AD626774

SECOND QUARTERLY PROGRESS REPORT, VOL. II

IMPROVED ELECTRON FRACTOGRAPHIC TECHNIQUES

CONTRACT NO. AF 33(615)-3014

1 OCTOBER to 31 DECEMBER 1965

RESEARCH & DEVELOPMENT REPORT SM-49150

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA CALIFORNIA

DOUGLAS

SECOND QUARTERLY REPORT

REPORT NO. SM-49150

IMPROVED ELECTRON FRACTOGRAPHIC TECHNIQUES
VOL. II

Prepared by:

B. V. Whiteson, V. Kerlins

and

A. Phillips

MISSILE AND SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.

1-14-66

Prepared For Aeronautical Systems Division
Wright-Patterson Air Force Base
Dayton, Ohio

Contract No. AF 33(615)-3014

NOTICE

PREFACE

This Second Quarterly Progress Report was prepared by the Douglas Aircraft Company, Santa Monica, California, under Contract No. AF 33(615)-3014 entitled "Improved Fractographic Techniques". The program was initiated and is monitored by the Materials Engineering Branch (MAAE), Air Force Materials Laboratory, with Mr. Russ Henderson as Project Engineer.

This report covers work performed from 1 October 1965 to 31 December 1965.

Approved For:

DOUGLAS AIRCRAFT COMPANY, INC.

Guy V. Bennett

G. V. Bennett, Chief
Metals-Ceramics Branch

TABLE OF CONTENTS

ABSTRACT

The work effort in the second quarter has consisted primarily of completion of most of the mechanical tests for the three tasks and preliminary data interpretation of Task I (Determination of Rapid-Crack-Propagation Direction in Metal Fractures). A chart showing the progress of all specimens in this program is enclosed.

I. INTRODUCTION

In fractographic analysis, the electron microscope has already proven its value by solving service failures that could not be resolved with standard analysis techniques. Although the use of this instrument for fractographic analysis has progressed significantly, there are still many unanswered problems that electron fractography may be instrumental in solving, providing care is taken in the preparation and interpretation of fracture features seen in the microscope.

The program is divided into three tasks, as follows:

Task I -- Determination of rapid-crack-propagation direction in metal fractures. Electron fractographic analysis will be employed to examine significant fracture features that will be instrumental in determining the propagation direction of rapid cracks in thin, high-strength metal alloys. High-magnification and low-magnification fractographic techniques will be employed. Using a technique of statistical analysis, overall surface features will be examined, as well as second-phase particle cleavage direction. In addition, the use of large silicone-rubber replicas will be evaluated for intrinsic properties that may be of significant value in relating fracture-surface profile to fracture direction.

Task II-- Determination of the characteristics distinguishing stress corrosion from hydrogen embrittlement. Three high-strength steels will be examined with electron fractography after the specimens have been charged with varying levels of hydrogen and have failed under sustained stresses. Special care will be taken to ensure that these failures are caused solely by hydrogen embrittlement. In addition, stress-corrosion specimens will be failed under conditions approaching pure stress corrosion as closely as possible, although some problems are anticipated in preventing hydrogen generation at the metal during corrosive action. All specimens will be examined for fine-scale features with the use of direct carbon replication techniques, where required. In addition, a novel technique utilizing autoradiography combined with fractography will be employed to determine whether fine-scale features seen in possible hydrogen-embrittled areas coincide with isotope-tagged areas. For this series of tests, tritium, the radioactive isotope of hydrogen, will be employed.

Task III-- Investigation of the correlation between fatigue striation spacing and stress environment. Several aluminum alloys will be fatigue fractured under very closely monitored conditions of crack growth in wide panels. The macroscopic propagation rate, stress, and fatigue striation spacing will be accurately measured to determine their relationships. These relationships will be determined under conditions of varying alternating stress, mean stress, test frequency, and thickness. Some specimens will be spectrum loaded on automatically controlled fatigue equipment utilizing typical aircraft service stresses to determine the variations in the relationship between fatigue striation spacing, macroscopic-growth rate, and applied cyclic stress. All macroscopic-crack growth and fatigue-stress cycles will be automatically recorded and monitored throughout the entire test.

2. WORK ACCOMPLISHED

The chart which shows the status of each individual specimen planned in this program is included in the appendix of this report. The codes used are explained in the chart. The last letter forming the bar for any specimen designates that the specimen is completed through this specific operation. In order to correlate the specimen numbers shown on the chart with an actual ma erial and testing conditio., refer to Tables I through 3.

2.1 Task I - Determination of rapid-crack-propagation direction in metal fractures.

2.1.1 The heat treatment schedule and the resulting mechanical properties of the control specimens are shown in Tables 4 and 5 respectively. The higher strength of the D6AC was probably due to the relatively high carbon content of this heat of steel.

2.1.2 The type of specimens used in tensile tear and combined tear and shear tests are shown in Figure 1.

2.1.3 Photomacrographs and shadowgraphs of fracture edge profiles have been obtained. Silicone rubber casts were made of the fracture surfaces in an attempt to correlate fracture surface profile characteristics with fracture direction. This technique was discontinued because profile characteristics showed poor correlation to fracture direction. The most promising technique for correlation of fracture features with crack propagation direction was replication of the fracture surface adjacent to the edge. There appears to be a consistent tear dimple (a dimple open to the edge) orientation relative to the fracture direction near the edge. This orientation relationship was macroscopic-crack growth and fatigue-stress cycles will be automatically recorded and monitored throughout the entire test.

2. WORK ACCOMPLISHED

The chart which shows the status of each individual specimen planned in this program is included in the appendix of this report. The codes used are explained in the chart. The last letter forming the bar for any specimen designates that the specimen is completed through this specific operation. In order to correlate the specimen numbers shown on the chart with an actual material and testing condition, refer to Tables 1 through 3.

2.1 Task 1 - Determination of rapid-crack-propagation direction in metal fractures.

2.1.1 The heat treatment schedule and the resulting mechanical properties of the control specimens are shown in Tables 4 and 5 respectively. The higher strength of the D6AC was probably due to the relatively high carbon content of this heat of steel.

2.1.2 The type of specimens used in tensile tear and combined tear and shear tests are shown in Figure 1.

2.1.3 Photomacrographs and shadowgraphs of fracture edge profiles have been obtained. Silicone rubber casts were made of the fracture surfaces in an attempt to correlate fracture surface profile characteristics with fracture direction. This technique was discontinued because profile characteristics showed poor correlation to fracture direction. The most promising technique for correlation of fracture features with crack propagation direction was replication of the fracture surface adjacent to the edge. There appears to be a consistent tear dimple (a dimple open to the edge) orientation relative to the fracture direction near the edge. This orientation relationship was

TABLE I

TASK I - CRACK PROPAGATION DIRECTION

MATERIAL	HEAT TREATMENT	TEST TYPE AND SPECIMEN: TEAR & SHEAR	TENSILE TEAR	
		t = 0.050 in.	t = 0.050 in.	t = 0.125 in.
4340	260/280 ksi	1 (1)	2	3
4340	180/200 ksi	4	5	6
D6AC	260/280 ksi	7	8	9
AM 350	SCT (850)	10	11	12
7075	T6	13	14	15
2024	T3	16	17	18
7079	T6	19	20	21
Waspalloy	Aged	22	23	24

(1) Specimen Number

TABLE 2

TASK II - HYDROGEN EMBRITTLEMENT - CADMIUM PLATED

MATERIAL AND STRENGTH LEVEL (KSI)	Pickle + Cd Fluoborate			Bright Cd Cyanide			Cd Fluoborate		
	50%	75%	90% (1)	50%	75%	90%	50%	75%	90%
4340 (260/280)	1,2	3,4	5,6	19,20	21,22	23,24	37,38	39,40	41,42
4330M (220/240)	7,8	9,10	11,12	25,26	27,28	29,30	43,44	45,46	47,48
D6AC (260/280)	13,14	15,16	17,18	31,32	33,34	35,36	49,50	51,52	53,54

TASK II - STRESS CORROSION - TAP WATER IMMERSION

MATERIAL AND STRENGTH LEVEL (KSI)	Bare			Vacuum Cd Plate		
	50%	75%	90%	50%	75%	90%
4340 (260/280)	55,56	57,58	59,60	73,74	75,76	77,78
4330M(220/240)	61,62	63,64	65,66	79,80	81,82	83,84
D6AC (260/280)	67,68	69,70	71,72	85,86	87,88	89,90

(1) Numbers in percent refer to applied sustained stress as percents of 0.2% offset yield stress.

