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602023



# AEROJET-GENERAL CORPORATION

AZUSA, CALIFORNIA 91705 • EO 4-8211

VON KARMAN CENTER

2 July 1964

Subject: Informal Monthly Report on the Investigation of Stress Corrosion Cracking of High Strength Steels for the Month of May 1964. Report LO414-02-8

To: Commanding Officer  
Frankford Arsenal  
Philadelphia, Pennsylvania

Reference: Contract DA-04-495-ORD-3069, Modification No. 4

This is the thirty-second in a series of informal progress reports submitted in partial fulfillment of the contract. It constitutes the eighth monthly report on the second one-year continuation of the original two-year program. The work was conducted by R. B. Setterlund who was supervised by A. Rubin.

## I. OBJECTIVES

- A. To study the stress-corrosion characteristics of 18% nickel maraging steel with respect to compositional variation.
- B. To study the effect of environmental temperature on the rate of stress-corrosion cracking in three alloys: 18% nickel maraging steel, a low-alloy martensitic steel, and a hot-worked die steel.
- C. To study the electropotential changes occurring in 18%-nickel maraging steel during stress-corrosion exposure, and the effect of applied potential.

## II. WORK PROGRESS

### A. COMPOSITIONAL VARIATION

To study the effect of compositional variation on stress-corrosion susceptibility of 18% nickel maraging steel, four different heats of material were evaluated. These heats, when taken in conjunction with the heats previously tested in earlier parts of the maraging-steel program, represent the compositional range of commercial production for this alloy. Material was obtained from three vendors: Republic Steel, Vanadium Alloys, and Latrobe Steel.

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## Best Available Copy

Table 1 shows the composition of all materials studied. They include five heats of maraging steel from the previous year's program and four heats from the present program. The titanium content for these heats ranged from 0.23 to 1.40%, with yield strengths from 181.5 to 323.3 psi. Mechanical properties are shown in Table 2. In addition to these materials, two alloys representing a hot-worked die steel and a low-alloy martensitic steel were tested to obtain comparison data. The test environments used were: (1) aerated distilled water, (2) aerated 3% NaCl solution, and a high-humidity atmosphere (140°F water-saturated air). Beam specimens were stressed elastically to 75% of the yield strength, and U-bend specimens were used to evaluate the plastic deformation condition.

Results indicate that the stress-corrosion susceptibility of 18% nickel maraging steel increases with strength level, which is largely determined by the titanium content. Even the lowest-strength-level material tested (181-ksi yield) showed some failures in the U-bend tests. It was also found that a 3% salt solution was a less severe medium than distilled water in causing stress-corrosion failure.

The test plan for Tasks A and B is shown in Table 3. The testing has been completed and results are now being evaluated for inclusion in the final report.

#### B. ENVIRONMENTAL TEMPERATURE

The effect of environmental temperature on stress-corrosion cracking of 18% nickel maraging steel was determined using bent-beam and U-bend specimens in controlled distilled-water environments at temperatures of 120 and 160°F. Environmental temperature was found to markedly increase stress-corrosion susceptibility of the maraging steel, with failure times decreased by one-half with an 18°F increase in temperature. The conventional high-strength steels, tested for comparison, displayed greater susceptibility at a given strength level, but showed virtually no increase in susceptibility as the temperature was raised from 70 to 160°F. The final results for all tests performed in Task B shown in Table 3 will be reported in detail in the next report, which will constitute the final summary report.

## C. ELECTROPOTENTIAL CHANGES

Electropotential changes occurring in a material exposed to conditions which induce stress-corrosion cracking are of interest because they may give some indication of the mechanism of failure. Two experiments were conducted in this regard, using a center-notched, pre-cracked tensile specimen of 18% nickel maraging steel.


1. The effect of applied tensile stress on crack-tip corrosion potential was measured. This potential was found to shift toward the anodic by 0.0175 mv for every 1000 psi of net stress applied.

