AD NUMBER

AD866333

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to DoD only; Administrative/Operational Use; 24 FEB 1970. Other requests shall be referred to Naval Air Development Center, Warminster, PA.

AUTHORITY

USNADC ltr, 26 Apr 1978

NAVAL AIR DEVELOPMENT CENTER

Johnsville, Warminster, Pennsylvania

REPORT NO: NADC-MA-6932 24 FEB 1970

EVALUATION OF SIZE EFFECT ON THE FATIGUE PROPERTIES OF ALUMINUM ALLOYS 7075, 7079 and X7080

WORK UNIT WF51 541 201 - OB

Each transmittal of this document outside the Department of Defense must have prior approval of the Commander, Naval Air Development Center, or Commander, Naval Air Systems Command.

Best
Available
Copy

NOTICE

PRODUCT ENDORSEMENT - The discussion or instructions concerning commercial products herein do not constitute an endorsement by the Government nor do they convey or imply the license or right to use such products.

DEPARTMENT OF THE NAVY
NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE
WARMINSTER, PA. 18974

Aero Materials Department

REPORT NO: NADC-MA-6932 24 FEB[redacted] [redacted]7Ø

EVALUATION OF SIZE EFFECT ON THE FATIGUE PROPERTIES OF ALUMINUM ALLOYS 7Ø75, 7Ø79 and X7Ø8Ø

WORK UNIT WF51-541-2Ø1 — 0B

The first phase of an evaluation to determine the size effect on the fatigue properties of 7075-T651, 7079-T651 aluminum alloy stretcher leveled plates and an X7080 aluminum alloy hand forging has been completed. Evaluation of the large section specimens (4 square inches test section) showed that the fatigue strength of the X7080 aluminum alloy hand forging, 40,000 p.s.i. at 10^6 cycles, was approximately 48% and 60% higher than the fatigue strengths of 27,000 p.s.i. and 25,000 p.s.i. for the 7075 and 7079 alloy stretcher leveled plates, respectively. The notched fatigue strength of the X7080 alloy, 14,000 p.s.i. at 10^6 cycles, was approximately 17% higher than the notched fatigue strength of 12,000 p.s.i. for the 7075 and 7079 alloys.

Additional phases of the investigation will involve evaluation of the fatigue properties of intermediate size specimens (0.4 square inches test section) and small size specimens (0.04 square inches test section), and an analytical comparison of the fatigue results to determine size effects.

REPORTED BY:
JOSEPH VIGLIONE

M. L. STELLABOTTE

APPROVED BY:
J. F. ERTHAL, Head
Mechanical Metallurgy Branch

F. S. WILLIAMS, Superintendent
Metallurgical Division

402 998

1473

SUMMARY

INTRODUCTION

Reference (a) authorized a fatigue evaluation of specimens having large, intermediate and small cross sections to ascertain, quantitatively, the influence of size on the fatigue properties of 7075-T651, 7079-T651 and X7080-T7 aluminum alloys.

A progress letter report, reference (b), was issued to summarize whatever investigational studies had been done as of that time, however incomplete. This current report includes the data presented in the previous report, as well as the new data obtained since its issuance. The data reported herein, the fatigue properties of smooth and notched large section fatigue specimens, completes the first phase of this investigation, to be followed later by the second and third phases; namely, the fatigue evaluation of the intermediate and small sections, respectively.

SUMMARY OF RESULTS

The fatigue strength of the X7080 hand forging aluminum alloy, 40,000 p.s.i. at 10^6 cycles, was approximately 48% and 60% higher than the fatigue strengths of 27,000 p.s.i. and 25,000 p.s.i. for the 7075 and 7079 aluminum alloy stretcher leveled plates, respectively.

The notched fatigue strength of the X7080 alloys, 14,000 p.s.i. at 10^6 cycles, was approximately 17% higher than the notched fatigue strength of 12,000 p.s.i. for both the 7075 and 7079 alloys.

