THE **BOEING** COMPANY

CODE IDENT. NO. 8 1205

THIS DOCUMENT IS:

CONTROLLED BY H-7304

ALL REVISIONS TO THIS DOCUMENT SHALL BE APPROVED BY THE ABOVE ORGANIZATION PRIOR TO RELEASE.

PREPARED UNDER
- ☐ CONTRACT NO.
- ☒ IR&D
- ☐ OTHER

DOCUMENT NO. D321-51134-1 MODEL IR&D ,

TITLE EFFECT OF COATINGS ON THE FATIGUE LIFE OF 15-5PH STAINLESS STEEL IN SEA WATER

ORIGINAL RELEASE DATE

ISSUE NO. TO

ADDITIONAL LIMITATIONS IMPOSED ON THIS DOCUMENT WILL BE FOUND ON A SEPARATE LIMITATIONS PAGE

PREPARED BY H. A. JOHNSON *H. A. Johnson* 11/5/81 J. N. MASTERS

SUPERVISED BY C. T. RAY

APPROVED BY C. T. RAY

MICROFILMED

10-U13837

DO 6001 2160 ORIG. 4/71

Table of Contents

List of Tables

List of Figures

ABSTRACT

Fatigue tests were conducted on samples of 15-5PH stainless steel that had been coated with selected coatings. Prior to testing, the coated samples were immersed in-sea water at Pier 91 for a period of 30 days. The fatigue tests were made in saltwater at a stress ratio of 0.05 and a frequency of 30Hz. The results indicated that an aluminum flame sprayed coating covered with a polyurethane coating protected the 15-5PH resulting in air fatigue properties when the specimens were tested in sea water. Under the test conditions, the Sermetel coatings with and without the polyurethane coating did not protect the 15-5PH.

KEY WORDS

15-5PH Stainless Steel
Coatings
Fatigue Strength
Corrosion Protection

1.0 INTRODUCTION

The precipitation hardening steels are susceptible to crevice and pitting corrosion when exposed to slow moving or quiescent sea water. One means of protecting these materials is using coatings. Two types of coatings can be used: Those that are inert that protect by excluding the water from contacting the metal surface and those sacrificial coatings that corrode preferentially to protect the substrate.

This program is part of an overall study to evaluate coatings for the corrosion protection of 15-5PH strut/foil components. A series of fatigue tests were planned to determine if a coating or combination of coatings would maintain the air fatigue strength of 15-5PH after exposure to sea water. The effects of three sacrificial coatings, flame sprayed aluminum, Sermetel W and Sermetel 725, and one passive coating, PR 1654, in combination with one of the sacrificial coatings were studied.

2.0 TEST DETAILS

2.1 TEST MATERIALS

The metallic substrate for the tests was 15-5PH stainless steel in the H1100 condition. Test specimens were machined to the configuration shown in Figure 1.

The coatings used were as follows:

1. Flame sprayed aluminum over a nickel aluminide bondcoat. The flame spraying was done in accordance with MIL-STD-869 using aluminum wire per MIL-W-6712 over a Metco 405 nickel aluminide bondcoat. The thickness of the bondcoat was 0.001 to 0.002" and the aluminum was 0.008" to 0.009".

2. Sermetel W applied per BAC 5840 to a thickness of 0.002" to 0.003".

3. Sermetel 725 coating applied by Sermetel, Inc.

4. PR 1654 polyurethane coating applied over MIL-P-24441/1 primer. The thickness of the PR 1654 was ~0.020" over a primer thickness of ~0.003".

2.2 TEST PROCEDURES

Forty-seven specimens were machined and processed as shown in Table 1. These specimens noted as having a damage strip were processed by masking either a 1/4" or 1" wide strip prior to coating. These strips were to simulate mechanical damage to the coating under service conditions. Figure 2 is a schematic showing the coating configurations. After coating, all but the air baseline specimens were immersed at Pier 91 for a period of 30 days. Figures 3 through 5 illustrate the appearance of the uncoated, the aluminum overcoated with PR 1654 and the Sermetel W overcoated with PR 1654 specimens after the immersion. After immersion; the specimens were cleaned and visually examined. After the visual examination some of the specimens were not tested because of obvious pitting or were sectioned for microscopic examination. These specimens are noted in Table 2.

The fatigue tests were conducted in a tension-tension mode with a stress ratio of 0.05 at a frequency of 30Hz (except for the air baseline specimens that were cycled at 10Hz). The load data are shown in Table 2,

2.3 TEST RESULTS

The fatigue test results are shown in Table 2 and are plotted in Figure 6. For comparative purposes, the approximate expected characteristic life for bare specimens in sea water for the JETFOIL design DFR of 62 ksi is also shown as a scatter band in Figure 6.