TASK II - HYDROGEN EMBRITTLEMENT - TRITIUM CHARGED

MATERIAL AND STRENGTH LEVEL (KSI)	TRITIUM CHARGE
4340 (260/280)	91, 92 93
4330M (220/240)	94, 95, 96
D6AC (260/280)	97, 98, 99

TABLE 3

TASK III - FATIGUE CRACK PROPAGATION

MATERIAL	Constant σ_{Mean} t = 0.050 in.(1) f = 1000 cpm (2)	Constant $\sigma_{Alt.}$ t = 0.050 in. f = 1000 cpm	Constant σ_{Mean} t = 0.050 in. f = 10 cpm	Constant σ_{Mean} t = 0.500 in. f = 1000 cpm
2024-T3	1 2 3	16 17 18	31 32	37 38 39
7075-T6	4 5 6	19 20 21	33 34	40 41 42
7075-T73	7 8 9	22 23 24	35 36	43 44 45
7079-T6	10 11 12	25 26 27		
6061-T6	13 14 15	28 29 30		

(1) t = thickness

(2) f = frequency

TASK III - FATIGUE CRACK PROPAGATION

MATERIAL	SPECTRUM LOAD	
	Constant σ_{Mean} t = 0.050 in. (1) f = 1000 cpm (2)	Constant $\sigma_{Alt.}$ t = 0.050 in. f = 1000 cpm
2024-T3	46	51
7075-T6	47	52
7075-T73	48	53
7079-T6	49	54
6061-T6	50	55

(1) t = thickness

(2) f = frequency

TABLE 4

TASK I HEAT TREATMENT PROCEDURES

MATERIAL	STRENGTH LEVEL (KSI)	HEAT TREAT ATMOSPHERE	AUSTENITIZING TEMP. (°F)	AUSTENITIZING TIME, HRS.	QUENCHING MEDIA	TEMPERING TEMP (°F)	TEMPERING TIME, HRS.	COOLING MEDIA
4340	260/280	Exothermic	1525	1-1/2	Oil	410	4	Air
4340	180/200	Exothermic	1525	1-1/2	Oil	900	1-1/2	Air
D6AC	250/280	Exothermic	1525	1-1/2	Oil	450	4	Air
AM350(SCT)	130/200	Air	1710	3/4	Air	-100 850	3 3	Air
Waspalloy	160/180	Argon	1825	4	Oil	1550	3	Furnace Cooled to 1400°F
						1400	17	Air

TABLE 5

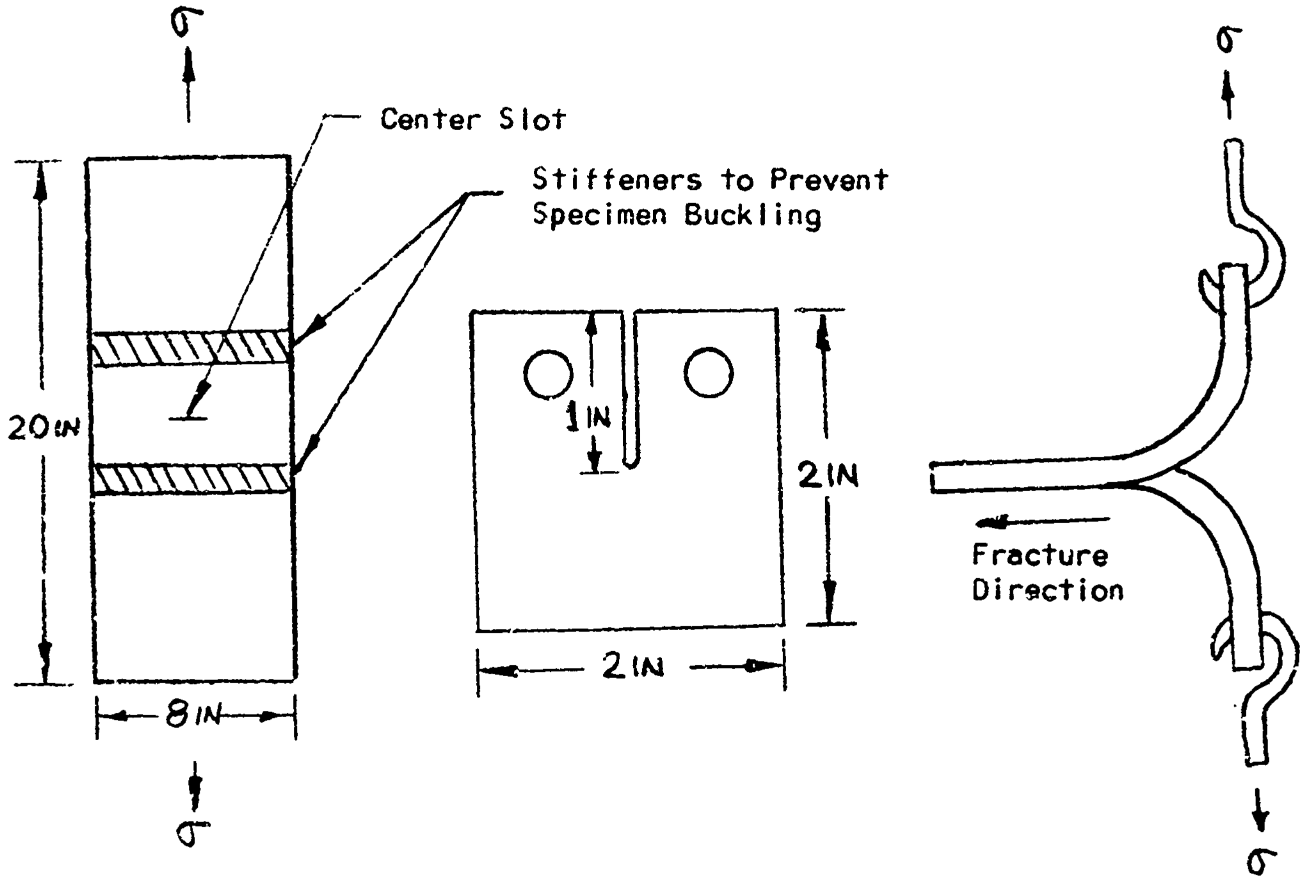
MECHANICAL PROPERTIES, TASK I

MATERIAL	THICKNESS (IN)	0.2% OFFSET YIELD STRENGTH (KSI)	ULTIMATE STRENGTH (KSI)	PERCENT ELONGATION (2 in. GAGE)
4340 (260/280)	0.050	206.6	260.5	7.5
		207.5	260.2	7.5
		209.0	261.4	7.2
4340 (260/280)	0.125	214.1	269.8	9.0
		215.7	269.8	9.5
		216.7	271.4	10.0
4340 (180/200)	0.050	167.4	182.2	7.5
		170.6	185.5	7.5
		172.1	186.7	7.5
4340 (180/200)	0.125	174.2	187.1	10.0
		176.4	187.9	10.0
		173.4	187.2	10.0
D6AC (260/280)	0.050	248.6	287.3	6.0
		245.5	287.9	5.0
		248.1	289.6	5.0
D6AC (260/280)	0.125	250.7	291.7	6.0
		251.9	294.0	6.0
		253.6	295.1	6.0
AM350 (SCT 850)	0.050	173.0	199.2	10.0
		176.4	205.6	10.0
		174.8	202.7	10.0
AM350 (SCT 850)	0.125	171.1	204.3	13.0
		173.9	204.5	13.0
		170.8	204.6	13.0
7075-T6	0.050	75.6	83.5	11.0
		76.1	84.3	11.0
		76.1	84.1	11.0
7075-T6	0.125	78.5	84.8	11.0
		78.5	84.7	11.0
		78.5	84.1	11.0
2024-T3	0.050	51.2	69.5	17.0
		51.0	69.4	18.0
		52.3	69.6	18.0
2024-T3	0.125	56.4	72.0	16.0
		56.3	71.8	16.0
		56.6	71.6	16.0

