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STRESS CORROSION AND FATIGUE TESTS ON 7001-T75 ALUMINUM ALLOY

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THE BOEING COMPANY
Wichita Division

TECHNICAL REPORT AFML-TR-66-12

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Air Force Materials Laboratory
Research and Technology Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

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FOREWORD

This investigation of the 7001-T75 aluminum alloy was conducted by The Boeing Company, Wichita Division, Wichita, Kansas under USAF Contract No. AF33(657)-7086 CCN4 (4N-860). This contract was initiated under Project No. 7381, "Materials Application," Task No. 738103, "Data Collection and Correlation." This work was under the direction of the Air Force Materials Laboratory, Research and Technology Division, Wright-Patterson Air Force Base, Ohio, with Mr. C. B. Ward and Lt D. E. Tibovich, Project Engineers. The contract period was from October 1963 through May 1966. The manuscript was released by the authors in June 1966 for publication as a technical report.

The data contained in this report pertaining to the 7075-T73, 7079-T6, 7079-T62, and 7079-T611 aluminum alloys was obtained from a separate test program which was under USAF Contract No. AF33(657)-7086 Supplemental Agreement Number 2.

The investigation of the 7001-T75 aluminum alloy was carried out under the direction of Mr. W. B. Evans and the report was prepared by Mr. A. G. Chambers.

This technical report has been reviewed and is approved.

W. P. Conrardy

A. P. CONRARDY, Chief
Systems Support Branch
Materials Applications Division
Air Force Materials Laboratory

ABSTRACT

Test specimens of 7001-T75 aluminum alloy were evaluated for resistance to stress corrosion and for fatigue characteristics. Alternate immersion stress corrosion tests were performed at gross area stress levels of 50 ksi, 30 ksi, and 20 ksi with steel Taper-Lok and titanium lockbolt fasteners installed in plain and cold worked holes. These fasteners were installed with clearance and interference fits. This report also includes, for comparison purposes, similar stress corrosion data on 7075-T73, 7079-T6, 7079-T62, and 7079-T611 aluminum alloy. The data for these four alloys was obtained from a separate contract. Fatigue tests were performed at 15 ± 5 ksi and 15 ± 10 ksi mean plus alternating stress levels. The test configurations included an open hole monoblock design and a strap reinforcement design with steel Taper Lok fasteners. This report also includes, for comparison purposes, similar fatigue test data on 7075-T73 and 7079-T62 aluminum alloys. The data for these two alloys was obtained from a separate contract. The 7001-T75 alloy exhibited very good resistance to stress corrosion cracking at 50 ksi gross area sustained stress. The limited number of fatigue tests indicated that the 7001-T75 alloy is potentially superior to 7075-T73 and 7079-T62.

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I.

INTRODUCTION

The best solution to the problem of stress corrosion cracking (SCC) of aluminum alloys is the development of alloys and tempers which are not susceptible under the operating stresses and environments. The long range objective of ARTC Project 16-61, "Stress Corrosion Cracking of Aluminum Alloys" was to encourage development of stress corrosion resistant alloys.

The Aluminum Company of America (Alcoa) and Harvey Aluminum have both developed high strength alloys resistant to SCC. Alcoa has a patent pending on their T73 temper for 7075 and Harvey for their T75 temper for 7001.

The objective of this program was to determine the stress corrosion and fatigue properties of 7001-T75 specimens having various fastener installations and to compare these results with similar data on 7075-T73, 7079-T6, 7079-T62, and 7079-T611. This data on 7075-T73 and the three tempers of 7079 was obtained from a separately contracted test program (Contract AF33(657)-7086-SA No. 2). For clarity, this latter data is included as an integral part of this report.

II.

STRESS CORROSION TESTS

1. Material

The 7001-T75 alloy plate was procured in the fully heat treated condition. The approximate size of the one-inch thick plate was 36 inches wide by 86 inches long. Specimens were machined in the long transverse grain direction as shown in Figure 1. The chemical composition and mechanical properties are tabulated in Tables I and II, respectively.

The 7075-T73 alloy plate was procured in the fully heat treated condition. The approximate size of the .75 inch thick plate was 44 inches wide by 72 inches long. Specimens were machined in the long transverse grain direction. The chemical composition and mechanical properties are tabulated in Tables I and II, respectively.

The 7079 alloy plate used in these tests was procured in the -F temper. The approximate size of the .75 inch thick plate was 44 inches wide by 72 inches long. The specimens were machined from the 7079 -F plate in the long transverse grain direction. The specimens were subsequently heat treated to the T-6, T-62, or T-611 temper at Boeing-Wichita. The -T6 temper as used in this report refers to solution treat at 820-840 degrees F plus quench in water less than 90 degrees F plus age at 230-250 degrees F for 46-48 hours. The -T62 temper is identical to the -T6 temper except quenching is accomplished in 140-160 degrees F water. The -T611 temper is identical with the -T6 temper except quenching is accomplished in 175-185 degrees F water. The chemical composition and mechanical properties of the plate are tabulated in Tables I and II, respectively.

2. Specimens

Test specimens were fabricated to process specifications and manufacturing quality standards utilized on military and commercial aircraft and components produced at the Wichita facility. Since the test articles were fabricated to representative process and quality standards, the test results offer a maximum validity for practical aircraft applications.

Specimen configuration and dimensions are shown in Figure 2. When required, holes were cold worked with a tapered steel mandrel of .0053 to .0067 inch greater diameter than the holes. Cold worked holes were deburred on the exit side by breaking the edge approximately .008 inch or 45 degree chamfer. Shot peening, when required, was done with stainless cut wire shot .047 inch in diameter. The specimens were peened all over to a depth of compression of .020 to .025 inch with a coverage of 200 percent. The shot peened specimens were carefully cleaned after peening.

3. Fasteners

After the preparation described in Paragraph 2, either steel Taper-Lok or titanium lockbolts were installed. Fastener types were 1/4 inch diameter. Interferences and clearances are shown in Tables III through XXVI.

4. Stress Corrosion Test Procedure

Specially designed constant load fixtures were used for the stress corrosion tests. The fixtures employed a lever arm arrangement and dead weights as shown in Figure 3. A specimen in the constant load test fixture is shown in Figure 4.

The actual load for each specimen was first determined using a load cell in place of the specimen. Load cells consisted of dummy specimens with strain gages attached. Loads were measured with a Baldwin SR-4 strain indicator and were accurate within ±1.0 percent at the lower loads and ±0.5 percent at the highest loads. After the required load had been determined, the load cell was removed, the specimen was inserted and the beam was releveled.

Alternate immersion was accomplished in a solution of 3.5 percent by weight NaCl in deionized water. A complete cycle consisted of pumping the solution into the tanks and holding for 10 minutes followed by gravity draining and drying for 50 minutes. The corrosion solutions were changed weekly.

5. Post Test Inspection

Specimens were removed from test after 2160 hours (90 days) or after failure, whichever occurred first. They were then sanded lightly and inspected for cracks. Fractographic analyses using optical and electron microscopy were made as required.

6. Test Conditions

Specimens were tested at gross area stress levels of 20, 30, and 50 ksi. These corresponded to net area stresses of 26.7, 40.0, and 66.7 ksi respectively, neglecting the stress concentration at the hole. For the 7075-T73 specimens, the applied 66.7 ksi net stress was considerably above the yield strength and was just below the ultimate. All tests were conducted to failure or to 2160 hours, whichever occurred first.

III.

STRESS CORROSION TEST RESULTS AND DISCUSSION

Stress corrosion results are tabulated in Tables III through XXVI. A comparison of stress corrosion failure times at the highest stress level, 50 ksi gross, is shown in Figures 10, 11, 12, and 13. An insufficient number of samples failed at the lower stress levels of 30 ksi and 20 ksi to make similar comparisons. A short discussion of stress corrosion results for each of the three gross area stress levels follows.

1. 20 ksi

   At 20 ksi, failure occurred in only two materials and one test condition. Two 7079-T611 and three 7079-T62 unpeened specimens with steel Taper-Lok fasteners installed in non-cold worked holes with the highest interference, .0080 to .0090 inch, failed. The 7075-T73, 7001-T75, and 7079-T6 specimens did not develop detectable cracks after 2160 hours. No cracks were found in any materials which had the titanium lockbolts installed. No 7079-T6 specimens with the Taper-Lok fastener installed with .0080 to .0090 inch interference were run.

2. 30 ksi

   At 30 ksi, all the 7079-T62 and 7079-T611 specimens with no peening and no hole cold working and with the steel Taper-Lok installed at .0080 to .0090 inch interference, failed. One shot peened 7079-T62 specimen with cold worked hole and Taper-Lok fastener installed with .0002 to .0007 inch interference failed outside the test area. One shot peened 7079-T62 specimen with unworked hole and titanium lockbolt installed with .0010 to .0020 inch clearance failed. One unpeened 7079-T611 specimen with cold worked hole and titanium lockbolt installed with .0010 to .0020 inch clearance failed outside the test area.

3. 50 ksi

   At 50 ksi gross area stress (net area stress - 66.7 ksi), failures occurred in all alloys tested. However, stress corrosion resistance at this stress level was strongly affected by some of the variables. For example, one of the 7001-T75 specimens with titanium lockbolts failed. At least one 7001-T75 specimen with the steel Taper-Lok

failed at each of the following conditions: Low interference, no shot peening, no hole cold work; low interference, shot peened, no hole cold work; medium interference, no shot peening, no hole cold work; high interference, shot peened, no hole cold work. Figure 5 shows a failed 7001-T75 specimen and Figure 6 shows a typical stress corrosion fracture face for the 7001-T75 alloy.

The 7075-T73 specimens were tested at a net area stress level greater than F_{TY} and close to F_{TU}. Therefore, for this alloy, the test results should not be compared directly with test results from the higher strength alloys. Three specimens broke on loading, which demonstrates that the net area stress was very close to the actual tensile strength of the material. Electron photomicrographs of a 7075-T73 specimen which survived 1161 hours of alternate immersion testing showed strong evidence of overload characterized by the preponderance of ductile dimples shown in Figure 7. However, this figure also shows an intergranular failure mode which is indicative of stress corrosion cracking. The main significance of these tests was that stress corrosion failures did occur in 7075-T73 at a stress just under the ultimate tensile strength of the material. The fact that some specimens did not fail during the 2160 hour test indicated that the critical stress level for stress corrosion cracking in this alloy (under the conditions tested) was just below the ultimate tensile strength.

Most of the 7079-T6, 7079-T62, and 7079-T611 specimens failed at 50 ksi. No significant failure pattern was evident between the alloys, type fastener, degree of interference, hole cold working, or shot peening.

