NASA TECHNICAL MEMORANDUM

NASA TM-82426

(NASA-TM-82426) CORROSION FATIGUE OF INCONEL 718 AND INCOLOY 903 (NASA) 16 p HC A02/MF A01 CSCL 11F

N81-28232

Unclas

G3/26 26970

CORROSION FATIGUE OF INCONEL 718 AND INCOLOY 903

By D. B. Franklin and E. E. Nelson
Materials and Processes Laboratory

June 1981

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

TABLE OF CONTENTS

PRECEDING PAGE BLANK NOT FILMED

LIST OF ILLUSTRATIONS

LIST OF TABLES

TECHNICAL MEMORANDUM

CORROSION FATIGUE OF INCONEL 718 AND INCOLOY 903

INTRODUCTION

The resistance of materials to the combined effects of a corrosive atmosphere and fatigue (corrosion fatigue) has become increasingly important over the past several years. This is particularly true in the Space Shuttle Main Engine Program because of the planned reusability of most components and the high levels of alternating stresses which many components experience. This results in a requirement for extended lifetimes, and long exposures in a coastal environment. Since testing is difficult and time consuming, there is a limited amount of corrosion fatigue data available, particularly on many of the materials used. These tests were made in order to gain experience in this area of materials evaluation and to evaluate the possible effects of corrosion fatigue on two materials which are used extensively in the Space Shuttle Main Engine.

EXPERIMENTAL PROCEDURE

Tests were conducted using two types of rotating beam fatigue machines. The method of loading and specimen configuration for each type are shown in Figures 1 and 2. For the first type of machine, the rotating specimen is fixed on one end and loaded on the other (cantilever beam). For the second machine the specimen functions as a simple beam symmetrically loaded at two points. The two materials evaluated were Inconel 718 and Incoloy 903. Inconel 718 was evaluated on the type of machine shown in Figure 1 and Incoloy 903 was evaluated as shown in Figure 2. Inconel 718 specimens were heat treated after final machining and the Incoloy 903 specimens were heat treated before final machining according to the schedule shown in Table 1. The specimens were polished with 4/0 emery paper and degreased in a hot alkaline cleaner prior to testing.

The specimens were loaded while rotating and the speed was then adjusted to 2500 rpm. The corrosive solution was dropped on the test section at a rate of 1 drop every 3 to 5 sec. The solutions used in this test were distilled water, 500 ppm NaCl, and 3.5% NaCl. All exposed parts of the fatigue tester and the test specimens (except for the reduced section) were coated with a protective coating to protect them from the test solution. A plastic enclosure was placed around the rotating test components, and the solution run-off was collected and allowed to drain off. Tests were run until failure or for 10^8 cycles (approximately 28 days). Fatigue tests in air were also run (to a maximum of 5×10^7 cycles) for comparative purposes.

RESULTS AND DISCUSSION

The data from the tests conducted on Inconel 718 are shown in Table 2 and Incoloy 903 in Table 3. These data are also plotted in Figures 3 and 4 along with curves showing the lower boundary of the data for each environment. The corrosion fatigue strength, CFS (the alternating stress that a given material will survive 10^8 cycles) for each environment was estimated from these curves and are shown in Table 4. As could be inferred from general corrosion data, the CFS of Inconel 718 was not reduced (over the endurance limit in air) nearly as much as the CFS of Incoloy 903. This is also shown in Table 4 where the ratio of the CFS to the endurance limit in air was calculated for the three environments tested. A further indication of the effects of corrosion can be seen in Figure 5 which shows SEM fractrographs of Incoloy 903 specimens which failed in air (typical fatigue failure) and in 3.5% NaCl where the predominant failure mode was corrosion. This effect is not nearly as pronounced for Inconel 718 as shown in Figure 6.