TABLE 5 (Continued)

MECHANICAL PROPERTIES, TASK I

MATERIAL	THICKNESS (IN)	0.2% OFFSET YIELD STRENGTH (KSI)	ULTIMATE STRENGTH (KSI)	PERCENT ELONGATION (2 in. GAGE)
7079-T6 (Chem Milled from 1/4" Plate)	0.050	65.7 64.6 64.4	71.8 72.0 72.0	9.0 9.0 9.0
7079-T6 (Chem Milled from 1/4" Plate)	0.125	65.7 64.6 64.4	71.8 72.0 72.0	9.0 9.0 9.0
Waspalloy (Aged)	0.050	124.6 126.2 125.2	186.4 187.6 186.3	25.0 25.0 25.0
Waspalloy (Aged)	0.125	130.3 129.9 132.0	187.5 188.1 188.4	21.0 25.0 22.0



A. Tensile Tear Specimen B. Combined Tear and Shear Specimen

CONFIGURATION OF SPECIMENS USED IN TASK I

FIGURE I

verified on both mating fracture surfaces. Figures 2 and 3 show the tear dimple orientation as related to fracture direction. Shear dimples which are closed to the fracture edge, as shown in Figure 4, have inconsistent correlation to fracture direction. Dimples located near the center of the fracture, Figure 3, are either equiaxed or randomly oriented, and therefore show no apparent correlation to fracture direction.

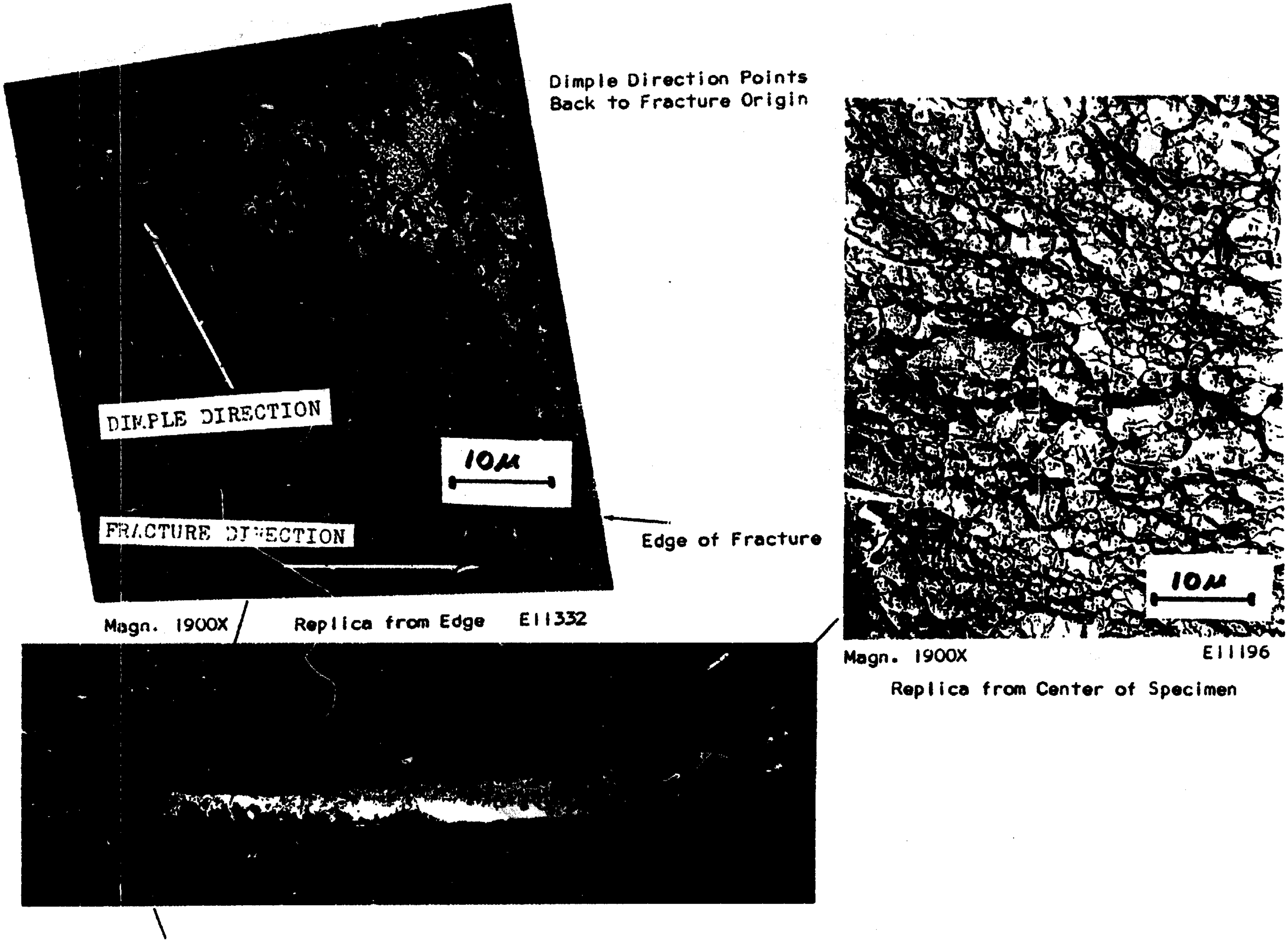
2.2 Task II - Determination of the Characteristics Distinguishing Stress Corrosion from Hydrogen Embrittlement

2.2.1 The configuration of the hydrogen embrittlement and stress corrosion specimens used in this task is shown in Figure 5.

2.2.2 The heat treatment schedule for the three different steels tested are shown in Table 6. Microhardness measurements confirmed the absence of either a decarburized or carburized surface. Table 7 shows the mechanical properties of the heat treatment control specimens. The D6AC was not retempered because the hardness was in the range of Rc53 to Rc54 (269-278ksi).

2.2.3 The various plating treatments for hydrogen embrittlement and stress corrosion specimens are shown in Table 8. After the processing all specimens were stored at sub-zero temperature (-6°F) prior to loading.

2.2.4 Triplicate specimens were stressed to 50%, 75% and 90% of 0.2% offset yield strength. The fixture used to load the specimens in a 30,000 lb. capacity Riehle tensile machine is shown in Figure 6. After loading, the hydrogen embrittlement specimens with their jigs were placed in plastic bags containing dessicant. The stress corrosion jigs were wax-coated and placed in an alternate immersion rack, Figure 7, to be immersed in deionized (ions of soluble salts removed) water for 10 minutes, followed by a 50 minute air drying cycle.