On examining the data at the 50 ksi stress level shown in Figures 10, 11, 12, and 13, the particular heat of 7001-T75 tested in this program did sustain the applied stress better than the other alloys. As discussed previously, the reason for its seemingly superior stress corrosion resistance as compared to 7075-T73 probably was that the 7075-T73 was operating very close to its ultimate tensile strength. However, the 7001-T75 was clearly superior to all tempers of 7079 tested.

Figure 8 is an electron photomicrograph taken on the fracture face at the hole-to-specimen surface interface. There is no evidence of stress corrosion in this figure. This indicates that the stress corrosion did not start at this point. Figure 9 shows the typical stress corrosion appearance of the 7001-T75. The intergranular failure mode and the surface corrosion indicated by the black dots is clearly evident.

VI.

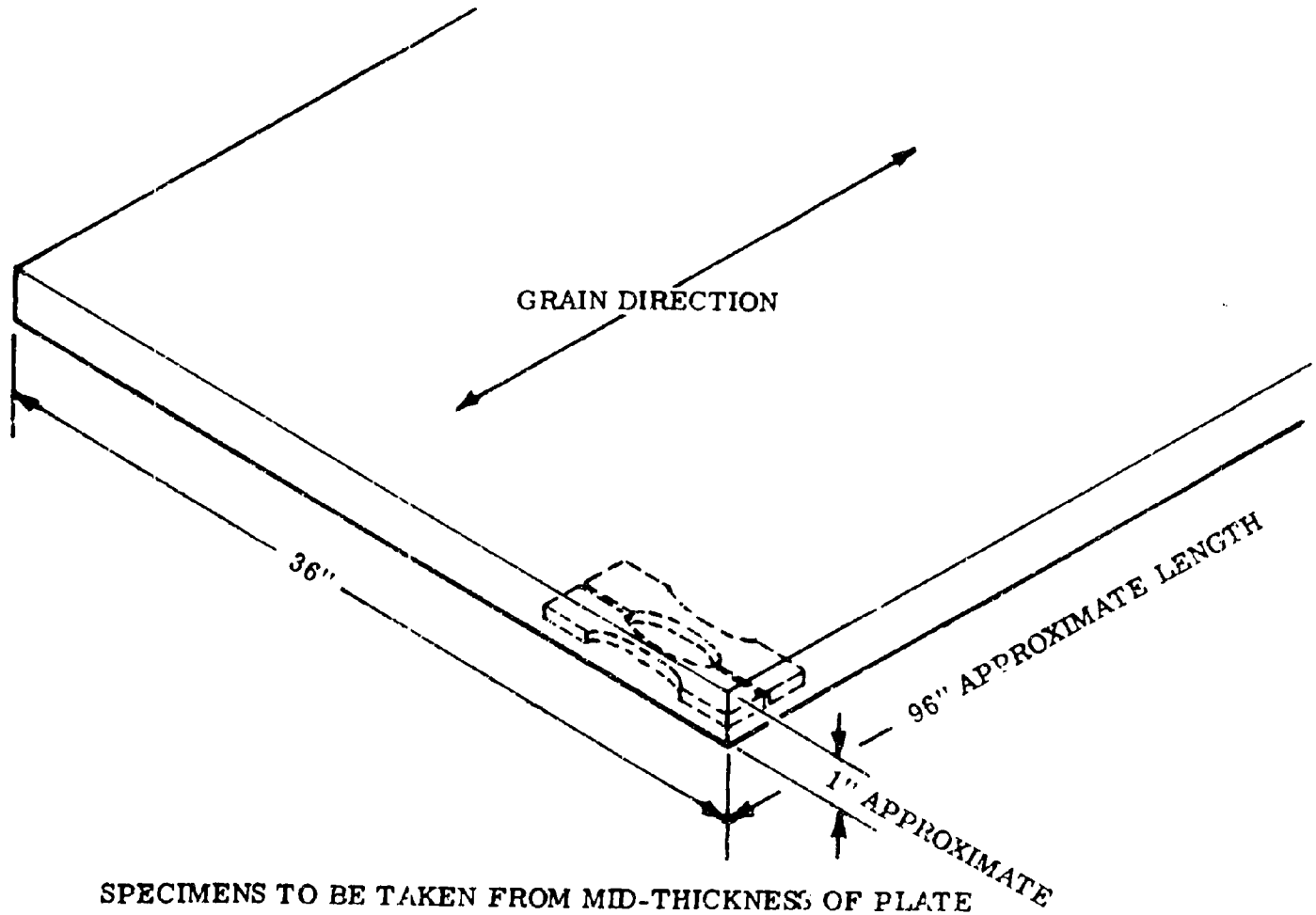
CONCLUSIONS AND RECOMMENDATIONS

1. The 7001-T75 alloy exhibited very good resistance to stress corrosion cracking at 50 ksi sustained gross stress.

2. The 7001-T75 alloy exhibited fatigue characteristics potentially superior to 7075-T73 and 7079-T62.

3. Further fatigue tests should be run so that statistically significant comparisons can be made.

4. The fracture toughness of 7001-T75 and the fabrication characteristics of this alloy should be determined.



SPECIMENS TO BE TAKEN FROM MID-THICKNESS OF PLATE

LAYOUT SKETCH - 7001-T75 PLATE FOR STRESS CORROSION SPECIMENS
FIGURE 1

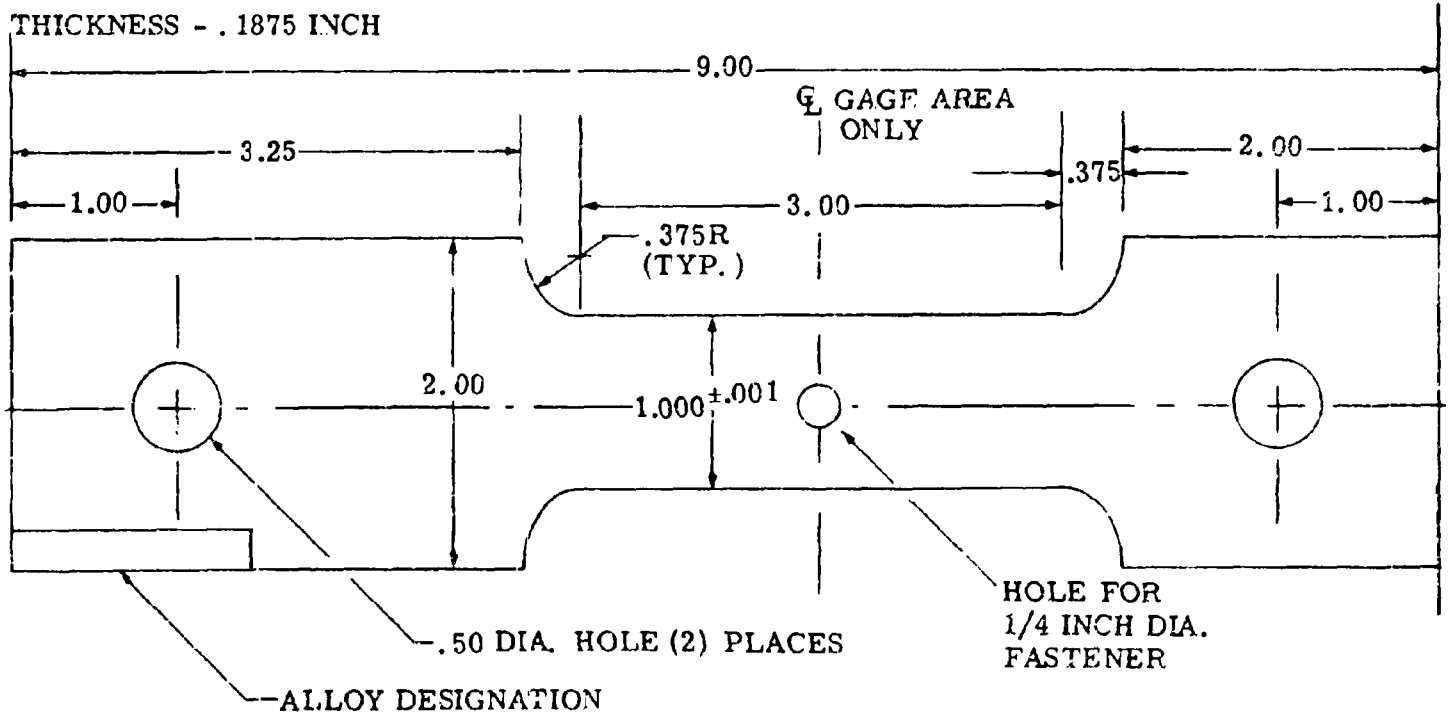
NOTES:

SPECIMEN SHALL BE SYMMETRICAL WITH $\mathbb{C}_L$ OF REDUCED SECTION WITHIN .001 INCH

MACHINE FINISH OF 63 RHR OR BETTER

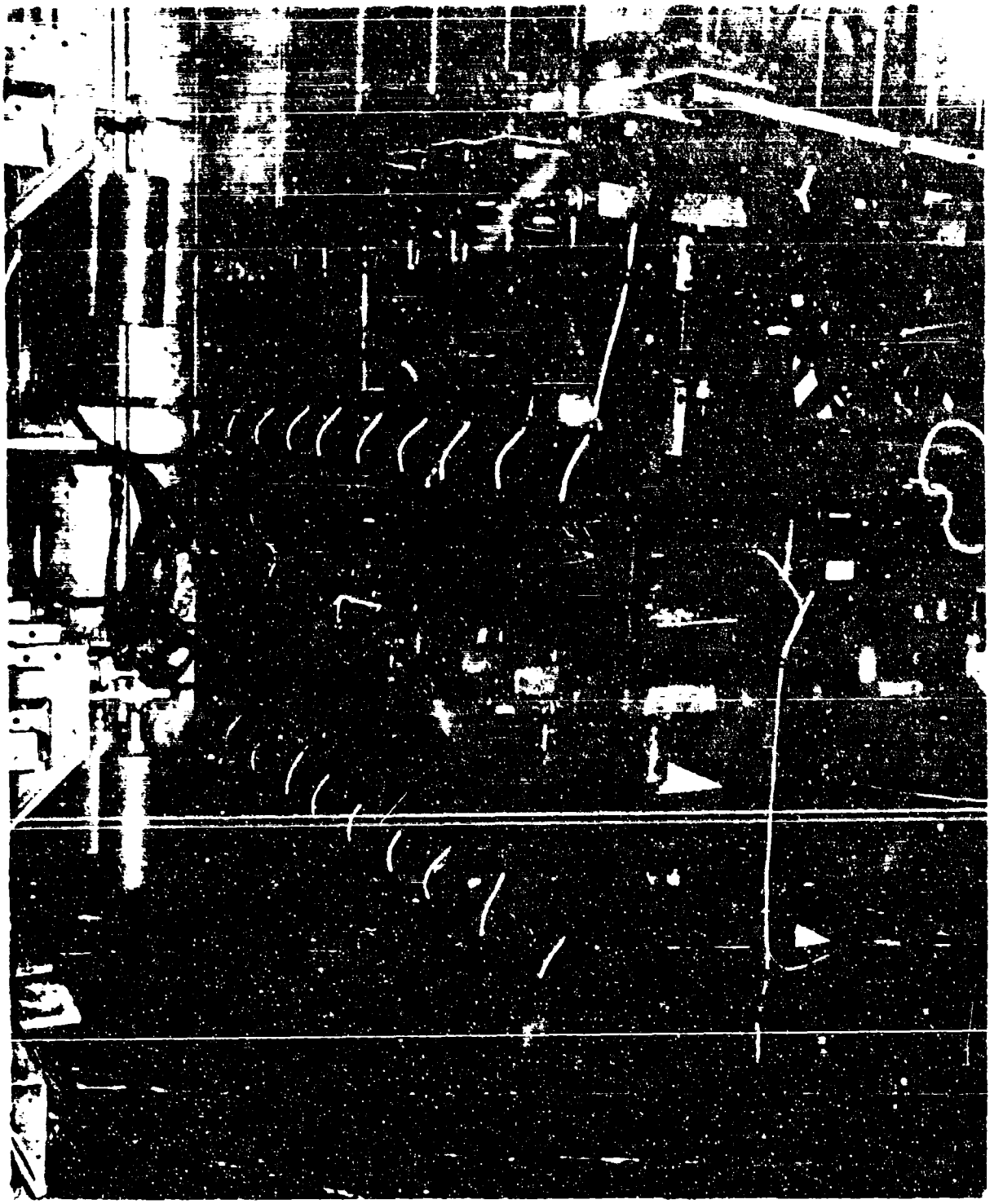
RADIUS TO BLEND SMOOTHLY INTO REDUCED AREA, NO UNDER-CUTTING PERMITTED

THICKNESS - .1875 INCH



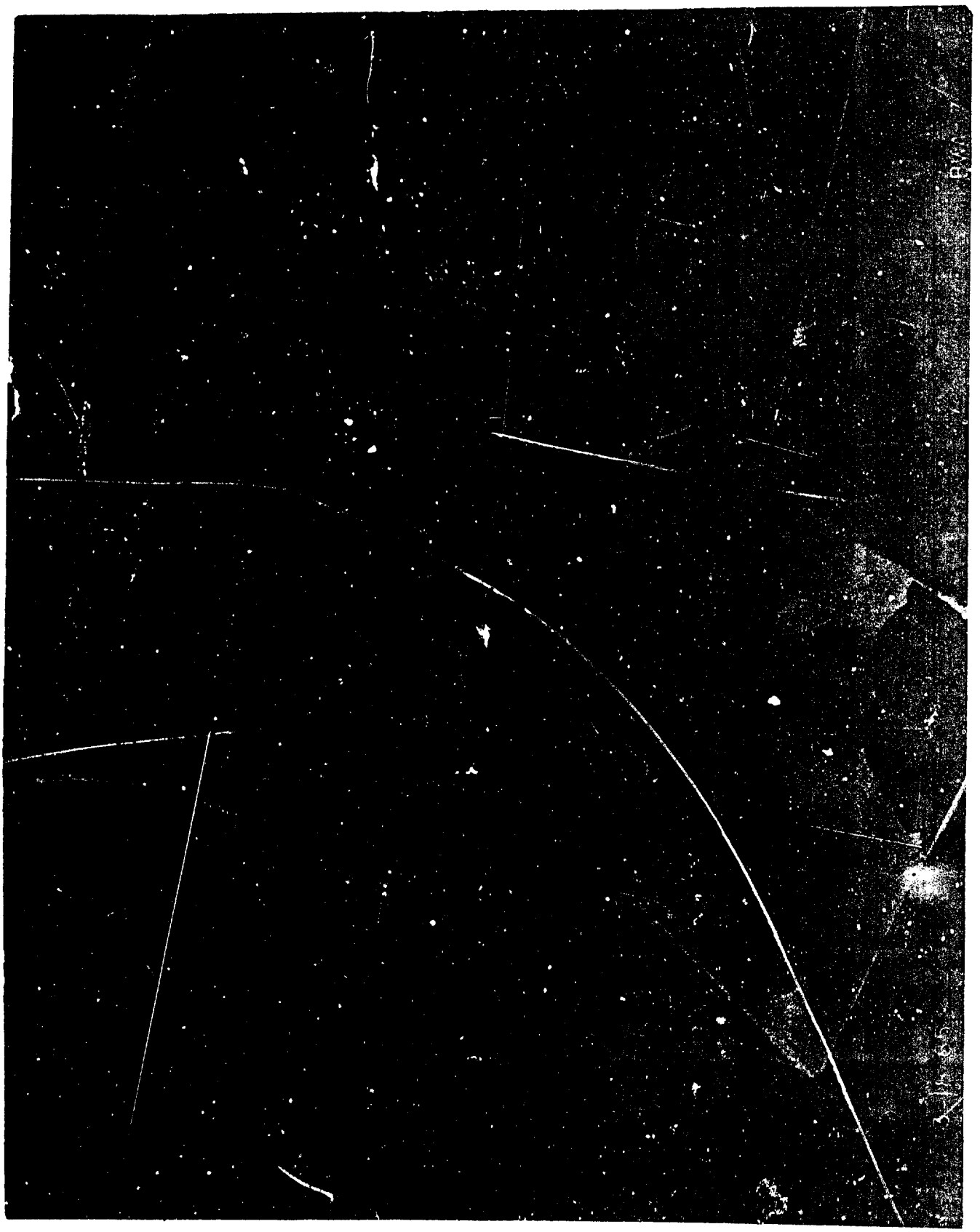
SPECIMEN CONFIGURATION - STRESS CORROSION TESTS