CONCLUSIONS

On the basis of the fatigue results obtained in the investigation reported herein for the large section specimens, it may be concluded that:

a. The fatigue strength of the X7080 aluminum alloy hand forging showed a marked superiority over those of the 7075 and 7079 aluminum alloy stretcher leveled plates, with the 7075 alloy having a slightly higher value than the 7079 alloy;

b. The notched fatigue strength of the X7080 aluminum alloy forging was only slightly superior to those of the 7075 and 7079 aluminum alloy stretcher leveled plates, which were of equal value.

RECOMMENDATIONS

In the light of the preliminary fatigue test results obtained in this investigation of the large section specimens, it is recommended that the X7080 aluminum alloy hand forgings be given prime consideration in applications where high fatigue strength of large section aluminum alloy components is of primary importance, all other things being equal.

FUTURE PLANS

It is planned to conduct a fatigue evaluation of the 7075, 7079 and X7080 aluminum alloys in the intermediate size sections (0.4 square inches test area) and the small size sections (0.04 square inches test area) for comparison with the large size sections (4 square inches test area).

TABLE OF CONTENTS

EXPERIMENTAL PROCEDURES

Materials

The materials initially available for this program consisted of three plates remaining from another program, size 3"x12"x48", as follows:

	Originally Identified As	Now Designated As
Two (2) plates	7075-T6 stretcher leveled	7075-T651
One (1) plate	7079-T6 stretcher leveled	7079-T651

Due to the fact that a large number of the specimens did not fail in the test section, because of the design of the specimens and the malfunctioning of the fatigue machine, the supply of 7075-T6 became exhausted before a fully established S-N curve for the smooth specimens had been developed. However, additional material to complete the objectives of this program were received, as follows:

Three (3) 7075-T651 plates, 3"x12"x36" (see reference (c))
One (1) X7080-T7 hand forging, 6"x15"x48" (see reference (d))

In this report, future reference to the aluminum alloys 7075-T651 and 7079-T651 stretcher leveled plates and the X7080-T7 hand forging will be made as 7075, 7079 and X7080, respectively, for convenience and brevity.

Specimen Preparation

The original large section specimens were dimensioned as shown on Figure 1, except that the grip lengths were 6" and the over-all lengths were 16", instead of the 7" and 18" as shown on the drawing, respectively. Increasing the over-all length of the specimens, and also increasing the diameters of the grip section from 3" to 3 1/2" eliminated the failures in the grip sections.

The area of the test section approximated 4 square inches and the notch configuration resulted in a K_t value of 3. In all cases, the longitudinal axis of the specimens corresponded to the direction of the grain flow of the plates and the hand forging.

Fatigue Machine

All tensile and fatigue tests of the large size specimens were conducted on a Budd UEH Testing Machine of 400,000 lbs capacity, equipped with a programmed load controller and an electronic readout system.

Essentially, the original machine comprised three major units; (1) the load frame with a single test area, (2) a high capacity hydraulic power package, and (3) a control console. Static or dynamic loads are applied hydraulically through a closed loop servo system, and are controlled and indicated electronically. As desired, the machine can be operated at a finitely controlled rate of strain, load or table motion. Any of these modes can be governed by linear or sinusoidal functions, including the holding of a set condition. In addition, a modification incorporating an MTS Systems Corporation program console adds the capability of applying a wide variety of programmed load spectra in fixed or random sequence. The machine is accurate to within 0.5% of the load or 0.1% of range capacity.

Test Procedure

For the purpose of this investigation, the specimens were subjected to tension-tension fatigue loading (stress ratio of 0.25) and tested to failure or one million cycles, whichever occurred first. In the interest of conserving time, it was decided to consider "run-outs" at one million cycles (because of the slow speed of the machine) rather than the one hundred million cycles, as is customary at NAVAIRDEVCEN when evaluating the fatigue properties of aluminum alloys. Specimens which failed in the shoulder after completing one million cycles were considered legitimate "run-outs" for data purposes.

RESULTS

The results of the fatigue evaluation are tabulated in Table 1 and are shown graphically on Figure 2.