2. The effect of applied constant potential on a U-bend specimen exposed to a 3% salt solution was determined. It was found that by applying the proper amount of cathodic current, stress-corrosion cracking of the sample could be prevented. When the current was increased over this amount, the failure time was the same as with no current, as illustrated by the following data:

<u>Volts to Saturated Calomel Cell</u>	<u>Initial Current Density (ma/in.<sup>2</sup>)</u>	<u>Failure Time (hr)</u>
-0.95	-3.6	2.1
-0.66	-2.0	no failure, 168 hr
-0.36	-0.4	2.1
none	none	2.3 (av.)

Complete results for this task will be shown in the final report now being prepared.

AERQJET-GENERAL CORPORATION



F. J. Darms, Manager  
Structural Engineering Department  
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## MILL-CERTIFIED CHEM

<u>Supplier</u>	<u>Heat No.</u>	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>
<b>(a) Maraging Steel from Previous Program</b>					
Republic Steel	9960902	0.02	0.08	0.007	0.00
Allegheny-Ludlum	448	0.024	0.002	0.004	0.00
Allegheny-Ludlum	W-24178	0.012	0.01	0.003	0.00
Allegheny-Ludlum	476	0.02	0.08	0.006	0.00
Allegheny-Ludlum	W-24254	0.009	0.09	0.002	0.00
<b>(b) Maraging Steel for Present Program</b>					
Republic Steel	9960523	0.029	0.06	0.005	0.00
Vanadium Alloys	07868	0.02	0.09	0.004	0.00
Larrobe Steel	C56898	0.03	0.03	0.004	0.00
Vanadium Alloys	07268	0.03	0.05	0.004	0.00
<b>(c) Conventional High-Strength Steels</b>					
Vanadium Alloys	07914	0.38	0.21	0.010	0.00
Allegheny-Ludlum	W-23217	0.495	0.62	0.009	0.00

\* Some material from previous program will be used to obtain samples.

Table 1

**TABLE 1**

**ANALYSIS OF PROGRAM MATERIALS**

S	Composition, %										
	Si	Mn	Co	Mo	Al	Cr	Zr	Ti	Ca	B	V
006	0.15	18.48	7.00	4.84	0.21	0.10	0.035	0.90	-	0.0036	-
008	0.009	18.51	8.48	4.92	0.089	-	-	0.52	-	-	-
005	0.01	18.69	8.90	4.92	0.029	-	0.003	0.62	0.006	0.002	-
005	0.014	18.60	9.05	4.90	0.078	-	-	1.00	-	-	-
005	0.06	20.41	-	-	0.29	-	0.002	1.40	0.004	0.003	-
006	0.05	17.79	8.90	3.48	0.13	-	-	0.23	-	-	-
005	0.10	17.75	7.60	4.60	0.08	-	0.017	0.52	0.05	0.004	-
008	0.05	18.54	8.00	4.75	0.11	-	0.03	0.49	-	0.004	-
006	0.04	18.54	9.06	4.88	0.09	-	0.088	0.55	0.02	0.003	-
008	0.92	-	-	1.33	-	4.75	-	-	-	-	0.51
005	0.20	0.57	-	0.94	-	1.00	-	-	-	-	0.05

analytical data.

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TABLE

MECHANICAL PROPERTIES  
(AEROJET)

Code No.	Supplier	Heat No.	Heat Treatment		0.2% Offset Yield Strength
			Hours Hold	°F	
(a) Maraging Steel Fr					
I-0	Republic Steel	5960502	3	900F	249.9
I-5	Allegheny-Ludlum	448 <sup>**</sup>	3	↓	255.4
I-1	↓	W-24173 <sup>***</sup>	3	↓	283.0
I-8	↓	675 <sup>**</sup>	3	900F	323.3
H-1	Allegheny-Ludlum	W-24254	4	850F	291.3
(b) Maraging Steel fo					
K	Republic Steel	5960523	3	900F	181.5
L	Vanadium Alloys	07868	3	↓	248.2
M	Larrobe Steel	056353	3	↓	263.7
N	Vanadium Alloys	07258	3	900F	279.1
(c) Conventional High					
A-4	Vanadium Alloys	07914	6-6	1075F	219.2
A-3	↓	↓	↓	1025F	232.6
A-2	↓	↓	↓	975F	223.5
A-1	Vanadium Alloys	07914	6-6	940F	222.2
B-4	Allegheny-Ludlum	W-25217	2	1100F	203.1
B-3	↓	↓	2	900F	204.6
B-2	↓	↓	2	800F	214.5
B-1	Allegheny-Ludlum	W-25217	2	600F	237.4