FIGURE 2



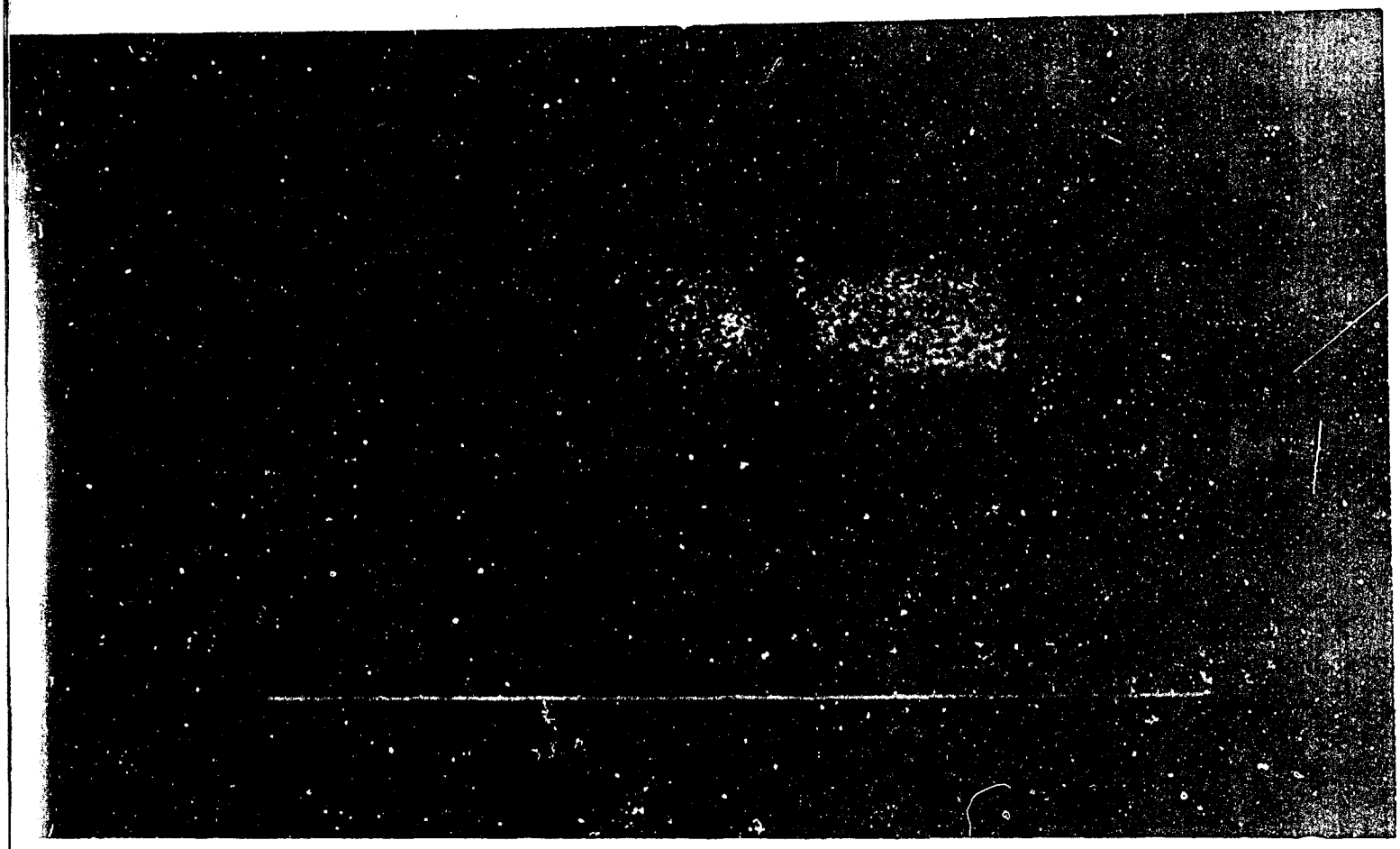
CONSTANT LOAD FIXTURE USED FOR STRESS CORROSION TESTING

FIGURE 3



SPECIMEN IN A CONSTANT LOAD STRESS CORROSION TEST FIXTURE

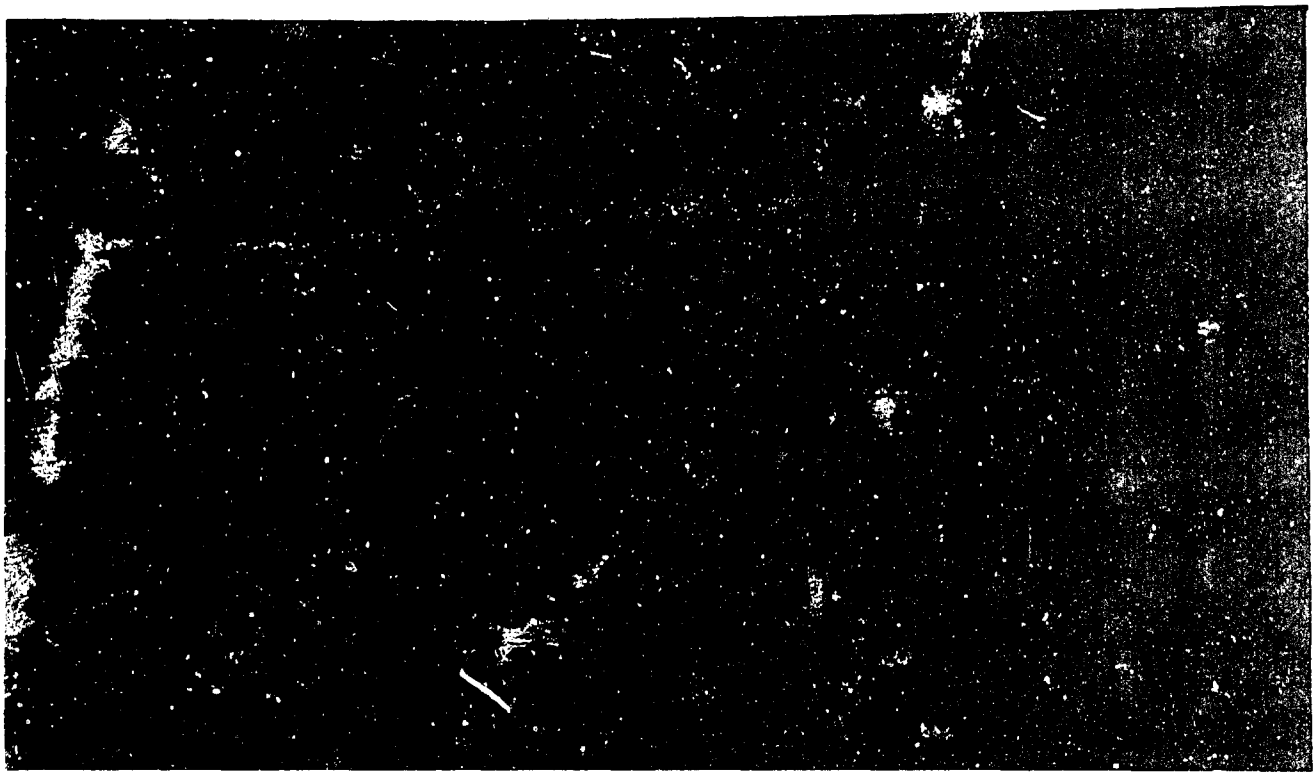
FIGURE 4



This is Specimen Number 37 which failed in 1684.6 hours at 50,000 psi gross area stress (66.7 ksi net area stress). Note the general corrosion attack in the test area. The surface of this specimen was not shot peened and the hole was not cold worked. Fastener interference was .0080 to .0090 inch.

TYPICAL 7001-T75 SPECIMEN WI.. STEEL TAPER-LOK FASTENER WHICH FAILED BY STRESS CORROSION

FIGURE 5



This is the fracture face of Specimen Number 121 which failed in 1992.1 hours at 50,000 psi gross area stress (66.7 ksi net area stress). The surface of this specimen was shot peened but the hole was not cold worked. A Taper-Lok fastener had been installed with .0080 to .0090 inch interference.

TYPICAL FRACTURE FACE OF 7001-T75 STRESS CORROSION SPECIMEN

FIGURE 6

10,000X

From two-stage carbon replica of fracture face on Specimen Number 229. Note the intergranular mode of failure coupled with fairly extensive ductile dimpling. This mode indicates that the failure was predominately stress corrosion and tensile overload. This specimen was not shot peened, had a titanium lockbolt installed and had no hole cold work. It failed after 1161.8 hours at 50 ksi (66.7 ksi net area stress).

ELECTRON PHOTOMICROGRAPH OF 7075-T73 STRESS CORROSION FAILURE

FIGURE 7

15,400X

From two-stage carbon replica on fracture face of Specimen Number 2. The ductile dimpling indicates the fracture mode was overload. This specimen was not shot peened, had a Taper-Lok fastener installed at .0033 to .0043 inch interference and had no hole cold work. It failed after 1992.1 hours at 50 ksi (66.7 ksi net area stress). The area shown was located at the hole-to-specimen surface intersection.

ELECTRON PHOTOMICROGRAPH OF 7001-T75 STRESS CORROSION FAILURE

FIGURE 8

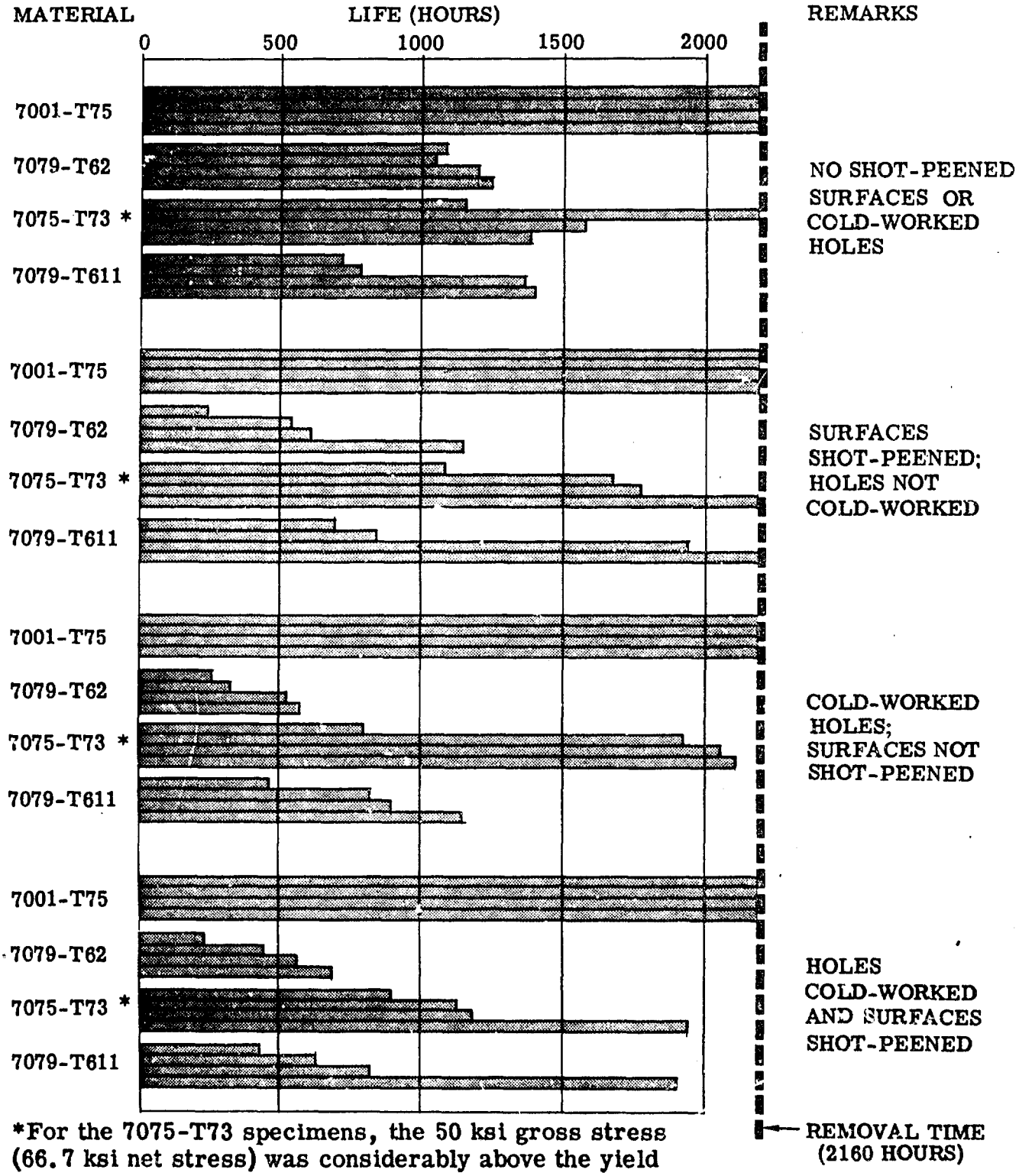
6,000X

From two-stage carbon replica on fracture face of Specimen Number 2. The blocky structure and corrosion indicated by the black dots is typical of stress corrosion. See Figure 8 for description of test conditions.

ELECTRON PHOTOMICROGRAPH OF 7001-T75 STRESS CORROSION FAILURE

FIGURE 9

STRESS CORROSION TEST RESULTS AT 50 KSI (GROSS AREA STRESS) OF SPECIMENS WITH 1/4-INCH DIAMETER TITANIUM LOCKBOLTS INSTALLED WITH .0010 TO .0020-INCH CLEARANCE

