AFML-TR-77-102

EXPLORATORY DEVELOPMENT FOR DESIGN DATA ON STRUCTURAL ALUMINUM ALLOYS IN REPRESENTATIVE AIRCRAFT ENVIRONMENTS

D. L. BROWNHILL
R. E. DAVIES
G. E. NORDMARK
B. M. PONCHEL

ALUMINUM COMPANY OF AMERICA
ALCOA LABORATORIES
ALCOA CENTER, PENNSYLVANIA 15069

7381 07

JUL [redacted] 77

196p.

F33615-74-C-5089

TECHNICAL REPORT AFML-TR-77-102
Final Report, [redacted] May [redacted]74 – Apr[redacted]77

Approved for public release; distribution unlimited.

AIR FORCE MATERIALS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

017 460

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This technical report has been reviewed and is approved for publication.

ALLAN W. GUNDERSON
Engineering & Design Data
Materials Integrity Branch

C. L. HARMSWORTH
Technical Manager
Engineering and Design Data
Materials Integrity Branch

FOR THE COMMANDER

THOMAS D. COOPER
Chief, Materials Integrity Branch
Systems Support Division

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

AIR FORCE/56780/6 February 1978 — 300

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFML-TR-77-102	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EXPLORATORY DEVELOPMENT FOR DESIGN DATA ON STRUCTURAL ALUMINUM ALLOYS IN REPRESENTATIVE AIRCRAFT ENVIRONMENTS		5. TYPE OF REPORT & PERIOD COVERED FINAL MAY 1, 1974-APRIL 30, 1977
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) D. J. BROWNHILL, R. E. DAVIES G. E. NORDMARK, B. M. PONCHEL		8. CONTRACT OR GRANT NUMBER(s) F33615-74-C-5089
9. PERFORMING ORGANIZATION NAME AND ADDRESS ALUMINUM COMPANY OF AMERICA ALCOA LABORATORIES ALCOA CENTER, PA. 15069		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 73810743
11. CONTROLLING OFFICE NAME AND ADDRESS UNITED STATES AIR FORCE AIR FORCE SYSTEMS COMMAND MATERIALS LABORATORY WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433		12. REPORT DATE JULY 1977
		13. NUMBER OF PAGES 178
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

2048	Plate	Bearing	Crack Propagation
7050	Hand Forgings	Modulus of Elasticity	Stress-Corrosion
7475	Tensile	Stress-Strain	Exfoliation
2219	Compressive	Fracture Toughness	
	Shear	Fatigue	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The mechanical properties, fracture toughness, fatigue, fatigue-crack growth rates in three environments and corrosion characteristics of 10 lots each of 2048-T851, 7050-T7351 and 7475-T7351 plate and 2219-T852 hand forgings have been evaluated.

Data for establishing MIL-HDBK-5 values, including modulus of elasticity and stress-strain are presented.

The plane-strain stress-intensity factors, K_{Ic}, for the plate products are generally higher, particularly for 7475-T7351

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

than those of other commercial alloys of comparable yield strength levels. The 2219-T852 hand forgings exhibit toughness levels higher than those of most other hand forging alloys.

Axial-stress fatigue strengths and rates of fatigue-crack propagation are generally comparable to those of corresponding products of 2XXX and 7XXX alloys. At medium stress intensities, fatigue-crack propagation rates in moist air and sump water are, respectively, 1.5 to 2 times and 2 to 9 times as fast as in dry air. However, at low stress intensities, crack arrest sometimes occurred in the sump water.

All of the products tested display the expected excellent resistance to exfoliation and stress corrosion. The only indications of any susceptibility to intergranular stress-corrosion cracking were obtained for short-transverse specimens from three lots of 2048-T851 plate when tested at an applied stress of 75 per cent of the minimum long-transverse yield strength. The tests of precracked double-cantilever beam specimens showed the same general trends as tests with smooth stress-corrosion specimens.

PREFACE

This investigation was conducted by Alcoa Laboratories, Aluminum Company of America, Alcoa Center, Pennsylvania under USAF Contract No. F33615-74-C-5089, Project No. 7381, for the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio, with Mr. A. W. Gunderson (AFML/MXA) as project engineer.

This report covers work done from May 1, 1974 through April 30, 1977.

The investigation was made under the supervision of Mr. D. J. Brownhill as project manager with Mr. R. E. Davies as project engineer for the phase covering the mechanical properties including fracture toughness and axial fatigue. The phase covering the fatigue-crack propagation rates was under the supervision of Mr. R. A. Kelsey, with Mr. G. E. Nordmark as project engineer. The phase covering the exfoliation and stress-corrosion characteristics was under the supervision of Mr. D. O. Sprowls, with Mr. B. M. Ponchel as project engineer. Significant advisory and technical assistance were supplied by Messrs. J. G. Kaufman, A. B. Thakker, G. T. Sha and D. J. Lege.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Concluded)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF TABLES
(Continued)

LIST OF TABLES
(Concluded)

SUMMARY

The mechanical properties, fracture toughness, fatigue, fatigue-crack growth rates in three environments and corrosion characteristics of 10 lots each of 2048-T851, 7050-T7351 and 7475-T7351 plate and 2219-T852 hand forgings have been evaluated.

Data for establishing MIL-HDBK-5 values, including modulus of elasticity and stress-strain are presented.

The plane-strain stress-intensity factors, K_{Ic}, for the plate products are generally higher, particularly for 7475-T7351, than those of other commercial alloys of comparable yield strength levels. The 2219-T852 hand forgings exhibit toughness levels higher than those of most other hand forging alloys.

Axial-stress fatigue strengths are in the same general range as those of corresponding products of 2XXX and 7XXX alloys.

In dry and moist air, rates of fatigue-crack propagation are generally similar for the hand forging and the three plate alloys and comparable to rates reported for other high-strength aluminum alloys. At medium stress intensities, fatigue-crack propagation rates are 1.5 to 2 times as fast in moist air as in dry air and 2 to 9 times as fast in sump water as in dry air; rates in sump water were slower for the 2XXX products than those for the 7XXX plate. However, at low stress intensities, propagation in the 7XXX plate and the 2219 hand forging slowed or arrested in the sump water, apparently due to a buildup of corrosion product on the fracture surface.

All of the products tested display the expected excellent resistance to exfoliation and stress corrosion. The only indications of any susceptibility to intergranular stress-corrosion cracking were obtained for short-transverse specimens from three lots of 2048-T851 plate when tested at an applied stress of 75 per cent of the minimum long-transverse yield strength. All of the lots of 2048-T851 plate display the expected excellent resistance to stress corrosion in the critical short-transverse direction at a test stress of 50 per cent of the minimum long-transverse yield strength. The tests of precracked double-cantilever beam specimens showed the same general trends as tests with smooth stress-corrosion specimens.

SECTION I

INTRODUCTION

The high performance required of aerospace structures demands that adequate consideration be given to the influence of service environments, and therefore the development of design related data must take such influence into account. The data in this investigation were generated to support the AFML service failure analysis efforts and to serve as a basis for evaluating the alloys for use in new Air Force systems. A considerable amount of this type of data has been developed previously for other alloys, tempers and products intended for such critical service[1-11].

The purpose of this investigation was to evaluate environmental fatigue crack-growth rates and corrosion characteristics as well as data for establishing design mechanical properties for four alloys which might be subjected to critical environmental service, i.e., 2048-T851, 7050-T7351 and 7475-T7351 plate and 2219-T852 hand forgings. Specifically, sufficient data have been developed for these products to establish statistically meaningful design mechanical properties for use in MIL-HDBK-5[12] and to provide a level of confidence in the data on fracture toughness, fatigue strength, fatigue-crack propagation rates, exfoliation and stress-corrosion resistance.

SECTION II

MATERIAL

The products tested in this investigation included ten lots each of the following:

Alloy and Temper	Product	Thickness Range, in.	Producer
2048-T851	Plate	0.5 to 4.0	Reynolds
7050-T7351	Plate	2.0 to 6.0	Alcoa
7475-T7351	Plate	0.5 to 4.0	Alcoa
2219-T852	Hand Forgings	2.0 to 7.5	Alcoa

These products were produced by commercial practices in use at the time of fabrication. The chemical compositions of each sample, determined at Alcoa Laboratories and shown in Tables 1 through 4, are within the specified limits shown in the same tables.

The tensile properties of all samples met their respective tentative minimum properties, Tables 5 through 9. Minimum properties have been established for the 2048-T851 plate in thicknesses 2.001 to 3.000 in. only. The minimum values can be expected to be about 5 to 6 ksi below the expected typical properties shown in Table 5.

Tentative minimum K_{Ic} values have been established for 7475-T7351 plate. The fracture toughness data obtained for the samples tested in this investigation developed K_{Ic}, or K_Q, values above the tentative minimum values. However, it was realized, after comparision with data from tests of lots produced prior to the contract, that the levels of fracture toughness developed were not representative of current production. The relatively low values obtained for the lots produced for the contract were attributed to the fabrication practices utilized at that time. These practices were subsequently revised to eliminate the possibility of conditions which lead to toughness levels lower than normally achievable in 7475-T7351 plate. Because the ten samples of 7475-T7351 plate were not considered to be representative of the capabilities of current production material, ten additional lots were fabricated and tested for toughness to demonstrate the high toughness of this product. A few of these samples were also tested for mechanical properties, fatigue, fatigue-crack propagation and corrosion characteristics.

SECTION III

PROCEDURE

A. Mechanical Properties

A.1. Tensile, Compressive, Shear and Bearing

The tensile, compressive, shear and bearing tests were made using the smallest suitable range of an Amsler 20,000-lb (type 105XBDA58), an Olsen Electromatic 30,000-lb and an Olsen Super-L 20,000-lb or a Southwark-Tate-Emery 50,000-lb capacity Universal Testing Machine. The machines were calibrated prior to and during the investigation. The accuracy of these machines was within that required by ASTM Method E4[13].

The test specimens and procedures used were, where appropriate, the same as those used in previous investigations of sheet, plate, extrusions and forgings[1-3, 6, 9-11, 14]. Single specimens were tested except where initial results indicated check tests were necessary. Where check tests were made for tensile properties, duplicate tests were made. Specimens were taken in the test directions and locations specified in ASTM B557[15]. Specimens (L and LT) from 0.5 to 1.0-in. thick plate were taken from T/2 (thickness/2) and for plate 1.75-in. thick and greater from T/4; short-transverse specimens were taken from T/2. All specimens from the 2219-T852 hand forgings were from T/2.

Tensile tests were made in accordance with ASTM E8[16] with 1/2-in. diameter tapered-seat specimens, except where it was necessary to use subsize round specimens (Fig. 1). The yield strengths were determined from autographically recorded load-strain diagrams.

Compressive tests were made in accordance with ASTM E9[17] using a subpress (Fig. 3 of ASTM E9). All specimens were the cylindrical type shown in Fig. 1. The yield strengths were determined from autographically recorded load-strain diagrams.

Shear tests were made using cylindrical specimens (Fig. 1); these specimens were tested in an Amsler double-shear tool in which a 1-in. length is sheared from the center of a 3-in. long specimen, the end thirds being supported throughout their length. In tests of longitudinal and long-transverse specimens, the loads were applied in the direction normal to the major surface of the product; in tests of short-transverse specimens, the loads were applied in the longitudinal direction[18].

Bearing tests were made in accordance with ASTM E238[19] using longitudinal and long-transverse specimens of the type shown in Fig. 2. Specimens were 0.094-in. thick. The bearing ultimate and yield strengths were determined at edge distance of 1.5 and 2.0 times the pin diameter. The bearing yield strength was obtained by determining the load at a permanent deformation of 2 per cent of the pin diameter as indicated on an autographic load-deformation diagram. Bearing specimens were taken flatwise from plate and edgewise from the hand forging. The specimens and test fixtures were cleaned ultrasonically as prescribed in ASTM E238.

Tensile and compressive stress-strain tests, including modulus of elasticity determinations, were made of longitudinal, long-transverse and, where possible, short-transverse specimens from four or five samples of each alloy and product. The tests were, in general, conducted in accordance with ASTM E111[20]. The tensile and compressive specimens were of the type shown in Fig. 1.

For the stress-strain tests, loads were measured with Revere Super Precision-type load cells having an accuracy, traceable to the National Bureau of Standards, of 0.1 per cent of rated output. Strains were measured with Micro-Measurements Types CEA-13-062UW-350 strain gages. These gages have a gage factor accuracy of 0.5 per cent and a resistance accuracy of 0.3 per cent. Overall accuracy of load measurement did not exceed 0.5 per cent of reading or 0.25 per cent of full scale, whichever was larger. Strain measurement accuracy was 0.7 per cent of reading or 0.5 per cent of full scale, whichever was larger; the accuracy of the gages was well within the requirements established for Class B1 extensometers in ASTM E83[21].

The specimens were tested to the 0.2 per cent offset yield strength of the material. The stress and strain data were recorded in computer storage for use in establishing typical stress-strain and compressive tangent-modulus curves. The modulus of elasticity values were determined from Tuckerman analysis plots of these data as described in ASTM E111.

A.2. Fracture Toughness

The plane-strain stress-intensity factor, K_{Ic}, was determined with fatigue-cracked compact specimens of the type shown in Fig. 3. Triplicate specimens were tested for the L-T, T-L and S-L orientations, Fig. 4. The dimensions and notches of the specimens and the fatigue-cracking and testing procedures were essentially in accordance with ASTM E399[22]. The specimens were fatigue cracked by axial loading (R = +0.1) in Krouse fatigue machines. The test setups for fatigue precracking and fracture toughness testing are shown in Figs. 5 and 6, respectively. Plots of load versus crack-opening displacement were recorded using a Mosley X-Y recorder. Candidate values of critical plane-strain stress-intensity factor, K_Q, were calculated using the load at 5 per cent secant offset which is equivalent to about 2 per cent of crack extension. If all the validity criteria specified in ASTM Method E399 were met, the candidate value was designated as K_{Ic}. Values of K_Q which failed to meet certain validity criteria by no more than 10 per cent were considered to be meaningful values, in that they were indicative of the fracture toughness of the material.

A.3. Axial-Stress Fatigue (Ambient Air)

Axial-stress smooth and notched fatigue specimens tested were of the type shown in Fig. 7. Longitudinal and long-transverse specimens were tested from each product and short-transverse specimens were tested from products equal to or greater than 3.5-in. in thickness. The specimens were taken from the same locations as the tensile specimens. Tests were made at a stress ratio of R* = 0.0. Sufficient tests were made of two lots of each alloy and product to determine fatigue strengths between about 10^3 and 10^7 cycles. Generally, three to five tests were made of the remaining lots tested. All tests were made in Krouse fatigue machines operating at 13.3, 25.0 or 28.8 Hz.

B. Fatigue-Crack Propagation Tests

Fatigue-crack propagation rates were determined for two sizes of hand forging and each plate alloy. The following additional variables were included for one or more of the four alloys: environment, frequency, stress ratio, specimen orientation, specimen size, and specimen location. One T-L specimen was taken from the surface of a 2219-T852 forging; all other specimens had their test sections taken from the middle third of the material. Specimens were taken in the L-T, T-L and, where possible, the S-L orientations. Typical dimensions for the compact specimens are shown in Fig. 8; because of product or material limitations, the plan dimensions of a few S-L specimens were proportionally smaller than shown. The 1-in. thick specimens were used to obtain data at medium to high-stress intensities whereas the 1/4-in. thick specimens were used for obtaining data at low-stress intensities approaching threshold.

---

* R, Stress Ratio = $\frac{\text{Minimum Stress}}{\text{Maximum Stress}}$

The cracks in some L-T specimens deviated considerably from the plane of the notch. Data for such specimens are of questionable value since neither length measurements nor the stress-intensity solutions are correct; a proposed specification[23] would classify data for crack fronts deviating by more than 5° as invalid. To reduce the likelihood of angled propagation, many of the L-T specimens had their widths (W) reduced to provide an H/W ratio = 0.6 instead of 0.485. Previous tests [10] have demonstrated that equivalent results are obtained for the two geometries of specimens.

Tests were made in load control using closed loop, servo-controlled, test systems in three environments: dry air, moist air and sump water. Humidity was controlled within test chambers such as shown in Fig. 9. Dry air (relative himidity <10 per cent) was obtained using dessicants; moist air (relative humidity 96 to 99 per cent) was obtained by forcing moist air through the chamber. Synthetic sump water was contained in small troughs bonded to the test section. The sump-tank water, composed of chlorides of various metals, was prepared as reported in Ref. 24. Its composition is shown below:

	Salt		Metal Ion,	Chloride
	Ppm	Weight, per cent	ppm	ppm
$CaCl_2$	50	0.005	18	32
$CdCl_2$	1000	0.100	490	310
$MgCl_2$	50	0.005	6	18
NaCl	100	0.010	20	30
$ZnCl_2$	10	0.001	4.7	5.2
$CrCl_3.6H_2O$	1	0.001	0.2	0.3
$CuCl_3.2H_2O$	1	0.001	0.4	0.4
$FeCl_3$	5	0.005	1.7	3.3
$MnCl_2.4H_2O$	5	0.005	1.4	1.8
$NiCl_2.6H_2O$	1	0.001	0.2	0.3
$PbCl_2$	1	0.001	0.7	0.3
Total	1224	0.135	543.3	401.6

To study the effect of test frequency, tests of many specimens were alternated between 20 and 2 Hz. For the large number of loadings required for the low-growth rate tests, data was obtained at 30 to 40 Hz. Some tests were slowed in late stages to maintain load stability or for running the test overnight.

The normal stress ratio for these tests was 1/3. To obtain some data on the effect of stress ratio, the minimum load for some low-growth rate specimens was increased when the test reached medium stress intensities to produce a stress ratio of 2/3.

Fatigue precracks for the high-growth rate tests were started at $R = 0.1$. For the low-growth rate tests, it was necessary to approach the test loads by successive load reductions of 10 to 15 per cent. The final portion of precracking was accomplished at test conditions. Visual-crack length measurements were made using low power magnification (15X) and a series of reference grid lines (0.02 in.) photographically printed on both sides of the specimen (Fig. 9). To increase the range of data obtained, the test loads were increased periodically during the test.

The rate of fatigue-crack growth, $\Delta a/\Delta N$, was determined from crack length (a) versus number of cycles (N) data evaluating incrementally the derivative of a versus N. These growth rates were plotted against the range in stress intensity evaluated at the average crack length over which the Δa increment was taken.

The expressions for stress intensity were:

$$\Delta K = \frac{\Delta P\sqrt{a}}{BW} Y,$$

Where: P = load, thousand pounds,

$$Y, \quad (H/W=0.485) = 30.96-195.8\left(\frac{a}{W}\right) + 730.6\left(\frac{a}{W}\right)^2 - 1186.3\left(\frac{a}{W}\right)^3 + 754.6\left(\frac{a}{W}\right)^4, \qquad \text{[Ref. 25]}$$

$$Y, \quad (H/W=0.6) = 29.6-185.5\left(\frac{a}{W}\right) + 655.7\left(\frac{a}{W}\right)^2 - 1017.0\left(\frac{a}{W}\right)^3 + 638.9\left(\frac{a}{W}\right)^4, \qquad \text{[Ref. 26]}$$

a, B, W, and H (see Fig. 8).

C. Corrosion Characteristics

C.1. Resistance to Exfoliation

The resistance to exfoliation of the various products was evaluated by means of 2 x 4 in. panels machined to the T/10 and the T/2 planes (10 or 50 per cent of the section thickness machined from one of the fabricated surfaces) and exposed to the EXCO test per ASTM G34-72[27]. The EXCO test involves total immersion in a 4N NaCl + 0.5 N KNO_3 0.1N HNO_3 solution. In addition, 3 x 5 in. panels from selected lots of each product were machined to the T/10 and the T/2 plane and exposed to the acidified salt-spray test (MASTMAASIS) as specified in MIL-A-8978, 8979, and 8980[28]. Specimens exposed to the two accelerated tests were rated visually using the photographic standards contained in ASTM G34-72[27], Fig. 10. The lots of each product selected for testing in the acidified salt-spray test were also evaluated by the exposure of 3 x 9 in. panels from the T/10 and T/2 plane to the seacoast atmosphere at Point Judith, Rhode Island. The Alcoa exposure station at Point Judith is located about 300 feet from the water's edge with the accompanying elements of considerable salt mist, persistent fog, and prevailing off-shore winds. Corrosive conditions at this location are severe and are comparable to those at the ASTM seacoast station at La Jolla, California.

