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Report 28-895

The Effect of Grinding on the Low-Cycle Fatigue Behavior of 5086-H116 and 5456-H117 Aluminum Alloy Weldments

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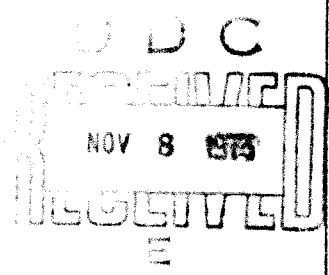
NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20034



THE EFFECT OF GRINDING ON THE LOW-CYCLE FATIGUE BEHAVIOR OF 5086-H116 and 5456-H117 ALUMINUM ALLOY WELDMENTS

by John G. Macco



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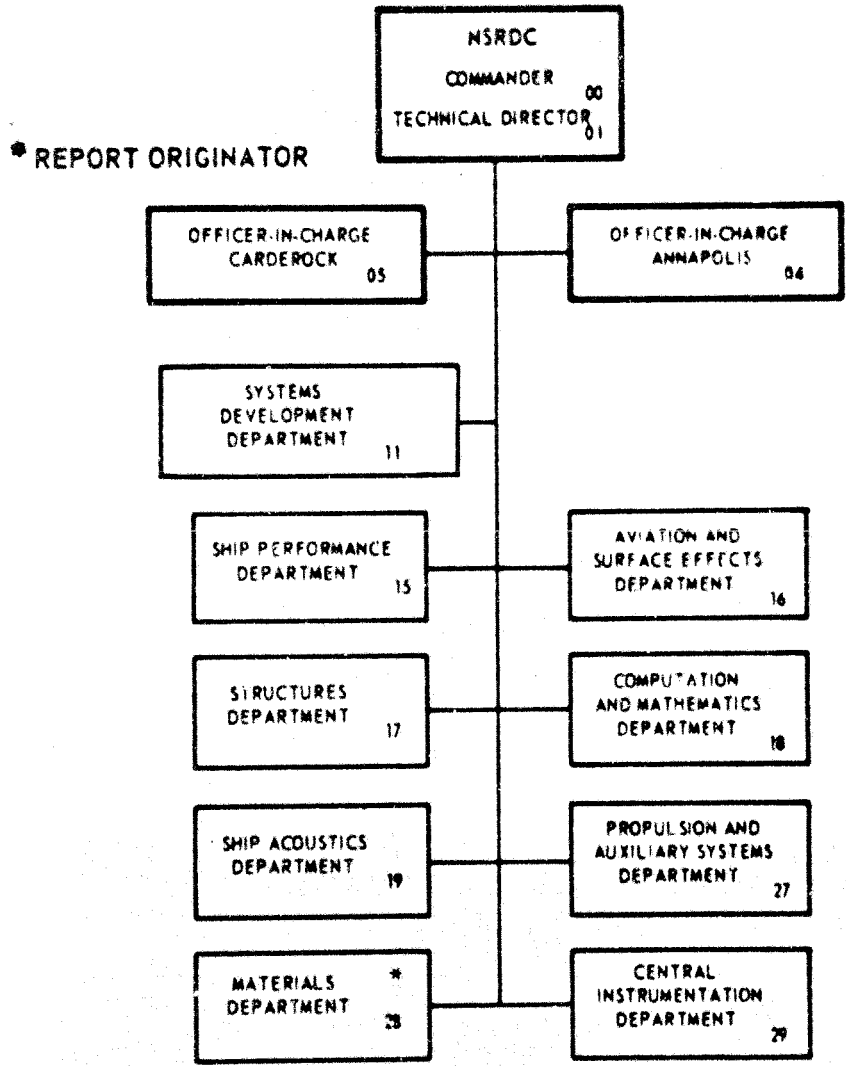
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FATIGUE BEHAVIOR OF 5086-H116 AND 5456-H117  
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### ABSTRACT

Low-cycle flexural fatigue tests in air and in sea-water environments were conducted on 1-inch-thick 5086-H116 and 5456-H117 aluminum alloy weldments in the ground condition. The results indicate that fatigue life is unaffected by the presence of sea water and that grinding significantly enhances fatigue behavior provided that the ground surfaces are free of porosity. Work on this program is continuing to determine the effects of mechanical peening and postweld-arc melting on the fatigue behavior of aluminum weldments.