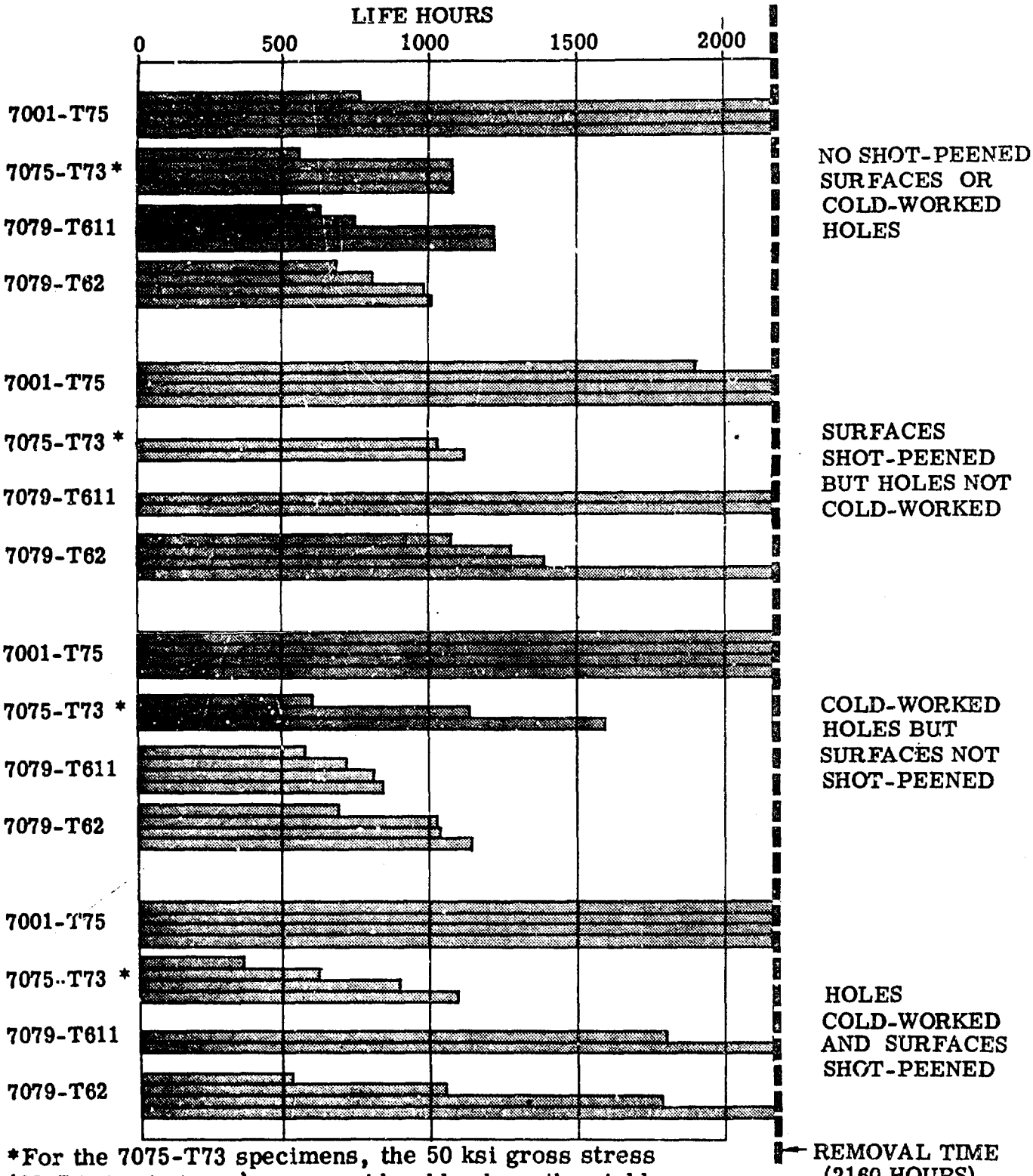


*For the 7075-T73 specimens, the 50 ksi gross stress (66.7 ksi net stress) was considerably above the yield strength and was just below the ultimate.

MATERIAL LIFE HOURS

FIGURE 10

STRESS CORROSION TEST RESULTS AT 50 KSI (GROSS AREA STRESS)
SPECIMENS WITH 1/4-INCH DIAMETER STEEL TAPER-LOK FASTENERS
INSTALLED WITH LOW INTERFERENCE FIT OF .0002 TO .0007

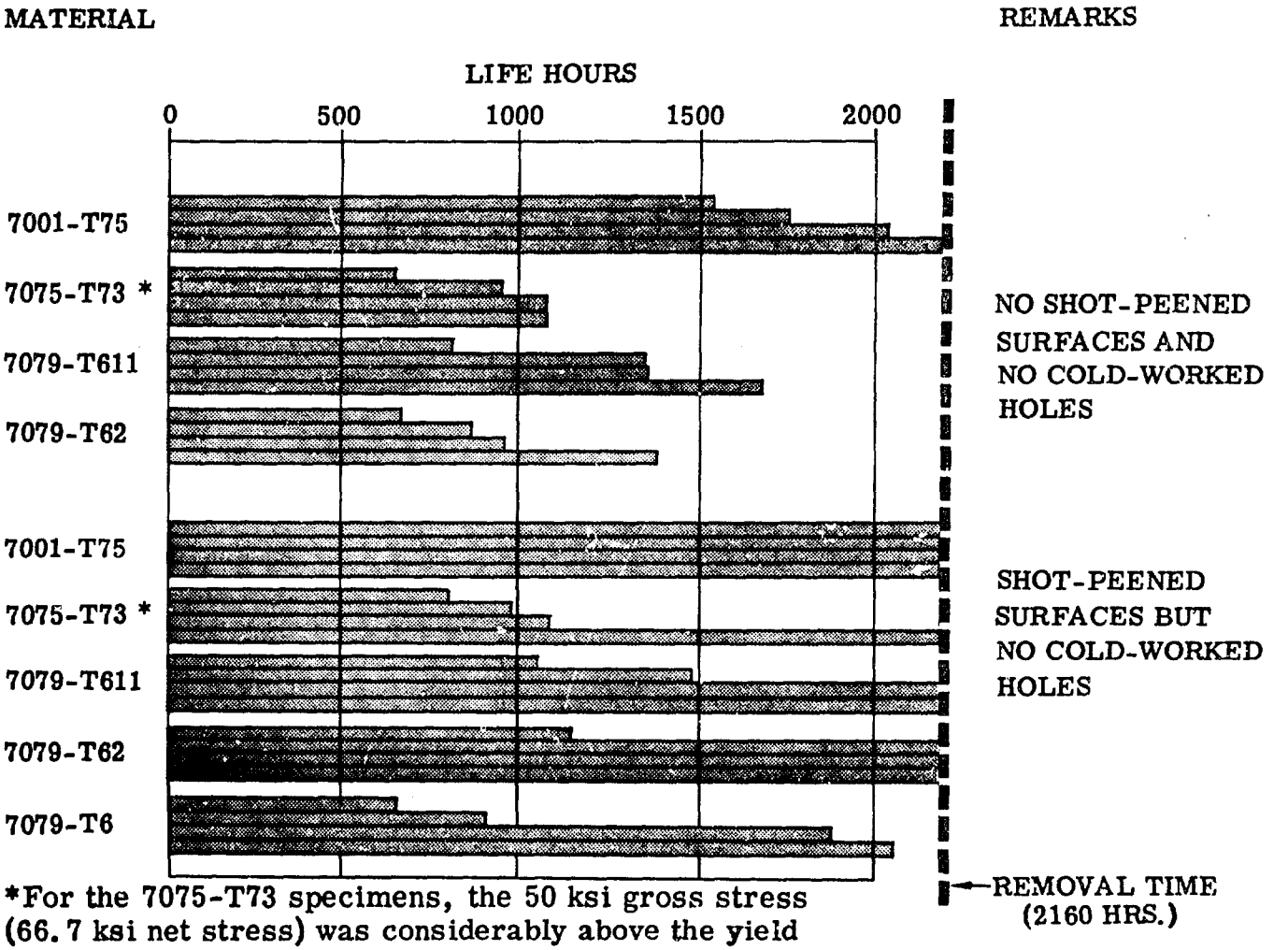


*For the 7075-T73 specimens, the 50 ksi gross stress (66.7 ksi net stress) was considerably above the yield strength and was just below the ultimate.

MATERIAL LIFE HOURS

FIGURE 11

STRESS CORROSION TEST RESULTS AT 50 KSI (GROSS AREA STRESS)
SPECIMENS WITH 1/4-INCH DIAMETER STEEL TAPER-LOK FASTENERS
INSTALLED WITH MEDIUM INTERFERENCE FIT OF .0033 TO .0043

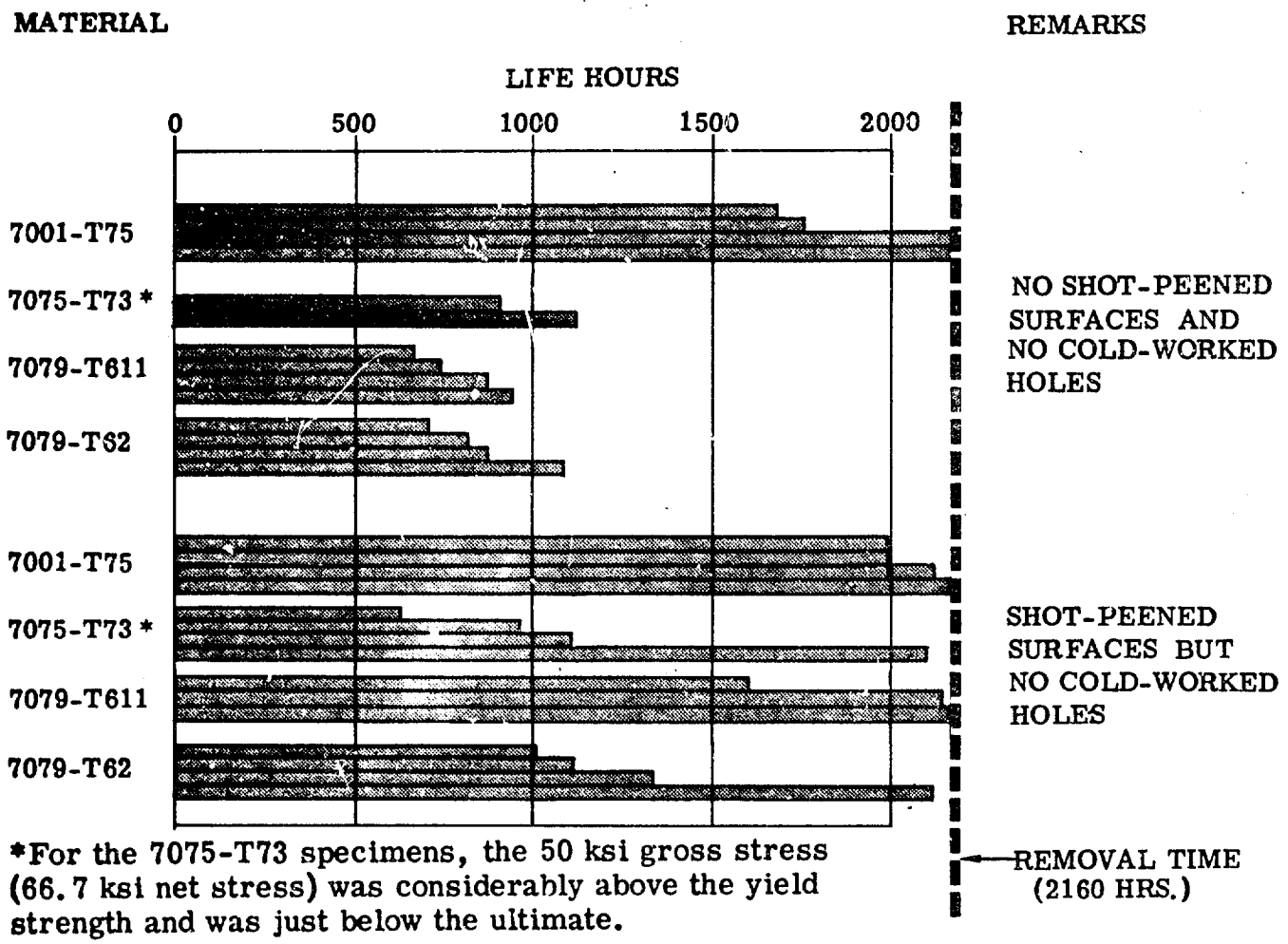


*For the 7075-T73 specimens, the 50 ksi gross stress (66.7 ksi net stress) was considerably above the yield strength and was just below the ultimate.