Listed below is a summary of the results of the fatigue evaluation:

Fatigue Strength* at 10^4 Cycles

	Fatigue Strength/psi	
Alloy	Smooth	Notched
7075-T651	61,000	31,000
7079-T651	61,000	31,000
X7080-T7	68,000	38,000

Fatigue Strength* at 10^6 Cycles

	Fatigue Strength/psi	
Alloy	Smooth	Notched
7075-T651	27,000	12,000
7079-T651	25,000	12,000
X7080-T7	40,000	14,000

*The fatigue strength values were determined from the S-N curves

As can be seen from the above results, the fatigue strength of the X7080 aluminum alloy was approximately 48% and 60% higher than the fatigue strengths of the 7075 and 7079 aluminum alloys, respectively. The notched fatigue strength was approximately 17% higher than the notched fatigue strengths of the 7075 and 7079 aluminum alloys, which were of equal value.

It must be emphasized that the above fatigue strength values are based on a life of one million cycles. If the customary life of one hundred million cycles had been used instead, as a life criteria, it could well be that the proportion of superiority of the X7080 alloy might prove to be quite different.

DISCUSSION OF RESULTS

An examination of the graphical presentation of the fatigue test data, shown on Figure 2, shows conclusively that the X7080 aluminum alloy has superior fatigue characteristics, particularly at the longer life of 10^6 cycles, where the fatigue strength is indicated as being 40,000 p.s.i., as compared to 27,000 p.s.i. and 26,000 p.s.i. for the 7075 and 7079 alloys, respectively.

The test plots for the 7075 and 7079 alloys fit well within the normal scatter band at the higher stress levels but there is a slight tendency for the 7075 alloy to exhibit greater fatigue strength as the life approaches 10^6 cycles. The difference is not too significant, so that for all practical purposes it may be stated that the fatigue properties of the 7075 and 7079 alloys are equal in the large sections investigated and reported herein.

Evaluation of the notched fatigue properties of the three alloys showed a slight superiority of the X7080 alloy over the 7075 and 7079 alloys. The combined test plots of the 7075 and 7079 alloys fall within the normal scatter band for the fatigue properties for either of the individual alloys, so that one curve was drawn as representative of the notched fatigue properties of both alloys.

Perhaps the notch sensitivities of the 7075 and 7079 alloys are more acutely divergent in the presence of a stress concentration factor greater than the K_t equal to 3 which was used in this investigation. It is planned to explore the notch sensitivities of these alloys in the smaller sizes, in the presence of notches having stress concentration factors of four and five as well as three.

The conventional type of fatigue fracture, typical of both the 7075 and 7079 alloy specimens, a flat granular appearance across the entire transverse direction, is shown on the photographic plate, Figure 3, together with the unusual type fracture of the X7080 alloy specimens. The fracture of the X7080 alloy specimens seemed to be of a fibrous nature, failure progressing in the longitudinal direction, as well as in the direction transverse to the application of the load. There was a marked change in the elevation of the fracture face with increasing longitudinal elevation as the crack propagated, leaving a very pronounced elevated section at the middle or far end of the facture face.

Because of the unusual type fatigue fracture of the X7080 alloy specimens, a microscopic examination was made of the three alloys. The examination of the 7075 and 7079 alloys showed a typical microstructure, that is, subgrain structure with precipitation and subgrain and grain boundaries (photomicrographs not shown herein). The microstructure of the X7080 alloy, on the other hand, as shown in Figure 4, exhibited, essentially, areas of heavy precipitation separated by light etching areas relatively devoid of any precipitation. This structure is typical of an aged condition. One would expect that the areas free of precipitacion would be weaker than the heavily precipitated areas, and under proper conditions, cracking could proceed longitudinally along such paths.

The implication of longitudinal crack propagation was somewhat verified by making a microscopic examination of a section taken at right angles to a typical longitudinal "step", as shown in Figure 5. The fracture edge of such a section is shown in Figure 5A, which illustrates the path of the failure as it progressed through the weaker light areas. Figure 5B depicts a different region of the same section with numerous instances of cracking along the light etching areas.

In summary, it appears as if the fatigue cracks progressed naturally along the paths of light etching weaker areas, which, in the case of the X7080 alloy, were in the longitudinal as well as in the transverse direction. Thus, the superior fatigue properties of the X7080 aluminum alloy hand forging may be attributed to the fact that time (cycles of stress) was involved in re-starting more of the injurious transverse fatigue cracks, after the fatigue cracks had propagated, less harmfully, in the longitudinal direction following the paths of longitudinal precipitate-free zones.

