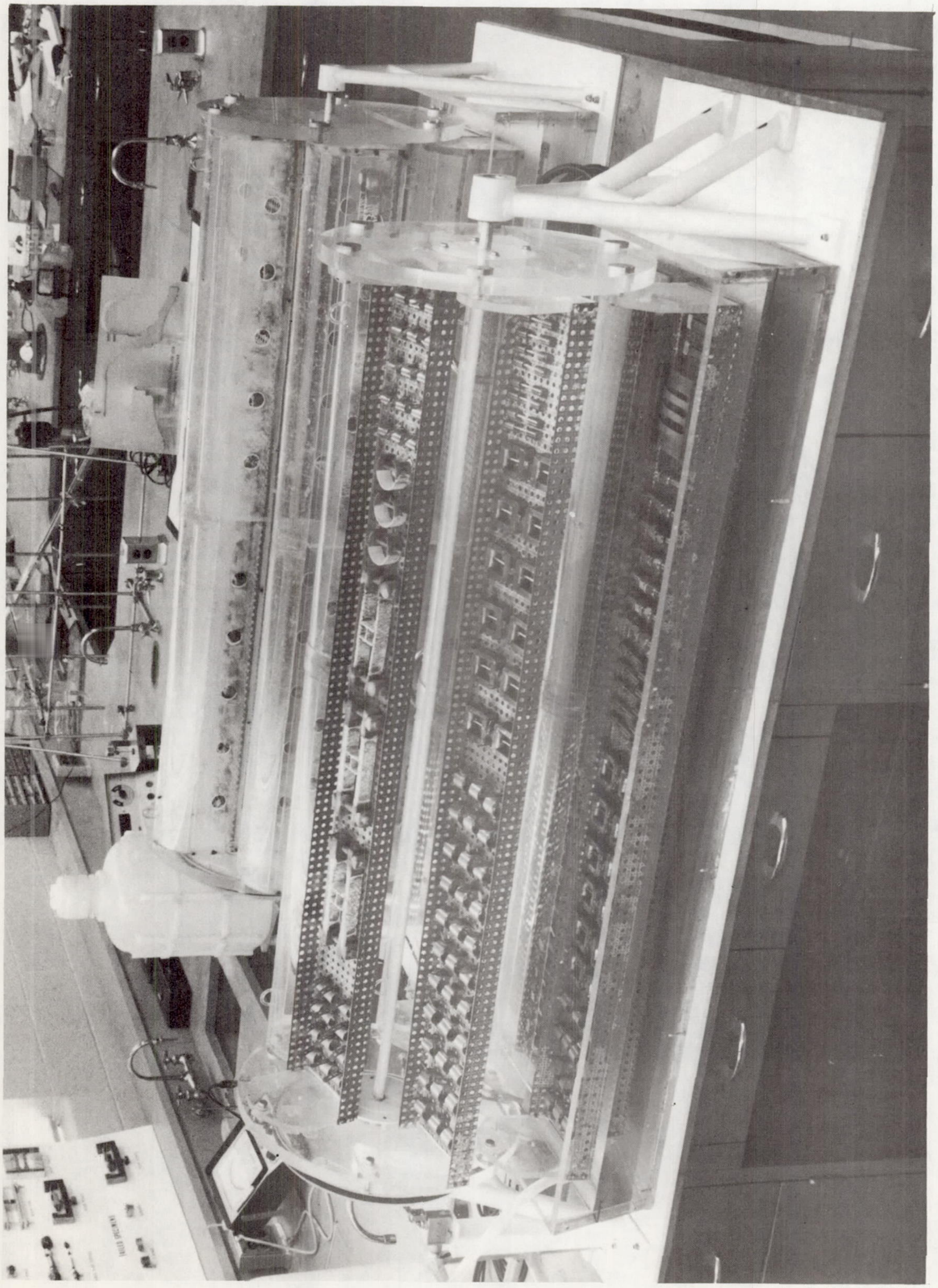

FIGURE 4 - ALTERNATE IMMERSION TESTER

APPROVAL TM X-53910

STRESS CORROSION CRACKING EVALUATION OF SEVERAL PRECIPITATION HARDENING STAINLESS STEELS

By

T. S. Humphries and E. E. Nelson

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

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