3.0 DISCUSSION

Examination of the exposed specimens and the fatigue test results indicates that the galvanic protection of the flame sprayed aluminum adequately protected the 15-5PH base metal from crevice attack during the sea water exposure and test period. The corrosion of the aluminum does create a voluminous corrosion product. The aluminum substrate, therefore, does provide adequate short term protection to the substrate and maintains the air fatigue properties in spite of any damage to the top urethane coating. The creation of the corrosion product does limit the protection to short time periods. As a consequence, the top coating should be repaired as soon as any damage is noted to minimize the extensive lifting of the urethane topcoat by the corrosion product.

Under the test conditions the Sermetel coatings did not protect the specimens. This lack of protection could be related to the ratio of the Sermetel coated area to the bare area, to the processing of the coating after disposition and the specimen preparation prior to coating. Additional study is being conducted to determine if the Sermetel coatings will provide short term protection.

4.0 CONCLUSIONS

1. **The aluminum flame sprayed coating adequately protected the 15-5PH base metal for a minimum of 30 days exposure at Pier 91.**

2. **The formation of the voluminous aluminum corrosion product necessitates repair of the damaged top coat as soon as possible.**

3. **The Sermetel coatings did not protect the 15-5PH under the test conditions.**

If the SERMETEL W had been burnished, then the coating would have worked (Per Boeing Co - Dewey Ehrwine; and per SERMETEL - MARK MOSSER). Burnishing with a wire brush or glass beads or heating to 1000°F is required to make SERMETEL W electrically conductive. It is this conductivity which provides the corrosion protection once the coating is damaged. Class 4 of the MIL SPEC invoked for the SERMETEL coating of the king post does require the burnishing. Therefore the PHM-2 thru PHM-6 king posts, which are coated, should be OK.

Philip Yarnell, Jr
10 June 1982

TABLE 1
SPECIMEN PROCESSING HISTORY

SPECIMEN NUMBERS	COATING	DAMAGE	COMMENT
1-3	None	None	Air Baseline
4-6	None	None	Sea Water Baseline
7-9	F.S.A.* + PR 1654	None	
10-12	F.S.A.* t PR 1654	1/4" to base metal	
13-15	F.S.A." + PR 1654	1" to base metal	
16-18	F.S.A." + PR 1654	1/4" to F.S.A.	
19-21	F.S.A." + PR 1654	1" to F.S.A.	
22-24	Sermetel W + PR 1654	1/4" to base metal	
25-27	Sermetel W + PR 1654	1" to base metal	
28-30	PR 1654	1/4" to base metal	
31-33	Sermetel W + PR 1654	None	
34-36	Sermetel W + PR 1654	1/4" to base metal	
37-39	Sermetel 725	None	
40-42	Sermetel W	None	
43-45	None	None	Sea Water Baseline
46	Sermetel [1] 1	None	
47	Sermetel W [2]	None	

[1] Heated to 650°F for 90 minutes rather than hand burnished

[2] Heated to 1000°F for 90 minutes rather than hand burnished

* F.S.A. = Flame Sprayed Aluminum

D6 6000 2145 ORIG. 4/71

TABLE 2
FATIGUE RESULTS

SPECIMEN NUMBERS	R	FREQUENCY (Hz)	LOAD (ksi)	CYCLES TO FAILURE	COMMENTS
1	0.5	10	105	70,200	Grip Failure .
2	0.5	10	105	39,040	Grip Failure
3	0.5	10	90	273,000	
4	0.5	30	75	110,000	
5	0.5	30	75	242,000	
6	0.5	J0	--	--	Specimen lost*
7	0.5	30	75	462,000	
8	0.5	30	75	838,000	
9	0.5	30	75	719,000	
10	0.5	30	75	3,933,000	
11	0.5	30	75	3,498,000	
12'	0.5	30	75	1,169,000	
13	0.5	30	75	4,536,000	
14	0.5	30	--	--	Specimen lost*
15	0.5	30	75	3,855,000	
16	0.5	30	75	1,629,000	
17	0.5	30	90	193,000	
18	0.5	30	90	43,000	Grip Failure
19	0.5	30	90	88,000	Grip Failure
20	0.5	30	75	828,000	
21	0.5	30	75	1,680,000	
22	0.5	30	75	68,000	
23	0.5	30	75	42,000	
24	0.5	30	75	29,000	
25	0.5	30	75	50,000	
26	0.5	30	75	45,000	
27	0.5	30	75	39,000	
28	0.5	30	75	78,000	