C.2. Resistance to Stress-Corrosion Cracking (SCC) - Smooth Specimens

The resistance to stress-corrosion cracking of aluminum alloy wrought products is most critical in the short-transverse direction; consequently the majority of the tests were made on specimens oriented in that direction. Four lots of each product were, however, selected for testing of longitudinal and long-transverse specimens in the accelerated stress-corrosion test at an applied stress of 75 per cent of the specified or tentative minimum long-transverse yield strength for the specific product and thickness. Short-transverse specimens from all lots of each product that were at least 2.0-in. thick were exposed to the accelerated stress-corrosion test at applied stresses of both 75 per cent and 50 per cent of the minimum long-transverse yield strength. The short-transverse specimen exposure program was duplicated for a seacoast and an industrial atmospheric exposure. Unstressed control specimens were included for each combination of product lot, test direction, and test environment. Unstressed specimens were exposed in duplicate and stressed specimens were exposed in triplicate.

The test specimens for all three test directions were 0.125-in. diameter threaded-end tension specimens meeting the requirements of ASTM E8. The short-transverse specimens were centered on the midplane of the products and the longitudinal and long-transverse specimens were taken on or immediately adjacent to the midplane. The stressed specimens were axially loaded in tension in a constant strain-type fixture, Fig. 11, using the synchronous loading device shown in Fig. 12.

The accelerated stress-corrosion test method was the 3.5 per cent sodium chloride by alternate immersion conforming to ASTM G44-75[29], and Federal Test Standard 151b, Method 823[30]. The alternate-immersion cycle consists of 10 minutes of total immersion followed by aeration and drying above the solution for the remaining 50 minutes of each hour, 24 hours per day. The exposure period for the accelerated test was 12 weeks with daily inspection of the test specimens for failures. All fractured specimens were subjected to visual and microscopic examination to determine the nature of the failure. Specimens that did not fail during the 12 week test were tension tested to determine the loss in strength as compared to the unstressed control specimens.

The atmospheric stress-corrosion testing in a seacoast environment is being conducted at Point Judith, Rhode Island. The conditions at this exposure station were previously discussed for the exfoliation testing being conducted at that location. The stress-corrosion tests in an inland industrial atmosphere are being conducted at the Alcoa Technical Center test station near New Kensington, Pennsylvania. Data obtained at New Kensington may be used to indicate conservatively the resistance of aluminum alloys to the atmosphere in most inland industrial areas and to atmospheres in substantially all non-industrial, non-marine areas.

C.3. Resistance to SCC - Precracked Specimens

Stress-corrosion cracking tests of precracked specimens were conducted on selected lots of the various products with double bolt-loaded double cantilever beam (DCB) specimens of the type shown in Fig. 13. Laboratory tests to evaluate the effect of DCB specimen geometry indicated that the optimum a/h ratio (crack length/half beam height) would be obtained by testing a specimen having a 1.0-in. beam height and a chevron-type notch 1.0-in. in depth. Specimens of this geometry were machined using short-transverse sections of S-L orientation removed from the center plane of the selected lots of the various products. The DCB specimens were precracked in tension to an initial crack length of approximately 0.1 in. Duplicate specimens were exposed to 3.5 per cent sodium chloride solution, to the inland industrial atmosphere at the Alcoa Technical Center, and to the seacoast atmosphere at Point Judith, Rhode Island.

The DCB specimens that were to be exposed to 3.5 per cent sodium chloride solution were precracked after a few drops of 3.5 per cent sodium chloride solution were placed in the notch. During the 30 day test the specimens were placed vertically and kept in a laboratory environment having a controlled temperature of 27°C ± 1°C and a controlled relative humidity of 45 ± 6 per cent. A few drops of the 3.5 per cent sodium chloride solution (reagent grade NaCl and deionized water) were added to the crack three times during each normal working day and once on Saturdays, Sundays, and holidays. Crack lengths at the half and quarter planes were measured three or four times each week using an ultrasonic detection device developed at the Alcoa Technical Center.

The average of the three crack-length measurements was used to calculate the pertinent stress-intensity values as a function of crack-opening displacement and crack length using the formula developed by Hyatt[31]. At the end of the 30 day exposure the specimens were unloaded and broken open to permit examination of the crack fronts.

Reduced specimen thickness DCB specimens, Fig. 14, from the center plane of 4.0-in. thick 2048-T851, 7050-T7351, and 7475-T7351 alloy plate were also tested by exposure of duplicate specimens to the 3.5 per cent sodium chloride solution for 30 days, although previous tests of 2024-T351 and 7075-T651[32] have suggested that crack-growth rates and threshold levels may be independent of the stress state. A plane-strain stress state was expected for the 1.0-in. thick specimen used for the bulk of the testing of precracked specimens. Reduced specimen thickness of 0.25 and 0.5 inches expected to result in a mixed mode stress state were used for the DCB specimens from the 4.0-in. thick plate of each alloy. A reduced specimen thickness of 0.8 in. was also tested for the 4.0-in. thick 7475 alloy contract plate.

SECTION IV

RESULTS OF TESTS

The results of the tensile, compressive, shear and bearing tests, the ratios among these test results, and the modulus of elasticity data are shown in Tables 5 through 15. Data for developing stress-strain and tangent-modulus curves are shown in Tables 16 through 20; the curves are shown in Figs. 15, 16, and 17 for the plate alloys.

The results of fracture toughness tests are shown in Tables 21 through 25 and plotted in Figs. 18, 19, and 20.

The axial-stress fatigue data are plotted in Figs. 21 through 30.

The results of the fatigue crack-growth tests are presented in the form of $\Delta a/\Delta N$ versus ΔK plots in Figs. 31 through 58; the results are grouped to demonstrate environmental effects. Comparison of average crack-growth curves for T-L specimens from thick plate is shown in Fig. 59. Table 26 lists average rates of propagation along with rates determined for other tempers or alloys.

The results of the exfoliation tests are given in Tables 27 through 30. The results of accelerated stress-corrosion tests of smooth specimens are presented Tables 31 through 34. Atmospheric stress-corrosion results are contained in Tables 35 through 38. The results for precracked specimens are shown in Tables 39 through 41 and Figs. 63 through 86.

SECTION V

DISCUSSION OF RESULTS

A. Mechanical Properties

A.1. Tensile, Compressive, Shear and Bearing

The tensile properties of the four alloys tested in this investigation met their respective tentative minimum values where established (Tables 5 through 9). The ten lots of 7475-T7351 plate produced by current practices, exhibited tensile properties (Table 8) a little higher than those tested under the contract (Table 7).

The long-transverse tensile ultimate and yield strengths were used for computing ratios among the tensile, compressive, shear and bearing properties (Tables 10 through 14). This procedure was in accordance with recent revisions in Chapter 9 of MIL-HDBK-5, Guidelines for Presentation of Data[12]. Under terms of the modified contract (F33615-74-C-5089), the statistical analyses of the ratios for determining reduced ratios were not included in the investigation. The reduced ratios will be computed prior to proposing design allowables for each alloy for inclusion in MIL-HDBK-5.

Although present, but not recognized in previous Air Force Contract data for 2XXX and 7XXX aluminum alloy plate[9, 14], the shear and bearing ratios for plate up through 1.500 in. thick usually differ from those greater than 1.500 in. thick. This difference can be attributed to the specification test location in the plate thickness, T/2 as opposed to T/4. The ratios for 7475-T7351 contract plate (Table 12) and those for the current production plate (Table 13), when combined, indicate the aforementioned differences for the two thickness ranges; these shear and bearing ratios should be analyzed separately. These differences are also indicated for the 7050-T7351 plate, but are not as evident for the 2048-T851 plate data.

The results of the modulus of elasticity tests obtained from the stress-strain tests are shown in Table 15. Average modulus values for use in MIL-HDBK-5 are as follows:

Alloy and Temper	Product	Modulus, 10^3 ksi	
		Tension, (E)	Compression(E_c)
2048-T851	Plate	10.4	10.7
7050-T7351	Plate	10.3	10.6
7475-T7351	Plate	10.3	10.6
2219-T852	Hand Forgings	10.2	10.4

The modulus values for plate are in the same range as those for other 2XXX and 7XXX plate alloys. The values for 2219-T852 hand forging average about 3 per cent lower than those for 2014-T652 and 2024-T852 hand forgings[6]. The modulus values for the two lots of current production 7475-T7351 plate (Table 8) are in agreement with those of the 7475-T7351 contract plate.

The longitudinal and short-transverse modulus values for plate average 1 per cent and 1 to 2 per cent, respectively, lower than the corresponding long-transverse values. The 2219-T852 hand forging modulus values are the same for the longitudinal and long-transverse directions; short-transverse values average 2 per cent lower than those for the long-transverse direction.

The typical tensile and compressive stress-strain curves and compressive tangent-modulus curves are plotted in Fig. 15, 16, and 17 for 2048-T851, 7050-T7351 and 7475-T7351 plate, respectively. Curves for 2219-T852 hand forgings could not be developed due to insufficient production data to establish typical tensile properties. The typical stress-strain data are shown in Tables 16 through 18 for the plate and Table 19 for the 2219-T852 hand forgings. The typical stresses are also shown in the tables for each strain departure as a percentage of the typical yield strength in the event that the typical yield strengths are revised for the plate, or developed for the 2219-T852 hand forgings; these percentages can then be applied to the new typical yield strength values to establish stress-strain curves.

The data for the typical compressive tangent-modulus curves for the plate are shown in Table 20. These data are applicable to the typical yield strengths shown for the stress-strain curves. Revisions in the typical yield strengths will require recomputing of the tangent-modulus data.

A.2. Fracture Toughness

The results of the fracture toughness tests, K_{Ic}, are shown in Tables 21 through 25. These data generally indicate that there is an increase in toughness as the product thickness decreases. While the L-T data for the 7475-T7351 contract plate seem to suggest a decrease as the plate thickness decreases, this results from the use of relatively small specimens in which large-scale yielding is obtained. The same trend is suggested by the T-L data for the same plate less than 2 in. in thickness. In fact, the K_Q values obtained with the smaller sizes of specimens are not indicative of the high levels of toughness of this alloy[33].

In order to obtain more meaningful estimates of the toughness of the current production plate (Table 24), the plan-view dimensions, W and 2H (Fig. 3), were increased for the L-T and T-L specimens in accordance with the guidelines developed by Kaufman[33] and shown in Aluminum Association Document T-5[34]. Kaufman showed that for a given lot of plate, essentially the same value of K (K_Q or K_{Ic}) is obtained with different thicknesses of specimen of a given plan size, so that if a specimen plan size is selected on the basis of obtaining valid data for thick specimens (i.e., $a \gtrsim 2.5 \left(\frac{K_{Ic}}{ys}\right)^2$ and $\frac{P_{max}}{P_Q} \lesssim 1.1$) estimates of toughness can be obtained with relatively thin specimens. In these tests, W and 2H were 4 and 4.8 in., respectively, for the T-L specimens of the 0.50 and 0.75-in. plate and 6 and 7.2 in., respecively, for the remaining L-T and T-L specimens from plate up to 3.50-in. thick. With the exception of the 0.50 and 0.75-in. specimens, all dimensions were within the standard or alternative limits specified by ASTM E399.

On this basis, it is evident from data in Table 24 that the toughness of 7475-T7351 plate less than about 2 in. in thickness, like that for thicker plate of all of the alloys tested, increases as thickness decreases. To ascertain that the difference in toughness indicated between the contract plate and the current production plate were not solely a specimen size effect, similar large plan-size specimens from the 0.50 and 1.00-in. contract plate were also tested. The results are summarized below for the two groups of thin 7475-T7351 plate:

Thickness, in.	K_Q, ksi$\sqrt{in.}$ (Large Plan View Specimens) L-T		T-L	
	Current	Contract	Current	Contract
0.50	60.0	53.6	42.6	40.5
0.75	58.9	--	43.7	--
1.00	--	51.6	--	38.0
Average	59.4	52.6	43.2	39.2

The above K_Q values for the current production plate average about 10 per cent higher than those obtained for the contract plate, and comparison of K_{Ic} values for the thicker plate (Tables 23 and 24) show similar differences. The plots of K_{Ic} versus yield strengths in Fig. 18 show that, for the levels of yield strength, the fracture toughness of the contract plate is outside the ranges of data for material produced with current optimum fabricating practices as well as those for plate fabricated prior to the contract[35]. Consequently, for reasons discussed in Section II, Materials, the levels of toughness developed by the contract plate are not indicative of the capabilities of current production, and so K_{Ic} values for the newer lots (Table 24) should be used in establishing the levels of toughness to be expected for 7475-T7351 at present and in the future.

Average values of K_{Ic}, including K_Q values considered meaningful in Tables 21 through 25, are summarized as follows:

Alloy and Temper	Product	Thickness Range, in.	K_{Ic}, ksi$\sqrt{in.}$ L-T	T-L	S-L
2048-T851	Plate	1.0-4.0	38.0	30.6	25.4
7050-T7351	Plate	2.0-4.0	37.0	31.2	28.2
		5.0-6.0	31.4	27.7	27.5
7475-T7351[a]	Plate	1.75-3.5	50.2	37.4	32.9
2219-T852	Hand Forgings	2.0-7.5	39.3	27.3	24.6

(a) Current Practice (Table 24) for contract plate (Table 23), 1.0-4.0 in. thick, values average: 45.1 (L-T), 33.3 (T-L) and 29.6 (S-L).

The K_{Ic} data (valid and meaningful values) for the 2048, 7050 and 7475 (current practice) plate are plotted in Fig. 19. The shaded areas indicate ranges of 2124-T851 plate and other 2XXX and 7XXX plate data. Most of the data points are, at comparable yield strengths, above the data represented by the shaded areas, the largest differences being for the L-T orientation. The 7475-T7351 values for the L-T orientation are twice the 2XXX and 7XXX mid-range data and the highest of all the three plate alloys tested. A similar comparison of data is made in Fig. 20 for the 2219-T852 hand forgings. The level of toughness for relatively large 2219-T852 hand forgings (up to 7.5 x 22 in.) is within, or a little above, the range for smaller sizes of forgings of other alloys, but the yield strengths are in the low end of the range.

A.3. Axial-Stress Fatigue

The results of the axial-stress fatigue tests (ambient-air environment, ^.0) of smooth and notched, $K_t = 3$, specimens are plotted in Fig.. 21 through 30. Prior to this investigation no fatigue data were developed for the short-transverse directions of other alloys so short-transverse comparisons cannot be made. Generally, the fatigue strengths for short-transverse specimens of plate, from 10^6 to 10^7 cycles, are about 2/3 to 3/4 of the strengths for longitudinal and long-transverse specimens. For 2219-T852 hand forgings, the data for the three test direction are about the same.

2048-T851 Plate (Smooth-Fig. 21 and Notched-Fig. 22)

The data for smooth specimens are generally comparable to, or beyond 10^6 cycles a few ksi higher than, those of 1-3/8-in. thick 2024-T851 plate[2]. The data for both smooth and notched specimens indicate the fatigue strengths of 2048-T851 plate to be somewhat higher than those represented by the curve for 2124-T851 plate[9], but they are in the same range as other data indicated by the bands[35]. Beyond 10^6 cycles, the data for smooth specimens of the 1 and 2-in. thick 2048-T851 plate and, beyond 10^5 cycles,the data for notched specimens are in the upper half of the respective bands.

7050-T7351 Plate (Smooth-Fig. 23 and Notched-Fig. 24)

For smooth specimens the data are comparable to data of 7050-T73651 plate[10]. Relative to 7075-T7351 plate[1, 35], 1.25 to 1.75-in. (Fig. 25), the data for 2 to 6-in. thick 7050-T7351 plate fall at the bottom of the 7075 band, except at 10^7 cycles where the data are at the center of the band.

Most of the fatigue data for notched specimens are within the band for 7050-T73651 plate, 2 to 6-in. thick. This band was based on a small number of tests and the upper end of the range at 10^7 cycles was established from two data points (L and LT) for 2-in. thick plate[10].

7475-T7351 Plate (Smooth-Fig. 25 and Notched-Fig. 26)

The data up to 10^6 cycles for smooth specimens (L and LT) of the 1 to 4-in. thick contract plate fall at the bottom of the band for 7075-T7351 plate, 1.25 to 1.75-in.[1, 35]. At 10^7 cycles the data for the 1 and 2-in. plate are near the center and for the 3 and 4-in. plate in the lower half of the band.

For notched specimens the data are comparable at stresses from 20 ksi and above, but average a few ksi below the curve for 1.375-in. thick 7075-T7351 plate[32] at stresses below 20 ksi.

7475-T7351 Plate, Current Practice (Smooth-Fig. 27 and Notched-Fig. 28)

Fatigue strengths at 10^6 to 10^7 cycles for both smooth and notched specimens from plate produced by current practices are higher than those of the contract data represented by the bands (L and LT) and the curve (ST). Although based on limited data, the improvement in fatigue strength for the short-transverse direction appears to be appreciable. The strengths (L and LT) are comparable to those of 7075-T7351 plate.

2048-T851, 7050-T7351, and 7475-T7351 Plate

Average fatigue strengths for the three plate alloys generally show a spread of no more than 2 to 3 ksi. An exception is that a wider spread is indicated in the average strengths beyond 10^5 to

10^7 cycles for notched short-transverse specimens; at 10^7 cycles the fatigue strength for 2048 is about 11 ksi and for 7050 and the contract 7475 is 7.5 and 7 ksi, respectively.

As discussed previously, the 7475-T7351 plate fabricated by current practices developed higher fatigue strengths than the contract 7475 plate. The strengths are also equivalent to or higher than those of 7050 and 2048, with the exception that for short-transverse notched specimens the fatigue strength at 10^7 cycles is 9 ksi compared to 11 ksi for 2048.

2219-T852 Hand Forgings (Smooth-Fig. 29 and Notched-Fig. 30)

Except at the high stress levels, the data for smooth specimens are within the band for 2219-T8-type plate[35]. At about 10^7 cycles the fatigue strengths are a little below those indicated by the curves for 2014-T652 and 2024-T852 hand forgings[6].

There are no hand forging data for comparison of tests of notched specimens; the fatigue strengths are equivalent to those of 2124-T851 plate (Fig. 22).

B. Fatigue Crack-Propagation Tests

The fatigue crack-propagation plots have a scale for stress intensity which emphasizes differences but also emphasizes scatter in the test data. Some of the plots show substantial scatter and overlap. Accordingly, differences in fatigue crack-growth rates of less than 50 per cent as summarized in Table 26 are not considered significant for product comparisons. In both dry-air and sump-water environments, though not in moist air, there is a general tendency for the tests at slower frequencies to show somewhat faster propagation. The effects of the other variables are discussed below:

2048-T851 Plate (Figs. 31 to 36)

1. At the higher stress intensities the L-T specimens had lower rates of propagation in dry air than the T-L or S-L specimens.
2. Propagation rates in sump water were generally two to three times faster than those in dry air; however, the T-L specimens from the 1.0-in. plate exhibited little environmental effect at high stress intensities.
3. Good agreement between the results of tests of 1/4-in. and 1.0-in. specimens is shown in Figs. 34 and 35 for tests in dry air and sump water, respectively.
4. The rates of propagation for T-L specimens in the thick plate are similar to those reported for 2124-T851 plate[9].

7050-T7351 Plate (Figs. 37 to 42)

1. The rates obtained for the two plate thicknesses and three orientations are essentially equivalent.
2. Fatigue-crack propagation rates in moist air and sump water were generally about 1-1/2 and 2 to 5 times faster, respectively, than rates in dry air.
3. The crack in the low-growth-rate T-L specimen tested in sump water (Fig. 41) stopped twice and cracking had to be reinitiated at higher loads.

4. The low-growth rate T-L specimen from the 4-in. plate (Fig. 40) was the only T-L specimen which had crack-front angulation; the rates determined for this tests are slower than those shown for the thicker, high-growth rate specimen.
5. The rates of propagation are comparable to those reported for 7050-T73651 plate in dry and moist air[10].

<u>7475-T7351 Contract Plate (Figs. 43 to 48)</u>

1. Compared to propagation in dry air, propagation is two to three times as fast in moist air and three to eight times as fast in sump water for all orientations.
2. The rates of propagation do not vary significantly with plate thickness or specimen orientation.
3. Figure 46 shows good agreement between rates determined for the 1/4-in. and 1-in. thick specimens tested in dry air.
4. Relatively slow rates of propagation were obtained for the 1/4-in. thick specimen in sump water (Fig. 47) at the low-stress intensities. Attempts to start the tests at lower stress intensities had resulted in crack arrest.