CONCLUSIONS

The results of these tests clearly indicate the effects that a corrosive environment have on the fatigue strength of a material. In both cases the effects were related to the general corrosivity of test solution; i.e., the effect of 3.5% NaCl was greater than 500 ppm NaCl which was greater than distilled water. For Inconel 718 exposed to 3.5% NaCl the CFS was 338 MPa (49 ksi) or a ratio of 0.75 to the endurance limit in air. For Incoloy 903 the effects were even greater. In this case the CFS ranged from 234 MPa (34 ksi) in distilled water (a ratio to the endurance limit of 0.68) to less than 103 MPa (15 ksi) in 3.5% NaCl (a ratio of 0.30). While no attempt was made to correlate these values with specific environmental exposure conditions, they do demonstrate that a significant reduction in fatigue strength can be expected when components are exposed to corrosive atmospheres, and the amount of reduction is related to the corrosivity of the atmosphere. Consequently, for those components which have limited fatigue life, an evaluation of the combined effects of fatigue and the corrosive atmosphere to which they are exposed must be considered in projecting useful lifetimes.

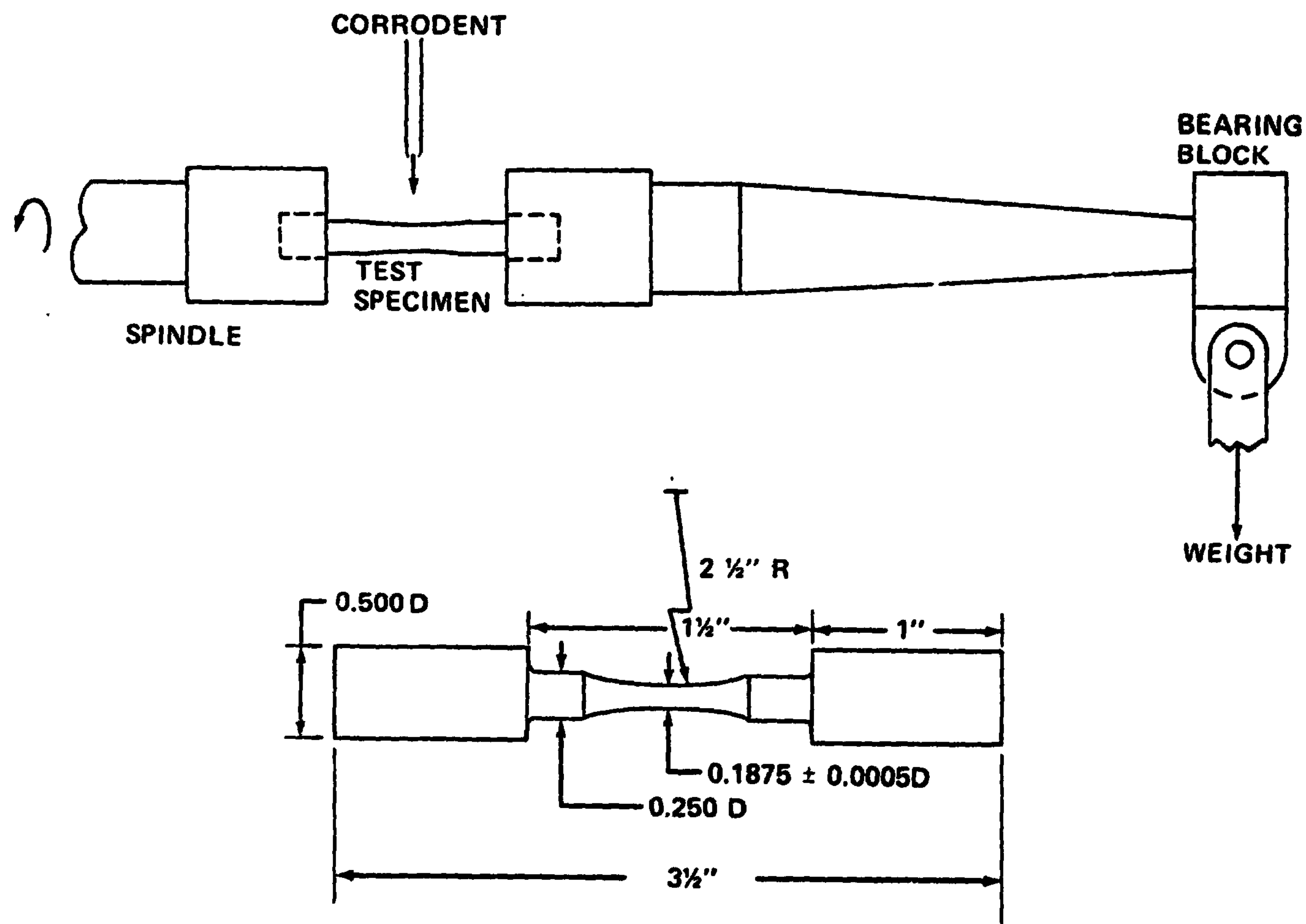


Figure 1. Corrosion fatigue test arrangement and test specimen (end loaded).