## ADMINISTRATIVE INFORMATION

This work was done under Work Unit 1-2814-107, Task Area SF43-422-70312, Task 15087, covering fatigue strength of structures for high performance surface ships. This report covers milestone 3 of fiscal year 1974 in the 1 November 1973, Program Summary.

The program manager for this work is Mr. C.H. Pohler, NAVSHIPS (SHIPS 03423), and the project manager is Mr. D.S. Wilson, NAVSEC (SEC 6128).

## ACKNOWLEDGMENT

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## INTRODUCTION

This laboratory is pursuing a comprehensive program for certification of aluminum as the hull material for high performance surface ships. One phase of the program, directed toward the destroyer-type hull, is to determine the low-cycle fatigue properties of 1-inch-thick aluminum plate. Previous reports<sup>1,2</sup> describe the fatigue behavior of base metal and as-welded plate specimens made of 5086-H116 and 5456-H117 aluminum alloys. This report covers the results of low-cycle fatigue tests on ground butt and tee weldments of these alloys.

## INVESTIGATION

### MATERIALS

The aluminum alloys selected for the investigation were 5086-H116 and 5456-H117, conforming to interim federal specifications QQ-A-00250/19 and QQ-A-00250/20, respectively. Typical mechanical properties determined for both alloys, together with corresponding specification requirements, are indicated in table 1. It should be noted that the yield strength of the 5456-H117 alloy is slightly below the minimum specified.

TABLE 1  
MECHANICAL PROPERTIES AND SPECIFICATION REQUIREMENTS

Alloy	Ultimate Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2-In.* Gage %
5086-H116	45.5	30.1	22.0
Specified, minimum	40.0	28.0	10.0
5456-H117	51.0	31.0	19.0
Specified, minimum	46.0	33.0	12.0

ksi - thousand pounds per square inch.

<sup>1</sup>Superscripts refer to similarly numbered entries in the Technical References at the end of the text.

\*Abbreviations used in this text are from the GPO Style Manual, 1973, unless otherwise noted.

## SPECIMEN FABRICATION

Butt- and tee-welded plate specimens of the types described in figure 1 were fabricated by the Titanium and Nonferrous Welding Branch. Details of the welding conditions employed are given in table 2. Figure 2 shows the joint designs used.

TABLE 2 - WELDING CONDITIONS EMPLOYED IN FABRICATING  
5086-H116 AND 5456-H117 ALUMINUM ALLOY  
BUTT- AND FILLET-WELD ASSEMBLIES

	Butt	Fillet
Process	GMAW (spray)	
Welding position	Flat	
Number of passes	6-8	8-10
Amperage	240-300	240-300
Voltage	26-33	26-33
Travel speed, in/min	14-28	16-24
Shielding gas, type gas/ft <sup>3</sup> /h	75He, 25Ar/60	
Filler wire diameter, in.	0.062	
Polarity	Direct current Reversed polarity	
GMAW - Gas metal arc weld		

Radiographic examination of selected butt and tee weldments indicated that the quality of the weld deposits met the requirements of the specification.<sup>3</sup>

## WELD GRINDING

The tension face on butt-welded specimens was ground flush by means of a 6-inch portable disk sander, using 36-, 100-, and 180-grit paper in the order indicated. Weld contours on tee-fillet-welded specimens were machined smooth by means of a 1/2-inch-diameter, high-speed steel rotary burr. Machining marks left by the tool were removed by grinding with a 1/2-inch-diameter, 100-grit, sanding drum. Grinding on all specimens was done so that all finishing scratches ran normal to the weld

length. Photographs of the ground specimens appear in figures 3 and 4.

#### METHODS

Low-cycle fatigue data presented herein were obtained from tests conducted in plate fatigue machines of the type shown in figure 5. In these machines the plate specimen is simply supported along the long edges, is free along the short edges, and is uniformly loaded over the whole lower surface with compressed air. Each specimen was set up in the machine and subjected to cyclical loading, zero to maximum flexure, at the rate of approximately 12 c/m. All specimens were cycled until a crack sufficiently large to cause a 100% increase in deflection beyond initial deflection was developed.

All specimens were evaluated in the ground condition, either in air or in sea water, which was contained in a well erected with sealing compound around the critical section. Natural sea water, obtained from the Francis L. LaQue Corrosion Laboratory, Wrightsville Beach, North Carolina, was used and was changed twice daily to maintain the salt concentration as constant as practicable.