<u>7475-T7351 Currect Production Plate (Figs. 49 to 52)</u>

1. The rates of propagation in the T-L and S-L specimens from the current production lots of 7475-T7351 plate were generally similar to those determined for the comparable contract materials.
2. The 1/4-in. T-L specimen tested in dry air had somewhat slower propagation than the 1-in. T-L specimen (Fig. 50).

3. The propagation of a 1/4-in. thick specimen (Fig. 51) stopped after sump water was added to a crack initiated at a low-growth rate in laboratory air.

2219-T852 Hand Forging (Figs. 53 to 58)

1. The rates of propagation at the higher stress intensities were slow for the L-T specimens from the larger hand forging (Fig. 55).
2. Equivalent rates of propagation were obtained for T-L specimens taken from the surface and T/2 locations (Fig. 56).
3. The rates of propagation were 1-1/2 to 2 times as fast in moist air as in dry air and about 3 times as fast in sump water as in dry air at medium stress intensities.
4. At low-stress intensities, rates of propagation were much slower in sump water (Fig. 57) than in dry air (Fig. 56). An attempt to obtain sump water data at a somewhat lower stress intensity resulted in crack arrest.
5. The large 2219-T852 hand forging did not show the large directional effect reported for the comparable 7050-T73652 hand forging[10]. Also rates are slower than reported for a large 7175-T736 hand forging[9].

Comparison of Products and Alloys

1. In moist air, propagation was similar for the hand forging and three plate alloys.
2. At medium and high stress intensities, Fig. 59 shows the propagation in sump water to be faster in 7050-T7351 and 7475-T7351 plate than in 2048-T851 plate; the environmental

effect was greatest for 7475-T7351 plate. At medium stress intensities, rates of propagation in sump water were comparable for 2048-T851 plate and 2219-T852 hand forgings.

3. At low stress intensities propagation in sump water slowed or arrested in alloys 7050-T7351, 7475-T7351, and 2219-T852 but not 2048-T851. Metallographic and scanning electron microscopic (SEM) examinations were made of a 7475-T7351 specimen whose crack arrested after 0.01 to 0.02 in. propagation in sump water. Before the sump water was added, the crack had been propagating in air at a slow rate (5×10^{-8} in/cycle). SEM examination, Fig. 60, showed that the "river markings," characteristic of Stage 1 propagation, were fanning out and formed scalloped crack fronts in the latter stages of the sump water propagation. SEM examination further revealed that the fracture surface was heavily contaminated with corrosion product. The primary elements in the product (as determined by X-ray analysis) were Cd and Cl, which are the predominant components of the sump water. Examination of the unloaded specimen had shown the crack to be wider in the tip region after the loadings in sump water than after the loadings in air. By partially filling the crack, the buildup apparently increased the load at which crack closure occurred; i.e., the crack was closed for a larger portion of the load cycle. Thus, the effective range of load and stress intensity was decreased. Depending on relative rates of buildup and propagation, progressive buildup of the corrosion product could slow or arrest the crack.

4. In each environment the rates of propagation were generally comparable for the 7050-T7351 and 7475-T7351 plate specimens irrespective of specimen orientation.
5. The 2048-T851 plate and 2219-T852 hand forgings showed more of a directional effect, with relatively slow rates shown at high-stress intensities for L-T specimens.

C. Corrosion Characteristics

C.1. Resistance to Exfoliation

All products except the 2.5-in. thick 2219-T852 hand forging (S. No. 478817, Table 27) displayed a high resistance to exfoliation in the EXCO immersion test (Tables 27 through 30). Panels from the 7050-T7351 and 2048-T851 alloy plates revealed no evidence of exfoliation. Minor exfoliation (E-A) was detected on panels from the other 2219-T852 hand forgings and on the panels from the mid-plane of the 7475-T7351 plate. The development of minor exfoliation of degree E-A in the agressive EXCO solution is believed to be of no practical importance because it has been shown that products that develop this degree of exfoliation in the accelerated test do not develop any evidence of exfoliation during exposure to the seacoast atmosphere at Point Judith, Rhode Island[36]. The total length of exposure to the EXCO solution was 144 hours for the 2219-T852 panels except for panels from the 2.5-inch thick hand forging and 96 hours for the other alloys. The panels were, however, examined and rated at various time periods including the 48 hour exposure specified in ASTM G34-72[27]. The general appearance and the ratings of the test panels did not change during extension of the test beyond the specified 48 hours.

Visual examination of the panels from the 2.5-in. thick 2219-T852 hand forging after 48 hours of exposure to the EXCO solution resulted in the panels being given an E-D rating using the photographic standards in ASTM G34-72[27]. Metallographic examination of the test panel from the mid-plane, T/2, did not, however, reveal the lifting of the surface normally associated with a high degree of susceptibility to exfoliation. The metallographic examination of the corroded specimen showed pitting plus intergranular attack with some presence of slip plane attack. The nature of the attack on the 2219-T852 specimens is shown in Figures 61 and 62. From the metallographic examination it would have been expected that the specimen rating would be no worse than E-A. The disparity between the visual and metallographic examination of the 2219-T852 specimen may indicate that the EXCO test presently recommended for 7XXX series alloy may not be entirely satisfactory for 2XXX series alloys.

No evidence of exfoliation was displayed during exposure to the acidified salt spray by any of the panels from selected lots of each product. The absence of any exfoliation in the acidified salt spray on panels from the 2.5-in. thick 2219-T852 hand forging leads to a further questioning of the suitability of the EXCO test for evaluation of the resistance to exfoliation of 2XXX series alloys. On the basis of the metallographic examination of 2219-T852 EXCO panel and the results obtained in the acidified salt spray it is believed that the accelerated tests indicate a high resistance to exfoliation for all of the tested products.

The results of exfoliation testing of selected lots of each product by exposure to the seacoast atmosphere at Point Judith, Rhode Island are encouraging, but the exposures of up to 570 days are not of sufficient duration to provide conclusive results. These specimens which presently show no evidence of exfoliation will continue to be examined during routine periodic inspection of specimens at this exposure station.

C.2. Resistance to Stress-Corrosion Cracking (SCC) - Smooth Specimens

None of the longitudinal and long-transverse specimens of the various products failed during exposure to the 3.5 per cent sodium chloride alternate-immersion test (Tables 31 through 34). This demonstrates the excellent resistance to stress corrosion that is expected of these products in these test directions. The losses in tensile properties of longitudinal and long-transverse specimens after 12 weeks of exposure indicate that 7475-T7351 has the highest resistance to general corrosion. The lowest resistance to general corrosion was displayed by 7050-T7351 with an average per cent loss in tensile properties that was about three times that of 7475-T7351. The 2219-T852 and 2048-T851 specimens displayed losses in tensile properties approximately midway between these two extremes. The reductions in tensile properties were about the same for the stressed and unstressed specimens except for 7050-T7351 alloy. The per cent losses in tensile properties of the stressed

7050-T7351 specimens were about 1.5 times the per cent losses obtained for the unstressed specimens.

A 30-day exposure to the 3.5 per cent sodium chloride alternate-immersion test has been commonly used to evaluate the stress-corrosion performance of high-strength aluminum alloy using 0.125-in. diameter, short-transverse tension specimens (Tables 31 through 34). None of the short-transverse specimens exposed to the alternate-immersion test at an applied stress of 50 per cent of the tentative or specified minimum long-transverse yield strength for the tested product lots failed during this 30-day exposure period. Two short-transverse specimens from the 3.0-in. thick 2048-T851 plate (S. No. 421083) did fail with longer exposure. Although longer exposures are necessary to obtain conclusive results none of the short-transverse specimens stressed to 50 per cent of the tentative or specified long-transverse yield strength have failed during atmospheric exposure at Point Judith, Rhode Island or at the Alcoa Technical Center for time periods of up to 496 days (Tables 35 through 38).

After 30 days of exposure to the alternate-immersion test, failure of short-transverse specimens stressed to 75 per cent of the tentative or specified minimum long-transverse yield strength had occurred for three lots of 2048-T851 alloy plate. Both lots of 2.[illegible]-in. thick plate (S. No. 421381, 421382) and one lot of 3.0-in. thick plate (S. No. 421083) of 2048-T851 alloy had one of the triplicate specimens failing to complete a 30-day test. These same lots of 2048-T851 alloy plate are the only lots of any alloy to have experienced specimen failures during exposure at Point Judith, Rhode Island. Continuation of the alternate-immersion testing of the short-transverse specimens stressed at 75 per cent did not result in any failures of the 7475-T7351 alloy specimens and only one failure of the 2219-T852 alloy specimens. However, nine additional specimens of 2048-T851 alloy and six specimens of 7050-T7351 alloy failed during the extended exposure.

Metallographic examination of the two earliest 2048-T851 failures in the alternate-immersion test revealed the failures to be tensile fractures with no evidence of secondary intergranular cracks. Metallographic examination of short-transverse specimens of 2048-T851 alloy that failed after longer periods of exposure did reveal clear evidence of intergranular cracks. The presence of intergranular cracking in these specimens and the failures obtained at Point Judith, Rhode Island, would seem to indicate that the lots of 2.0-in. thick plate and the one lot of 3.0-in. thick plate of 2048-T851 alloy do have some susceptibility to intergranular stress corrosion at the higher stress.

C.3. Resistance to SCC of Precracked Specimens

Table 39 lists the lots of each product that were selected to be tested with the short-transverse (S-L) tension precracked DCB specimens. The initial average crack length, initial total crack-opening displacement (V), and initial stress intensity (K_{Ii}) are shown for each individual DCB test specimen. The results of plane-strain fracture toughness tests of the selected materials are also shown. The initial stress-intensity values (K_{Ii}) are in very good agreement with the plane-strain fracture toughness values (K_{Ic}). The DCB specimen geometry used in the tests, Figure 13, is believed to be responsible for this good agreement.

Individual crack-growth curves for the specimens exposed to the 3.5 per cent sodium-chloride solution are presented in Figures 63 through 73. The DCB specimens of 7475-T7351 alloy, Figures 72 and 73, displayed a crack growth that was about the smallest change that can be detected with the Alcoa Technical Center ultrasonic measuring device. The crack growth for the other products showed considerable variability for the various lots and in several cases even between duplicate specimens from the same lot. The most significant crack growth, Figure 66, was experienced with the duplicate specimens from the 2.0-in. thick 2048-T851 plate, but the crack growth was considerably less than that incurred by highly susceptible materials such as 7075-T651 and 7079-T651.

Examination of the crack surface of the specimens at the completion of the 30-day test indicated that the environmental crack growth of most of the specimens was the result of typical intergranular stress-corrosion cracking. The stress-corrosion growth generally proceeded on various planes giving a fracture surface with many small steps. The tendency for flat SCC facets was less with thicker sections making the SCC more difficult to recognize. The presence of actual SCC is, however, questionable for the 4.0-in. thick 7475-T7351 plate and for the 4.5 and 7.5-in. thick 2219-T852 hand forgings. Rough measurements of the environmental crack growth on the fracture surfaces gave a reasonably good check with the ultrasonic measurements except for the 7475-T7351 and 2219-T852 specimens that had very small amounts of crack growth.

Crack-growth rate versus stress-intensity data were calculated for each of the test specimens. The plateau velocities for the K-rate curves were determined by an arbitrary procedure to avoid the erratic shapes of crack-growth curves during the initiation of SCC and the extraneous effect of corrosion product wedging. The total amount of crack-growth that occurred during the first 360 hours (15 days) of exposure was used to calculate the overall average growth rate for that period. These results are shown in Table 40. This procedure has been found to represent best the initial sustained crack growth which is considered to be one of the most significant features of the K-rate curves. The K_I-rate data for the various products are illustrated in Figure 74. Data for plate of alloys 7079-T651, 7075-T651, and 7075-T7351[32] are included for comparison. The overall average plateau velocity of 1.5×10^{-4} in. per hour for the 7050-T7351 alloy plate is in good agreement with the average plateau velocity obtained for 7050-T73651 plate in previous investigations[37]. The range in plateau velocities of from 2.8×10^{-5} to 4.8×10^{-4} is a somewhat larger variation than previously encountered. This larger variation is due to the greatly different performance of the two lots of 6.0-in. thick 7050-T7351 alloy plate. No explanation is available for the difference in performance of these two lots or for the unexpectedly large amount of SCC growth encountered with one of the lots. The overall average plateau velocity for the four lots of 7475-T7351 plate was 2.5 x 10^{-5} in. per hour which compares favorably with the average plateau velocity for 7075-T7351 alloy plate.

The DCB specimen data provide questionable values for the threshold stress intensity due to the fact that the crack growth did not reach an actual arrest during the 30-day test. It is difficult to be sure of a definite arrest because the formation of corrosion products on the surfaces of the precrack and corrosion crack can form wedges that drive the SCC ahead. A 30-day exposure was selected for the present tests on the basis of previous test experience with similar materials. Actually from the environmental crack-growth curves it would appear that a 20-day exposure was sufficient for all specimens except the specimens for the 2.0-in. thick 2048-T851 alloy plate. Therefore, estimates of threshold stress intensities were calculated for the crack lengths at the end of 20 days. These values would be expected to be good estimates of the true threshold stress intensity for samples that give indications of crack arrest or samples that show very low crack-growth rates. The estimates would, however, be overly optimistic for specimens, such as those from the 2.0-in. thick 2048-T851 alloy plate, Figure 66, that continue to show significant crack growth after 20 days of exposure. The estimates of the threshold stress intensity presented in Table 40 demonstrate that except for 2.0-in. thick 2048-T851 alloy plate and one of the lots of 6.0-in.

thick 7050-T7351 alloy plate, all of the products had high estimated threshold stresses that ranged from 89 to 99 per cent of the initial pop-in stress intensity. Although it is questionable whether these values are valid for design considerations, they do provide a basis for comparison of the various alloys and tempers at the selected length of exposure. This is also true for the average velocities listed in Table 40.

The alloys and tempers would, on the basis of the precracked DCB specimen data, be ranked in the following order of decreasing performance, 7475-T7351, 2219-T852, 7050-T7351, and 2048-T851. This is the same ranking order that is obtained from the results of the smooth specimen stress corrosion tests

Effect of DCB Specimen Thickness

Previous tests of 2024-T351 and 7075-T651[32] suggested that crack-growth rates and threshold levels may be independent of the stress state. This suggestion was subjected to further examination by the exposure to 3.5 per cent sodium-chloride solution of reduced thickness DCB specimens, Figure 14, from the center plane of 4.0-in. thick 2048-T851, 7050-T7351, and 7475-T7351 alloy plate. The 1.0-in. thick DCB specimens for which a plane-strain stress was expected had initial stress-intensity values (K_{Ii}) that were in very good agreement with the plane-strain fracture toughness values (K_{Ic}). The initial stress-intensity values shown in Table 41 for the 0.25-in. reduced thickness DCB specimens expected to have a mixed mode stress state, of course, were considerably higher than the fracture toughness

(K_{Ic}) values. The high initial stress intensities were the result of the higher total crack-opening displacement of the reduced thickness specimens.

The crack-growth curves for the reduced thickness specimens are presented in Figures 75 through 84. Figures 77, 80, and 84 compare the environmental crack growth of 1.0, 0.5, and 0.25-in. thick DCB specimens of each plate alloy. The reduced thickness specimens generally showed less crack growth than the 1.0-in. thick specimens. This is especially evident for the 4.0-in. thick 7050-T7351 alloy plate, Figure 80. For the stress-corrosion resistant alloys and tempers in this investigation departure from a plane-strain stress state appears to have a tendency to reduce the calculated crack-growth rates and to give higher estimates for the threshold stress intensity.

<u>Corrosion Data for Current Production Lots of 7475-T7351</u>

The stress-corrosion data for the current lots of 7475-T7351 plate are presented in Tables 42 through 45 and in Figures 85 and 86. These results are in complete agreement with the main body of test results and provide additional evidence of the outstanding resistance to stress corrosion of all of the tested lots of 7475-T7351 plate.

SECTION VI

SUMMARY AND CONCLUSIONS

The mechanical properties, including fracture characteristics and axial-stress fatigue, fatigue crack-growth rates and corrosion characteristics have been evaluated for 2048-T851, 7050-T7351, and 7475-T7351 plate and 2219-T852 hand forgings produced by commercial practices. Based on the data developed in this investigation, the following summary statements and conclusions have been made:

A. Mechanical Properties

A.1. Tensile, Compressive, Shear and Bearing

1. Ratios among the tensile, compressive, shear and bearing properties have been computed. These ratios are suitable for use in developing reduced ratios to establish derived design allowables for inclusion in MIL-HDBK-5.

2. The average modulus of elasticity values developed from stress-strain tests are as follows:

Alloy and Temper	Product	Modulus, 10^3 ksi	
		Tension(E)	Compression(E_c)
2048-T851	Plate	10.4	10.7
7050-T7351	Plate	10.3	10.6
7475-T7351	Plate	10.3	10.6
2219-T852	Hand Forgings	10.2	10.4

3. Tensile and compressive stress-strain and compressive tangent-modulus curves have been developed for 2048-T851, 7050-T7351 and 7475-T7351 plate for inclusion in MIL-HDBK-5. Stress-strain data for 2219-T852 hand forgings have been

presented in a form suitable for developing curves when sufficient tensile property data have been obtained from production lots to establish typical tensile yield strengths.

A.2. Fracture Toughness

1. All three alloys of plate developed levels of fracture toughness appreciably higher than other commercial alloys having comparable yield strengths. Alloy 7475 exhibited the highest fracture toughness in all three orientations, particularily for the L-T.
2. The toughness levels of the 7475-T7351 plate, although above current minimum values, were not representative of current production. Data for ten additional lots produced by current production practices (Table 24) demonstrated the high-toughness capabilities expected of this alloy and so these K_{Ic} values should be used in establishing the levels of toughness to be expected for 7475-T7351 at present and in the future.
3. The 2219-T852 hand forgings, sizes up to 7.5 x 22 in., developed the levels of toughness higher than those of most other hand forging alloys, but yield strengths are in the low end of the range.

A.3. Axial-Stress Fatigue

1. The axial-stress fatigue strengths for smooth and notched, K_t = 3, specimens are in the same general range as those of corresponding products of 2XXX and 7XXX alloys.

2. Fatigue strengths of the 7475-T7?51 plate produced by current production practices are comparable to those of 7075-T7351 plate. The fatigue strengths for the plate tested under the contract are generally lower than those of 7075-T7351 plate.
3. The average fatigue strengths of the three plate alloys are in the same general range except for short-transverse notched specimens ($K_t = 3$); the fatigue strength of the 2048 plate at 10^7 cycles is 11 ksi compared to 9 and 7 ksi for 7475 and 7050, respectively.

B. Fatigue-Crack Propagation

1. In moist air, propagation was similar for the hand forging and the three plate alloys.
2. At medium-stress intensities, crack propagation rates in moist air are 1.5 to 2 times those in dry air, and rates in sump water are 2 to 9 times those in dry air. Propagation in sump water was twice as fast in 7050-T7351 and 7475-T7351 plate as in 2048-T851 plate and 2219-T852 hand forgings. Environmental effects were less at high-stress intensities.
3. At low-stress intensities, propagation in alloys 7050-T7351, 7475-T7351 and 2219-T852 slowed or arrested in sump water. This behavior is attributed to a build-up of corrosion product which effectively reduced the stress intensity range.
4. In both dry air and sump water, though not in moist air, there is a tendency for crack propagation at the slower loading rates to be somewhat faster than at higher loading rates.
5. For the 7050-T7351 and 7475-T7351 plate specimens, rates of propagation are independent of specimen orientation. The 2048-T851 plate and 2219-T852 hand forgings show some

directional effect, with lower rates for L-T specimens at high-stress intensities than for T-L and S-L specimens.

6. In several cases, good agreement was found between growth rates determined for 1/4-in. and 1-in. thick specimens tested in dry air.
7. The rates of propagation determined for the current production lots of 7475-T7351 plate are generally similar to those of the contract materials.
8. The rates of propagation obtained for these alloys in dry and moist environments are generally comparable to reported values for similar aircraft alloys.

C. Corrosion Characteristics

1. All products have a high resistance to exfoliation in the accelerated tests and after up to 570 days in a seacoast atmosphere.
2. All products have the expected excellent resistance to stress corrosion when tested in the longitudinal and long-transverse direction.
3. All products display excellent resistance to stress corrosion in the critical short-transverse direction when tested at an applied stress of 50 per cent of the specified or tentative minimum long-transverse yield strength. The only failures encountered at this stress level were for duplicate specimens of 2048-T851 alloy during extended exposure in the 3.5 per cent alternate-immersion test beyond the normal 30-day exposure.