REFERENCES

(a) WEPTASK RRMA 02 180/200 1/R007 05 01 fwdg PAN 10-36 of 14 May 1963

(b) NAEC ltr M-71-MLS:cb 10310(5563) of 13 Sept 1965 to Bureau of Naval Weapons

(c) Alcoa Reqn. 921-184 of 24 Nov 1965

(d) Alcoa Memo of 3 March 1966 from Mr. Paul L. Mehr to Mr. F.C. Pyne

ACKNOWLEDGMENT

The authors wish to express their appreciation to Mr. Ronald Trabocco of the Physical Metallurgy Branch, Aero Materials Department, for his contribution to this investigation, namely, the metallographic studies contained herein.

TABLE 1

FATIGUE TEST RESULTS

Smooth Specimens

7075-T651 Alloy

Stress/psi	Cycles
70,000	4,952
50,000	24,504
35,000	328,024
30,000	421,087
28,000	410,468
25,000	1,000,080*
26,000	1,000,000*

Fatigue Strengths
10^4 Cycles - 61,000psi
10^6 Cycles - 27,000psi

7079-T651 Alloy

Stress/psi	Cycles
60,000	13,054
48,000	25,458
40,000	72,246
36,000	127,630
30,000	126,178
28,000	256,069
25,000	1,033,154

Fatigue Strengths
10^4 Cycles - 61,000 psi
10^6 Cycles - 25,000 psi

X7080-T7 Alloy

Stress/psi	Cycles
70,000	10,211
60,000	21,322
50,000	130,674
45,000	259,255
40,000	1,134,932

Fatigue Strengths
10^4 Cycles - 68,000 psi
10^6 Cycles - 40,000 psi

Notched Specimens

7075-T651 Alloy

Stress/psi	Cycles
60,000	1,320
45,000	4,091
30,000	15,579
14,000	231,416
12,000	1,008,897

Fatigue Strengths
10^4 Cycles - 31,000 psi
10^6 Cycles - 12,000 psi

7079-T651 Alloy

Stress/psi	Cycles
60,000	1,261
40,000	3,400
20,000	69,371
15,000	191,801
10,000	1,040,049*
12,000	1,508,412*