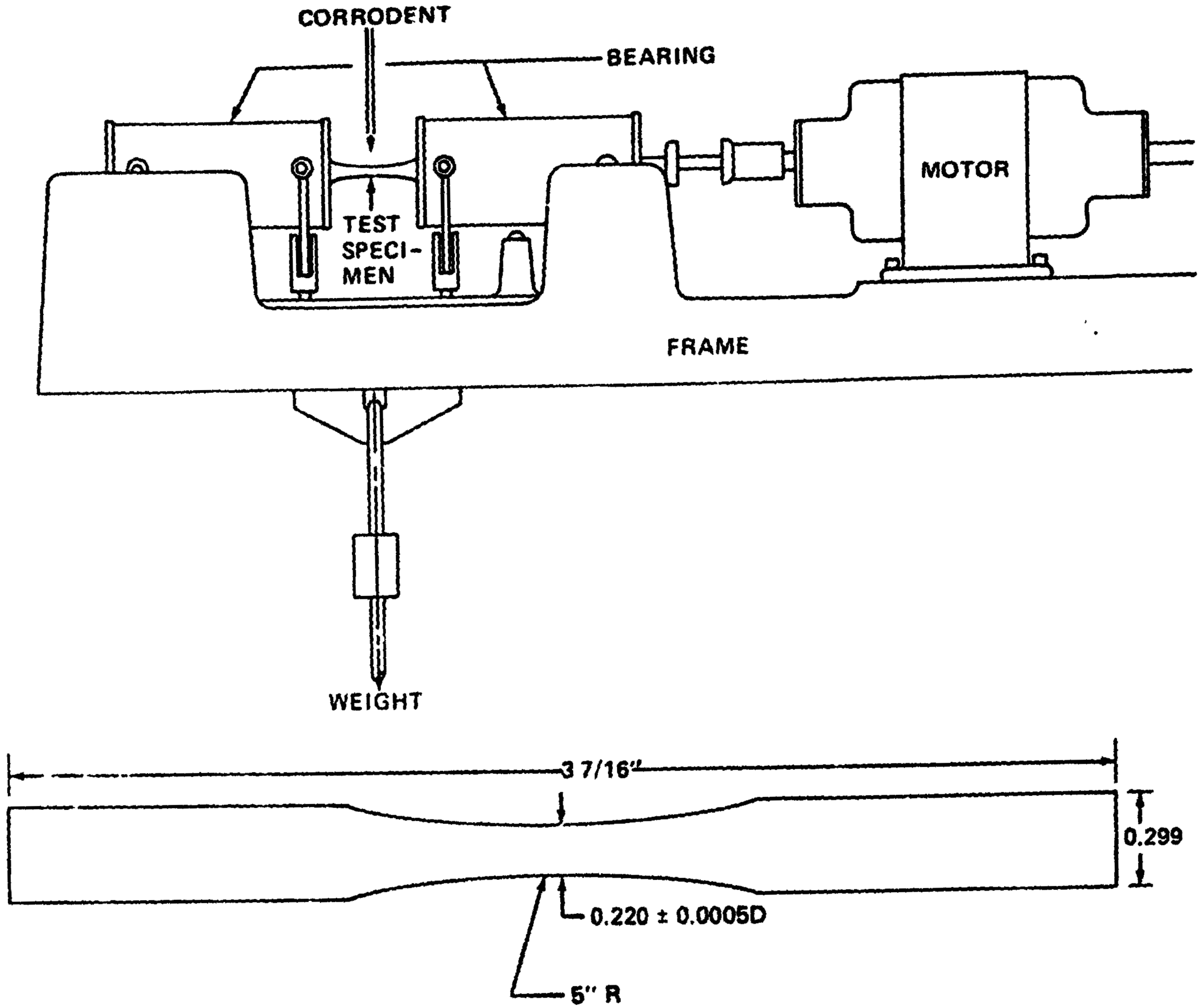


Figure 2. Corrosion fatigue test arrangement and test specimen (symmetrical beam).