4. Short-transverse specimens of 7475-T7351, 2219-T852, and 7050-T7351 display excellent resistance to stress corrosion at an applied stress of 75 per cent of the specified or tentative minimum long-transverse yield strength. One specimen of 2219-T852 alloy and six specimens of 7050-T7351 alloy failed during extended exposure in the 3.5 per cent sodium-chloride alternate-immersion test (>30 days).

5. Short-transverse specimen failures in less than thirty days in the alternate-immersion test and specimen failures in the seacoast environment at Point Judith demonstrate that the lots of 2.0-in. thick plate and one lot of 3.0-in. thick plate of 2048-T851 alloy do have some susceptibility to intergranular stress corrosion at an applied stress of 75 per cent of the minimum long-transverse yield strength.

6. Tests of precracked DCB specimens showed the same general trends as tests with smooth specimens and result in the following ranking in order of decreasing performance: 7475-T7351, 2219-T852, 7050-T7351, and 2048-T851.

7. Testing of reduced thickness DCB specimens using tensile pop-in precracking indicates that the stress state can have an effect on the crack-growth rate and estimated threshold stress intensity values for the stress corrosion resistant alloys and tempers evaluated in this investigation.

REFERENCES

1. J. G. Kaufman, G. E. Nordmark and B. W. Lifka, "Fracture Toughness, Fatigue and Corrosion Characteristics of 7075-T651, 7075-T7351 and 7079-T651 Aluminum Alloys," Technical Report AFML-TR-65-170, May 1965.

2. J. G. Kaufman, G. E. Nordmark and B. W. Lifka, "Fracture Toughness, Fatigue and Corrosion Characteristics of 2020-T651, 2024-T851, 2219-T851 and 7001-T75 Aluminum Alloys," Technical Report AFML-TR-66-291, September 1966.

3. D. J. Brownhill, R. E. Davies and D. O. Sprowls, "Mechanical Properties, Including Fracture Toughness and Fatigue, and Resistance to Stress Corrosion Cracking, of Stress-Relieved Stretched Aluminum Alloy Extrusions," Technical Report AFML-TR-68-34, February 1968.

4. J. T. Staley, "Investigation to Improve the Stress-Corrosion Resistance of Aluminum Aircraft Alloys Through Alloy Additions and Specialized Heat Treatment," Final Report under Naval Air Systems Command Contract N00019-68-C-0146, February 1969.

5. J. T. Staley, "Investigation to Develop a High-Strength, Stress-Corrosion Resistant Aluminum Aircraft Alloy," Final Report under Naval Air Systems Command Contract N00019-69-C-0292, January 1970.

6. D. J. Brownhill, C. F. Babilon, G. E. Nordmark and D. O. Sprowls, "Mechanical Properties Including Fracture Toughness and Fatigue, Corrosion Characteristics and Fatigue Crack Propagation Rates of Stress-Relieved Aluminum Alloy Hand Forgings," Technical Report AFML-TR-70-10, February 1970.

7. J. T. Staley, "Investigation to Develop a High-Strength, Stress-Corrosion Resistant Naval Aircraft Alloy," Final Report under Naval Air Systems Command Contract N00019-70-C-0118, November 1970.

8. J. T. Staley, "Further Development of Aluminum Alloy X7050," Final Report under Naval Air Systems Command Contract N00019-71-C-0131, May 1972.

9. C. F. Babilon, R. H. Wygonik, G. E. Nordmark and B. W. Lifka, "Mechanical Properties, Fracture Toughness, Fatigue, Environmental Fatigue Crack Growth Rates and Corrosion Characteristics of High Toughness Aluminum Alloy Forgings, Sheet and Plate," Technical Report AFML-TR-73-83, April 1973.

10. R. E. Davies, G. E. Nordmark and J. D. Walsh, "Design Mechanical Properties, Fracture Toughness, Fatigue Properties, Exfoliation and Stress-Corrosion Resistance of 7050 Sheet, Plate, Hand Forgings, Die Forgings and Extrusions," Naval Air Systems Command Contract N00019-72-C-0512, July 1975.

11. J. T. Staley, J. E. Jacoby, R. E. Davies, G. E. Nordmark, J. D. Walsh and F. R. Rudolph, "Aluminum Alloy 7050 Extrusions," AFML-TR-76-129, March 1977.

12. Military Standardization Handbook, Metallic Materials and Elements for Aerospace Vehicle Structures, Volume 1, August 29, 1975.

13. "Standard Methods of Verification of Testing Machines, E4-76," 1976 Book of ASTM Standards, Part 10.

14. G. W. Stickley and D. J. Brownhill, "Mechanical Properties of Stress-Relieved Stretched Aluminum Alloy Plate," Technical Report AFML-TDR-64-105, May 1964.

15. "Standard Methods of Tension Testing Wrought and Cast Aluminum and Magnesium Alloy Products, B557-74," 1976 Book of ASTM Standards, Part 7.

16. "Standard Methods of Tension Testing of Metallic Materials, E8-69," 1976 Book of ASTM Standards, Part 10.

17. "Standard Methods of Compression Testing of Metallic Materials, E9-70," 1976 Book of ASTM Standards, Part 10.

18. R. E. Davies and J. G. Kaufman, "Effects of Test Method and Specimen Orientation on Shear Strengths of Aluminum Alloys," ASTM Proceedings, Vol. 64, 1974, pp. 999-1010.

19. "Standard Method for Pin-Type Bearing Test of Metallic Materials, E238-68," 1976 Book of ASTM Standards, Part 10.

20. "Standard Method for Determination of Young's Modulus at Room Temperature, E111-61," 1976 Book of ASTM Standards, Part 10.

21. "Standard Method of Verification and Classification of Extensometers, E83-67," 1976 Book of ASTM Standards, Part 10.

22. "Standard Method of Test for Plane-Strain Fracture Toughness of Metallic Materials, E399-74," 1976 Book of ASTM Standards, Part 10.

23. "Tentative Method of Test for Constant-Load-Amplitude Fatigue Crack Growth Rates Above 10^{-8} in./cycle," ASTM Tentative Standard EXXXX.

24. "Elastomers for Fuel Systems Containing Micro-organism-controlling Additives," AFML Technical Documentary Report No. RTD-TDR-63-4195, Part II, January 1965.

25. W. G. Clark, Jr., ASTM E24.4, "Fatigue Crack Growth Rate Testing Round Robin Program," Task Group Progress Report No. 3, May 14, 1971.

26. E. T. Wessel, "State of the Art of the WOL Specimen for K_{Ic} Fracture Toughness Testing," Journal of Engineering, Fracture Mechanics, Vol. 1, No. 1, June 1968, p. 77.

27. "Standard Method of Test for Exfoliation Corrosion Susceptibility in 7XXX Series Copper-Containing Aluminum Alloys (EXCO Tests)," G34-72, 1976 Book of ASTM Standards, Part 10.

28. B. W. Lifka and D. O. Sprowls, "An Improved Exfoliation Test for Aluminum Alloys," Corrosion, Vol. 22, No. 1, 1966, pp. 7-15.

29. "Standard Recommended Practice for Alternate Immersion Stress Corrosion Testing in 3.5% Sodium Chloride Solution," G44-75, 1976 Book of ASTM Standards, Part 10.

30. "Federal Test Method Standard No. 151b," November 1967.

31. M. V. Hyatt, "Use of Precracked Specimens in Stress-Corrosion Testing of High-Strength Aluminum Alloy," Corrosion, Vol. 26, No. 11, November 1970, pp. 487-503.

32. D. O. Sprowls, M. B. Shumaker, J. D. Walsh and J. W. Coursen, "Evaluation of Stress-Corrosion Crack Susceptibility Using Fracture Mechanics Techniques," Final Report - Part I, May 31, 1973, prepared for George C. Marshall Space Flight Center, Contract No. NAS 8-21487.

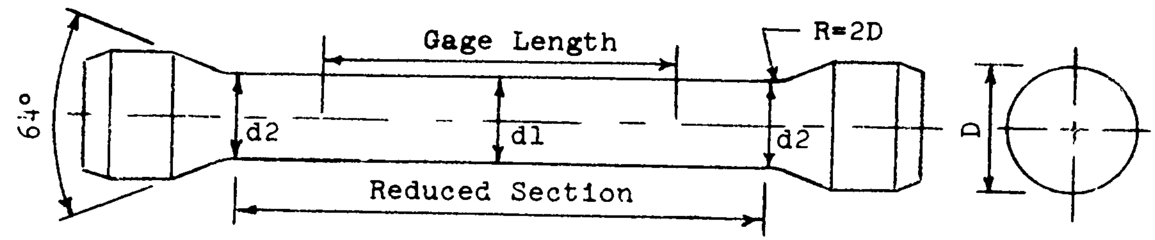
33. J. G. Kaufman and F. G. Nelson, "More on Specimen Size Effects in Fracture Toughness Testing," ASTM STP 559, American Society for Testing and Materials, 1974, pp. 74-85.

34. J. G. Kaufman, R. L. Lake, G. Schmauch and R. E. Zinkham, "The Aluminum Association Position on Fracture Toughness Requirements and Quality Control Testing," An Interim Report, T-5, September 1974.

35. Unpublished Data, Alcoa Laboratories.

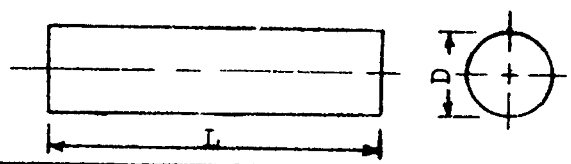
36. B. W. Lifka and D. O. Sprowls, "Relationship of Accelerated Test Methods for Exfoliation Resistance in 7XXX Series Aluminum Alloys with Exposure to a Seacoast Atmosphere," Corrosion in Natural Environments STP 558, American Society for Testing and Materials, 1974, pp. 306-333.

37. D. O. Sprowls, J. W. Coursen and J. D. Walsh, "Evaluating Stress-Corrosion Crack-Propagation Rates in High Strength Aluminum Alloys with Bolt Loaded Precracked Double-Cantilever-Beam Specimens," Stress Corrosion-New Approaches, ASTM STP 610, American Society for Testing and Materials, 1976, pp. 143-156.



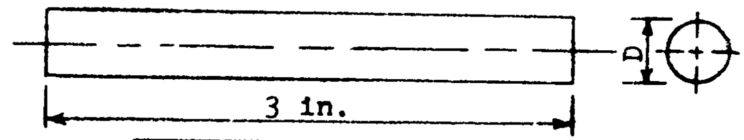
Diameter, in.		Gage Length, in.	Reduced-Section Length, in.	Diameter, (D) in.
d1	d2			
0.500±0.005	$d1+\frac{0.005}{0.003}$	2.0	3-1/8	3/4
0.357±0.00	$d1+\frac{0.004}{0.003}$	1.4	2-15/64	17/32
0.250±0.00	$d1+\frac{0.002}{0.001}$	1.0	1-9/16	3/8
0.160±0.002	$d1+\frac{0.002}{0.001}$	0.64	1	15/64

Tensile Specimen



Nominal Diameter, in.	Diameter, (D) in.	Length, (L) in.
3/4	$\frac{0.7515}{0.7485}$	3
1/2	$\frac{0.4980}{0.4950}$	1-7/8

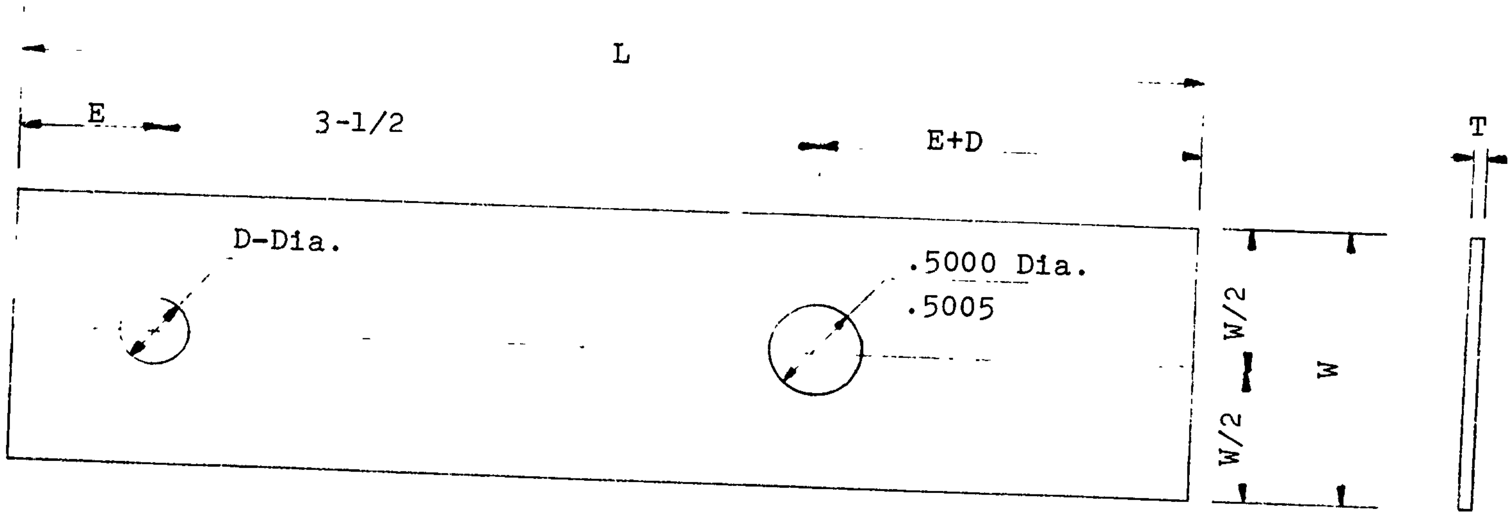
Compressive Specimen



Nominal Diameter, in.	Diameter, (D) in.
3/8	$\frac{0.3730}{0.3720}$

Shear Specimen

Fig. 1 General Dimensions of Tensile, Compressive and Shear Specimens



Specimen Type	T, in.	W, in.	W/2, in.	L, in.	D, in.	E, in.	E/D
E/D=1.5	0.094	1.496 / 1.504	0.748 / 0.752	5	0.3750 / 0.3755	0.5615 / 0.5635	1.5
E/D=2.0	0.094	1.496 / 1.504	0.748 / 0.752	5-3/8	0.3750 / 0.3755	0.749 / 0.751	2.0

