TID/5NA -- 2082

MATERIALS MEMO 71-110

AEROJET NUCLEAR SYSTEMS COMPANY
SACRAMENTO, CALIFORNIA

TO: J. L. Watkins (4) 17 March 1971
N4350:MM 71-110
FROM: M. L. Murchison MLM:jat
Project No. 187
SUBJECT: Preliminary Screening Stress Corrosion Evaluation of
ARMCO Alloy 22-13-5
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ENCLOSURE: (1) List of References
(2) Table 1 - Chemistry and Mechanical Properties of ARMCO
22-13-5, Heat No. 590558
(3) Table 2 - Results of Exposure of ARMCO 22-13-5 to Boiling
42% MgCl₂ Solution

MASTER

1.0 SUMMARY

1.1 Evaluation of stress corrosion susceptibility of ARMCO 22-13-5 stainless steel was required for NERVA nozzle application. Testing of sustained stressed tuning fork specimens stressed to 45 ksi was conducted in boiling (309°F) 42% MgCl₂ solution for an accelerated laboratory assessment of its stress-corrosion behavior in chloride environments.

1.2 Results showed failure times and transgranular fracture of both annealed or simulated NERVA braze cycle material are typical of annealed austenitic stainless steels, Type 347 and Type 316. This behavior is expected of annealed 22-13-5 and is highly favorable for NERVA braze cycled material.

1.3 Further testing of both parent metal and welded forms is recommended for both accelerated environments and marine atmospheres.

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2.0 DISCUSSION OF RESULTS

2.1 Background

2.1.1 The stress corrosion evaluation of ARMC0 22-13-5 is part of the overall evaluation of this alloy detailed in Reference (a). ARMC0 reports in Reference (b), "In common with most stainless steels, under certain circumstances, ARMC0 22-13-5 may stress corrosion crack in hot chloride environments. When tested in boiling 42% MgCl_2 solution, 22-13-5 is as resistant to cracking as Type 316." The purpose of this preliminary evaluation is to determine if the conditions of the NERVA braze cycles required for nozzle fabrication seriously deteriorate the stress corrosion properties of 22-13-5.

2.2 Recommendations

2.2.1 Conduct marine environment stress corrosion evaluation of this alloy to confirm nonsusceptibility under anticipated NERVA storage conditions.

2.2.2 Conduct stress corrosion cracking and intergranular corrosion testing of welded forms of this alloy in both accelerated and marine atmosphere environments.

2.3 Test Results

2.3.1 Ten tuning fork stress corrosion specimens of ARMC0 alloy 22-13-5 (P/N 1137812) were received for testing. These specimens were machined from bar stock, ARMC0 Heat No. 590558 (AGC P.O. N-00117). Five of these specimens were in the "as-received" + 2050°F (retort cooled) condition [Treatment A, Reference (c)] and were serialized 1 - 5. Five others received the NERVA braze cycles as additional treatment [Treatment B, Reference (c)] and were serialized 6 - 10. Details of mechanical properties, chemistry and grain size are given in Table 1.

2.3.2 Three specimens of each group were stressed by deflection to 45 ksi. Two other specimens of each group were reserved for exposure on the beach at Kennedy Space Center. The six stressed specimens were exposed by immersion to boiling (309°F) 42% MgCl_2 solutions according to procedures outlined in Reference (d). Results of these exposures are given in Table 2. All specimens from Treatment A and Treatment B failed by cracking in 5 to 6.3 hours.

2.3.3 Specimens #1 and 7 were examined metallographically for mode of fracture. Specimen #1 was in condition A and #7 was in condition B. Both specimens exhibited transgranular fracture, typical of stress corrosion fracture of annealed austenitic stainless steels in boiling 42% MgCl_2 .

2.3.4 There was no evidence of pitting corrosion attack or intergranular corrosion on any of the specimens exposed to boiling MgCl_2 .

2.4 Significance of Results

2.4.1 Accelerated boiling MgCl_2 exposures cannot be directly related to marine ambient atmospheres for stress corrosion behavior. The results obtained confirm the similarity of stress corrosion behavior of ARMCO 22-13-5 to that of Type 316 and Type 347 in hot chloride environments. This similarity probably extends to marine ambient atmospheres as well. To determine this, four ARMCO 22-13-5 specimens, two each of treatments A and B will be exposed on the beach at Kennedy Space Center.