DO 6000 2145 ORIG. 4/71

TABLE 2 (Continued)

FAT1 GUE RESULTS

SPECIMEN NUMBERS	R	FREQUENCY (Hz)	LOAD (ksi)	CYCLES TO FAILURE	COMMENTS
29	0.5	30	75	9,000	
30	0.5	30	75	27,000	
31	0.5	30	--	Not tested	Severe Crevice Attack
32	0.5	30	--	--	Specimen lost*
33	0.5	30	--	--	Specimen lost*
34	0.5	30	--	Not tested	Severe Crevice Attack
35	0.5	30	75	36,000	
36	0.5	30	--	Not tested	Severe Crevice Attack
37	0.5	30	75	98,000	
38	0.5	30	75	152,000	
39	0.5	30	75	117,000	
40	0.5	30	--	Not tested	Severe Crevice Attack
41	0.5	30	75	168,000	
42	0.5	30	--	Not tested	Severe Crevice Attack
43	0.5	30	--	Not tested	Crevice Attack under Unplanned Paint strip
44	0.5	30	75	207,000	
45	0.5	30	75	203,000	
46	0.5	30	75	80,000	
47	0.5	30	75	285,000	

* Dropped at Pier 91

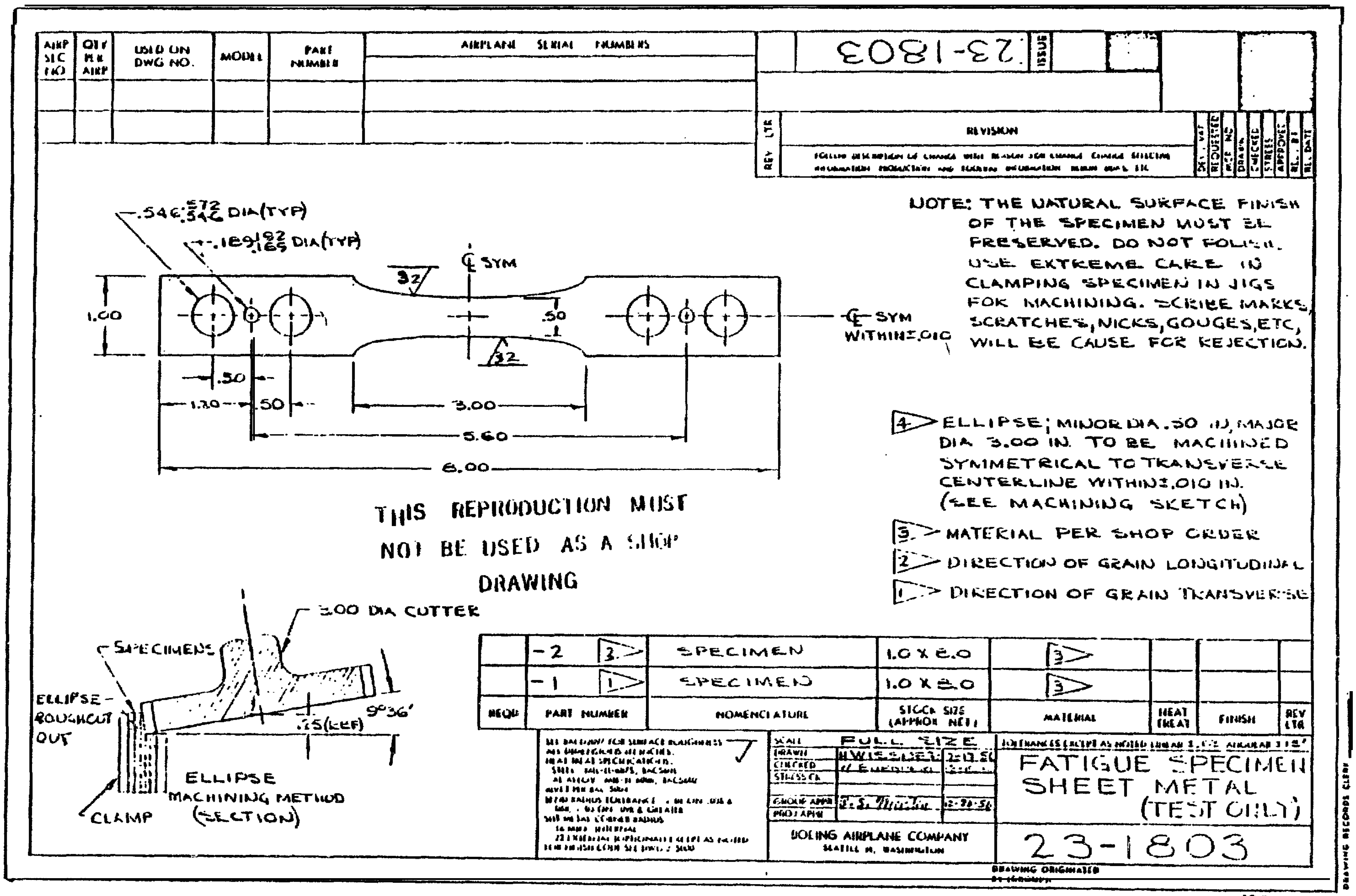


FIGURE 1 TEST SPECIMEN

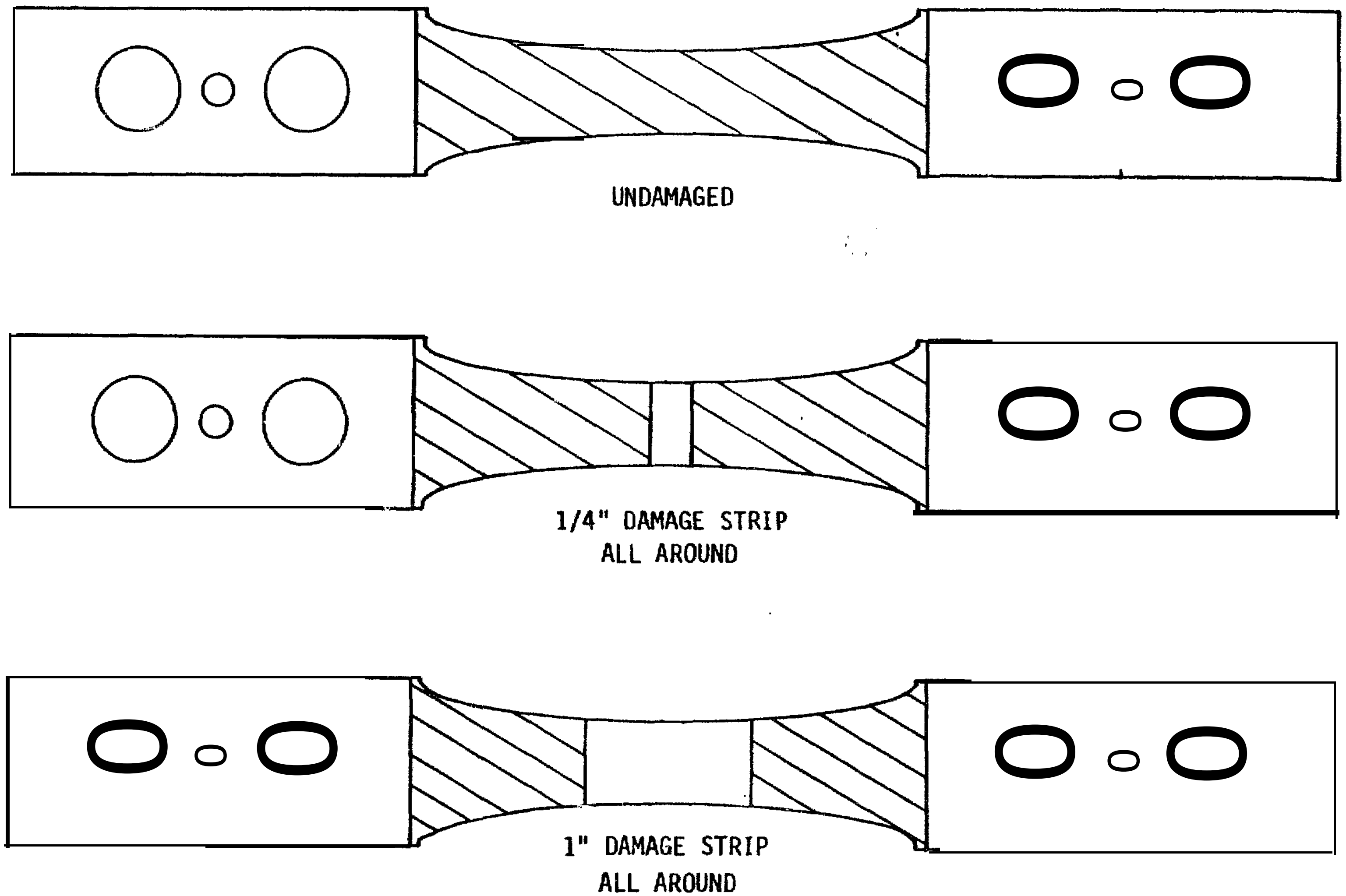
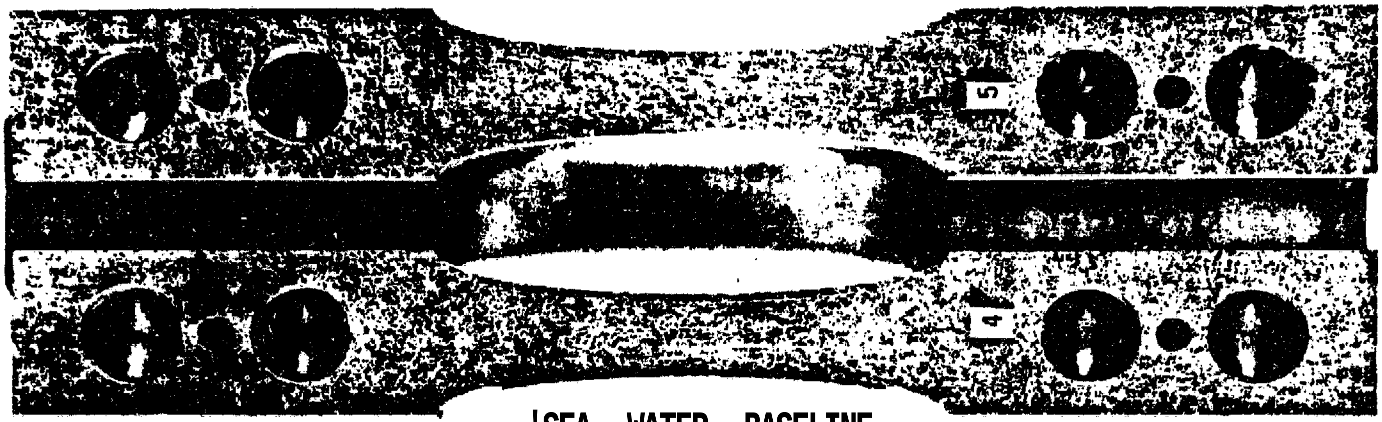
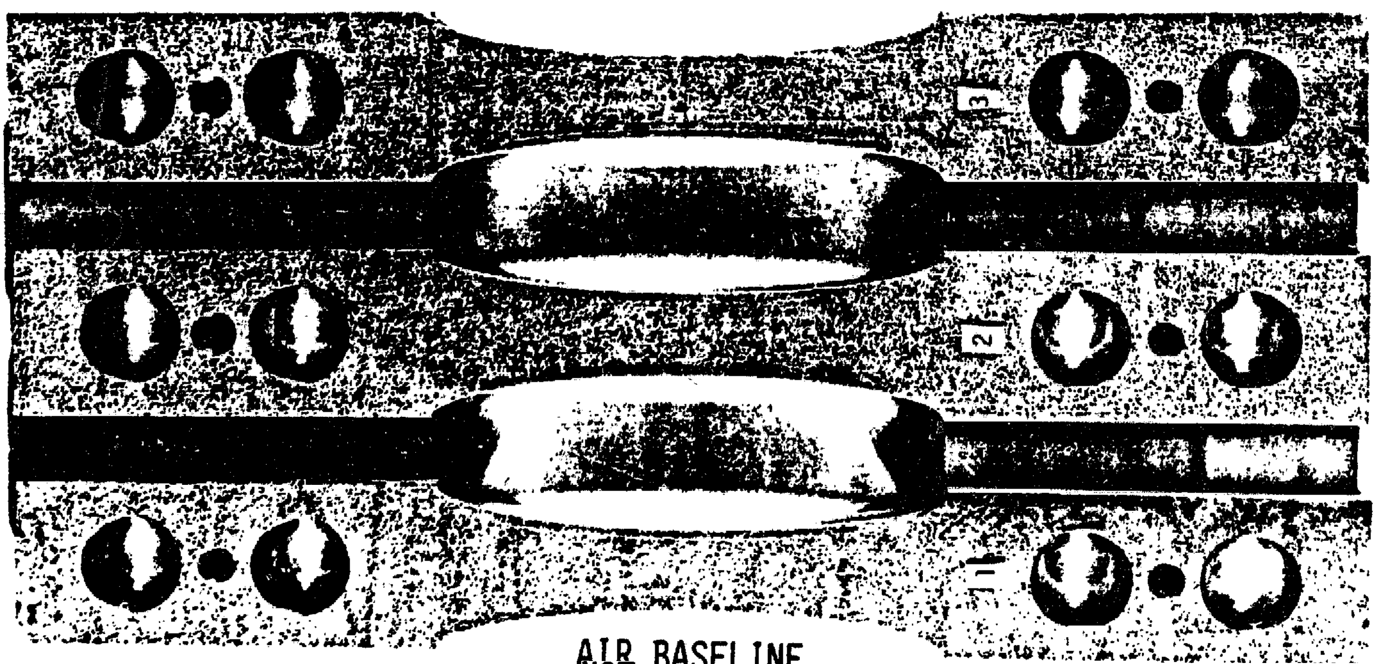