Fig. 2 General Dimensions of Bearing Specimens

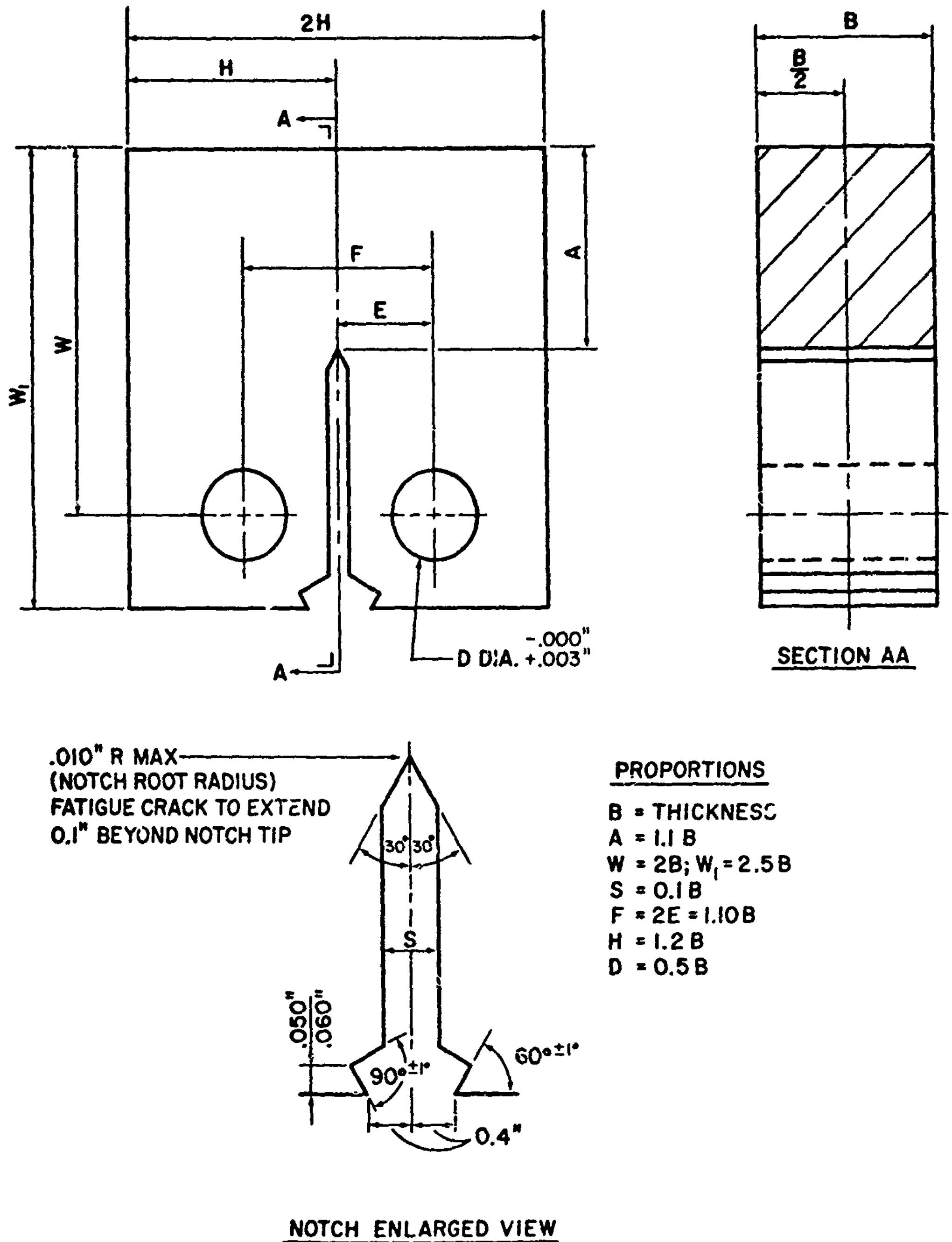


Fig. 3 COMPACT FRACTURE TOUGHNESS SPECIMEN

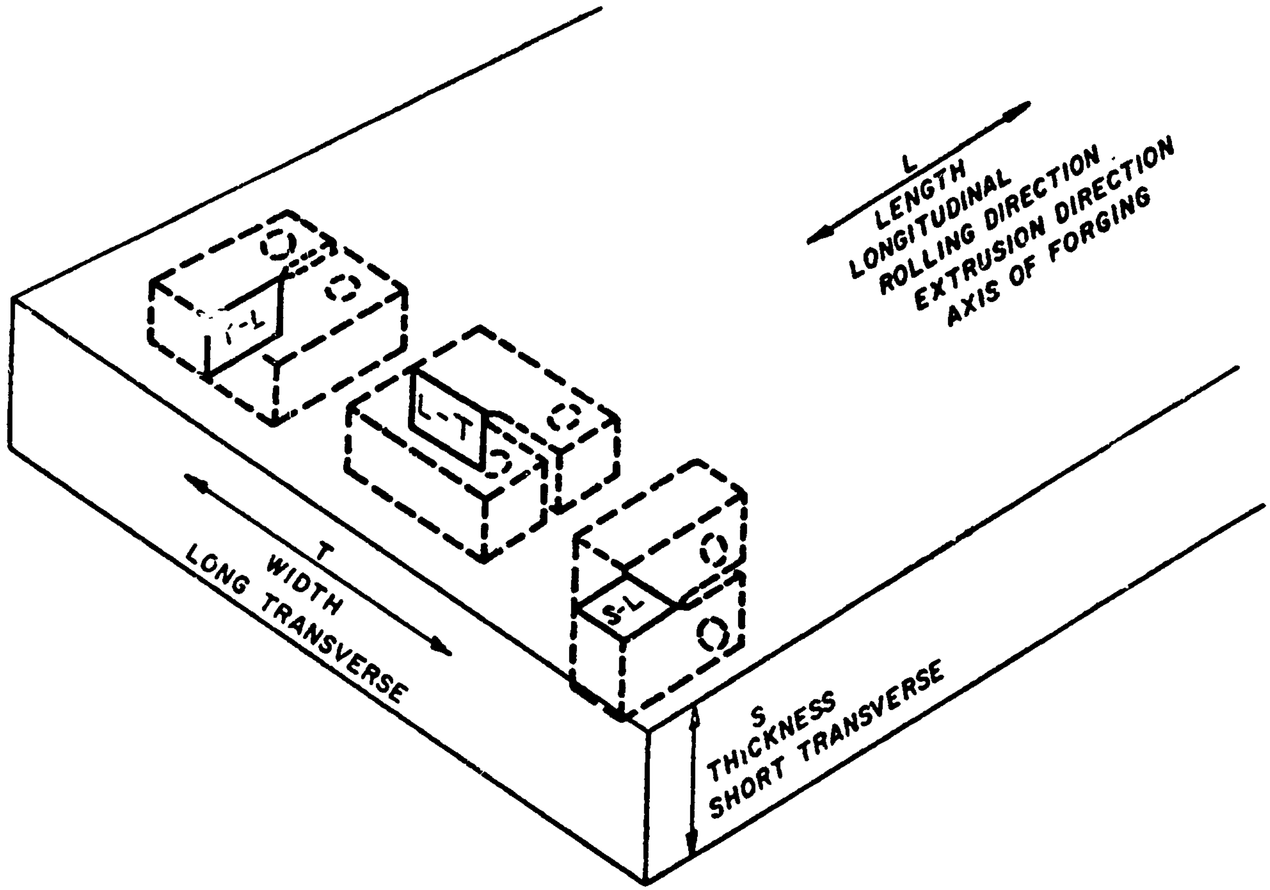


Fig. 4 **FRACTURE SPECIMEN ORIENTATIONS**

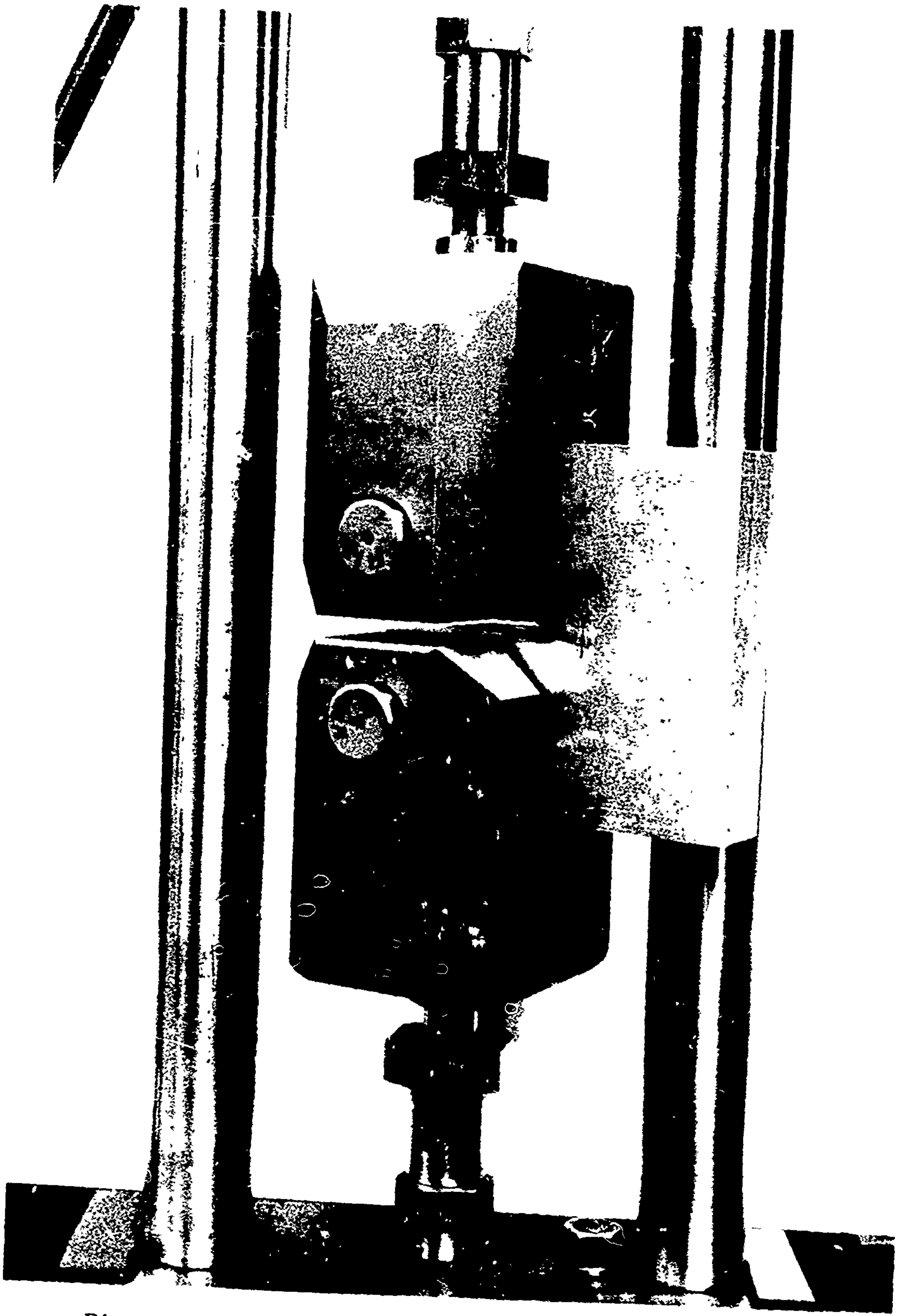


Fig. 5 Setup for Fatigue Precracking of Compact Fracture Toughness Specimens.

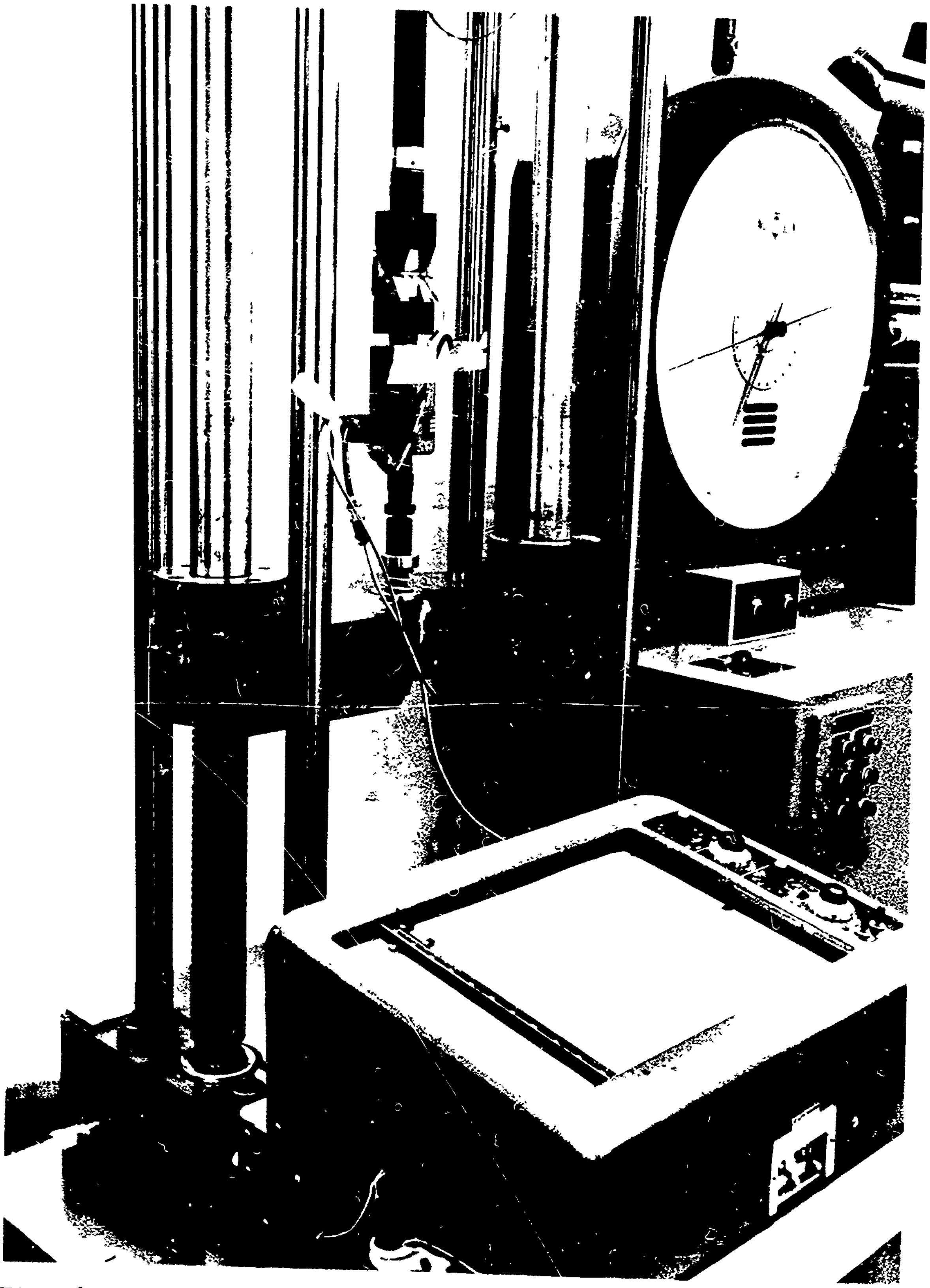
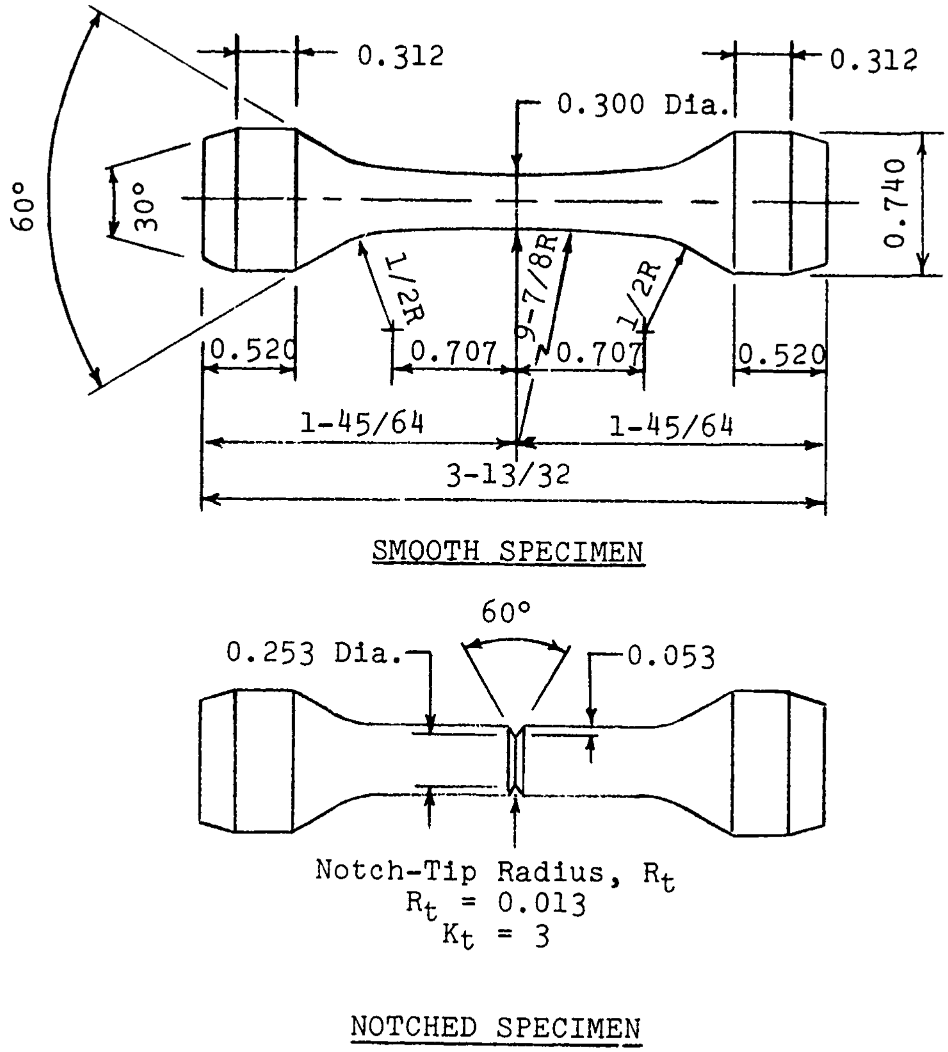
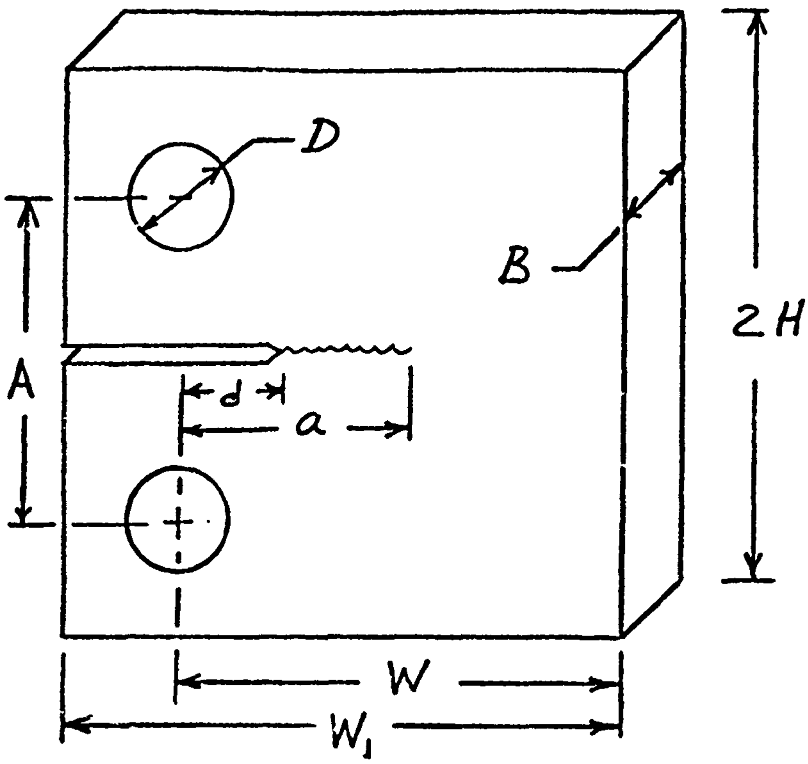


Fig. 6 Setup for Testing Compact Fracture Toughness Specimens.



NOTE: All dimensions in inches.

Fig. 7 Smooth and Notched Axial-Stress Fatigue Specimens



a = crack length

Special Dimensions - Inches

B	2H	W	A	D	d	W_1	H/W
1.00	3.72	3.805	1.650	0.75	1.151	4.80	0.485
1.00	3.72	3.100	1.650	0.75	1.151	4.10	0.6
0.25	2.48	2.550	1.100	0.375	0.62	3.200	0.485

Fig. 8 Dimensions for Compact Fatigue Crack-Propagation Specimen

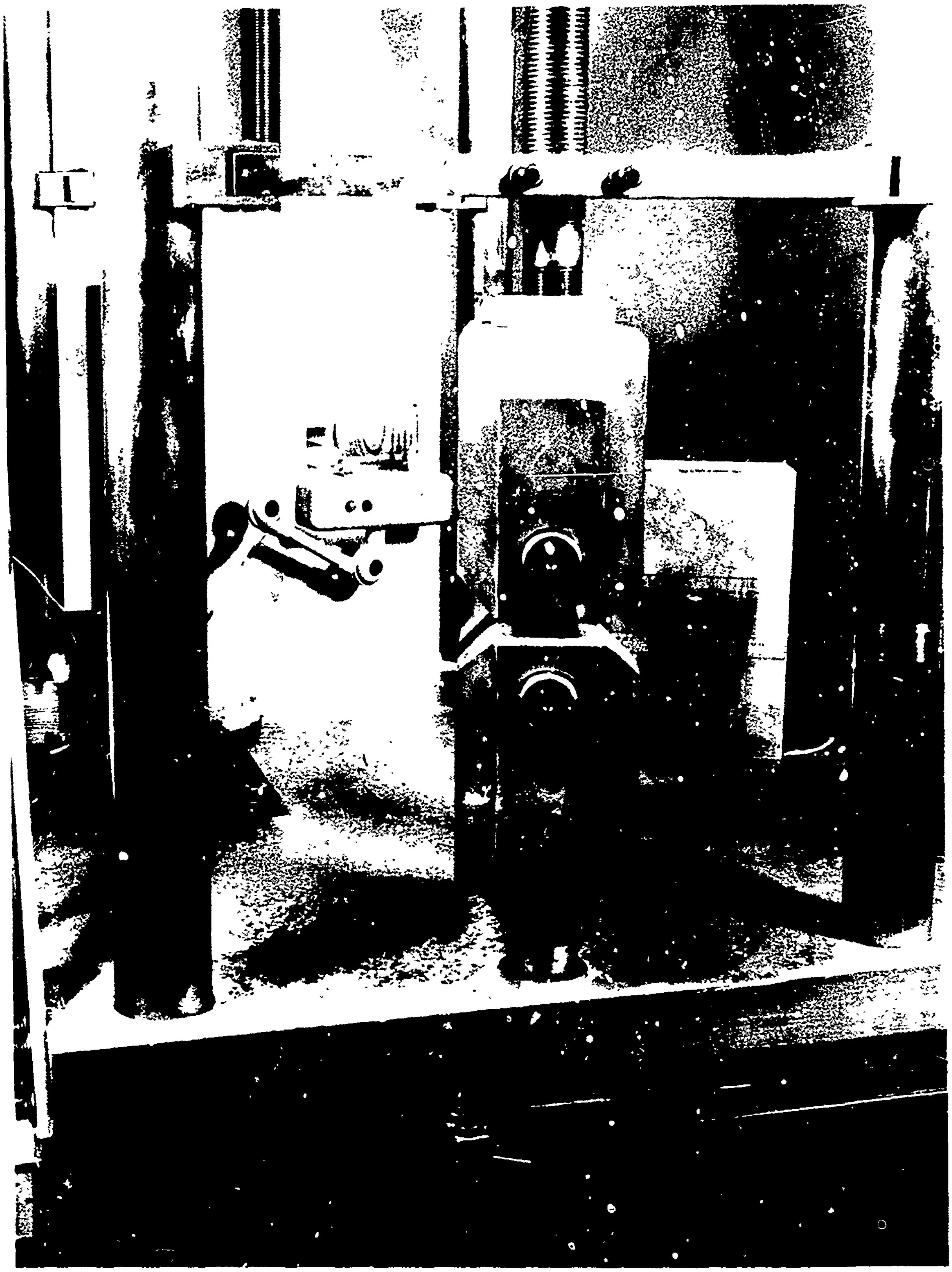
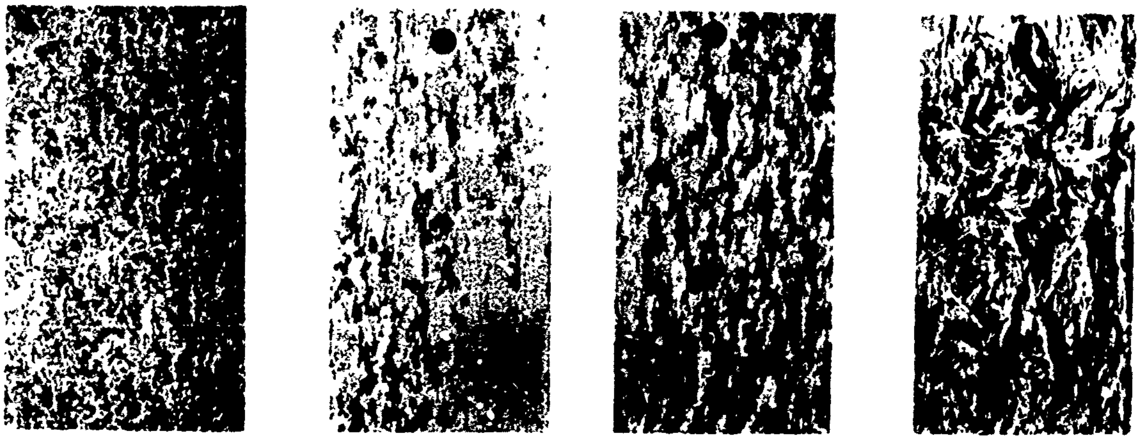
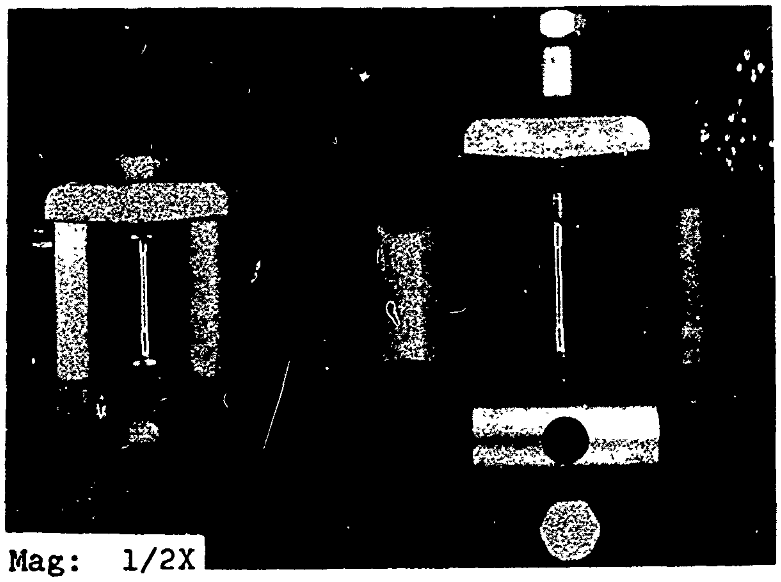


Fig. 9 Fatigue Crack-Growth Tests of Compact Specimens.