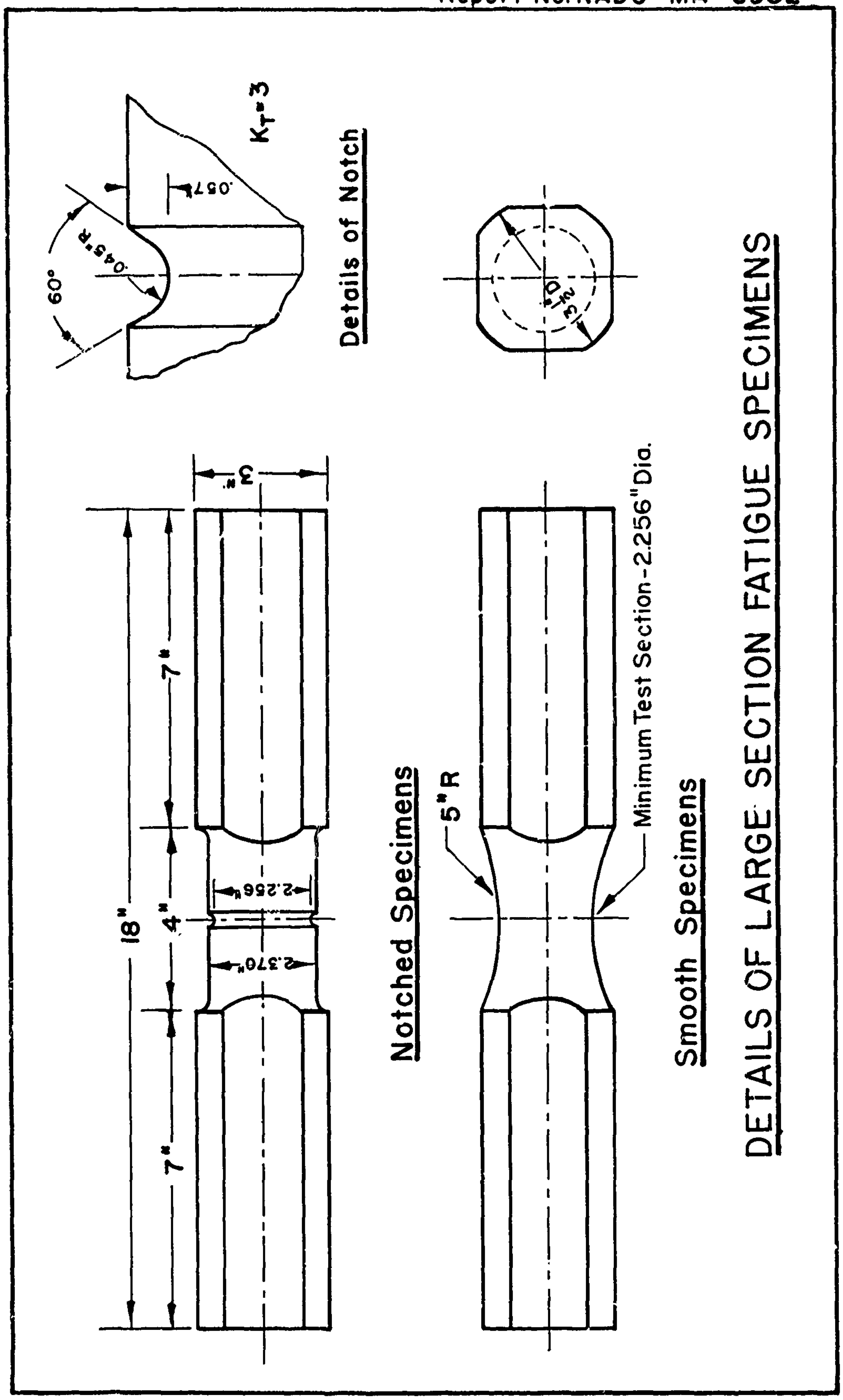
Fatigue Strengths
10^4 Cycles - 31,000 psi
10^6 Cycles - 12,000 psi

X7080-T7 Alloy

Stress/psi	Cycles
60,000	1,475
40,000	8,147
30,000	18,556
20,000	138,912
15,000	332,850
14,000	1,000,000*

