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VON KARMAN CENTER

Subject:

To:
Commanding Officer
Frankford Arsenal
Philadelphia, Pennsylvania

Reference:
Contract DA-04-055-ORD-569, Modification No. 5

This is the thirtieth in a series of informal progress reports submitted in partial fulfillment of the contract. It constitutes the sixth monthly report on the second 1-year continuation of the original 2-year program. It was written 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

In order to study the effects of compositional variation, four heats of 18% nickel maraging steel were obtained from three vendors. It was felt that these four heats, in conjunction with the heats previously tested, represent the compositional range of material under present commercial production.
Particular attention is centered around the 250 ksi yield strength level, where the 18% nickel maraging steel appears to have the greatest interest. The chemical analysis of these materials are shown in Table 1, group b, and the mechanical properties in Table 2, group b.

These four heats along with conventional alloys (group c, Tables 1 and 2), are being tested in the three environments that caused the most rapid failures in the previous years work. These are: (1) aerated distilled water, (2) aerated 3% NaCl solution, and (3) 140°F water saturated air. Three replicate tests are being conducted for each test condition, using beam specimens stressed elastically to 75% of the yield strength, as well as plastically deformed U-bend specimens. As shown in Table 3 most all of these specimens have failed. The only maraging steel in the present series to resist cracking in the ambient distilled and salt water environments has been the 180 ksi yield material, tested at 75% of yield strength. However, even this alloy has tested in the plastically deformed condition. All maraging steel specimens have failed in the 140°F water saturated air environment. Complete data showing failure times will be presented in the next quarterly report.

B. ENVIRONMENTAL TEMPERATURE

In order to assess the effects of environmental temperature, bent-beam and U-bend specimens were tested in distilled water environments controlled to 120 and 160°F. All U-bend specimens in both environments have failed except for the low-alloy steel tempered at 1100°F. Environmental temperature was found to have a large effect on the failure time of maraging steel with the susceptibility doubling for every 18°F increase in temperature. These data will be shown in detail in the next quarterly report.

C. OTHER WORK

Center-notch specimens have been employed to date to determine (1) the critical crack growth energy ($G_c$), (2) the effect of stress on failure time, and (3) the effect of solution pH on failure time. Crack growth energies measurements are complete except two heat-treat conditions for the hot-worked die steel and are listed in Table 2. The stress-intensity factor, $K$, was
found to have a large effect on failure time of maraging steels. Conversely, solution pH over the range 3 to 11 was found to have little effect on failure time of maraging steels at constant K values. These data will also be shown in the next quarterly report.

Coating evaluation tests on maraging steel are still under way. No failures have occurred since the last quarterly report.

It has been decided that U-bend specimens be utilized to measure the effects of applied potential on failure time of maraging steel. These tests will constitute the major effort during the final quarter of the contract period.

AEROJET GENERAL CORPORATION

Dr. J. Baglant, Manager
Materials Engineering Department
Structural Materials Division
### TABLE 1

**MILL-CERTIFIED CHEMICAL ANALYSIS OF PROGRAM MATERIALS**

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Heat No.</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Si</th>
<th>Ni</th>
<th>Co</th>
<th>Mo</th>
<th>Al</th>
<th>Cr</th>
<th>Zr</th>
<th>Ti</th>
<th>Ca</th>
<th>B</th>
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</thead>
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<tr>
<td>Republic Steel</td>
<td>590592</td>
<td>0.02</td>
<td>0.03</td>
<td>0.007</td>
<td>0.006</td>
<td>0.15</td>
<td>18.28</td>
<td>7.00</td>
<td>4.54</td>
<td>0.21</td>
<td>0.12</td>
<td>0.035</td>
<td>0.50</td>
<td>-</td>
<td>0.0036</td>
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<tr>
<td>Allegheny-Ludlum</td>
<td>474</td>
<td>0.029</td>
<td>0.002</td>
<td>0.004</td>
<td>0.008</td>
<td>0.009</td>
<td>18.51</td>
<td>8.88</td>
<td>4.92</td>
<td>0.089</td>
<td>-</td>
<td>-</td>
<td>0.62</td>
<td>-</td>
<td>-</td>
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<td>0.005</td>
<td>0.01</td>
<td>18.69</td>
<td>8.90</td>
<td>4.92</td>
<td>0.029</td>
<td>-</td>
<td>0.003</td>
<td>0.62</td>
<td>0.006</td>
<td>0.002</td>
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<td>0.002</td>
<td>0.005</td>
<td>0.06</td>
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<td>-</td>
<td>0.002</td>
<td>1.40</td>
<td>0.004</td>
<td>0.003</td>
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</table>

(a) Reusing Steel from Previous Program
(b) Reusing Steel for Present Program
(c) Conventional High-Strength Steels

*Some material from previous program will be used to obtain supplementary data.*
### Table 2

**Mechanical Properties of Program Materials**

(Ability Data)

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<tr>
<th>Code</th>
<th>Supplier</th>
<th>Heat No.</th>
<th>Heat Treatment</th>
<th>0.2% Offset</th>
<th>Yield Strength</th>
<th>Ultimate Tensile Strength</th>
<th>Elongation</th>
<th>Reduction in Area</th>
<th>Rockwell</th>
<th>Energy (GPa)</th>
<th>Crack Growth</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>%</td>
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<td></td>
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<tr>
<td><strong>(a) Existing Steel from Previous Program</strong></td>
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<td>I-4</td>
<td>Republic Steel</td>
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<td><strong>(b) Existing Steel for Present Program</strong></td>
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<tr>
<td><strong>(c) Conventional High Strength Steels</strong></td>
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<td>960F</td>
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<tr>
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<td>800F</td>
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<td>6</td>
<td>25</td>
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</tbody>
</table>

*Some material from previous program will be used to obtain supplementary data. See 200 lb laboratory heats.*

**Note:** Received 50% cold reduced, annealed 1 hr at 1500°F.
### Table 3

**STATUS OF STRESS CORROSION TESTING**

<table>
<thead>
<tr>
<th>Test</th>
<th>Earliest</th>
<th>Latest</th>
<th>Tests End</th>
<th>Pass</th>
<th>Fail</th>
<th>Pass</th>
<th>Fail</th>
<th>Pass</th>
<th>Fail</th>
<th>Pass</th>
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<th>Pass</th>
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<tbody>
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<td>A</td>
<td>X</td>
<td>A</td>
<td>A</td>
<td>(S)</td>
<td>A</td>
<td>(P)</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>(S)</td>
<td>A</td>
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<tr>
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<td>X</td>
<td>A</td>
<td>(S)</td>
<td>(S)</td>
<td>A</td>
<td>A</td>
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<td>A</td>
<td>A</td>
<td>A</td>
<td>(P)</td>
<td>(S)</td>
<td>(S)</td>
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<td>12C7 Distilled Water</td>
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<tr>
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</tr>
</tbody>
</table>

**Code**

- A - All samples have failed.
- F - Some have failed, some have not.
- N - No failures to date.
- ( ) - Material presently in test.
- - - No test planned.