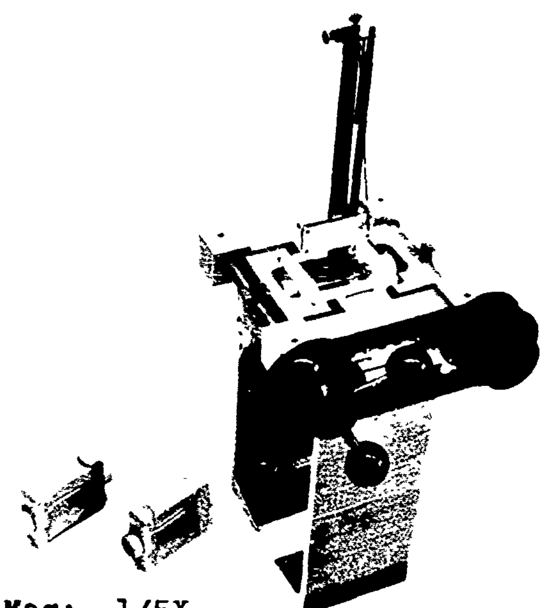
E-A E-B E-C E-D

Fig. 10 Four Degrees of Severity of Exfoliation Corrosion Per ASTM Standard Method Test G34-72.



Mag: 1/2X

Fig. 11 1/8-in. Diameter Tensile Specimen, Various Parts of the Stressing Frame and Final Stressed Assembly for Stress Corrosion Tests.



Mag: 1/5X

Fig. 12 Synchronous Loading Device Used to Stress Specimens Stressed Assembly and One Assembled Finger Tight Ready For Stressing Are Shown to the Left.

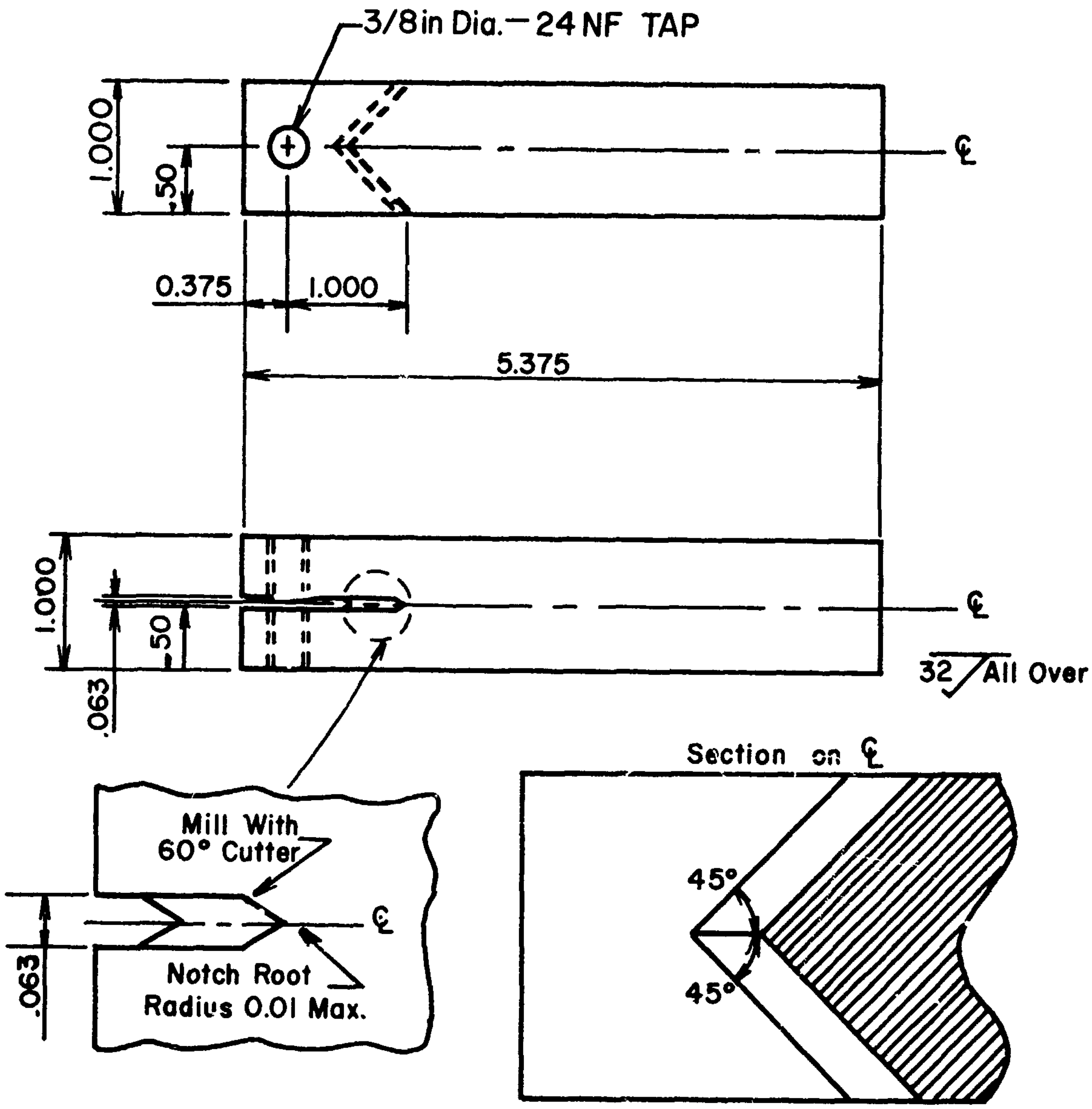


Fig. 13 Configuration of Double Cantilever Beam (DCB) Specimen Used for SCC Tests

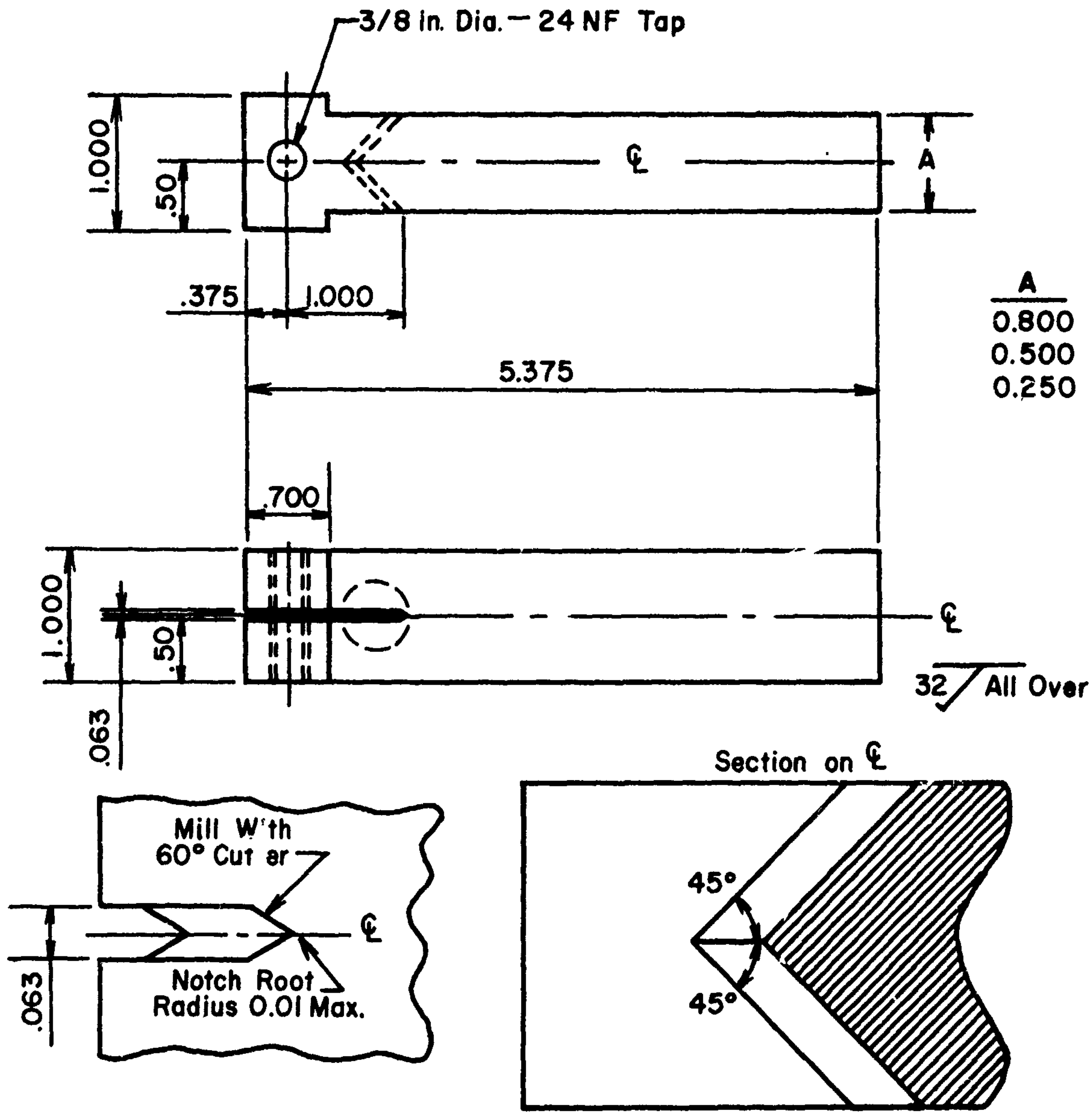
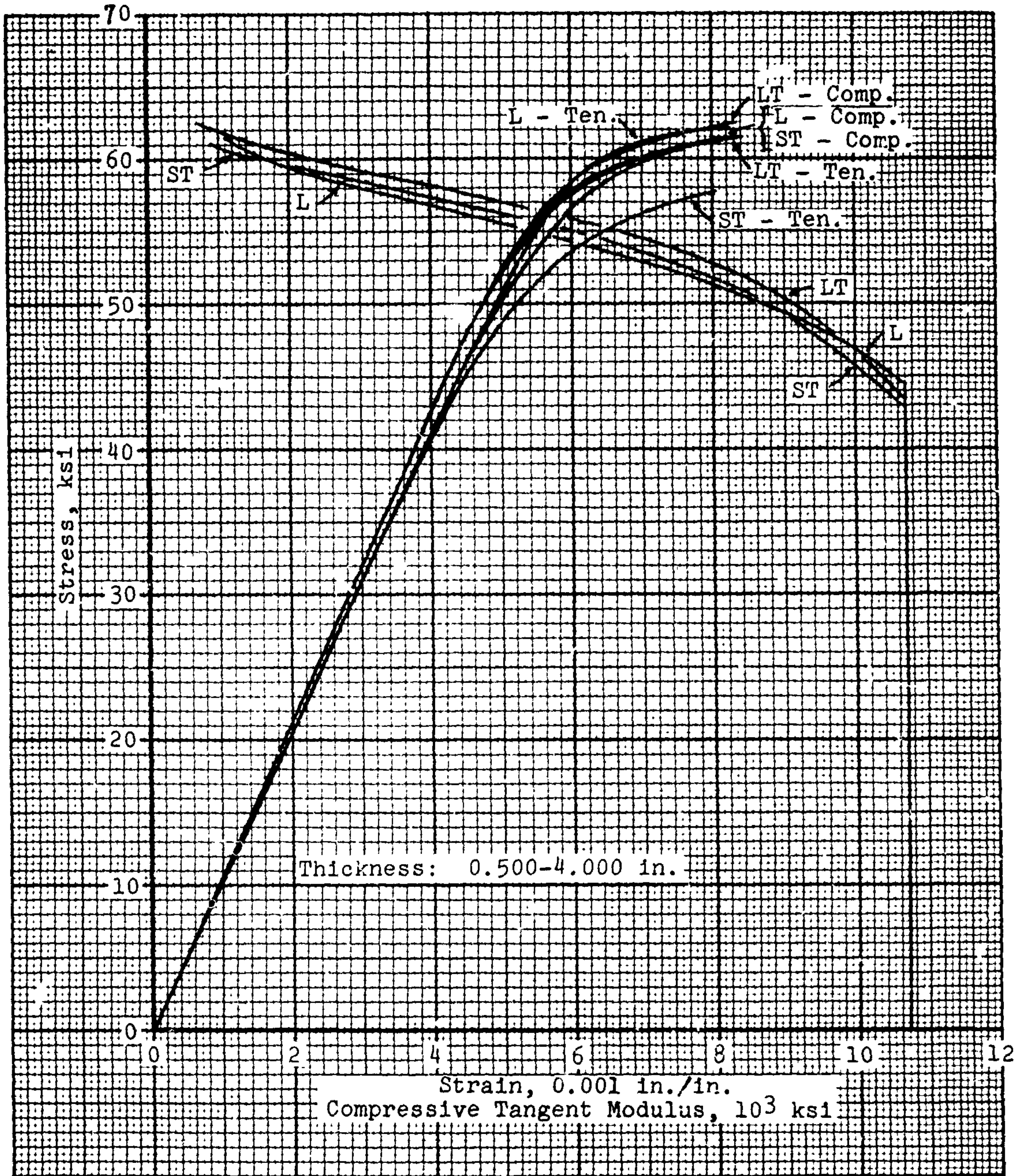


Fig. 14 Configuration of Reduced Thickness Double Cantilever Beam (DCB) Specimen Used for SCC Tests

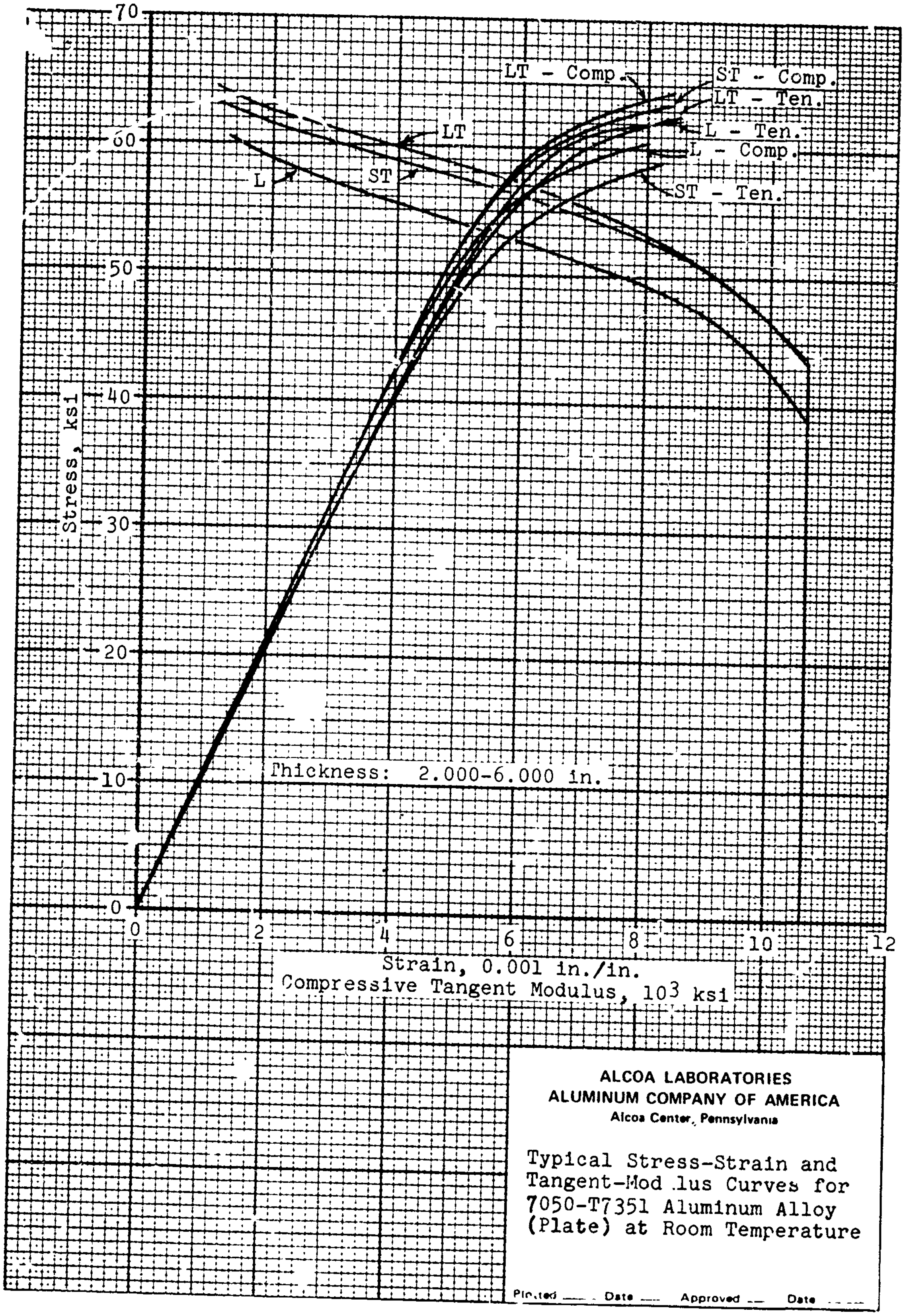


ALCOA LABORATORIES
ALUMINUM COMPANY OF AMERICA
Alcoa Center, Pennsylvania

Typical Stress-Strain and Tangent-Modulus Curves for 2048-T851 Aluminum Alloy (Plate) at Room Temperature