Fatigue Strengths
10^4 Cycles - 38,000 psi
10^6 Cycles - 14,000 psi

* Indicates no failure



DETAILS OF LARGE SECTION FATIGUE SPECIMENS

Figure I

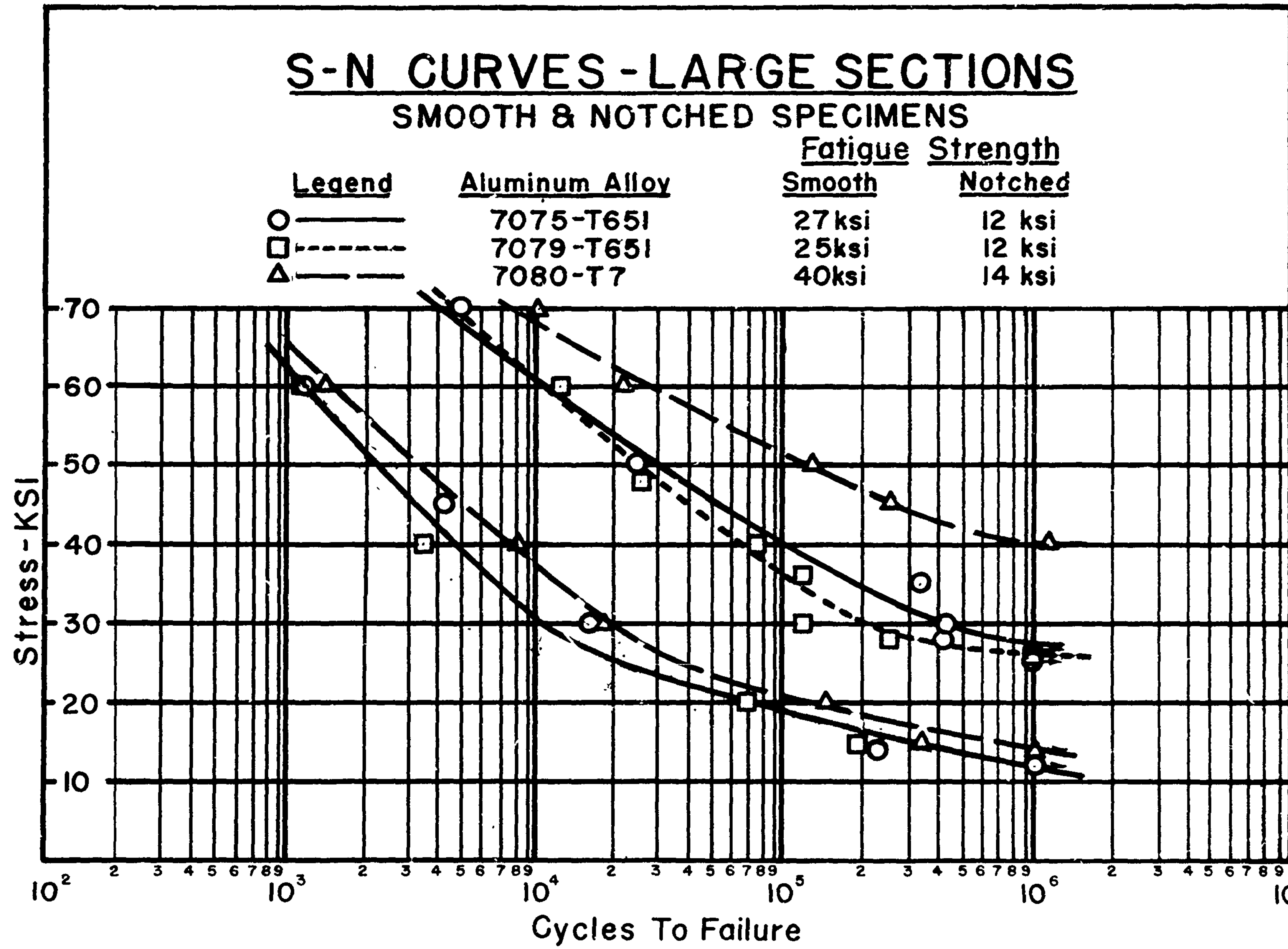
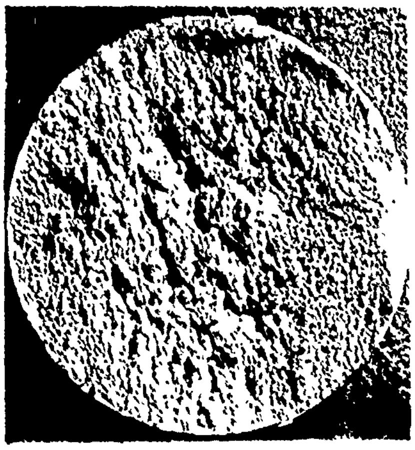
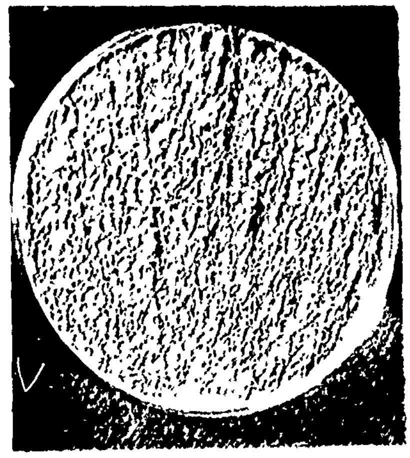

S-N CURVES - LARGE SECTIONS
SMOOTH & NOTCHED SPECIMENS
Legend
Aluminum Alloy
Fatigue Strength
Smooth
Notched
7075-T651
27 ksi
12 ksi
7079-T651
25 ksi
12 ksi
7080-T7
40 ksi
14 ksi
Stress - KSI
70
60
50
40
30
20
10
Cycles To Failure
10^2
10^3
10^4
10^5
10^6
10^7