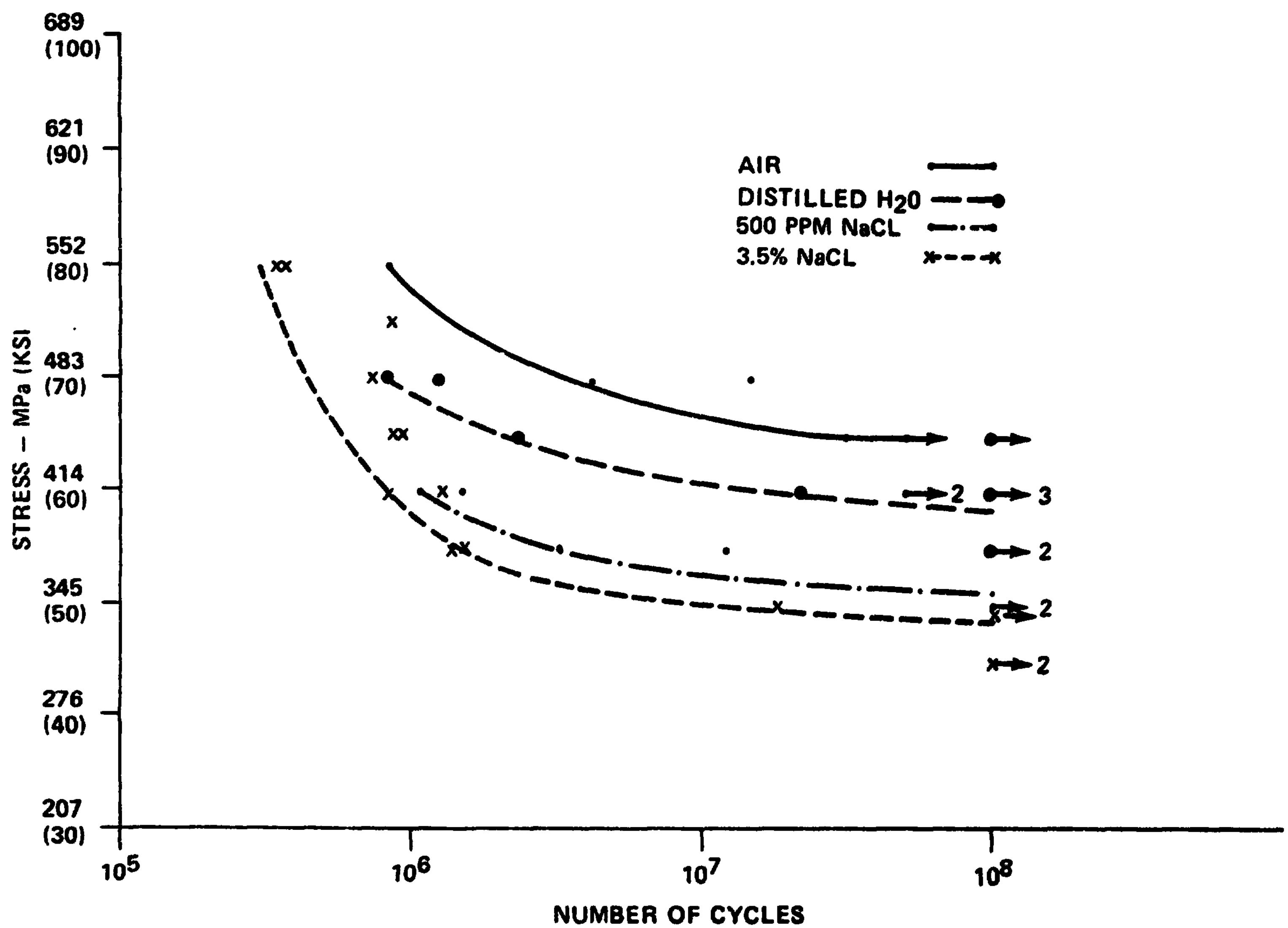


Figure 3. Corrosion fatigue strength of Inconel 718.