#### RESULTS AND DISCUSSION

Results of low-cycle fatigue tests conducted on welded aluminum alloy plate specimens in the ground condition are summarized in table 3. The fatigue lives of these specimens, based on 10% increase in deflection over the initial deflection, are plotted in figure 6 together with S-N curves for as-welded specimens.<sup>2</sup> A value of 10% was selected as a criterion of fatigue failure because it represents substantial structural damage to the specimens and the start of rapid increase in deflection, a warning of impending failure. It may be seen from the butt-welded data that the presence of sea water has no significant effect on the low-cycle fatigue properties of the aluminum alloys investigated.

TABLE 3  
SUMMARY OF FATIGUE RESULTS FOR ALUMINUM  
ALLOY WELDED SPECIMENS, GROUND

Specimen No.	Thickness inch	Nominal Stress ksi	Number of Stress Cycles		
			Initial Crack	% Increase in Deflection	
				10	100
<u>Butt Welds - Air</u>					
EWf-12	0.988	28,500	150,000	176,100	181,900
EWI-13 <sup>(1)</sup>	0.982	28,800	52,000	80,000	84,720
EWf-14	0.994	39,600	108,000	127,150	127,950
EWI-10 <sup>(1)</sup>	0.975	40,200	21,350	30,800	33,070
<u>Butt Welds - Sea Water</u>					
EWf-13	0.995	24,700	355,500	358,000	362,000
EWI-14 <sup>(1)</sup>	0.976	27,300	36,000	60,230	63,620
EWf-11	0.982	40,700	126,000	145,000	154,700
EWI-16	0.969	45,500	48,500	55,500	57,150
<u>Tee Welds - Air</u>					
EWI-7	0.972	25,000	94,000	102,100	104,530
EWf-7	0.980	28,000	39,000	47,450	50,970
EWf-8	0.982	28,000	38,900	48,680	50,740
EWI-8	0.962	38,000	20,000	22,700	23,790
<sup>(1)</sup> Visible porosity after grinding. EWf - 5456-H117 alloy EWI - 5086-H116 alloy					

It is readily apparent from the S-N curves that grinding significantly enhances the fatigue behavior of aluminum alloy weldments, provided that the ground surfaces are free of porosity. Values of fatigue lives at a nominal stress of 30,000 lb/in<sup>2</sup> (yield strength) are as follows.

	<u>Fatigue Life, cycles</u>	
<u>Specimen</u>	<u>As-Welded</u>	<u>Ground</u>
Butt-weld	45,000	225,000
Tee-weld	22,500	50,000

It is seen that fatigue lives of ground tee- and butt-welded specimens are, at least two and five times longer, respectively, than the lives of corresponding as-welded specimens.

Butt-welded specimens with visible surface porosity after grinding exhibited fatigue lives essentially similar to those of as-welded butt welds. It appears, therefore, that if improved fatigue life is to be achieved by removal of the reinforcement notch, exposed surface porosity must be eliminated. In this regard the Titanium and Nonferrous Welding Branch is currently investigating means for precluding porosity in aluminum alloy weldments.

#### CONCLUSIONS

The following conclusions are based on the low-cycle flexural fatigue data presented herein on 1-inch-thick 5086-H116 and 5456-H117 aluminum alloy weldments:

- Grinding significantly improves the fatigue behavior of aluminum alloy weldments in flexure provided that the ground surfaces are free of porosity.
- Ground weldments with exposed surface porosity have fatigue lives essentially equal to those for weldments in the as-welded condition.
- Low-cycle fatigue life is unaffected by the presence of sea water.

#### FUTURE PLANS

The completion of low-cycle fatigue tests on welded aluminum plate specimens in the mechanically peened and postweld-arc remelted conditions is planned for the future, with submission of a report about June 1974.