\* Same material from previous program will be used to obtain supplementary  
<sup>\*\*</sup> 200 lb laboratory heats.  
<sup>\*\*\*</sup> Received 50% cold reduced, annealed 1 hr 1500°F.

Table 2

TABLE 2

TEST DATA OF PROGRAM MATERIALS  
(TEST DATA)

Ultimate Tensile Strength	Elongation	Reduction in Area	Rockwell Hardness	Crack Growth Energy (J/cm <sup>2</sup> )
From Previous Program*				
254.1	4.0	37.0	50.5	570.0
265.9	5.0	3.0	52.0	550.0
294.0	8.0	38.0	53.5	552.0
330.0	2.5	27.0	56.0	402.0
302.2	3.0	17.0	54.0	58.5
for Present Program				
190.7	5.0	43.0	42.0	658.0
248.2	4.0	-	49.0	692.0
275.7	5.0	34.0	51.5	640.0
213.1	4.0	18.0	52.0	560.0
High Strength Steels				
257.7	7.0	44	49	-
284.8	6.0	42	52.5	-
280.6	6.5	43	53	45.4
292.4	7.0	40	54	32.9
218.5	11	46	44	563
226.4	7.5	43.5	44	385
241.2	7	38	45.5	323
281.3	6	25	51.5	182

ry data.

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TAI  
STRESS CORRO  
TASKS

	Material Condition (						
	<u>H-1</u>	<u>I-4</u>	<u>I-6</u>	<u>I-1</u>	<u>I-8</u>	<u>K</u>	<u>L</u>
<u>Bent Beam Tests</u>							
Aerated Distilled Water	A	A	N	A	A	N	A
Aerated Salt Water	A	A	N	A	A	N	N
120F Distilled Water	-	A	-	A	A	A	A
140F Saturated Air	A	A	A	A	A	A	A
160F Distilled Water	A	A	A	A	A	A	A
<u>U-Bend Tests</u>							
Aerated Distilled Water	A	A	-	-	-	A	A
Aerated Salt Water	A	-	-	-	-	P	A
120F Distilled Water	A	A	-	-	-	A	A
140F Saturated Air	-	A	-	-	-	A	A
160F Distilled Water	A	A	-	-	-	A	A

Code

- A - All samples have failed.
- P - Some have failed, some have not.
- N - No failures to date.
- - No test planned.
- \* - Single maverick specimen; two of group of three have failed much earlier.

Table 3

TABLE 1  
 EROSION PROGRAM  
 SITES A AND B

(Table of Code Numbers)

<u>M</u>	<u>N</u>	<u>A-1</u>	<u>A-2</u>	<u>A-3</u>	<u>A-4</u>	<u>B-1</u>	<u>P-1</u>	<u>B-2</u>	<u>B-3</u>
A	A	A	A	A	A	A	A	A	N
A	A	A	A	A	A	P	F	N	N
A	A	A	A	A	A	A	A	F	N
A	A	A	A	A	N	A	A	A	N
A	A	A	A	A	A	A	A	A	N
A	F	A	A	A	A	A	A	A	N
A	A	A	A	A	A	A	A	F	N
A	A	A	A	A	A	A	A	A	N
A	A	A	A	A	A	A	A	A	N
A	A	A	A	A	A	A	A	A	N

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