MATERIAL LIFE HOURS

FIGURE 12

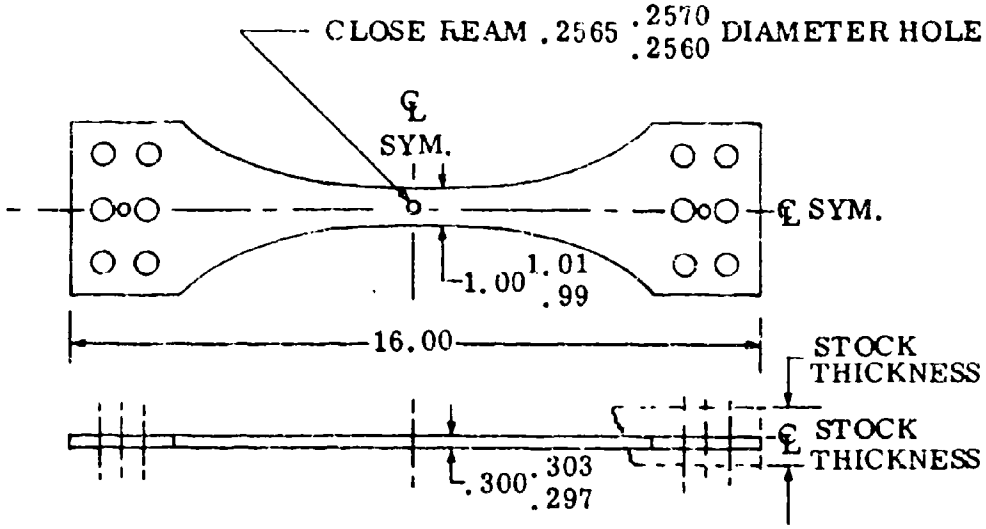
STRESS CORROSION TEST RESULTS AT 50 KSI (GROSS AREA STRESS SPECIMENS WITH 1/4-INCH DIAMETER STEEL TAPER-LOK FASTENERS INSTALLED WITH HIGH INTERFERENCE FIT OF .0080 to .0090



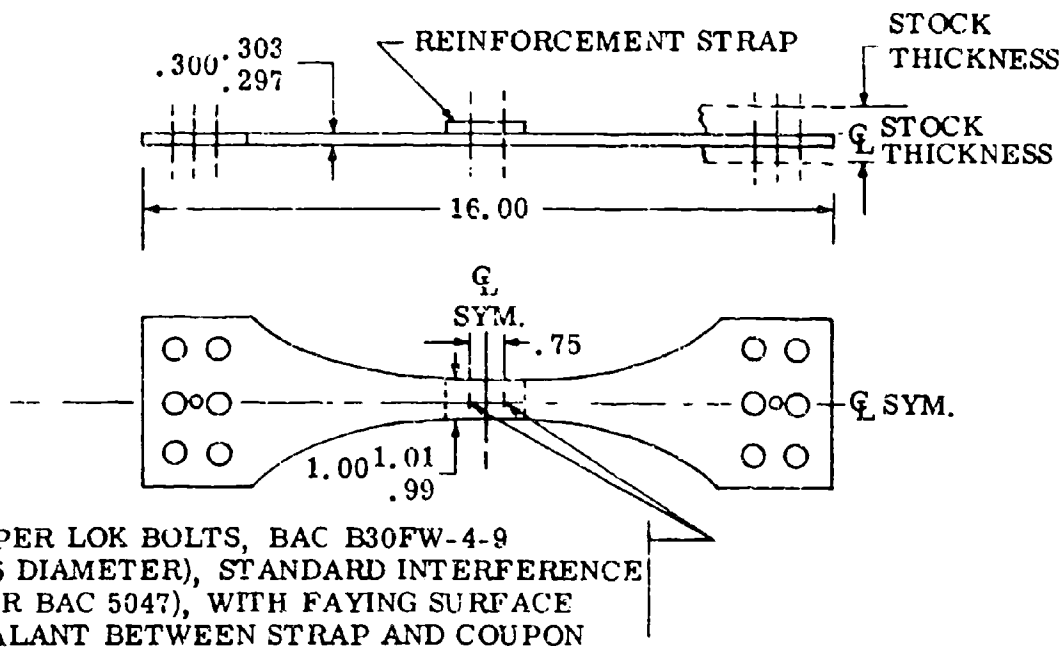
*For the 7075-T73 specimens, the 50 ksi gross stress (66.7 ksi net stress) was considerably above the yield strength and was just below the ultimate.

MATERIAL LIFE HOURS

FIGURE 13



OPEN HOLE MONOBLOCK CONFIGURATION



TAPER LOK BOLTS, BAC B30FW-4-9 (.25 DIAMETER), STANDARD INTERFERENCE (PER BAC 5047), WITH FAYING SURFACE SEALANT BETWEEN STRAP AND COUPON

STRAP REINFORCEMENT
SPECIMEN CONFIGURATION - FATIGUE TESTS

FIGURE 14

TABLE I

CHEMICAL COMPOSITION OF 7079, 7001, AND 7075

Element	Composition, Wt. Percent 7079*	7075*	7001*	7001**	
Si	0.06	0.07	0.09	0.35	MAX.
Fe	0.11	0.13	0.12	0.40	MAX.
Cu	0.58	1.7	2.1	1.6-2.6	
Mn	0.20	---	Trace	0.20	MAX.
Mg	3.5	2.6	3.1	2.6-3.4	
Cr	0.22	0.26	0.21	0.18-0.40	
Zn	4.2	5.5	7.2	6.8-8.0	
Ti			Trace	0.20	MAX.
Others				0.15	MAX.
Balance	Al	Al	Al	Al	
Lot No.	649-891	189-521			

* Analysed by Point-To-Plane Optical Emission Spectrography

** Harvey Requirement

TABLE II

MECHANICAL PROPERTIES OF TEST MATERIAL

Identification	Material	Test Direction	0.2% F_{ty} KSI	F_{tu} KSI	Elong., % in 2 Inches
Harvey Job No. 55-4424	7001-T75	Long.	74.2	81.2	12.0
			74.3	81.5	12.0
			73.6	81.3	11.0
			68.2	77.5	11.0
			68.6	78.0	12.5
		Trans.	73.6	82.0	10.5
			73.7	82.4	10.0
Boeing-1		Trans.	72.9	81.4	10.5
-2			72.6	81.4	9.5
-3			72.2	81.3	10.0
-4			72.7	81.3	10.0
Boeing	7079-T6		67.7 to 68.7	78.8 to 79.5	13
Note: Values shown are extreme values. Six specimens were run. Remaining four values were between extremes					
Boeing	7075-T73		59.6 to 60.1	70.6 to 71.1	10.5 to 12.0
Note: Values shown are extreme values. Six specimens were run. Remaining four values were between extremes					

TABLE III

FAILURE TIMES AT 50 KSI FOR 7079-T62 AND 7079-T6 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
		7079-T62		
25	.0002	Yes	No	1140.0
26	to	↓	↓	1036.1
27	.0007	↓	↓	1022.6
28	↓	↓	↓	697.0
49	↓	No	No	1005.1
50	↓	↓	↓	814.1
51	↓	↓	↓	979.5
52	↓	↓	↓	686.7
109	↓	Yes	Yes	1795.5
110	↓	↓	↓	1554.7
111	↓	↓	↓	NF
112	↓	↓	↓	1029.9
133	↓	No	Yes	1072.0
134	↓	↓	↓	1292.0
135	↓	↓	↓	1398.3
136	↓	↓	↓	NF
1	.0033	No	No	873.0
2	to	↓	↓	964.8
3	.0043	↓	↓	1398.1
4	↓	↓	↓	675.5
13	↓	No	No	841.8
14	↓	↓	↓	873.8
15	↓	↓	↓	642.0
16	↓	↓	↓	1031.8
97	↓	No	Yes	2060.3
98	↓	↓	↓	1149.4
99	↓	↓	↓	2164.1
100	↓	↓	↓	NF
37	.0080	No	No	813.2
38	to	↓	↓	1083.6
39	.0090	↓	↓	859.6
40	↓	↓	↓	708.0
121	↓	No	Yes	2114.6
122	↓	↓	↓	1337.2
123	↓	↓	↓	1107.0
124	↓	↓	↓	1008.6
		7079-T6		
85	.0033	No	Yes	1875.5
86	to	↓	↓	920.3
87	.0043	↓	↓	657.6
88	↓	↓	↓	2052.7

NF No Failure

TABLE IV

FAILURE TIMES AT 30 KSI FOR 7079-T62 AND 7079-T6 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
		7079-T62		
33	.0002	Yes	No	NF
34	to			NF
35	.0007			NF
36				NF
57		No	No	NF
58				NF
59				NF
60				NF
117		Yes	Yes	NF
118				1879.4*
119				NF
120				NF
141		No	Yes	NF
142				NF
143				NF
144				**
9	.0033	No	No	NF
10	to			NF
11	.0043			NF
12				NF
21		No	No	NF
22				NF
23				NF
24				NF
105		No	Yes	NF
106				NF
107				NF
108				NF
45	.0080	No	No	1630.6
46	to			1599.5
47	.0090			1511.0
48				1142.5
129		No	Yes	NF
130				NF
131				NF
132				NF
		7079-T6		
93	.0033	No	Yes	367.0*
94	to			NF
95	.0043			NF
96				NF