#### TECHNICAL REFERENCES

- 1 - Macco, J.G., "Low-Cycle Fatigue Behavior of 5086-H116 and 5456-H117 Aluminum Alloys," NSRDC Rept 28-547 (Feb 1973)
- 2 - Macco, J.G., "Low-Cycle Fatigue Behavior of 5086-H116 and 5456-H117 Aluminum Alloy Weldments," NSRDC R&D Rept 4151 (July 1973)
- 3 - "X-Ray Standard for Bare Aluminum Electrode Welds," MIL-STD-437A (9 Dec 1958)

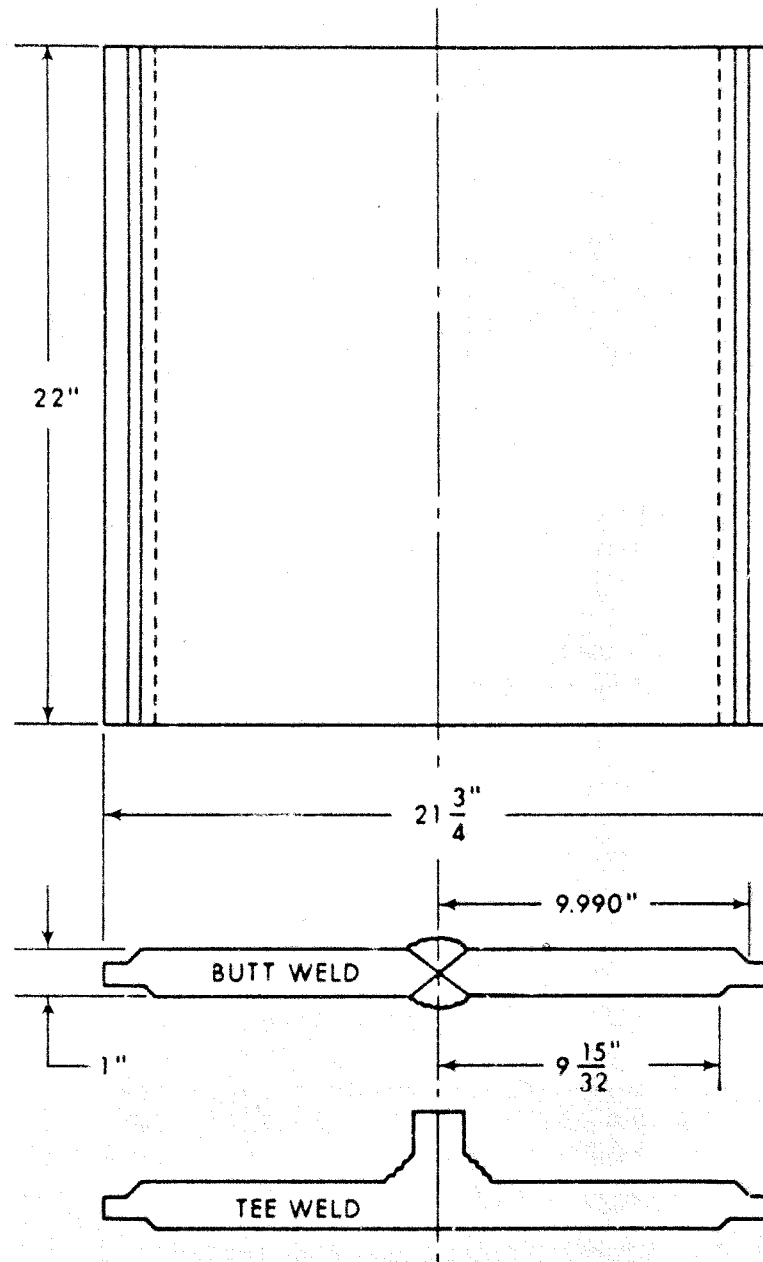
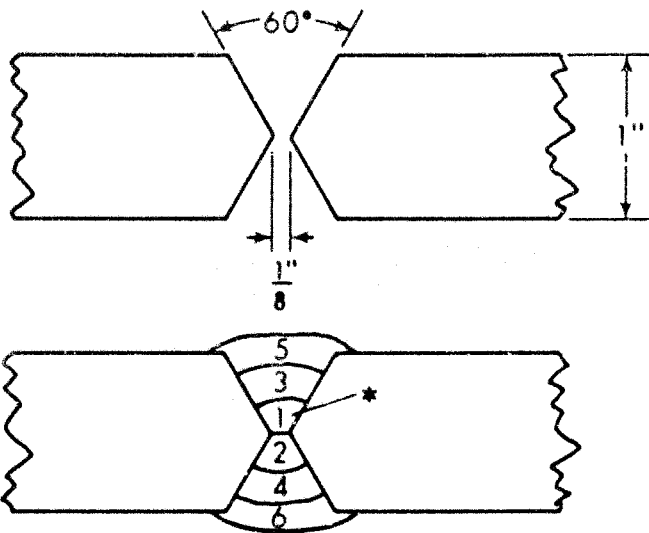
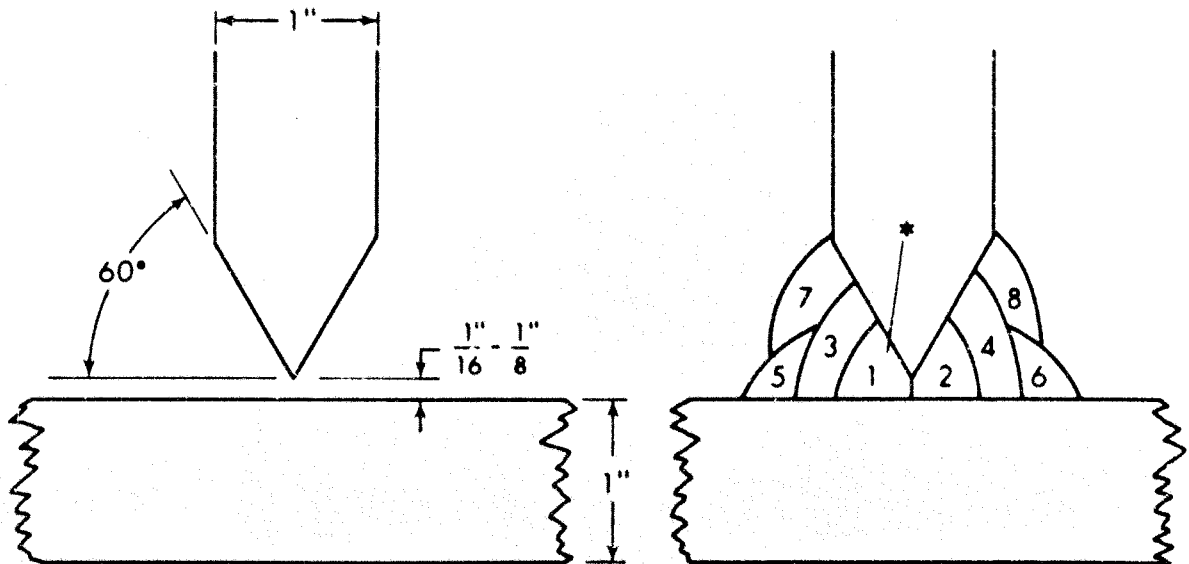