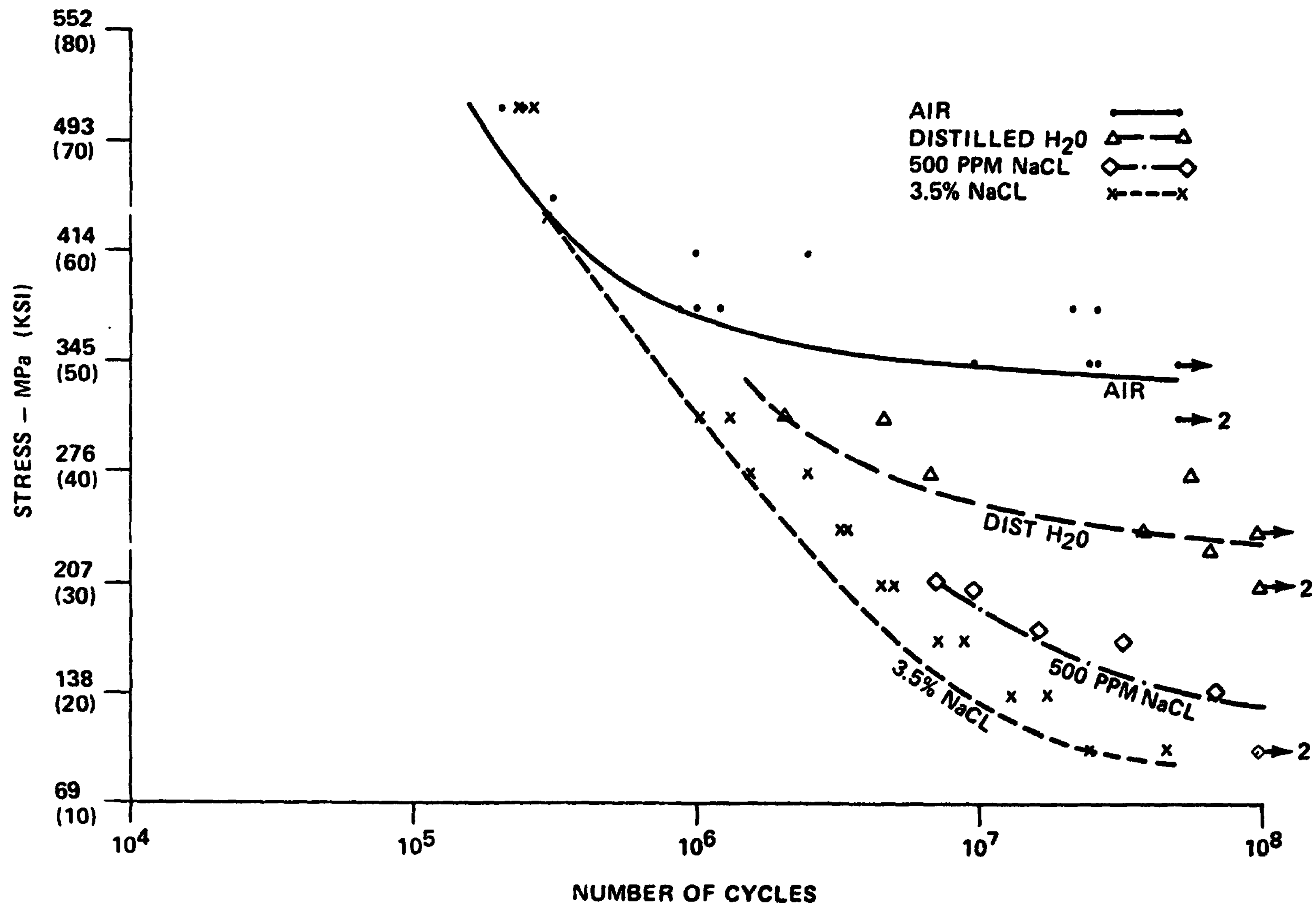
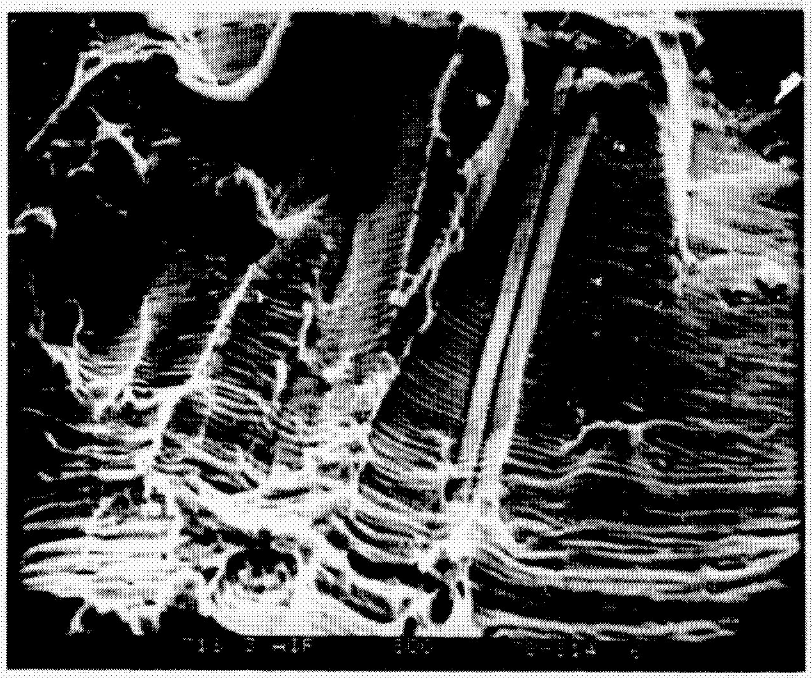