* Failed Outside Test Area
** Destroyed in Machining
NF No Failure

TABLE V

FAILURE TIMES AT 20 KSI FOR 7079-T62 AND 7079-T6 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
		7079-T62		
29	.0002	Yes	No	NF
30	to			NF
31	.0007			NF
32				NF
53		No	No	NF
54				NF
55				NF
56				NF
113		Yes	Yes	NF
114				NF
115				NF
116				NF
137		No	Yes	NF
138				NF
139				NF
140				NF
5	.0033	No	No	NF
6	to			NF
7	.0044			NF
8				NF
17		No	No	NF
18				NF
19				NF
20				NF
101		No	Yes	NF
102				NF
103				NF
104				NF
41	.0080	No	No	1491.0
42	to			NF
43	.0090			1880.0
44				1537.6
125		No	Yes	NF
126				NF
127				NF
128				NF
		7079-T6		
89	.0033	No	Yes	NF
90	to			NF
91	.0043			NF
92				NF

NF No Failure

TABLE VI

FAILURE TIMES AT 50 KSI FOR 7079-T62 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
61	.0010	No	No	1085.0
62	to	↓	↓	1041.7
63	.0020	↓	↓	1205.2
64	↓	↓	↓	1245.2
73	↓	Yes	No	570.0
74	↓	↓	↓	261.6
75	↓	↓	↓	528.8
76	↓	↓	↓	328.7
145	↓	No	Yes	236.0
146	↓	↓	↓	1152.6
147	↓	↓	↓	612.0
148	↓	↓	↓	540.2
157	↓	Yes	Yes	236.0
158	↓	↓	↓	443.7
159	↓	↓	↓	694.0
160	↓	↓	↓	568.9

TABLE VII

FAILURE TIMES AT 30 KSI FOR 7079-T62 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
69	.0010	No	No	NF
70	to	↓	↓	NF
71	.0020	↓	↓	NF
72	↓	↓	↓	NF
81	↓	Yes	No	NF
82	↓	↓	↓	NF
83	↓	↓	↓	NF
84	↓	↓	↓	NF
153	↓	No	Yes	NF
154	↓	↓	↓	NF
155	↓	↓	↓	NF
156	↓	↓	↓	1940.0
165	↓	Yes	Yes	NF
166	↓	↓	↓	NF
167	↓	↓	↓	NF
168	↓	↓	↓	NF

NF No Failure

TABLE VIII

FAILURE TIMES AT 20 KSI FOR 7079-T62 SPECIMENS
WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
65	.0010	No	No	NF
66	to	↓	↓	NF
67	.0020	↓	↓	NF
68	↓	↓	↓	NF
77	↓	Yes	No	NF
78	↓	↓	↓	NF
79	↓	↓	↓	NF
80	↓	↓	↓	NF
149	↓	No	Yes	NF
150	↓	↓	↓	NF
151	↓	↓	↓	NF
152	↓	↓	↓	NF
161	↓	Yes	Yes	NF
162	↓	↓	↓	NF
163	↓	↓	↓	NF
164	↓	↓	↓	NF

NF No Failure

TABLE IX
FAILURE TIMES AT 50 KSI FOR 7079-T611 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
361	.0002	No	No	636.2
362	to			1225.6
363	.0007			753.4
364				1225.9
385		Yes	No	814.0
386				845.5
387				574.9
388				724.8
445		No	Yes	353.0*
446				NF
447				373.4
448				NF
469		Yes	Yes	**
470				1812.0
471				NF
472				2030.0*
337	.0033	No	No	339.5
338	to			581.5
339	.0043			764.6
340				748.2
349		No	No	1366.9
350				1477.7
351				1368.0
352				814.3
421		No	Yes	NF
422				1053.0
423				1485.0
424				NF
433		No	Yes	NF
434				NF
435				1211.6
436				1394.5
373	.0080	No	No	659.0
374	to			942.7
375	.0090			739.5
376				861.2
457		No	Yes	1598.3
458				NF
459				1133.0*
460				2140.0

* Failed Outside Test Area
** Destroyed During Machining
NF No Failure

TABLE X

FAILURE TIMES AT 30 KSI FOR 7079-T611 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
369	.0002	No	No	NF
370	to	↓	↓	NF
371	.0007	↓	↓	NF
372	↓	↓	↓	NF
393	↓	Yes	No	NF
394	↓	↓	↓	NF
395	↓	↓	↓	NF
396	↓	↓	↓	NF
453	↓	No	Yes	NF
454	↓	↓	↓	NF
455	↓	↓	↓	NF
456	↓	↓	↓	NF
477	↓	Yes	Yes	NF
478	↓	↓	↓	NF
479	↓	↓	↓	NF
480	↓	↓	↓	NF
345	.0033	No	No	NF
346	to	↓	↓	NF
347	.0043	↓	↓	NF
348	↓	↓	↓	NF
357	↓	No	No	NF
358	↓	↓	↓	NF
359	↓	↓	↓	NF
360	↓	↓	↓	NF
429	↓	No	Yes	NF
430	↓	↓	↓	NF
431	↓	↓	↓	NF
432	↓	↓	↓	**
441	↓	No	Yes	NF
442	↓	↓	↓	NF
443	↓	↓	↓	NF
444	↓	↓	↓	**
381	.0080	No	No	1922.0
382	to	↓	↓	1608.0
383	.0090	↓	↓	888.0
384	↓	↓	↓	1748.0
465	↓	No	Yes	NF
466	↓	↓	↓	NF
467	↓	↓	↓	NF
468	↓	↓	↓	**

** Destroyed During Machining
NF No Failure

TABLE XI

FAILURE TIMES AT 20 KSI FOR 7079-611 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
365	.0002	No	No	NF
366	to			NF
367	.0007			NF
368				NF
389		Yes	No	NF
390				NF
391				NF
392				NF
449		No	Yes	NF
450				NF
451				NF
452				NF
473		Yes	Yes	NF
474				NF
475				NF
476				NF
341	.0033	No	No	NF
342	to			NF
343	.0043			NF
344				NF
353		No	No	NF
354				NF
355				NF
356				NF
425		No	Yes	NF
426				NF
427				NF
428				NF
437		No	Yes	NF
438				NF
439				NF
440				NF
377	.0080	No	No	1864.0
378	to			781.0
379	.0090			NF
380				NF
461		No	Yes	NF
462				NF
463				NF
464				NF

NF No Failure

TABLE XII

FAILURE TIMES AT 50 KSI FOR 7079-T611 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
397	.0010	No	No	782.4
398	to			1365.2
399	.0020			721.0
400				1403.0
409		Yes	No	464.8
410				1151.2
411				900.9
412				823.6
481		No	Yes	841.8
482				694.8
483				NF
484				1940.0
493		Yes	Yes	637.7
494				819.7
495				1905.3
496				473.0

NF No Failure

TABLE XIII

FAILURE TIMES AT 30 KSI FOR 7079-T611 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
405	.0010	No	No	NF
406	to	↓	↓	NF
407	.0020	↓	↓	NF
408	↓	↓	↓	NF
417	↓	Yes	No	NF
418	↓	↓	↓	1893.0*
419	↓	↓	↓	NF
420	↓	↓	↓	NF
489	↓	No	Yes	NF
490	↓	↓	↓	NF
491	↓	↓	↓	NF
492	↓	↓	↓	NF
501	↓	Yes	Yes	NF
502	↓	↓	↓	NF
503	↓	↓	↓	NF
504	↓	↓	↓	NF

NF No Failure
* Failed Outside Test Area

TABLE XIV

FAILURE TIMES AT 20 KSI FOR 7079-T611 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
401	.0010	No	No	NF
402	to	↓	↓	NF
403	.0020	↓	↓	NF
404	↓	↓	↓	NF
413	↓	Yes	No	NF
414	↓	↓	↓	NF
415	↓	↓	↓	NF
416	↓	↓	↓	NF
485	↓	No	Yes	NF
486	↓	↓	↓	NF
487	↓	↓	↓	NF
488	↓	↓	↓	NF
497	↓	Yes	Yes	NF
498	↓	↓	↓	NF
499	↓	↓	↓	NF
500	↓	↓	↓	NF

NF No Failure

TABLE XV

FAILURE TIMES AT 50 KSI FOR 7075-T73 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
193	.0002	No	No	566.9
194	to			1086.6
195	.0007			1086.7
196				1086.6
217		Yes	No	605.9
218				1135.1
219				299.8*
220				1603.7
277		No	Yes	BOL
278				**
279				1014.2
280				1122.3
301		Yes	Yes	354.0
302				910.7
303				1096.0
304				625.8
169	.0033	No	No	979.4
170	to			1157.6
171	.0043			BOL
172				1557.8
181		No	No	656.0
182				1074.1
183				1074.0
184				958.7
253		No	Yes	941.7
254				1829.7
255				1306.8
256				BOL
265		No	Yes	812.0
266				NF
267				981.7
268				1086.0
205	.0080	No	No	222.0*
206	to			715.0*
207	.0090			915.1
208				1135.1
289		No	Yes	1109.6
290				961.8
291				2101.9
292				624.1

* Failed Outside Test Area
** Destroyed During Machining
NF No Failure
BOL Broke On Loading

TABLE XVI

FAILURE TIMES AT 30 KSI FOR 7075-T73 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
201	.0002	No	No	NF
202	to	↓	↓	NF
203	.0007	↓	↓	NF
204	↓	↓	↓	NF
225	↓	Yes	No	NF
226	↓	↓	↓	NF
227	↓	↓	↓	NF
228	↓	↓	↓	NF
285	↓	No	Yes	NF
286	↓	↓	↓	NF
287	↓	↓	↓	NF
288	↓	↓	↓	NF
309	↓	Yes	Yes	NF
310	↓	↓	↓	NF
311	↓	↓	↓	NF
312	↓	↓	↓	NF
177	.0033	No	No	NF
178	to	↓	↓	NF
179	.0043	↓	↓	NF
180	↓	↓	↓	NF
189	↓	No	No	NF
190	↓	↓	↓	NF
191	↓	↓	↓	NF
192	↓	↓	↓	NF
261	↓	No	Yes	NF
262	↓	↓	↓	NF
263	↓	↓	↓	NF
264	↓	↓	↓	NF
273	↓	No	Yes	NF
274	↓	↓	↓	NF
275	↓	↓	↓	NF
276	↓	↓	↓	NF
213	.0080	No	No	NF
214	to	↓	↓	NF
215	.0090	↓	↓	NF
216	↓	↓	↓	NF
297	↓	No	Yes	NF
298	↓	↓	↓	NF
299	↓	↓	↓	NF
300	↓	↓	↓	NF