Figure 1  
 Typical Welded Plate Specimens

Double V-Butt



Double V-Fillet



\*First pass was background to remove traces of unfused metal in the root of the weld.

Figure 2 - Joint Design for Aluminum Alloy Tee and Butt Weldments

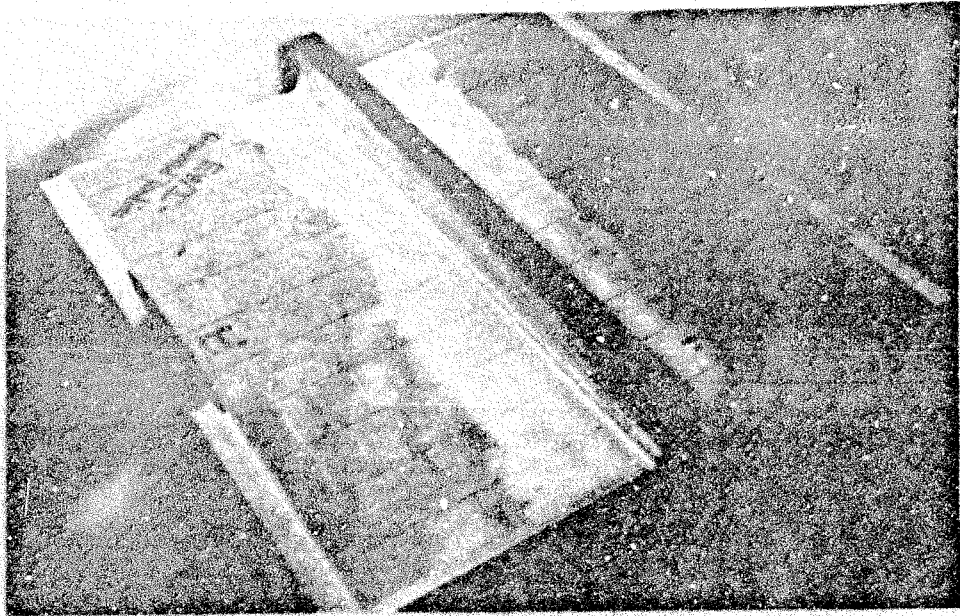


Figure 3  
Ground Tee-Fillet-Welded Plate Specimen