Figure 4. Corrosion fatigue strength of Incoloy 903.

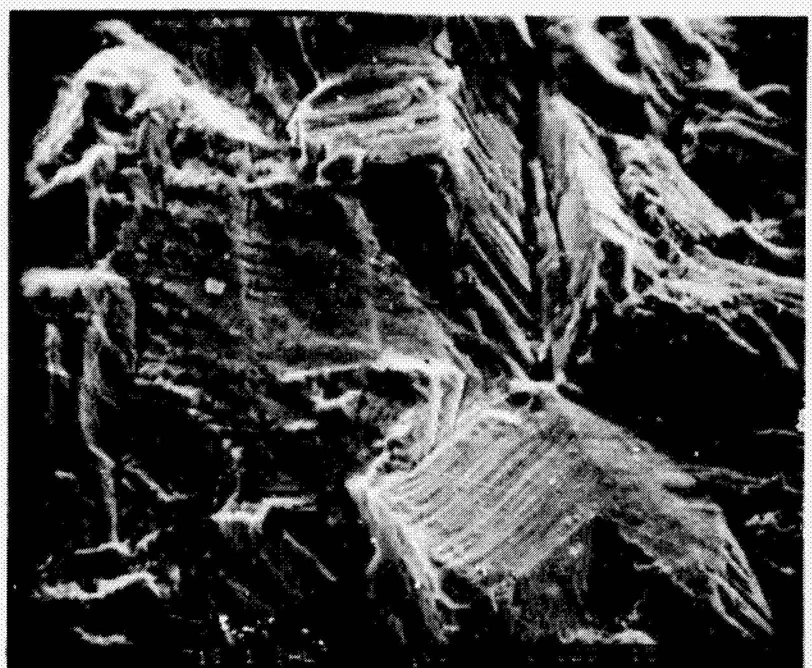
Air 2.43X10^7 Cycles Mag. 500X

3.5% NaCl 2.43X10^7 Cycles Mag. 500X

Figure 5. SEM micrographs of fractured Incoloy 903.



Air $\quad$ 1.37×10^6 Cycles $\quad$ Mag. 800X



3.5% NaCl $\quad$ 8.5×10^5 Cycles $\quad$ Mag. 800X

Figure 6. SEM micrographs of fractured Inconel 718.