Figure 2

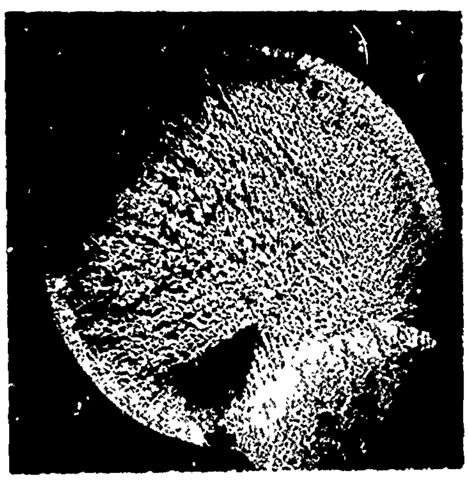


Smooth



Notched

Magnification - 1X
Fracture Surfaces, 7075 and 7079 Alloy

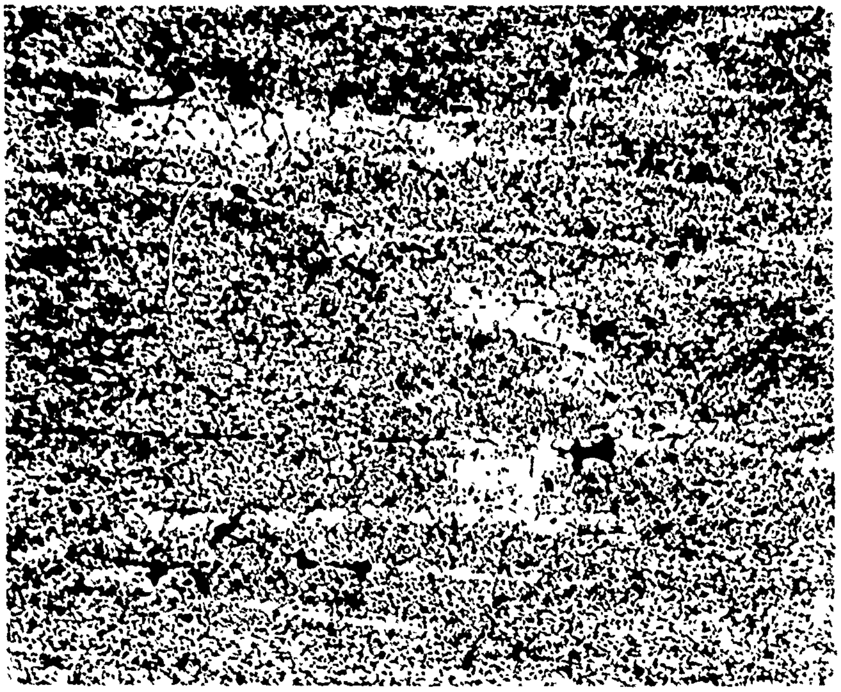


Smooth

Notched

Magnification - 1X
Fracture Surfaces, X7080 Alloy

TYPICAL FATIGUE FRACTURES FIGURE 3



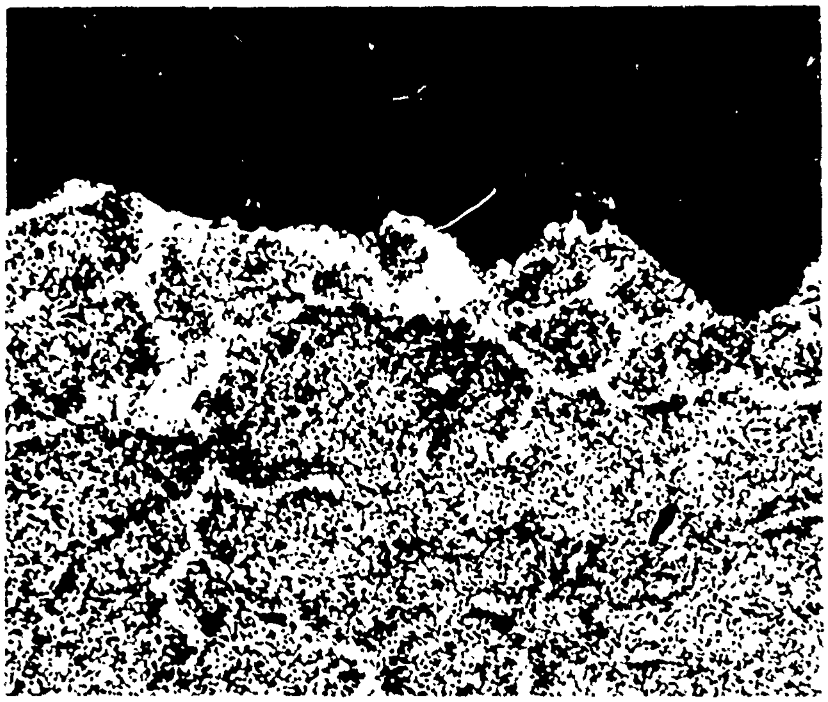
This micrograph, taken close to the failure area of a specimen, shows areas of heavy precipitation separated by banded, lighter etching areas which are relatively free of precipitation.