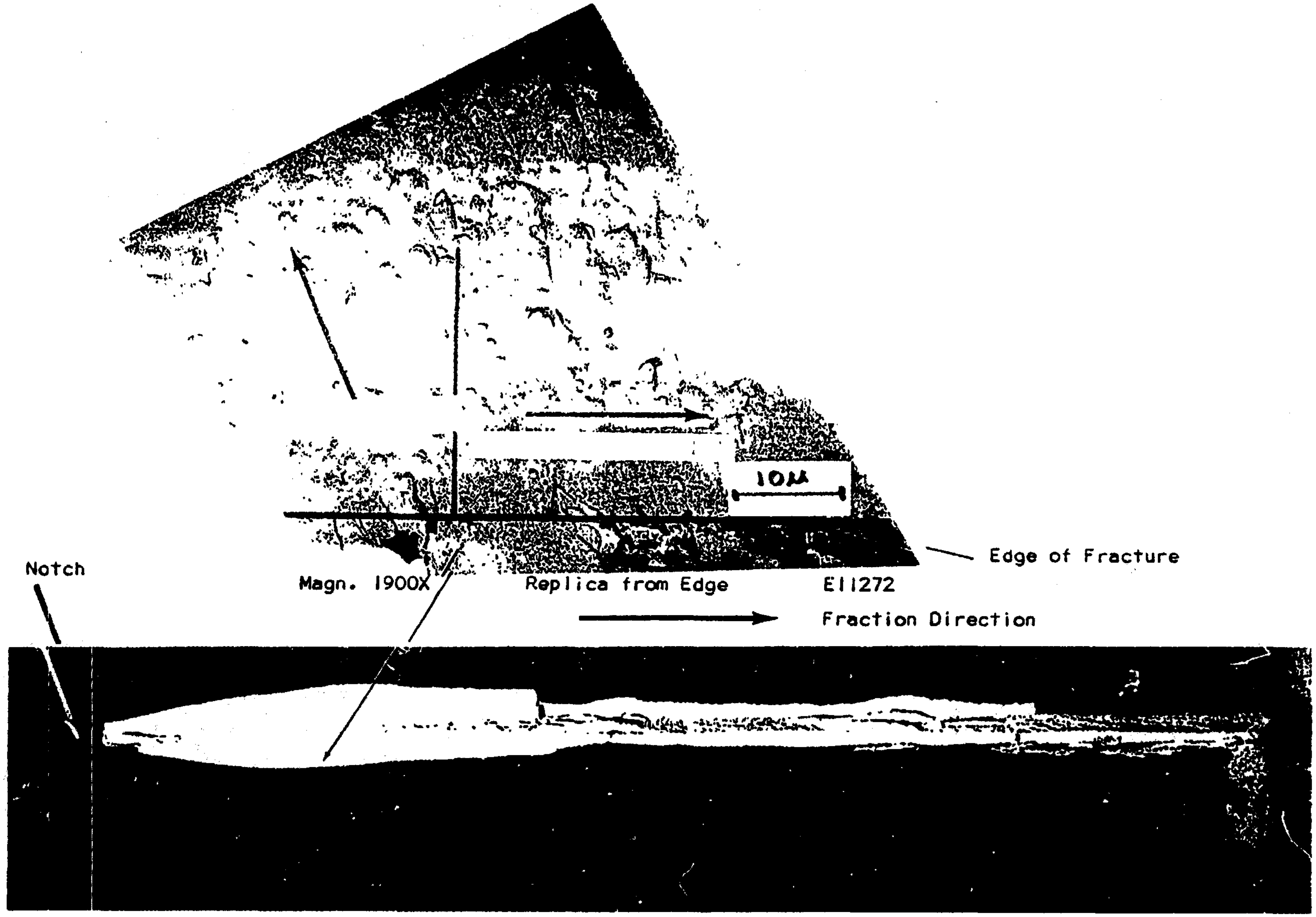
Magn. 1900X Replica from Edge E11332

Magn. 1900X E11196

Replica from Center of Specimen

SHEAR AND TEAR, 7079-T6 ALUMINUM SHEET, 0.050" THICK

FIGURE 3



TENSILE TEAR, AM350 STAINLESS, 0.125" THICK

FIGURE 2

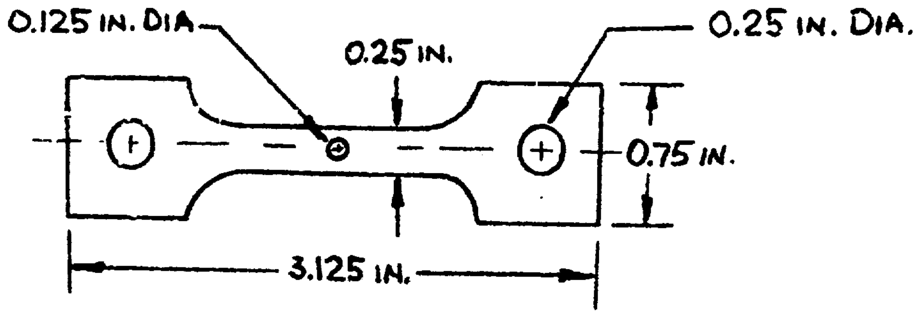
Edge of Fracture

E11332

Magn. 1900X

EXAMPLE OF SHEAR DIMPLES CLOSE TO THE FRACTURE EDGE.
THIS TYPE OF DIMPLE NOT A GOOD FRACTURE DIRECTION INDICATOR.

FIGURE 4



CONFIGURATION OF HYDROGEN EMBRITTLEMENT AND STRESS
CORROSION SPECIMENS USED IN TASK II

FIGURE 5

<u>TABLE 7</u>

<u>MECHANICAL PROPERTIES - TASK II</u>
(TRANSVERSE GRAIN DIRECTION)

MATERIAL	TYPE OF SPECIMEN	0.2% OFFSET YIELD STRENGTH (KSI)	ULTIMATE STRENGTH, BASED ON NET AREA, (KSI)	PERCENT ELONGATION (1 in. GAGE)
4340 (260/280)	Standard Tensile	246.3 232.2 245.1	271.1 278.4 282.0	3.0 BOGM* 6.0
	Standard Tensile with 1/8" Center Hole	— —	280.0 282.2	— —
4330M (220/240)	Standard Tensile	195.6 193.7 191.9	226.2 223.2 223.9	4.0 5.0 5.0
	Standard Tensile with 1/8" Center Hole	— —	224.0 233.0 229.0	— — —
D6AC (260/280)	Standard Tensile	243.9 242.5	290.9 288.3	BOGM 5.0
	Standard Tensile with 1/8" Center Hole	—	279.9	—

*BOGM - Broke Outside Gage Marks

TABLE 6

TASK 11 HEAT TREATMENT CYCLES FOR HIGH STRENGTH STEEL

MATERIAL	HEAT TREATMENT	ATMOSPHERE	AUSTENITIZING TEMP. (°F)	AUSTENTIZING TIME, HRS.	QUENCHING MEDIA	TEMPERING TEMP (°F)	COOLING MEDIA
4340	260/280 ksi	Endothermic	1540	1	Oil	2 hr @ 410+ 2-1/2 hr @ 410	Air
4330M	220/240 ksi	Endothermic	1550	1	Oil	2 hr @ 525	Air
D6AC	260/280 ksi	Endothermic	1650	1	Oil	2 hr @ 500	Air

TABLE 7

MECHANICAL PROPERTIES - TASK II
(TRANSVERSE GRAIN DIRECTION)

MATERIAL	TYPE OF SPECIMEN	0.2% OFFSET YIELD STRENGTH (KSI)	ULTIMATE STRENGTH, BASED ON NET AREA, (KSI)	PERCENT ELONGATION (1 in. GAGE)
4340 (260/280)	Standard Tensile	246.3 232.2 245.1	271.1 278.4 282.0	3.0 BOGM* 6.0
	Standard Tensile with 1/8" Center Hole	— —	280.0 282.2	— —
4330M (220/240)	Standard Tensile	195.6 193.7 191.9	226.2 223.2 223.9	4.0 5.0 5.0
	Standard Tensile with 1/8" Center Hole	— —	224.0 233.0 229.0	— — —
D6AC (260/280)	Standard Tensile	243.9 242.5	290.9 288.3	BOGM 5.0
	Standard Tensile with 1/8" Center Hole	—	279.9	—

*BOGM - Broke Outside Gage Marks

TABLE 8

SPECIAL PROCESSING OF HIGH STRENGTH STEEL SPECIMENS
FOR HYDROGEN EMBRITTLEMENT AND STRESS CORROSION SUSTAINED LOAD TESTS

A. PICKLE, CADMIUM FLUOBORATE

Pickle; Cadmium Fluoborate Plate; No bake or post treatment

Acid Pickle	-	20% HCl 2 min.		
Cd Fluoborate Plate	-	Operating Conditions:		
		Cadmium Fluoborate	-	32 oz/gal.
		Cadmium (Free Metal)	-	13 oz/gal.
		Ammonium Fluoborate	-	8 oz/gal.
		Boric Acid	-	3.6 oz/gal.
		Brightner	-	0.15 oz/gal.
		Temp.	-	70-100°F
		Current	-	30-60 amps/ft^2
		Voltage	-	4-6 V.
		PH	-	3-3.5
		Anode/Cathode	-	2-1
		Time	-	8 min.
		Thickness	-	0.3 mil