FIGURE 2 COATING CONFIGURATION



'SEA WATER BASELINE
IMMERSED 30 DAYS



AIR BASELINE
NOT IMMERSED

FIGURE 3

UNCOATED SPECIMENS

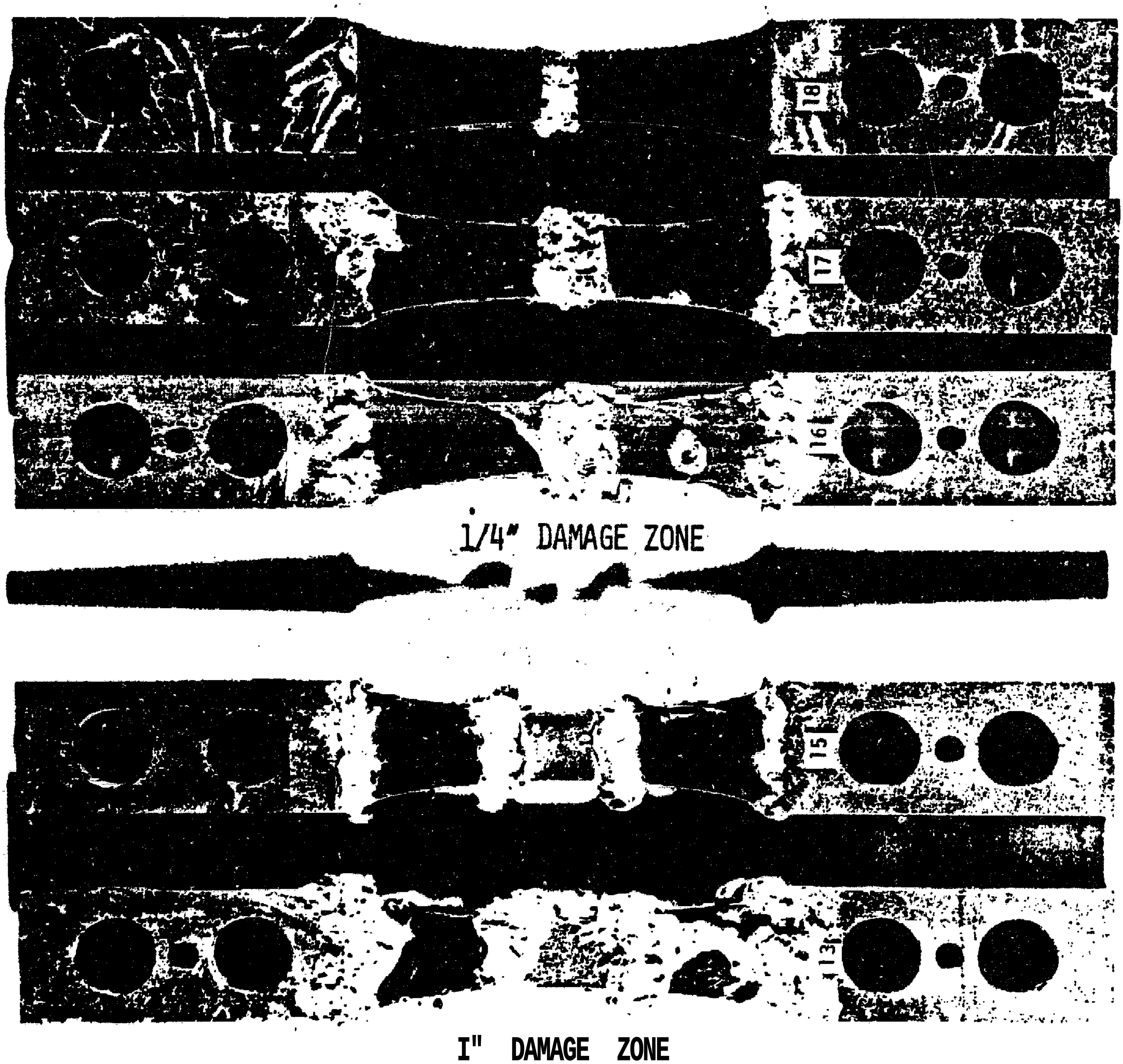


FIGURE 4
ALUMINUM FLAME SPRAYED SPECIMENS
WITH PR 1654 OVERCOAT AFTER 30 DAY IMMERSION