2.4.2 The significance of microstructure of ARMCO 22-13-5 in the two conditions, treatments A and B, in stress corrosion behavior has not been fully developed. Photomicrographs reproduced in Reference (c) indicate that grain boundaries of ARMCO 22-13-5, as a result of Treatment B, are outlined by a precipitate not present in material of Treatment A. This precipitate (sigma, chromium nitride, or other) is apparently the cause of some deterioration of cryogenic ductility. No difference, however, was noted in stress corrosion behavior of the two treatments in boiling MgCl_2 exposure either in time to fracture or mode of fracture. This observation probably means that 22-13-5 in Treatment B will not be subject to intergranular stress corrosion cracking in marine atmospheres. In the solution annealed-annealed condition, the austenitic stainless steels are not susceptible to stress corrosion cracking during marine environmental exposure at ambient temperature. On the other hand, sensitized austenitic grades are susceptible to intergranular stress-corrosion cracking in marine atmospheres [Reference (e)]. Apparently, ARMCO 22-13-5 is not sufficiently sensitized by Treatment B to promote intergranular cracking in hot chloride exposure. The behavior of ARMCO 22-13-5 in marine atmospheres will be determined by specimen exposure on the beach at Kennedy Space Center.

2.4.3 The absence of pitting or intergranular corrosion attack on specimens of Treatments A and B is regarded as highly favorable, indicating a relatively low susceptibility of this material to pitting and intergranular corrosion in chloride environments.

2.4.4 Stainless steel alloy Type 347 is a part of this investigation. However, specimens for this material have not been received for testing. Three of these specimens will be subjected to boiling MgCl_2 and two others will be sent to Kennedy Space Center to be exposed to the marine atmosphere on the beach along with specimens of alloy 22-13-5.

2.5 Action Required

2.5.1 In this preliminary screening test utilizing boiling MgCl_2 exposure, ARMCO 22-13-5 exhibited stress-corrosion cracking behavior typical of austenitic stainless steels 316 and 347. Additional testing is required to fully qualify this alloy for marine atmospheres: exposure

on the beach at Kennedy Space Center of both parent metal and welded specimens after processing cycles typical of NERVA nozzle processing. Although there was no evidence of pitting or intergranular attack on specimens of either condition in exposure to boiling MgCl_2 , additional testing is required to determine the intergranular corrosion susceptibility of this alloy after NERVA braze cycle treatment.

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Metallurgical Engineer
Materials and Processes

LIST OF REFERENCES

- (a) Materials Memo 70-332, H. W. Spaletta to J. L. Watkins, Subject: Preliminary Screening Evaluation of ARMCO Alloy 22-13-5, dated 2 September 2, 1970
- (b) ARMCO Data Sheet S-45
- (c) Materials Memo 70-448, H. W. Spaletta to J. L. Watkins, Subject: ARMCO 22-13-5 Preliminary Screening Evaluation Results, dated 22 December 1970
- (d) Uhlig, Corrosion Handbook, John Wiley and Sons, 1948, p. 174
- (e) Fink and Boyd, The Corrosion of Metals in Marine Environments, Bayer and Co., 1970, p. 28

TABLE 1

CHEMICAL ANALYSIS AND MECHANICAL PROPERTIES OF
ARMCO 22-13-5; HEAT NO. 590558

	<u>TREATMENT A</u>	<u>TREATMENT B</u>
1. Chemical Analysis*, Weight Percent	Carbon 0.050, Manganese 5.44, Phosphorus 0.015, Sulfur 0.010, Silicon 0.42, Chromium 21.48, Nickel 12.36, Molybdenum 2.12, Columbium 0.19, Nitrogen 0.27, Vanadium 0.20	
2. Mechanical Properties, Room Temperature		
a. UTS, ksi	111	109.8
b. 0.2% YS, ksi	50	50.2
c. % Elong in 1 Inch	54.4	37.2
d. % Reduction in Area	70.5	37.6
3. Grain Size, ASTM	No. 3	1-1 1/2

*ARMCO Certification, AGC P.O. N00117, ARMCO Mill Order 000117978-8041

TABLE 2

RESULTS OF ARMCO 22-13-5 EXPOSURE
TO BOILING (309°F) 42% MgCl_2

<u>SPECIMEN IDENTIFICATION</u>	<u>TIME TO FRACTURE (HOURS)</u>	<u>MODE OF FRACTURE</u>
a. TREATMENT A		
1	6.3	TRANSGRANULAR
2	6.3	TRANSGRANULAR
3	5	TRANSGRANULAR
b. TREATMENT B		
6	6.3	TRANSGRANULAR
7	6.3	TRANSGRANULAR
8	6.3	TRANSGRANULAR

*Results logged in Research Notebook No. A7612, page A7612-25.