B. BRIGHT CADMIUM CYANIDE

Vapor Honed; Cyanide Cadmium Plate; No bake or post treatment

Vapor Honed	-	Wet Abrasive		
Cyanide Cadmium Plate	-	Operating Conditions:		
		Cadmium Oxide	-	2.9-5.5 oz/gal.
		Sodium Cyanide	-	12.0-20.0 oz/gal.
		Sodium Carbonate	-	2.0-8.0 oz/gal.
		NaCN/Cdo	-	2.8-6.0
		Sodium Hydroxide	-	1.0-3.2 oz/gal.
		No Brightner		
		Temp.	-	70-90°F
		Current	-	60-80 amps/ft^2
		Voltage	-	——
		PH	-	above 12
		Time	-	8 min.
		Thickness	-	0.3 mil

C. CADMIUM FLUOBORATE

Same as Treatment A except no Pickle. Vapor Honed to clean; No bake

D. BARE SPECIMENS

No treatment. Vapor Honed cleaned only.

TABLE 8 (Continued)

SPECIAL PROCESSING OF HIGH STRENGTH STEEL SPECIMENS

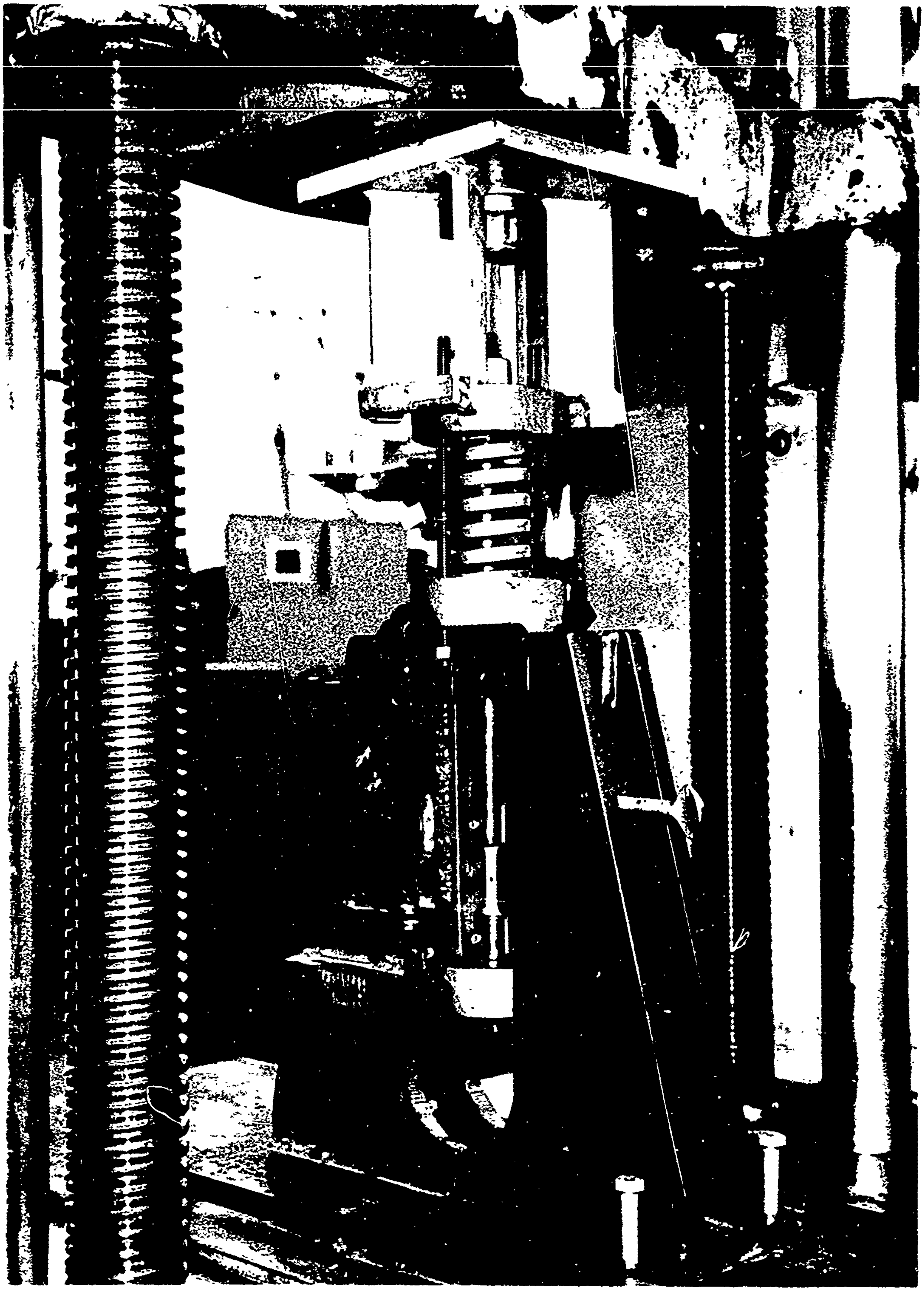
FOR HYDROGEN EMBRITTLEMENT AND STRESS CORROSION SUSTAINED LOAD TESTS

E. VACUUM CADMIUM PLATED

Vapor Honed; Vacuum Cadmium Plate; No bake; Chromate post treatment

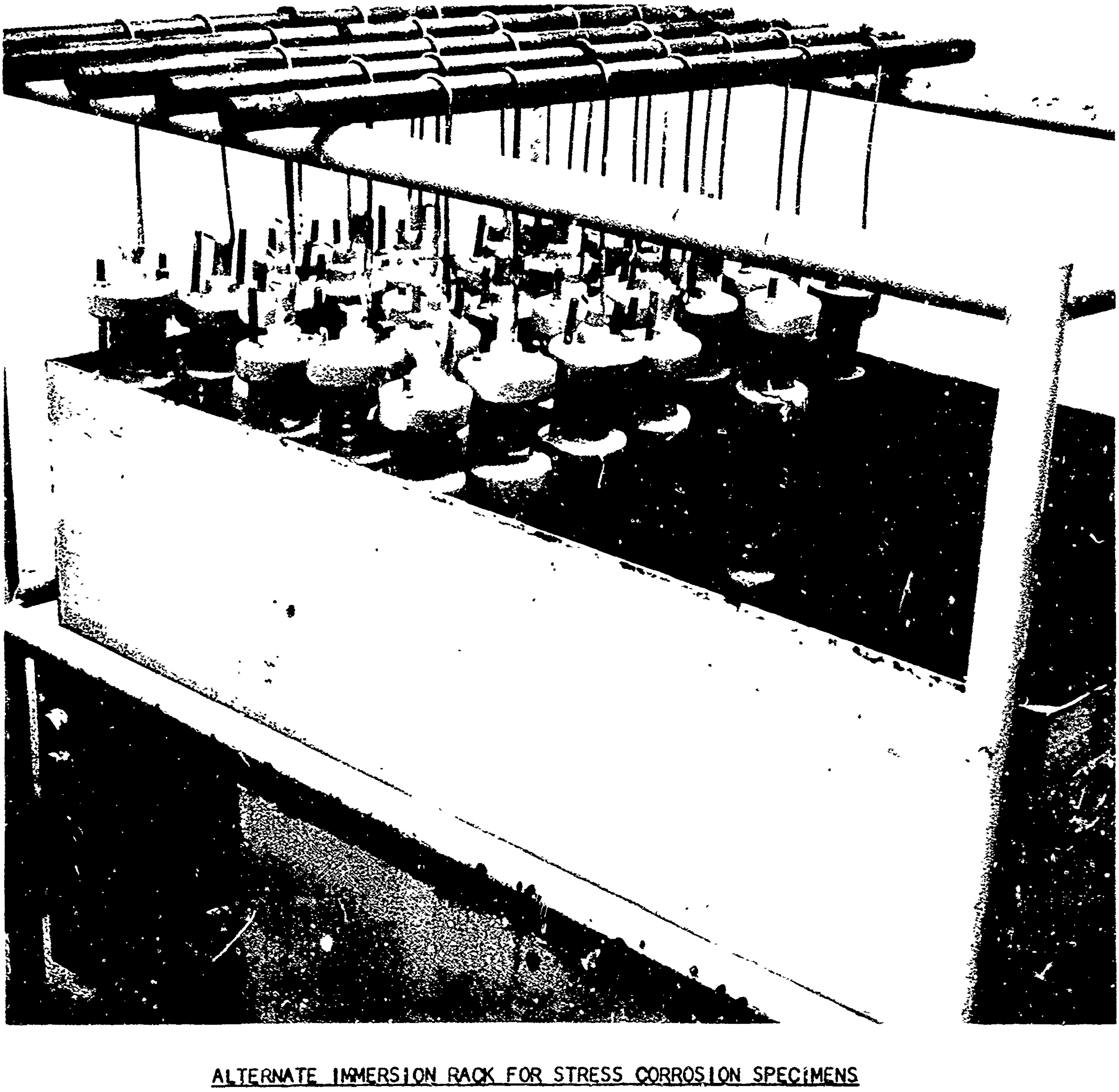
Vapor Hone	-	Wet Abrasive
Vacuum Cadmium Plate	-	Outside Vendor: Anadite, Inc. 10647 Garfield Ave. Southgate, Calif. 90280 SP 3-4210
Chromate Post Treatment	-	Solution:

Chromic Acid	-	32g./700 ml
Sulfuric Acid (Conc.)	-	15ml/700 ml
Nitric Acid (Conc.)	-	16ml/700 ml
Time	-	30 sec.



ALIGNMENT FIXTURE USED IN LOADING STRESSING JIGS

FIGURE 6



ALTERNATE IMMERSION RACK FOR STRESS CORROSION SPECIMENS

FIGURE 7

2.3 Task III - Investigation of a Correlation Between Fatigue Striations Spacing and Applied Cyclic Stress

2.3.1 The aluminum alloys in this task were received in the heat treated condition with the exception of the 7075-T73 condition. The T73 condition was obtained by aging the 7075-T6 material at 350°F for 9 hours. Table 9 shows the mechanical properties of the heat treatment control specimens.

2.3.2 The configuration of the crack propagation specimen is shown in Figure 8.

2.3.3 The various fatigue stress levels used in this task are shown in Tables 10 and 11. The stresses selected were chosen to avoid compressive stresses during the fatigue cycle. This was done in order to prevent damage to the fractured surfaces.

2.3.4 The progress of each individual fatigue crack was monitored by both visual observation and by special crack propagation gages as shown in Figure 9. These gages consisted of twenty individual strands 0.10 inches apart. The consecutive breaking of individual strands due to their intersection by the fatigue crack is recorded. The crack propagation was also followed by visually noting and recording the progress of the crack tip with reference to a 0.10 scribed grid. The number of cycles, propagation gage indications and visual records were recorded simultaneously on a strip chart. The complete test setup is shown in Figure 10.

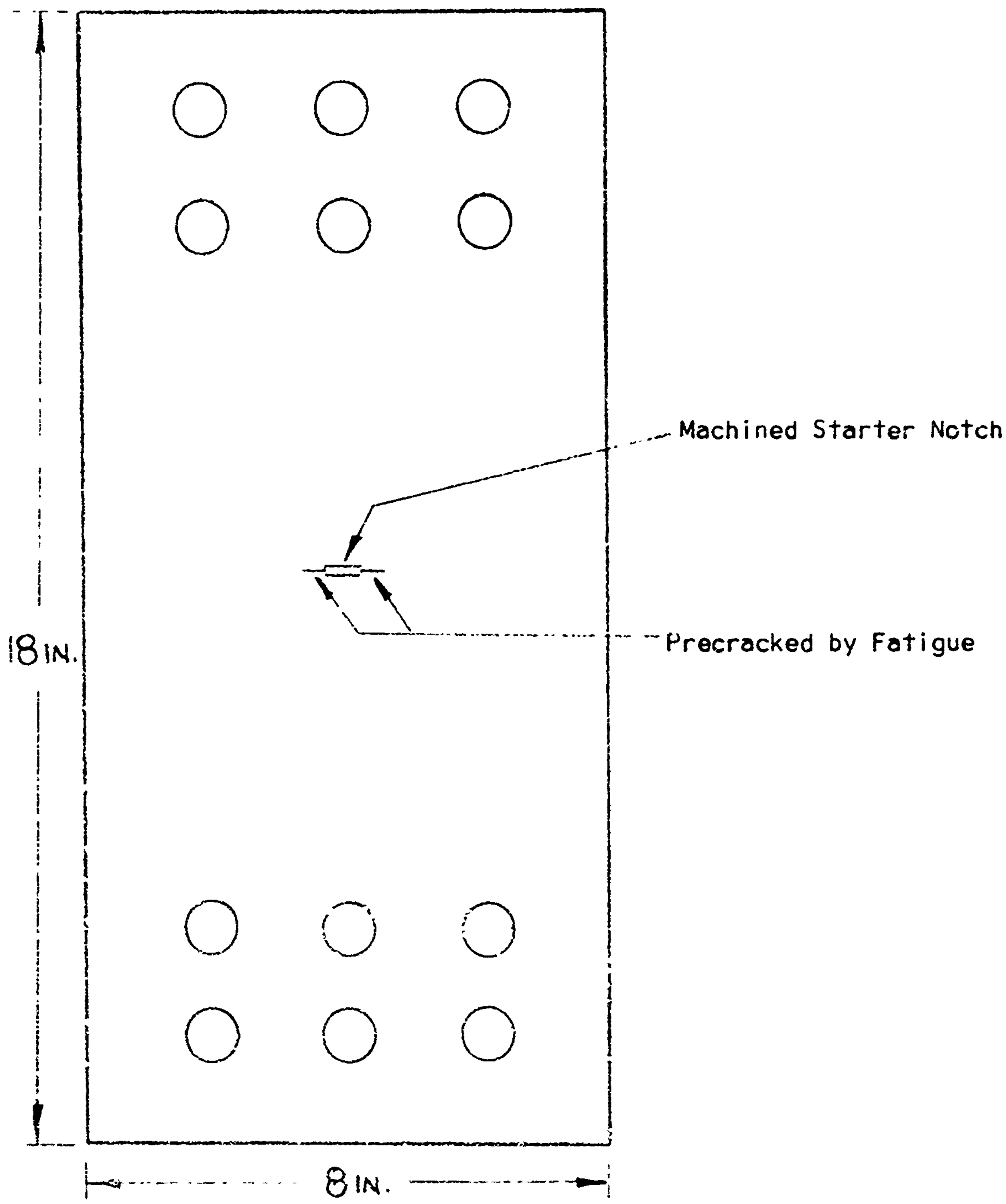
3. SUMMARY

The mechanical testing of Task I and Task III has been completed with the exception of the spectrum load specimens in Task III. Data analysis of

TABLE 9

MECHANICAL PROPERTIES - TASK III

MATERIAL	THICKNESS, (IN)	0.2% OFFSET YIELD STRENGTH (KSI)	ULTIMATE STRENGTH (KSI)	PERCENT ELONGATION (2 in. GAGE)
2024-T3	0.050	51.2	69.5	17.0
		51.0	69.4	18.0
		52.4	69.6	18.0
2024-T3	0.500	56.0	66.0	18.0
		56.6	66.6	18.0
		56.4	66.6	20.0
7075-T6	0.050	75.6	83.5	11.0
		76.1	84.3	11.0
		76.1	84.1	11.0
7075-T6	0.500	75.6	82.4	12.0
		74.7	82.0	11.0
		78.2	84.3	7.0
7075-T73	0.050	66.9	77.7	9.0
		67.8	78.5	10.0
		65.8	76.6	10.0
7075-T73	0.500	63.8	73.7	13.0
		64.1	74.2	12.0
		62.0	73.0	13.0
7079-T6	0.050	65.7	71.8	9.0
		64.6	72.0	9.0
		64.4	72.0	9.0
6061-T6	0.050	42.1	47.4	11.0
		42.0	47.4	11.0
		42.3	47.6	12.0