TABLE 1. HEAT TREATMENT OF INCONEL 718 AND INCOLOY 903

INCONEL 718
Solution Treat 1311°K (1900°F) for 1/2 hr
Air Cool
Age 1033°K (1400°F) for 10 hr
Furnace cool to 922°K (1200°F)
Hold at 922°K (1200°F) for total time of 20 hr
Air Cool
INCOLOY 903
Solution Treat 1227°K (1750°F) for 1 hr
Air Cool
Age 991°K (1325°F) for 8 hr
Furnace cool to 894°K (1150°F)
Hold at 894°K (1150°F) for 8 hr
(Total Age of 18 hr)
Air Cool

TABLE .. CORROSION FATIGUE OF INCONEL 718

Air		Distilled H_2O		500 ppm NaCl		3.5% NaCl	
Stress MPa (ksi)	Cycles	Stress MPa (ksi)	Cycles	Stress MPa (ksi)	Cycles	Stress MPa (ksi)	Cycles
552 (80)	864,900	483 (70)	1,261,000	414 (60)	1,113,400	552 (80)	370,300
552 (80)	847,500	433 (70)	823,300	414 (60)	1,519,600	552 (80)	351,300
483 (70)	14,560,400	448 (65)	2,10[illegible],000	379 (55)	3,247,900	483 (70)	700,50[illegible]
483 (70)	4,055,700	448 (65)	100,000,000[a]	379 (55)	11,198,200	483 (70)	844,500
488 (65)	31,328,000	414 (60)	100,000,000[a]	345 (50)	100,000,000[a]	483 (70)	862,900
448 (65)	50,000,000[a]	414 (60)	21,377,000	345 (50)	100,000,000[a]	448 (65)	885,800
414 (60)	50,000,000[a]	414 (60)	100,000,000[a]			4[illegible] (65)	905 [illegible]90
414 (60)	50,000,000[a]	414 (60)	100,000,000[a]			414 (60)	1,039,300
		379 (55)	100,000,000[a]			414 (60)	732,000
		379 (55)	100,000,000[a]			379 (55)	1,491,000
						379 (55)	1,411,000
						345 (50)	100,000,000[a]
						345 (50)	18,544,800
						310 (45)	100,000,000[a]
						310 (45)	100,000,000[a]

a. Test terminated, specimen did not fail.

TABLE 3. CORROSION FATIGUE OF INCOLOY 903

Air		Distilled H_2O		500 ppm NaCl		3.5% NaCl	
Stress MPa (ksi)	Cycles	Stress MPa (ksi)	Cycles	Stress MPa (ksi)	Cycles	Stress MPa (ksi)	Cycles
503 (73)	243,000	310 (45)	4,557,000	207 (30)	7,232,000	503 (73)	263,000
503 (73)	204,000	310 (45)	2,071,000	207 (30)	9,078,000	503 (73)	232,000
448 (65)	311,000	276 (40)	6,326,000	172 (25)	32,004,000	310 (45)	1,058,000
448 (65)	265,000	276 (40)	55,553,000	172 (25)	19,918,000	310 (45)	1,328,000
414 (60)	2,461,000	241 (35)	32,819,000	138 (20)	68,185,000	276 (40)	1,532,000
414 (60)	967,000	241 (35)	100,000,000[a]	138 (20)	59,119,000	276 (40)	2,247,000
379 (55)	21,115,000	207 (30)	100,000,000[a]	103 (15)	100,000,000[a]	241 (35)	3,016,000
379 (55)	834,000	207 (30)	100,000,000[a]	103 (15)	100,000,000[a]	241 (35)	3,443,000
379 (55)	1,207,000					207 (30)	4,941,000
379 (55)	1,020,000					207 (30)	4,504,000
345 (50)	24,274,000					172 (25)	7,054,000
345 (50)	50,000,000[a]					172 (25)	8,423,000
345 (50)	9,667,000					138 (20)	12,943,000
345 (50)	25,942,000					138 (20)	17,223,000
310 (45)	50,000,000[a]					103 (15)[b]	45,317,000
310 (45)	50,[illegible],000[a]					103 (15)[b]	24,319,000

a. Test terminated, specimen did not fail.

b. Lowest limit of machine.

TABLE 4. ESTIMATED CORROSION FATIGUE STRENGTH (CFS)

Environment	Inconel 718		Incoloy 903	
	CFS MPa (ksi)	CFS/E.L.[a]	CFS MPa (ksi)	CFS/E.L.[a]
Air	448 (65)	–	345 (50)	–
Distilled H_2O	400 (58)	0.89	234 (34)	0.68
500 ppm NaCl	352 (51)	0.78	131 (19)	0.38
3.5% NaCl	338 (49)	0.75	103 (<15)	<0.30

a. Ratio of CFS to endurance limit in air.