Plotted ____ Date ____ Approved ____ Date ____

Fig. 15

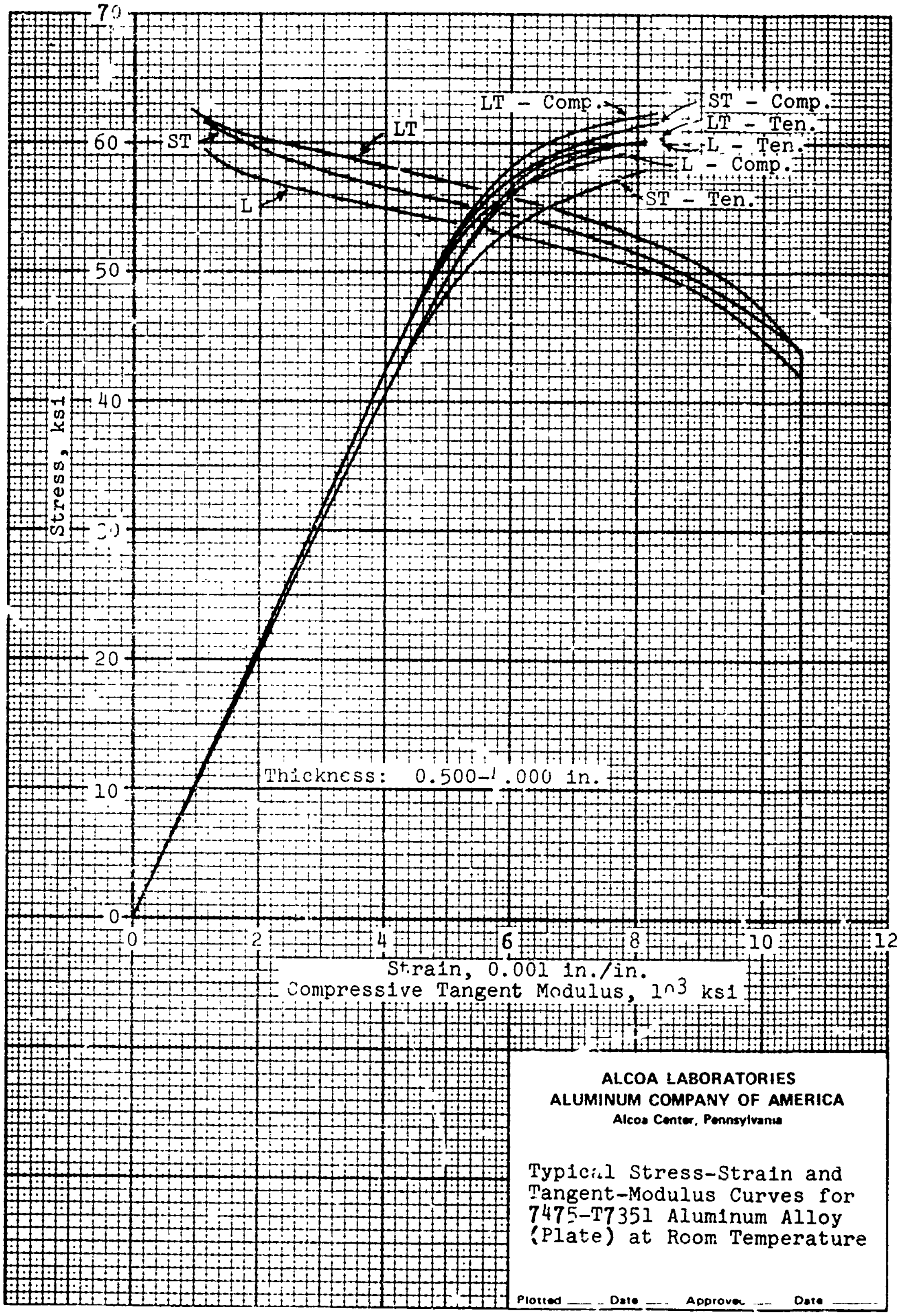


ALCOA LABORATORIES
ALUMINUM COMPANY OF AMERICA
Alcoa Center, Pennsylvania

Typical Stress-Strain and Tangent-Mod lus Curves for 7050-T7351 Aluminum Alloy (Plate) at Room Temperature

Plotted ___ Date ___ Approved ___ Date ___

Fig. 16



ALCOA LABORATORIES
ALUMINUM COMPANY OF AMERICA
Alcoa Center, Pennsylvania

Typical Stress-Strain and Tangent-Modulus Curves for 7475-T7351 Aluminum Alloy (Plate) at Room Temperature

Plotted ____ Date ____ Approved ____ Date ____

Fig. 17

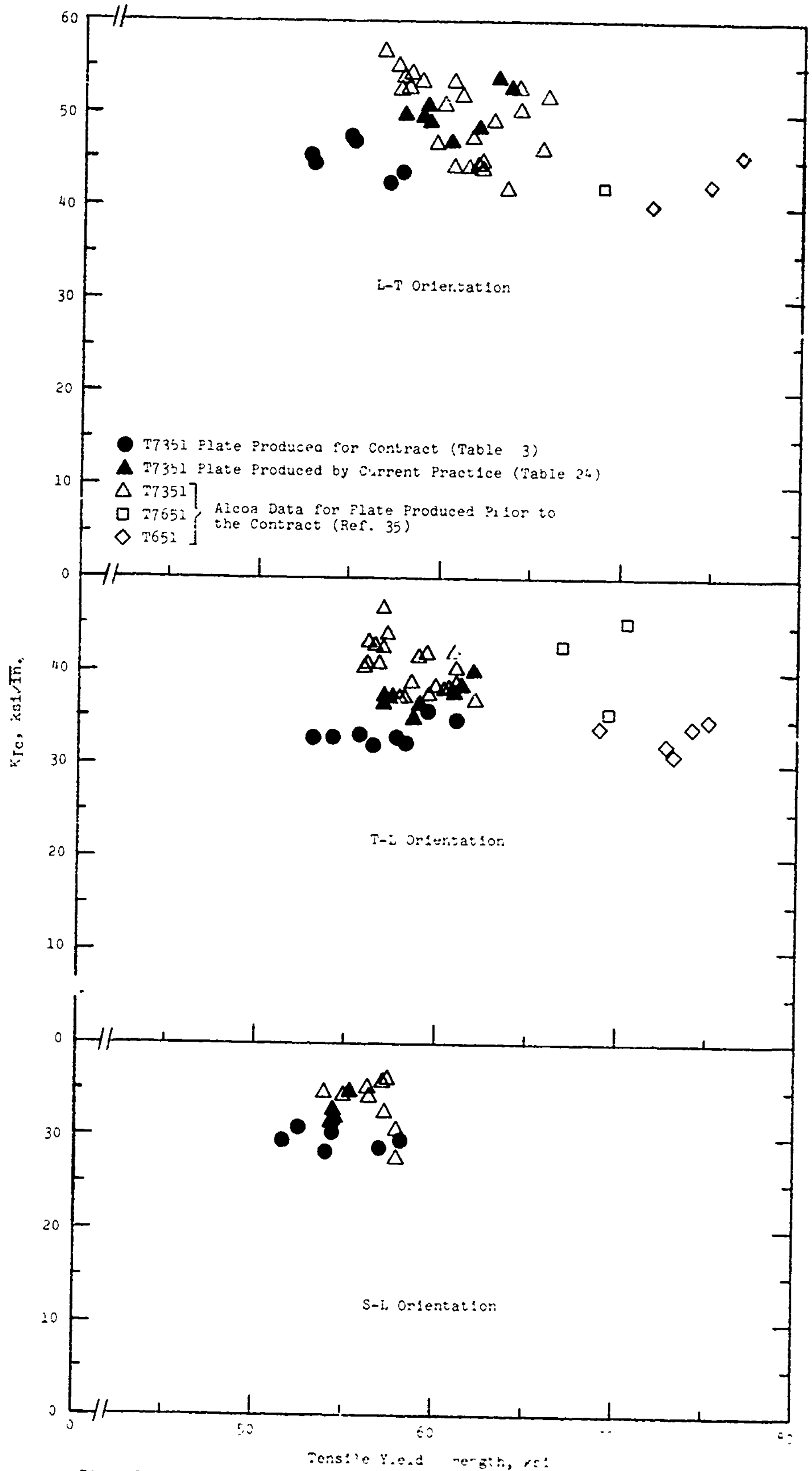


Fig. 15 [illegible] Tensile Yield Strength of [illegible] Plate, [illegible]

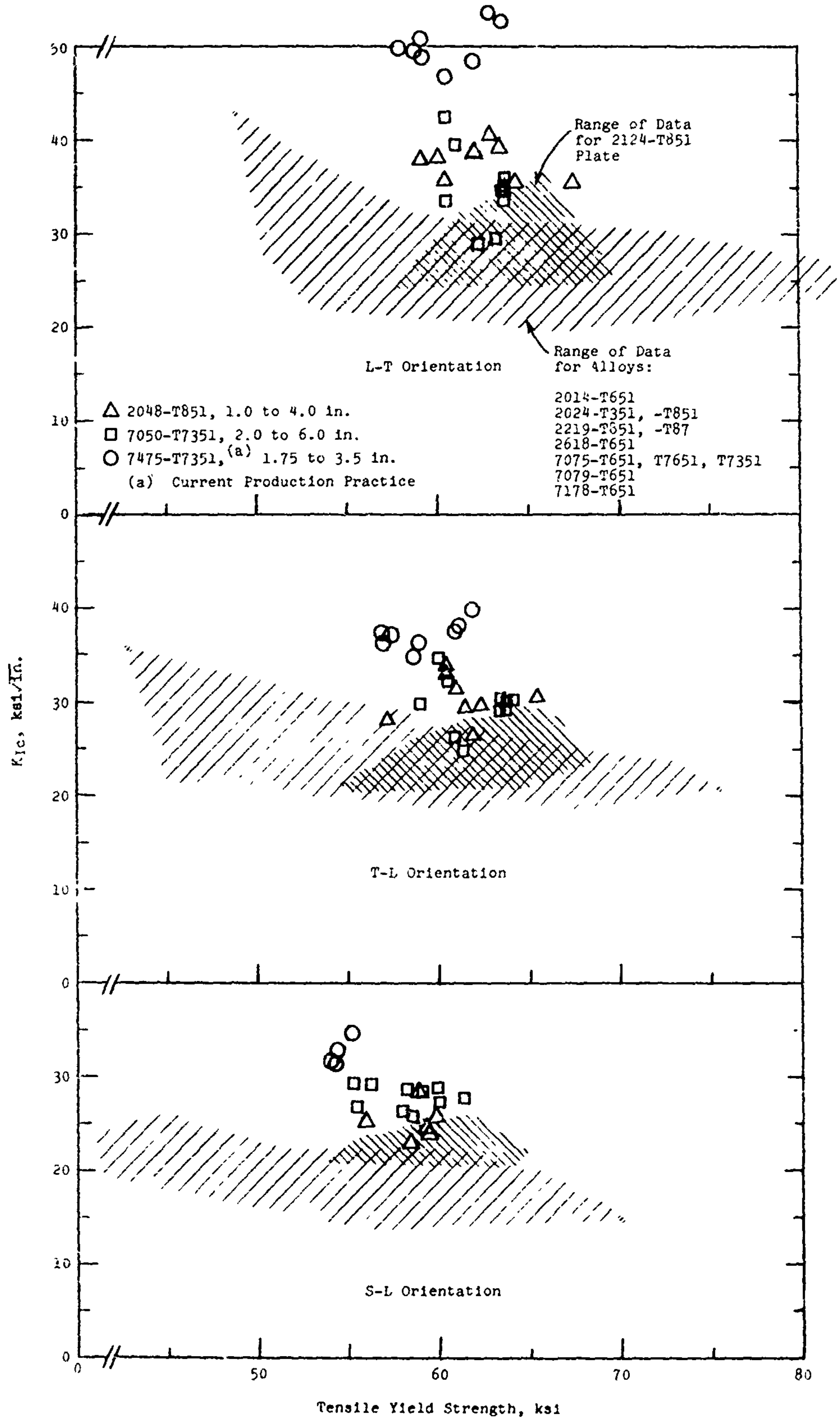


Fig. 19 K_{Ic} Vs Tensile Yield Strength of 2048-T851, 7050-T7351 and 7475-T7351 Plate

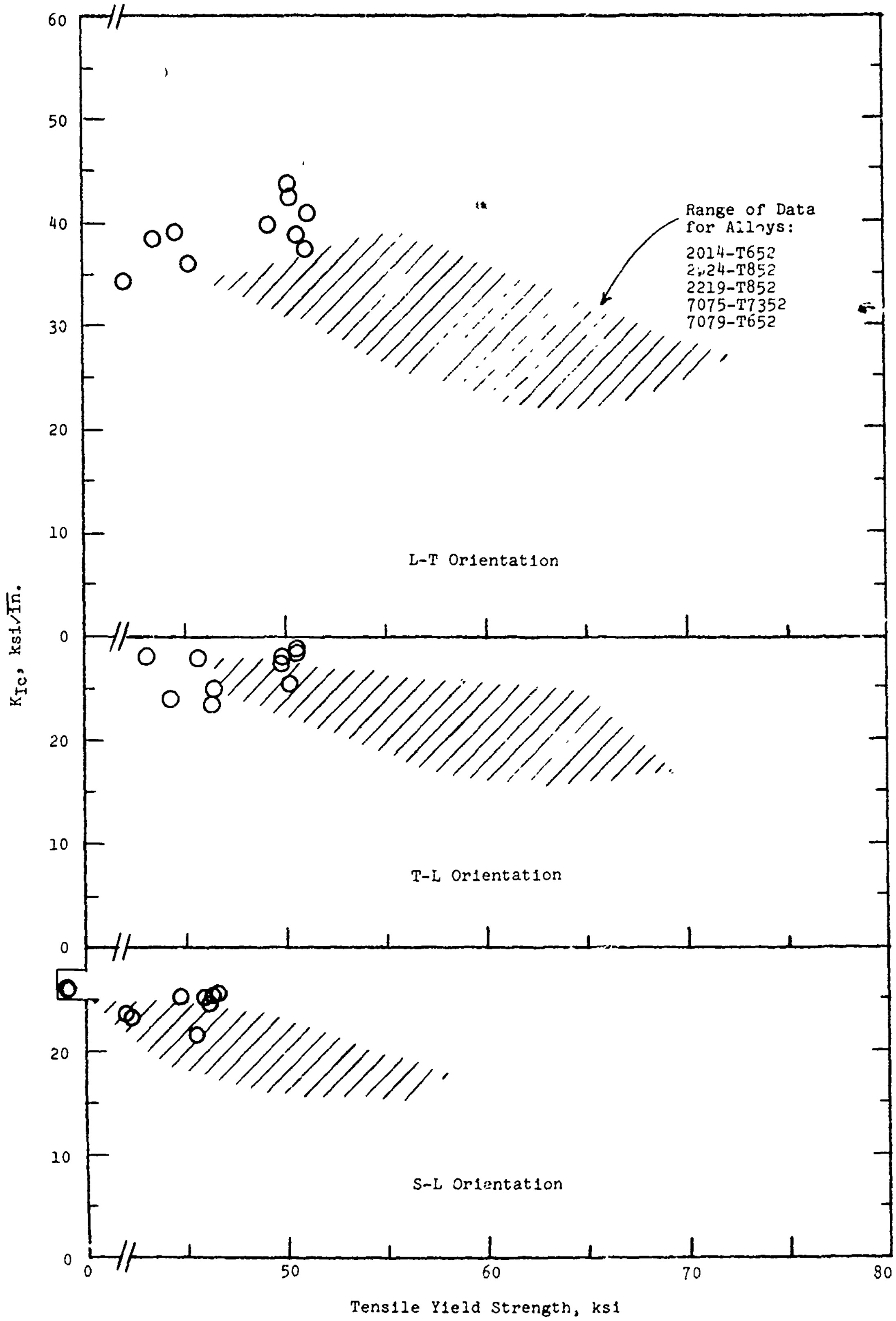


Fig. 20 K_{Ic} Vs Tensile Yield Strength of 2219-T852 Hand Forgings, 2.0 to 7.5-In. Thick

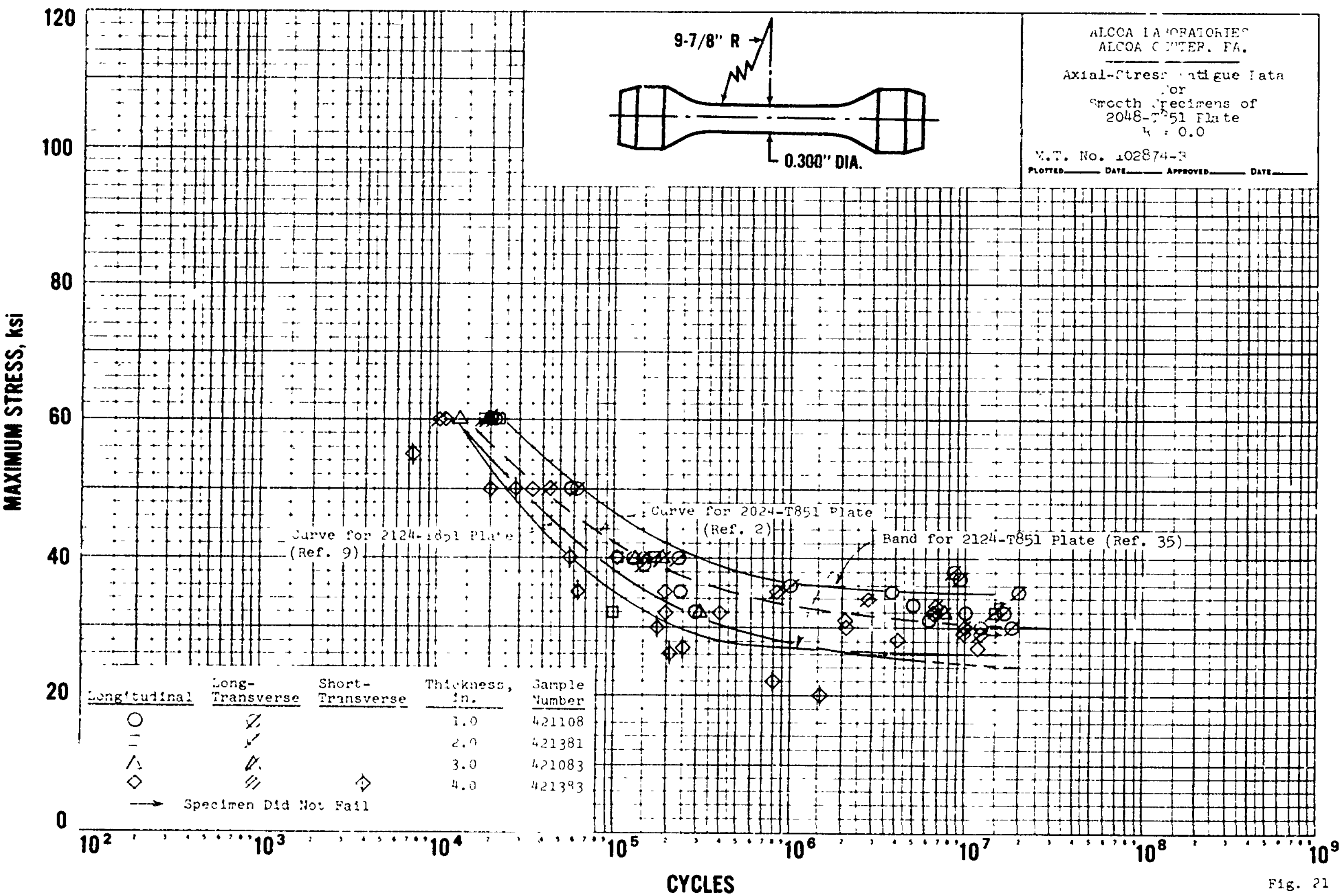

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data
for
Smooth Specimens of
2048-T851 Plate
R = 0.0
W.T. No. 102874-B
PLOTTED DATE APPROVED DATE
9-7/8" R
0.300" DIA.
Curve for 2024-T851 Plate (Ref. 2)
Curve for 2124-T851 Plate (Ref. 9)
Band for 2124-T851 Plate (Ref. 35)
Longitudinal
Long-Transverse
Short-Transverse
Thickness, in.
Sample Number
1.0
421108
2.0
421381
3.0
421083
4.0
421383
Specimen Did Not Fail
MAXIMUM STRESS, ksi
CYCLES
120
100
80
60
40
20
0
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9