0321-51134-l

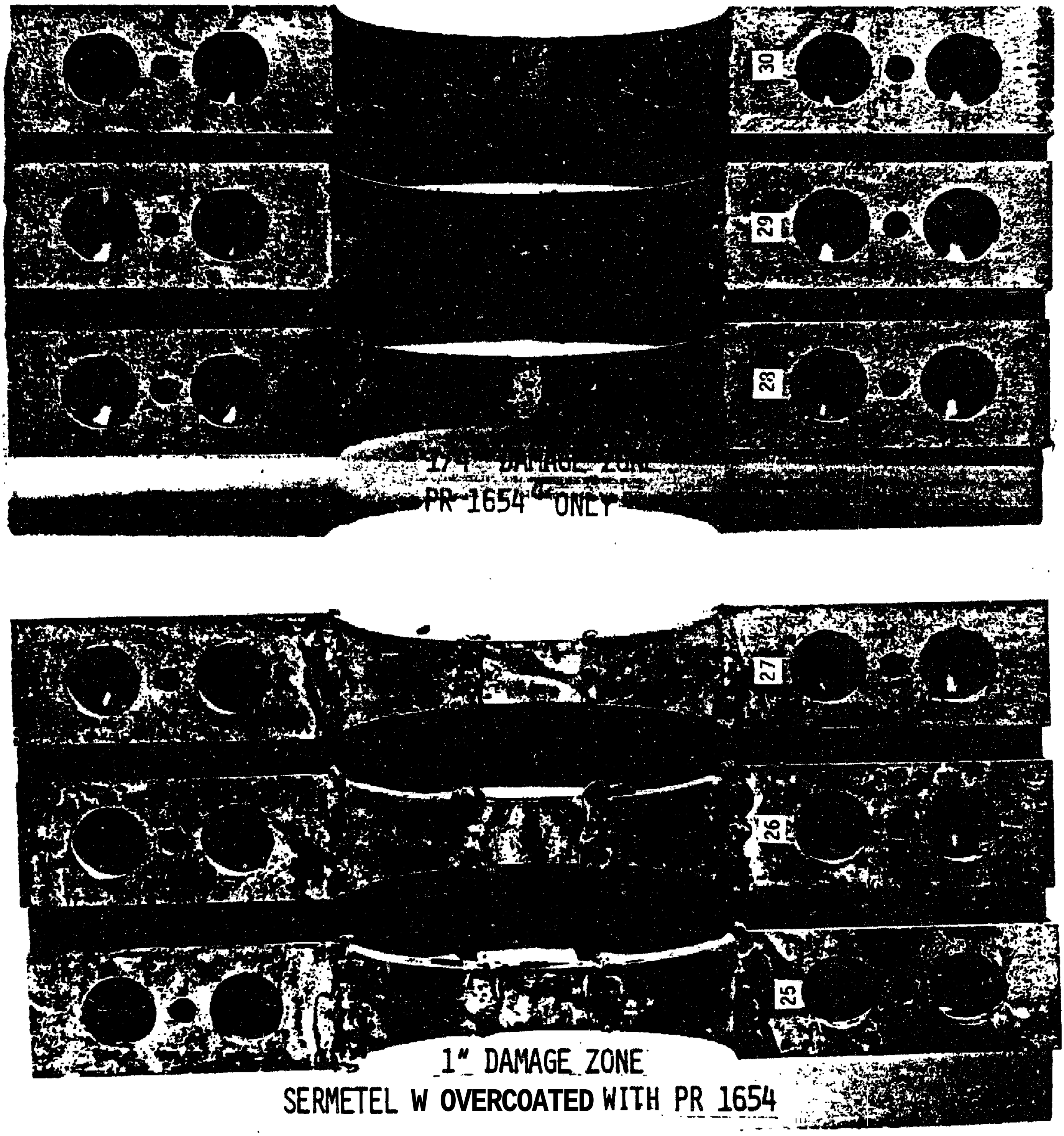


FIGURE 5

COATED SPECIMENS AFTER 30 DAY IMMERSION

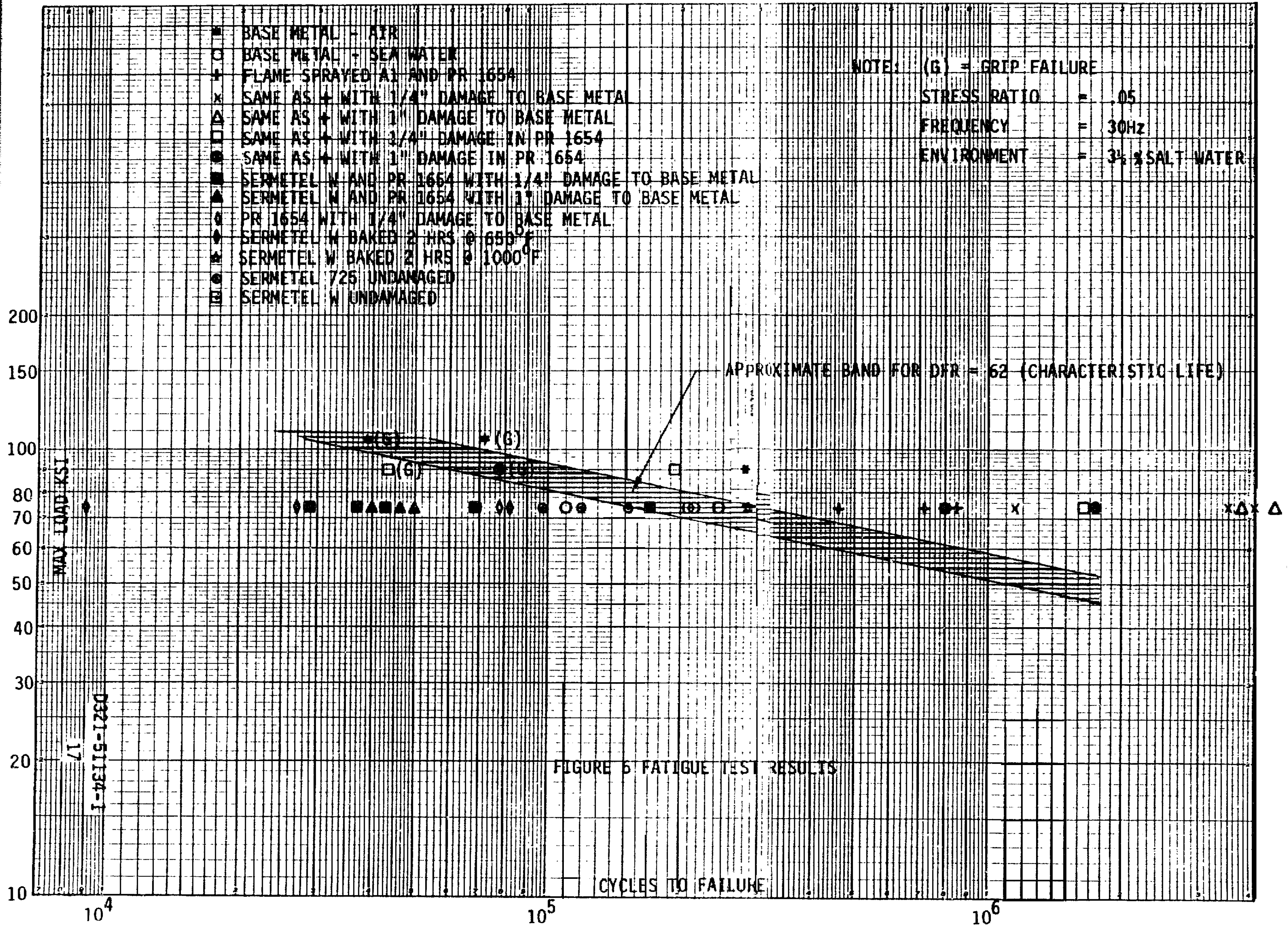


FIGURE 6 FATIGUE TEST RESULTS

THE **BOEING** COMPANY

ACTIVE SHEET RECORD

SHEET NO.	REV LTR	ADDED SHEETS				SHEET NO.	REV LTR	ADDED SHEETS			
		SHEET NO.	REV LTR	SHEET NO.	REV LTR			SHEET NO.	REV LTR	SHEET NO.	REV LTR
1											
2											
3											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											

DO 6000 2158 ORIG. 4/71