NF No Failure

TABLE XVII

FAILURE TIMES AT 20 KSI FOR 7075-T73 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
197	.0002	No	No	NF
198	to	↓	↓	NF
199	.0007	↓	↓	NF
200	↓	↓	↓	NF
221	↓	Yes	No	NF
222	↓	↓	↓	NF
223	↓	↓	↓	NF
224	↓	↓	↓	NF
281	↓	No	Yes	NF
282	↓	↓	↓	NF
283	↓	↓	↓	NF
284	↓	↓	↓	NF
305	↓	Yes	Yes	NF
306	↓	↓	↓	NF
307	↓	↓	↓	NF
308	↓	↓	↓	NF
173	.0033	No	No	NF
174	to	↓	↓	NF
175	.0043	↓	↓	NF
176	↓	↓	↓	NF
185	↓	No	No	NF
186	↓	↓	↓	NF
187	↓	↓	↓	NF
188	↓	↓	↓	NF
257	↓	No	Yes	NF
258	↓	↓	↓	NF
259	↓	↓	↓	NF
260	↓	↓	↓	NF
269	↓	No	Yes	NF
270	↓	↓	↓	NF
271	↓	↓	↓	NF
272	↓	↓	↓	NF
209	.0080	No	No	NF
210	to	↓	↓	NF
211	.0090	↓	↓	NF
212	↓	↓	↓	NF
293	↓	No	Yes	NF
294	↓	↓	↓	NF
295	↓	↓	↓	NF
296	↓	↓	↓	NF

NF No Failure

TABLE XVIII

FAILURE TIMES AT 50 KSI FOR 7075-T73 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
229	.0010	No	No	1161.8
230	to	↓	↓	NF
231	.0020	↓	↓	1576.4
232	↓	↓	↓	1383.3
241	↓	Yes	No	800.9
242	↓	↓	↓	2053.8
243	↓	↓	↓	2050.9
244	↓	↓	↓	1920.6
313	↓	No	Yes	1083.8
314	↓	↓	↓	NF
315	↓	↓	↓	1771.0
316	↓	↓	↓	1672.4
325	↓	Yes	Yes	1129.6
326	↓	↓	↓	1936.0
327	↓	↓	↓	1183.7
328	↓	↓	↓	904.1

NF No Failure

TABLE XIX

FAILURE TIMES AT 30 KSI FOR 7075-T73 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
237	.0010	No	No	NF
238	to	↓	↓	NF
239	.0020	↓	↓	NF
240	↓	↓	↓	NF
249	↓	Yes	No	NF
250	↓	↓	↓	NF
251	↓	↓	↓	NF
252	↓	↓	↓	NF
321	↓	No	Yes	NF
322	↓	↓	↓	NF
323	↓	↓	↓	NF
324	↓	↓	↓	NF
333	↓	Yes	Yes	NF
334	↓	↓	↓	NF
335	↓	↓	↓	NF
336	↓	↓	↓	NF

NF No Failure

TABLE XX

FAILURE TIMES AT 20 KSI FOR 7075-T73 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
233	.0010	No	No	NF
234	to			NF
235	.0020			NF
236				NF
245		Yes	No	NF
246				NF
247				NF
248				NF
317		No	Yes	NF
318				NF
319				NF
320				NF
329		Yes	Yes	NF
330				NF
331				NF
332				NF

NF No Failure

TABLE XXI

FAILURE TIMES AT 50 KSI FOR 7001-T75 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
25	.0002	No	No	NF
26	to			777.8
27	.0007			NF
28				NF
49		Yes	No	NF
50				NF
51				NF
52				NF
109		No	Yes	NF
110				NF
111				1902.0
112				NF
133		Yes	Yes	NF
134				NF
135				NF
136				NF
1	.0033	No	No	NF
2	to			2039.3
3	.0043			1660.0
4				1540.7
13		No	No	2105.3
14				NF
15				NF
16				NF
85		No	Yes	NF
86				NF
87				NF
88				NF
97		No	Yes	NF
98				NF
99				NF
100				NF
37	.0080	No	No	1684.6
38	to			1760.4
39	.0090			NF
40				NF
121		No	Yes	1992.1
122				1992.1
123				NF
124				2125.4

NF No Failure

TABLE XXII

FAILURE TIMES AT 30 KSI FOR 7001-T75 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
29	.0002	No	No	NF
30	to			NF
31	.0007			NF
32				NF
53		Yes	No	NF
54				NF
55				NF
56				NF
113		No	Yes	NF
114				NF
115				NF
116				NF
137		Yes	Yes	NF
138				NF
139				NF
140				NF
5	.0033	No	No	NF
6	to			NF
7	.0043			NF
8				NF
17		No	No	NF
18				NF
19				NF
20				NF
89		No	Yes	NF
90				NF
91				NF
92				NF
101		No	Yes	NF
102				NF
103				NF
104				NF
41	.0080	No	No	NF
42	to			NF
43	.0090			NF
44				NF
125		No	Yes	NF
126				NF
127				NF
128				NF

NF No Failure

TABLE XXIII

FAILURE TIMES AT 20 KSI FOR 7001-T75 SPECIMENS WITH 1/4 INCH STEEL TAPER-LOK FASTENERS

Specimen No.	Interference, Inch	Cold Worked Holes	Shot Peened	Failure Times Hours
33	.0002	No	No	NF
34	to	↓	↓	NF
35	.0007	↓	↓	NF
36	↓	↓	↓	NF
57	↓	Yes	No	NF
58	↓	↓	↓	NF
59	↓	↓	↓	NF
60	↓	↓	↓	NF
117	↓	No	Yes	NF
118	↓	↓	↓	NF
119	↓	↓	↓	NF
120	↓	↓	↓	NF
141	↓	Yes	Yes	NF
142	↓	↓	↓	NF
143	↓	↓	↓	NF
144	↓	↓	↓	NF
9	.0033	No	No	NF
10	to	↓	↓	NF
11	.0043	↓	↓	NF
12	↓	↓	↓	NF
21	↓	No	No	NF
22	↓	↓	↓	NF
23	↓	↓	↓	NF
24	↓	↓	↓	NF
93	↓	No	Yes	NF
94	↓	↓	↓	NF
95	↓	↓	↓	NF
96	↓	↓	↓	NF
105	↓	No	Yes	NF
106	↓	↓	↓	NF
107	↓	↓	↓	NF
108	↓	↓	↓	NF
45	.0080	No	No	NF
46	to	↓	↓	NF
47	.0090	↓	↓	NF
48	↓	↓	↓	NF
129	↓	No	Yes	NF
130	↓	↓	↓	NF
131	↓	↓	↓	NF
132	↓	↓	↓	NF

NF No Failure

TABLE XXIV

FAILURE TIMES AT 50 KSI FOR 7001-T75 SPECIMENS
WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
61	.0010	No	No	NF
62	to	"	"	NF
63	.0020	"	"	NF
64	"	"	"	NF
73	"	Yes	No	NF
74	"	"	"	NF
75	"	"	"	NF
76	"	"	"	NF
145	"	No	Yes	NF
146	"	"	"	NF
147	"	"	"	NF
148	"	"	"	NF
157	"	Yes	Yes	NF
158	"	"	"	NF
159	"	"	"	NF
160	"	"	"	NF

NF No Failure

TABLE XXV

FAILURE TIMES AT 30 KSI FOR 7001-T75 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
65	.0010	No	No	NF
66	to	"	"	NF
67	.0020	"	"	NF
68	"	"	"	NF
77	"	Yes	No	NF
78	"	"	"	NF
79	"	"	"	NF
80	"	"	"	NF
149	"	No	Yes	NF
150	"	"	"	NF
151	"	"	"	NF
152	"	"	"	NF
161	"	Yes	Yes	NF
162	"	"	"	NF
163	"	"	"	NF
164	"	"	"	NF

NF No Failure

TABLE XXVI

FAILURE TIMES AT 20 KSI FOR 7001-T75 SPECIMENS WITH 1/4 INCH TITANIUM LOCKBOLT FASTENERS

Specimen No.	Clearance, Inch	Cold Worked Holes	Shot Peened	Failure Time Hours
69	.0010	No	No	NF
70	to			NF
71	.0020			NF
72				NF
81		Yes	No	NF
82				NF
83				NF
84				NF
153		No	Yes	NF
154				NF
155				NF
156				NF
165		Yes	Yes	NF
166				NF
167				NF
168				NF

NF No Failure

TABLE XXVII

FATIGUE TEST RESULTS

Test Stress and Specimen Configuration	Specimen No.	Cycles to Failure 7001-T75	7075-T73	7079-T62
15 ±5 ksi Monoblock W/Open Hole	1	10,000,000+	121,000	85,000
	2	4,000,000+	223,000	291,000
	3	4,000,000+	141,000	97,000
	4	4,000,000+	205,000	93,000
	Log Mean (Scatter)	4,000,000+ --	167,000 (61%)	123,000 (167%)
15 ±10 Monoblock W/Open Hole	1	42,000	36,000	13,000
	2	44,000	27,000	14,000
	3	47,000	34,000	15,000
	4	55,000	21,000	17,000
	Log Mean (Scatter)	47,000 (28%)	29,000 (52%)	15,000 (27%)
15 ±10 Strap Reinforcement W/Taper-Lok Fasteners	1	405,000	450,000	1,934,000
	2	376,000	391,000	312,000
	3	366,000	370,000	753,000
	4	677,000	362,000	561,000
	Log Mean (Scatter)	438,000 (71%)	392,000 (23%)	711,000 (228%)

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13. ABSTRACT

Test specimens of 7001-T75 aluminum alloy were evaluated for resistance to stress corrosion and for fatigue characteristics. Alternate immersion stress corrosion tests were performed at gross area stress levels of 50 ksi, 30 ksi, and 20 ksi with steel Taper-Lok and titanium lockbolt fasteners installed in plain and cold worked holes. These fasteners were installed with clearance and interference fits. This report also includes, for comparison purposes, similar stress corrosion data on 7075-T73, 7079-T7, 7079-T62, and 7079-T611 aluminum alloy. The data for these four alloys was obtained from a separate contract. Fatigue tests were performed at 15 ± 5 ksi and 15 ± 10 ksi mean plus alternating stress levels. The test configurations included an open hole monoblock design and a strap reinforcement design with steel Taper-Lok fasteners. This report also includes, for comparison purposes, similar fatigue test data on 7075-T73 and 7079-T62 aluminum alloys. The data for these two alloys was obtained from a separate contract. The 7001-T75 alloy exhibited very good resistance to stress corrosion cracking at 50 ksi gross area sustained stress. The limited number of fatigue tests indicated that the 7001-T75 alloy is potentially superior to 7075-T73 and 7079-T62.

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Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
7001-T75 7075-T73 7079-T6 7079-T62 7079-T611 stress corrosion fatigue						

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