CRACK PROPAGATION SPECIMEN USED IN TASK III

FIGURE 8

TABLE 10

TASK III FATIGUE STRESS LEVELS

(Stress Levels Listed in Parentheses are in KSI)

MATERIAL	σ MEAN CONSTANT = (13.75) MATERIAL THICKNESS = 0.05 FREQUENCY = 1000 CPM	σ MEAN CONSTANT = (16.5) t = 0.05 f = 1000 CPM	σ ALTERNATING CONSTANT = (6.75) t = 0.05 f = 1000 CPM	σ MEAN CONSTANT = (13.75) t = 0.05 f = 10 CPM	σ MEAN CONSTANT = (13.75) t = 0.50 f = 1000 CPM
2024-T3	σA_1(2.5), σA_2(7.5), σA_3(11.25)	σA_4(13.5)	σM_1(8.25), σM_2(22.5)	σA_2(7.5), σA_3(11.25)	σA_1(2.5), σA_2(7.5), σA_3(11.25)
7075-T6	σA_1(2.5), σA_2(7.5), σA_3(11.25)	σA_4(13.5)	σM_1(8.25), σM_2(22.5)	σA_2(7.5), σA_3(11.25)	σA_1(2.5), σA_2(7.5), σA_3(11.25)
7075-T73	σA_1(2.5), σA_2(7.5), σA_3(11.25)	σA_4(13.5)	σM_1(8.25), σM_2(22.5)	σA_2(7.5), σA_3(11.25)	σA_1(2.5), σA_2(7.5), σA_3(11.25)
7079-T6	σA_1(2.5), σA_2(7.5), σA_3(11.25)	σA_4(13.5)	σM_1(8.25), σM_2(22.5)		
6061-T6	σA_1(2.5), σA_2(7.5), σA_3(11.25)	σA_4(13.5)	σM_1(8.25), σM_2(22.5)		
	Varying Alternating Stress As Shown		Varying Mean Stress As Shown	Varying Alternating Stress As Shown	

STRESS CYCLES IN FATIGUE TESTING

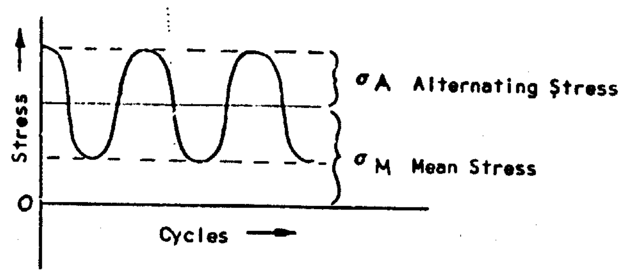


TABLE II

TASK III FATIGUE SPECTRUM LOADS

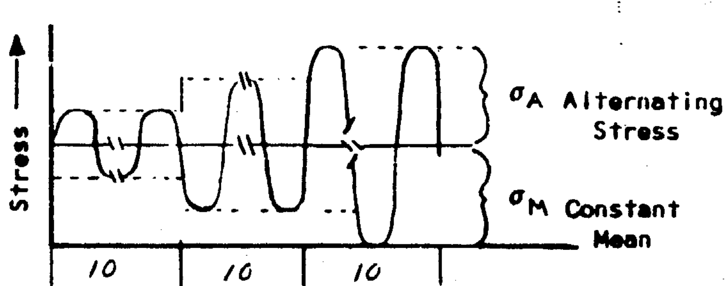
(Stress Levels, KSI, Listed in Parentheses)

MATERIAL	MEAN CONSTANT = (13.75) MATERIAL THICKNESS = 0.050 FREQUENCY = 600 CPM	ALTERNATING CONSTANT = (6.75) MATERIAL THICKNESS = 0.050 FREQUENCY = 600 CPM
2024-T3	$\Delta\sigma_A$ (2.5, 7.5, 11.25) (1)	$\Delta\sigma_M$ (8.25, 13.75, 22.5) (2)
7075-T6	$\Delta\sigma_A$ (2.5, 7.5, 11.25)	$\Delta\sigma_M$ (8.25, 13.75, 22.5)
7075-T73	$\Delta\sigma_A$ (2.5, 7.5, 11.25)	$\Delta\sigma_M$ (8,25, 13.75, 22.5)
7079-T6	$\Delta\sigma_A$ (2.5, 7.5, 11.25)	$\Delta\sigma_M$ (8.25, 13.75, 22.5)
6061-T6	$\Delta\sigma_A$ (2.5, 7.5, 11.25)	$\Delta\sigma_M$ (8.25, 13.75, 22.5)

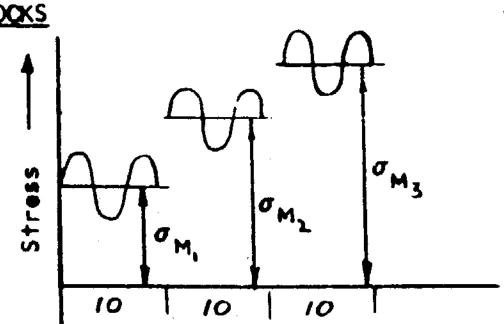
(1) Varying Alternating Stress in Blocks of 10 cycles per Stress Level