Figure 4  
Ground Butt-Welded Plate Specimen

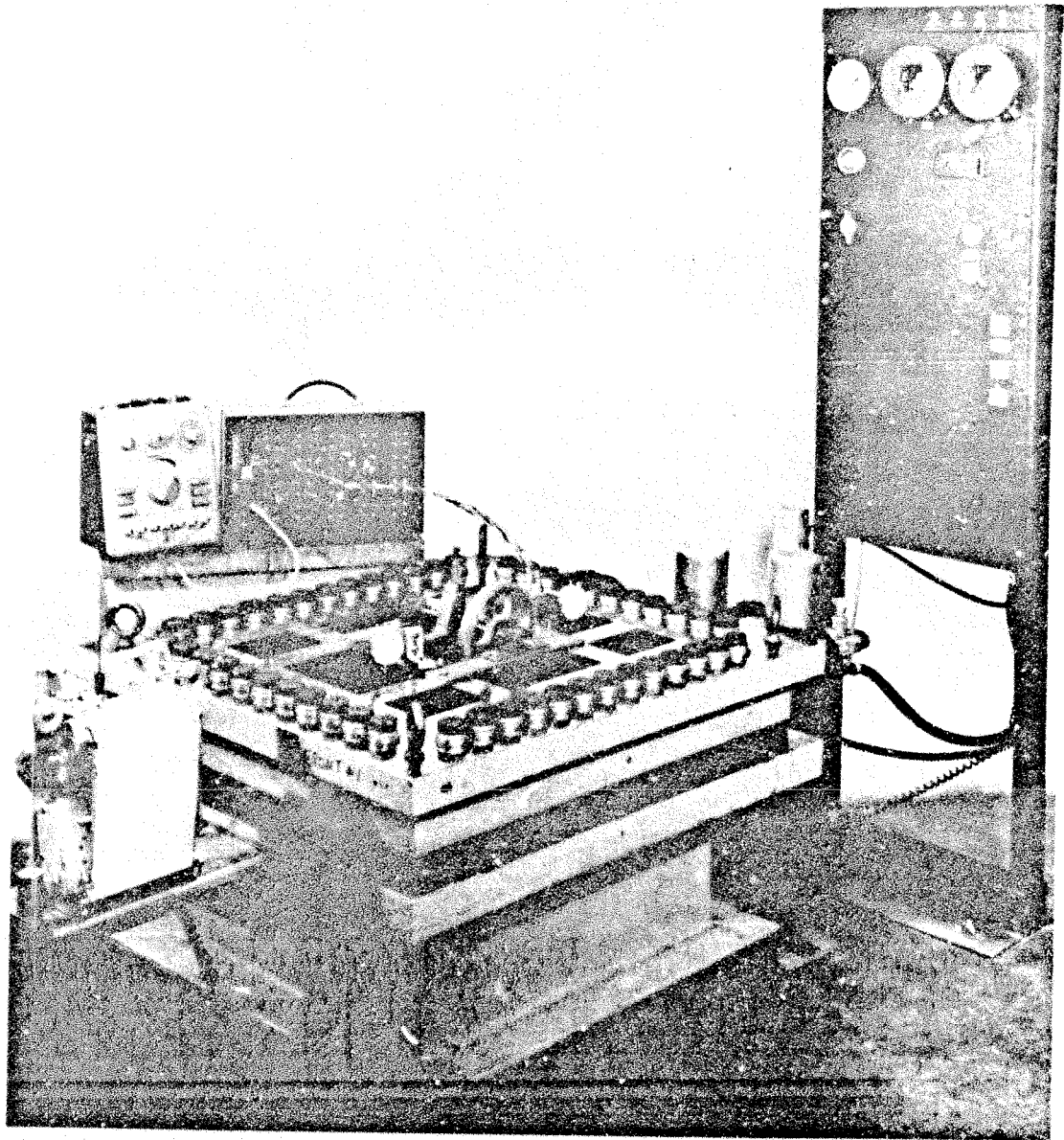


Figure 5  
Plate-Type Fatigue Machine

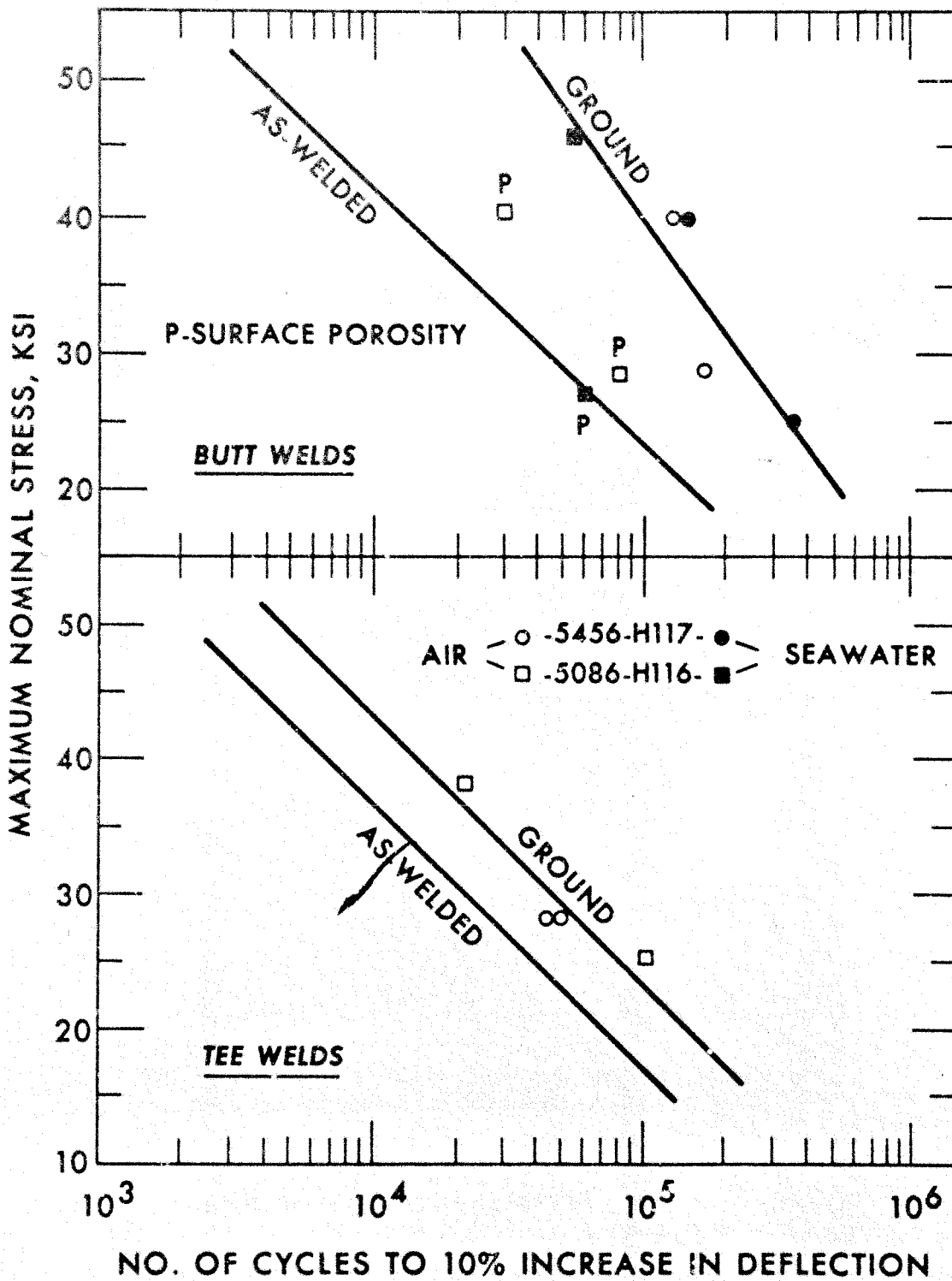


Figure 6 - Fatigue Curves for (Ground) Welded Aluminum Specimens Subjected to Flexural Loading

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