A. Longitudinal Section (Kellers, 300X)

This micrograph, taken at 90° to the one above, exhibits, generally, the same structure.

B. Transverse Section (Kellers, 300X)

ETCHED MICROSTRUCTURE OF X7080 ALUMINUM ALLOY FIGURE 4



This micrograph, showing a longitudinal section containing a longitudinal fracture, indicates that this type of cracking occurred in the weaker, white, precipitation free areas.

A. Fracture Edge at "Stepped" Region (500X)

This micrograph, showing a longitudinal section adjacent to the fracture face, indicates that longitudinal cracking occurred quite freely in the weaker, white, precipitation free areas.

B. Cracking in Longitudinal Denuded Areas in "Stepped" Region (500X)

MICROSTRUCTURE OF AREAS ADJACENT TO FRACTURE FACE OF X7080 ALUMINUM ALLOY

FIGURE 5

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) AERO MATERIALS DEPARTMENT NAVAL AIR DEVELOPMENT CENTER JOHNSVILLE, WARMINSTER, PA. 18974	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

EVALUATION OF SIZE EFFECT ON THE FATIGUE PROPERTIES OF ALUMINUM ALLOYS 7075, 7079 and X7080

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

JOSEPH VIGLIONE M. L. STELLABOTTE

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
24 Feb 1970	11	4

8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. Work Unit WF51 541 201 - OB d.	9a. ORIGINATOR'S REPORT NUMBER(S) REPORT NO. NADC-MA-6932 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Each transmittal of this document outside the Department of Defense must have prior approval of Commander, Naval Air Development Center, or Commander, Naval Air Systems Command, Washington, D. C. 20360

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY NAVAL AIR SYSTEMS COMMAND DEPARTMENT OF THE NAVY WASHINGTON, D. C. 20360

13. ABSTRACT

The first phase of an evaluation to determine the size effect on the fatigue properties of 7075-T651, 7079-T651 aluminum alloy stretcher leveled plates and an X7080 aluminum alloy hand forging has been completed. Evaluation of the large section specimens (4 square inches test section) showed that the fatigue strength of the X7080 aluminum alloy hand forging, 40,000 p.s.i. at 10^6 cycles, was approximately 48% and 60% higher than the fatigue strengths of 27,000 p.s.i. and 25,000 p.s.i. for the 7075 and 7079 alloy stretcher leveled plates, respectively. The notched fatigue strength of the X7080 alloy, 14,000 p.s.i. at 10^6 cycles, was approximately 17% higher than the notched fatigue strength of 12,000 p.s.i. for the 7075 and 7079 alloys.

1,000,000

Additional phases of the investigation will involve evaluation of the fatigue properties of intermediate size specimens (0.4 square inches test section) and small size specimens (0.04 square inches test section), and an analytical comparison of the fatigue results to determine size effects.

DD FORM 1473 1 NOV 65 (PAGE 1)

S/N 0101-807-6811

UNCLASSIFIED

Security Classification

A-31408

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fatigue						
Aluminum						
Stress Concentration						
Size Effects						

DD FORM 1 NOV 65 1473 (BACK)
S/N 0101-807-6821

UNCLASSIFIED
Security Classification

A-31409