(2) Varying Mean Stress in Blocks of 10 cycles per Stress Level

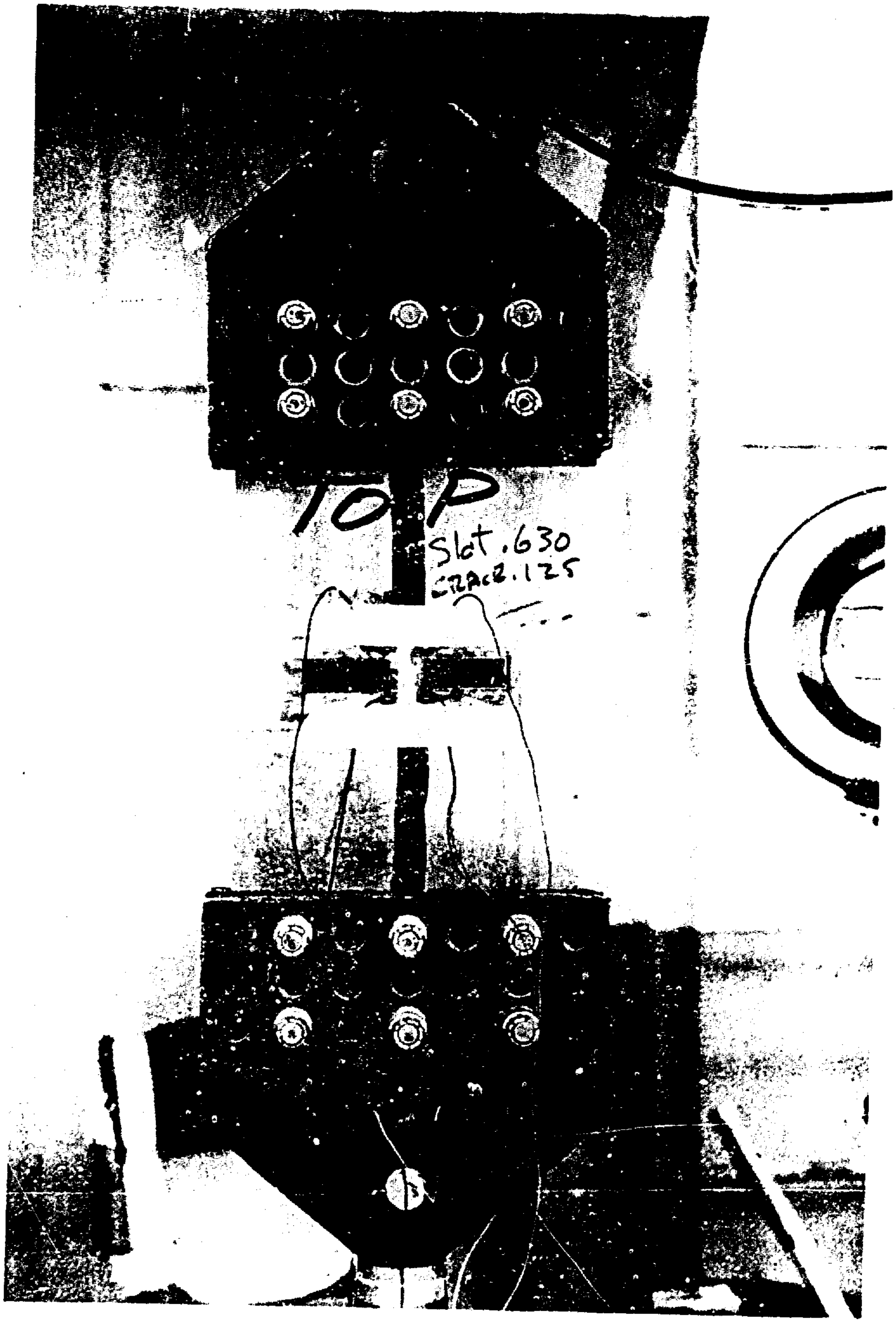
FATIGUE SPECTRUM BLOCKS



Constant Mean Stress
Vary Alternating Stress

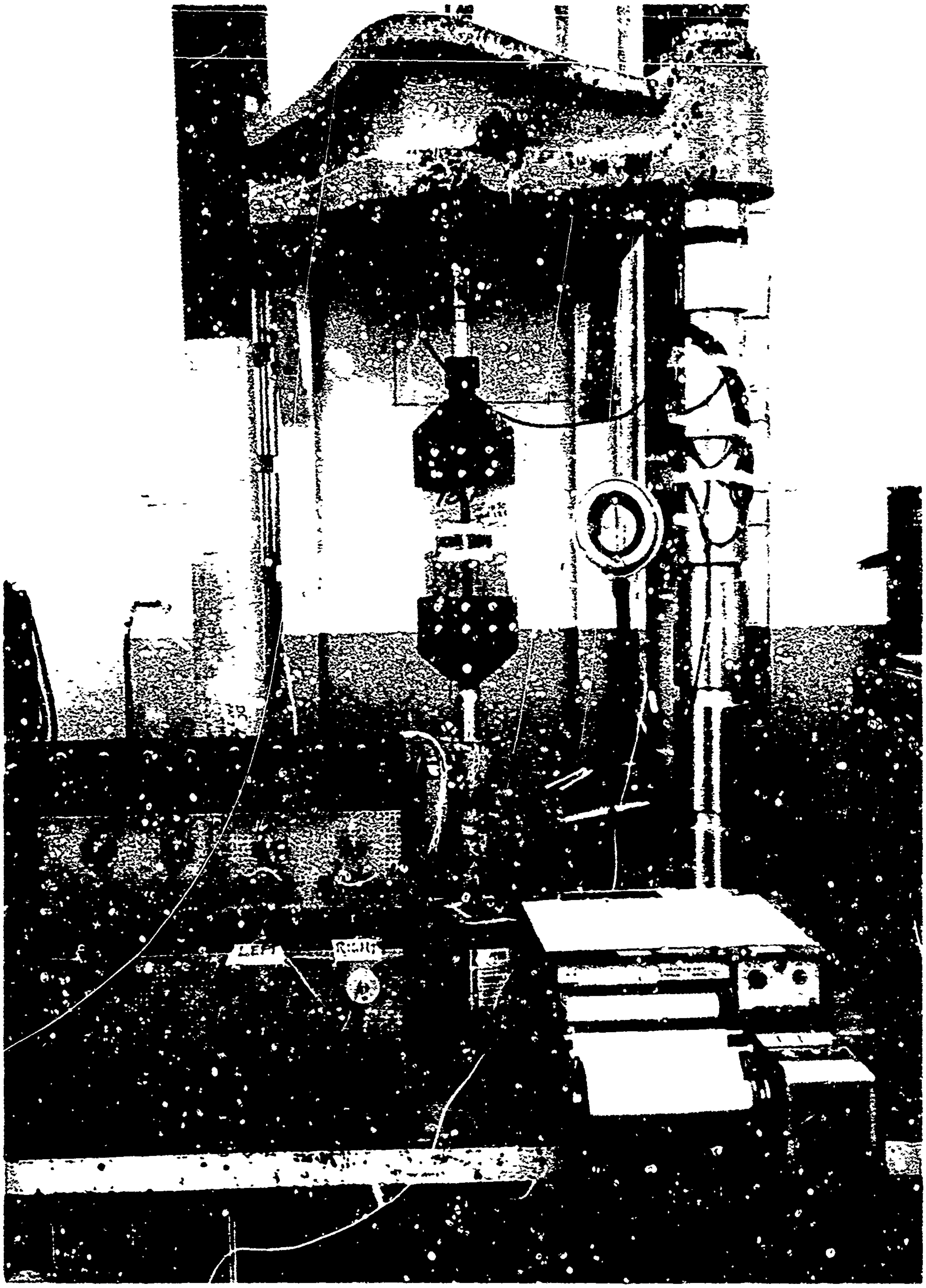


Constant Alternating Stress
Varying Mean Stress



LOCATION OF CRACK PROPAGATION GAGES

FIGURE 9



FATIGUE CRACK PROPAGATION TEST IN PROGRESS

FIGURE 10

these two tasks are in progress. Preliminary data indicates that there is a correlation between tear dimple orientation at the fracture edge and fracture direction.

Sustained load tests of Task II are in progress.

4. FUTURE WORK

During the third quarter spectrum load tests of Task III will be completed and data analysis in all tasks will proceed as specimens become available.

PROGRESS CHART | IMPROVED ELECTRON FRACTOGRAPHIC T

TASK I - DETERMINATION OF CRACK PROPAGATION DIRECTION

SPECIMEN CODE PREFIX-1	TENSILE TEAR																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
DEGREE OF COMPLETION	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

TASK II - TEST PROCEDURE FOR HYDROGEN EMBRITTLEMENT A

SPECIMEN CODE PREFIX-2	HYDRO																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
DEGREE OF COMPLETION	D	D	D	D	D	D					D	D	D	D	D	D	D	D	D	D	D	D
	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
					STRESS																	
	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
	D	D	D	D					D	D								D	D	D	D	D
	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

TASK III - INVESTIGATION OF THE POSSIBILITY OF CORRELATIO

SPECIMEN CODE PREFIX-3	M = C																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
DEGREE OF COMPLETION	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

A

TE; TECHNIQUES

LEGEND

A-EXAMINATION COMPLETED

B-REPLICATION

C-MACRO PHOTOGRAPH COMP

D-MECHANICAL TEST COMPLETED

E-HEAT TREATED

F-SPECIMEN MACHINED

G-MATERIAL PROCURED

ON ON IN METAL FRACTURES

21	22	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
D	D	D	D	D	D												
E	E	E	E	E	E												
F	F	F	F	F	F												
G	G	G	G	G	G												

AN AND STRESS CORROSION

DROGE/DROGEN EMBRITTLEMENT

21	22	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
D	D	D	D	D	D			D	D	D	D	D	D	D	D	D	D			D	D	D	D				D				D
E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

ESS CGESS CORROSION — TRITIUM

71	72	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
D	D	D	D			D	D	D									D			D	D									
E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

TIONTION BETWEEN FATIGUE STRIATIONS AND STRESS ENVIRONMENTS

A		A = C										M = C						M = C									SPECTRUM									
21	22	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D										
E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
G	C	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

B