Fig. 21

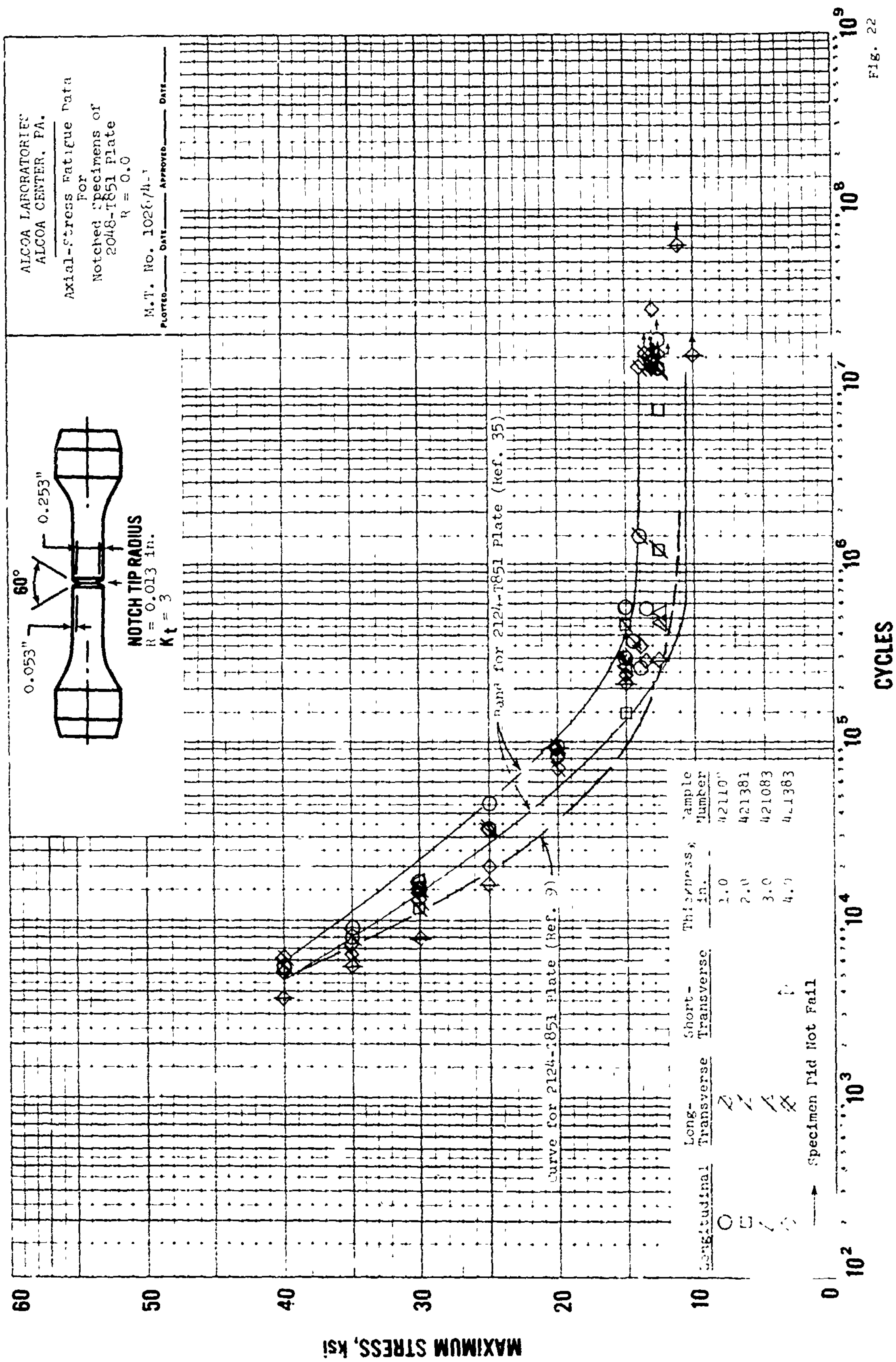

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data For Notched Specimens of 2048-T851 Plate R = 0.0
NOTCH TIP RADIUS
R = 0.013 in.
Kt = 3
0.053"
0.253"
60°
Band for 2124-T851 Plate (Ref. 35)
Curve for 2124-T851 Plate (Ref. 9)
Longitudinal
Long-Transverse
Short-Transverse
Specimen Did Not Fail
MAXIMUM STRESS, ksi
CYCLES

Fig. 22

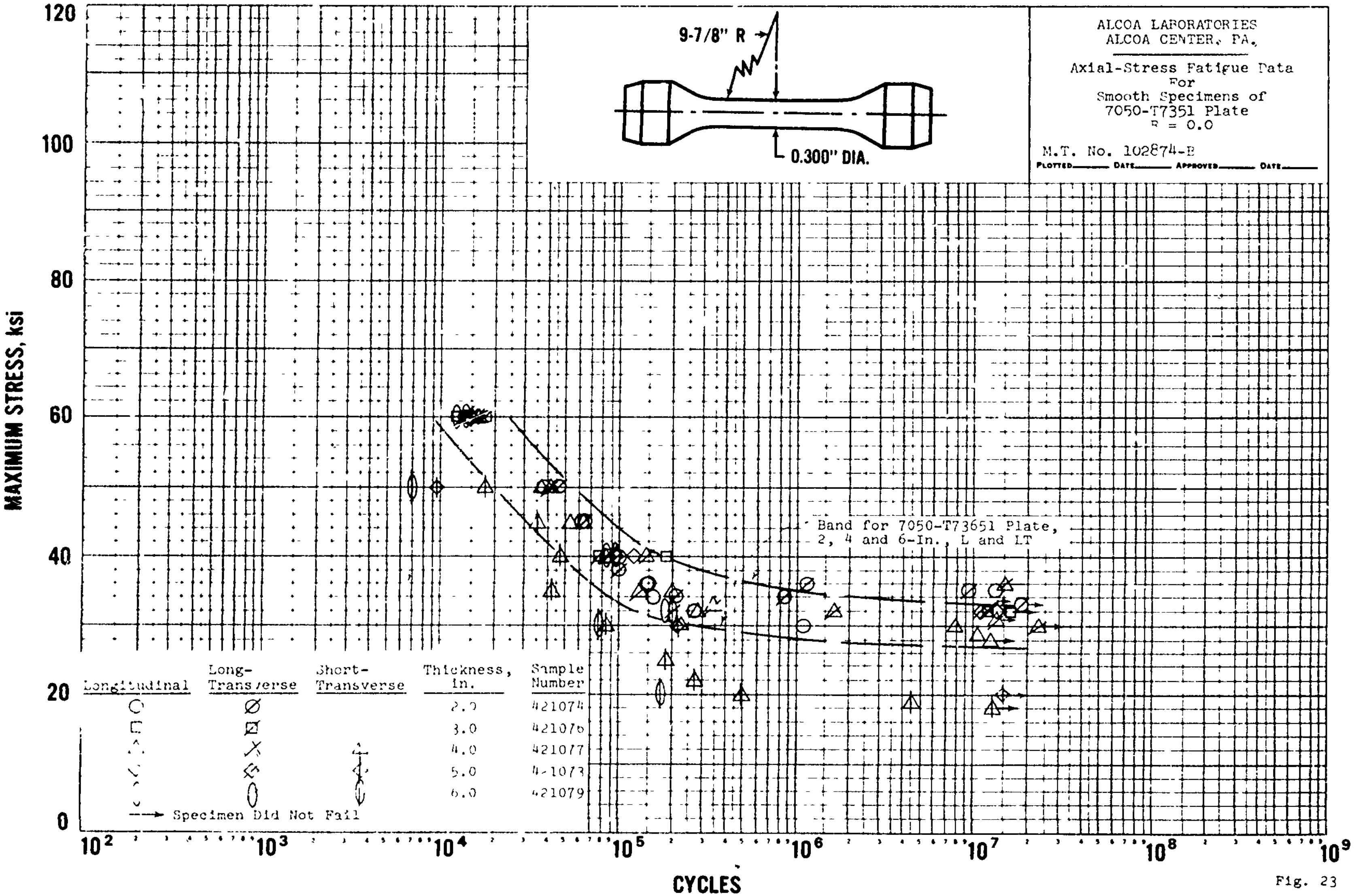

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data
For
Smooth Specimens of
7050-T7351 Plate
R = 0.0
M.T. No. 102874-B
PLOTTED DATE APPROVED DATE
9-7/8" R
0.300" DIA.
Band for 7050-T73651 Plate, 2, 4 and 6-In., L and LT
Longitudinal
Long-Transverse
Short-Transverse
Thickness, In.
Sample Number
2.0
3.0
4.0
5.0
6.0
421074
421076
421077
421073
421079
Specimen Did Not Fail
MAXIMUM STRESS, ksi
CYCLES
120
100
80
60
40
20
0
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9

Fig. 23

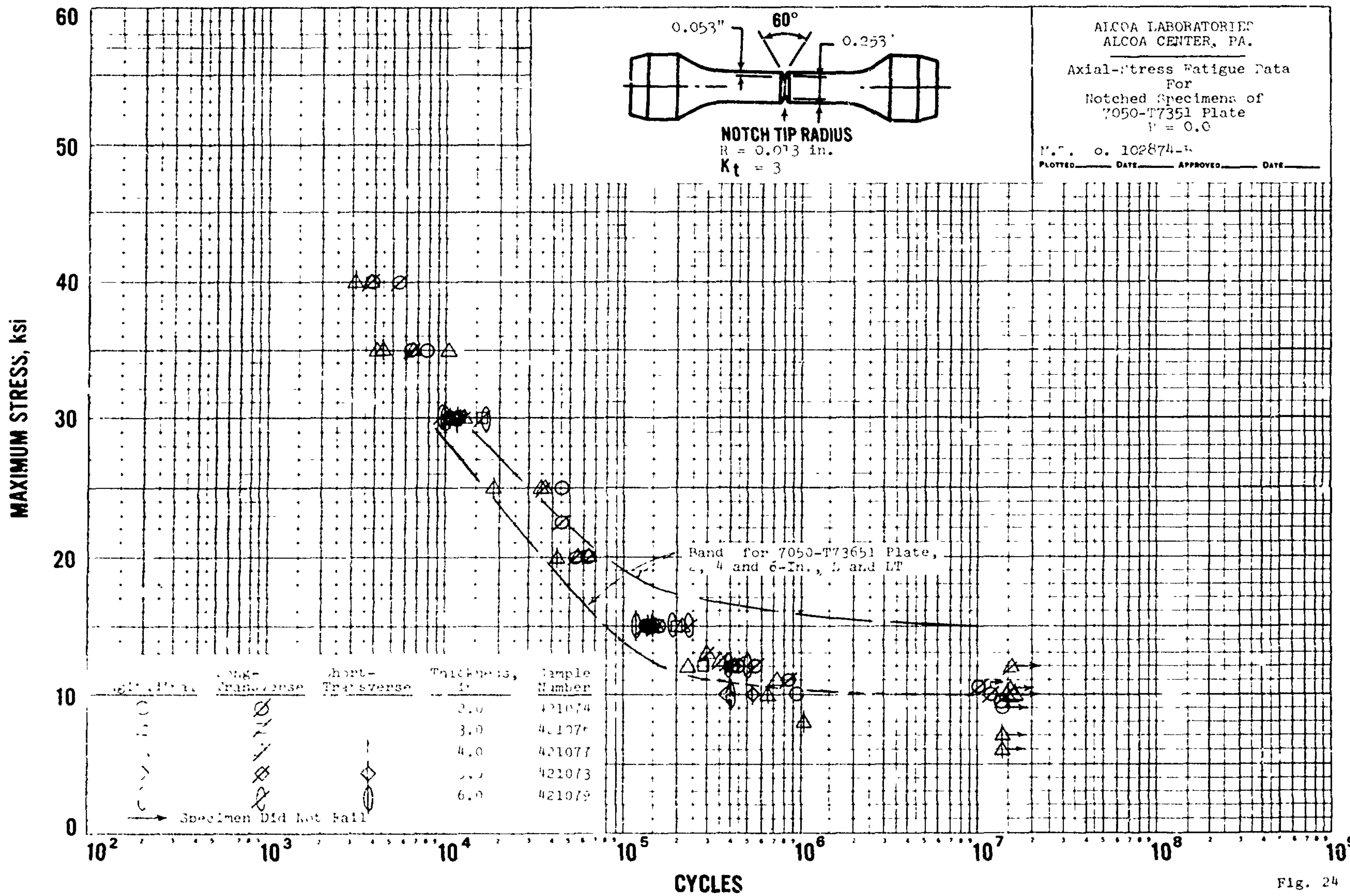

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data
For
Notched Specimens of
7050-T7351 Plate
R = 0.0
PLOTTED DATE APPROVED DATE
60°
0.053"
0.253"
NOTCH TIP RADIUS
R = 0.013 in.
K_t = 3
Band for 7050-T73651 Plate, 2, 4 and 6-In., L and LT
Long-Transverse
Short-Transverse
Thickness, In.
Sample Number
2.0
3.0
4.0
6.0
421074
421077
421073
421079
Specimen Did Not Fail
MAXIMUM STRESS, ksi
CYCLES
0
10
20
30
40
50
60
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9

Fig. 24

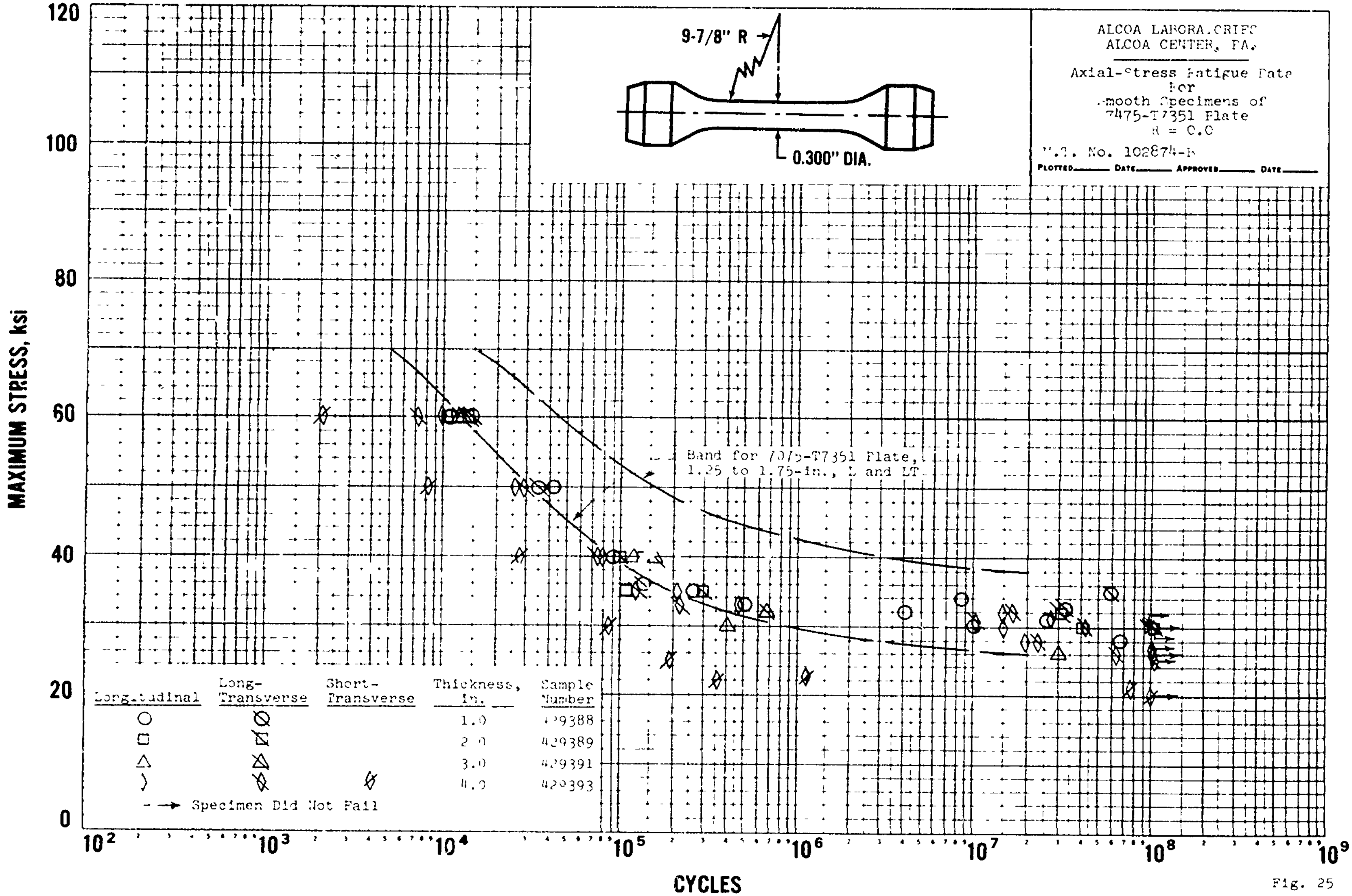

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data
For
Smooth Specimens of
7475-T7351 Plate
R = 0.0
W.O. No. 102874-B
PLOTTED DATE APPROVED DATE
9-7/8" R
0.300" DIA.
Band for 7075-T7351 Plate, 1.25 to 1.75-in., L and LT
Longitudinal
Long-Transverse
Short-Transverse
Thickness, In.
Sample Number
1.0
2.0
3.0
4.0
429388
429389
429391
429393
Specimen Did Not Fail
MAXIMUM STRESS, ksi
CYCLES
0
20
40
60
80
100
120
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9

Fig. 25

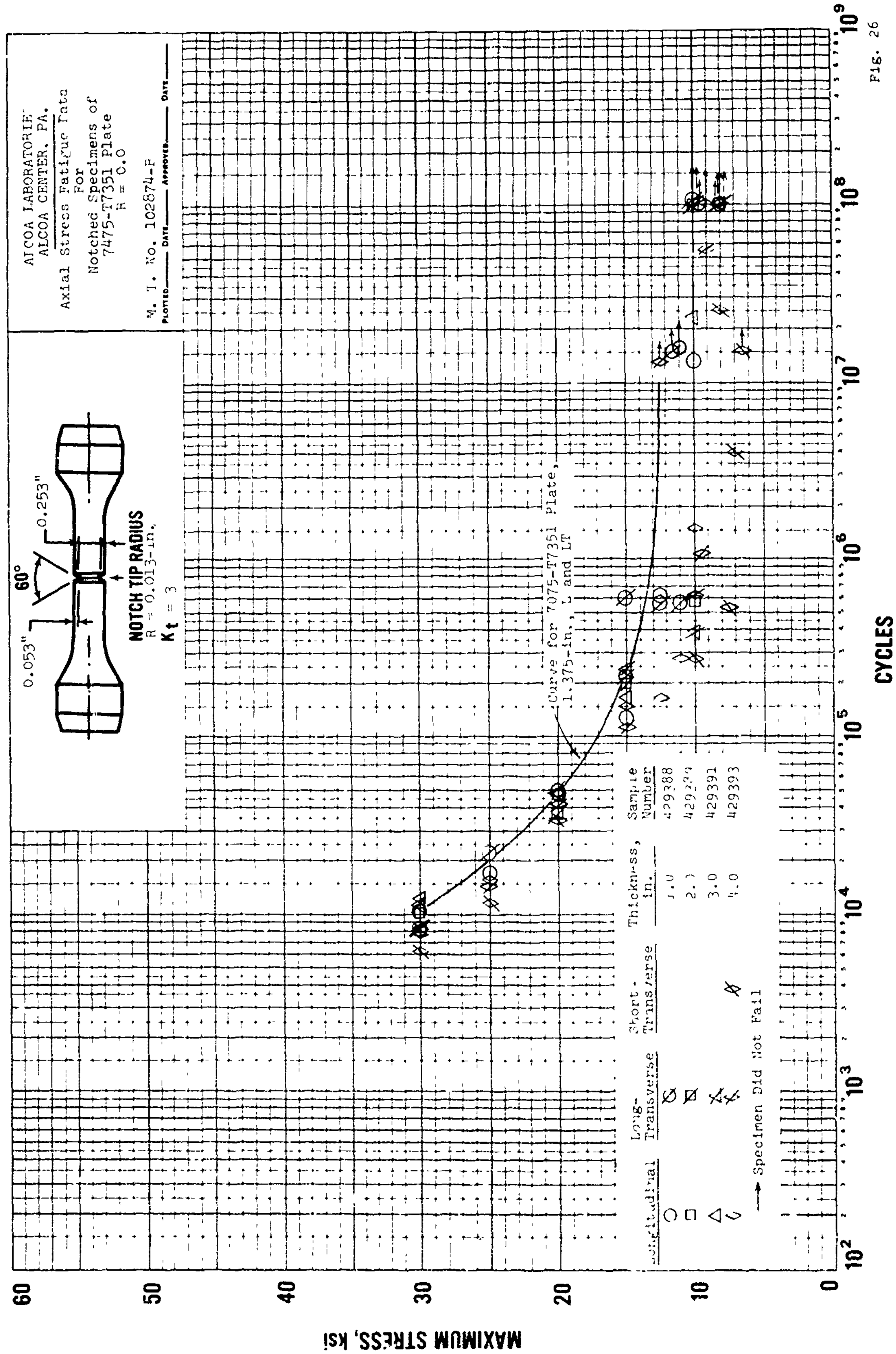

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial Stress Fatigue Data
For
Notched Specimens of
7475-T7351 Plate
R = 0.0
M. T. No. 102874-F
PLOTTED
DATE
APPROVED
DATE
0.053"
60°
0.253"
NOTCH TIP RADIUS
R = 0.013-in.
Kt = 3
Curve for 7075-T7351 Plate,
1.375-in., L and LT
Longitudinal
Long-Transverse
Short-Transverse
Thickness, in.
1.0
2.0
3.0
4.0
Sample Number
429388
429391
429393
Specimen Did Not Fail
MAXIMUM STRESS, ksi
CYCLES

Fig. 26

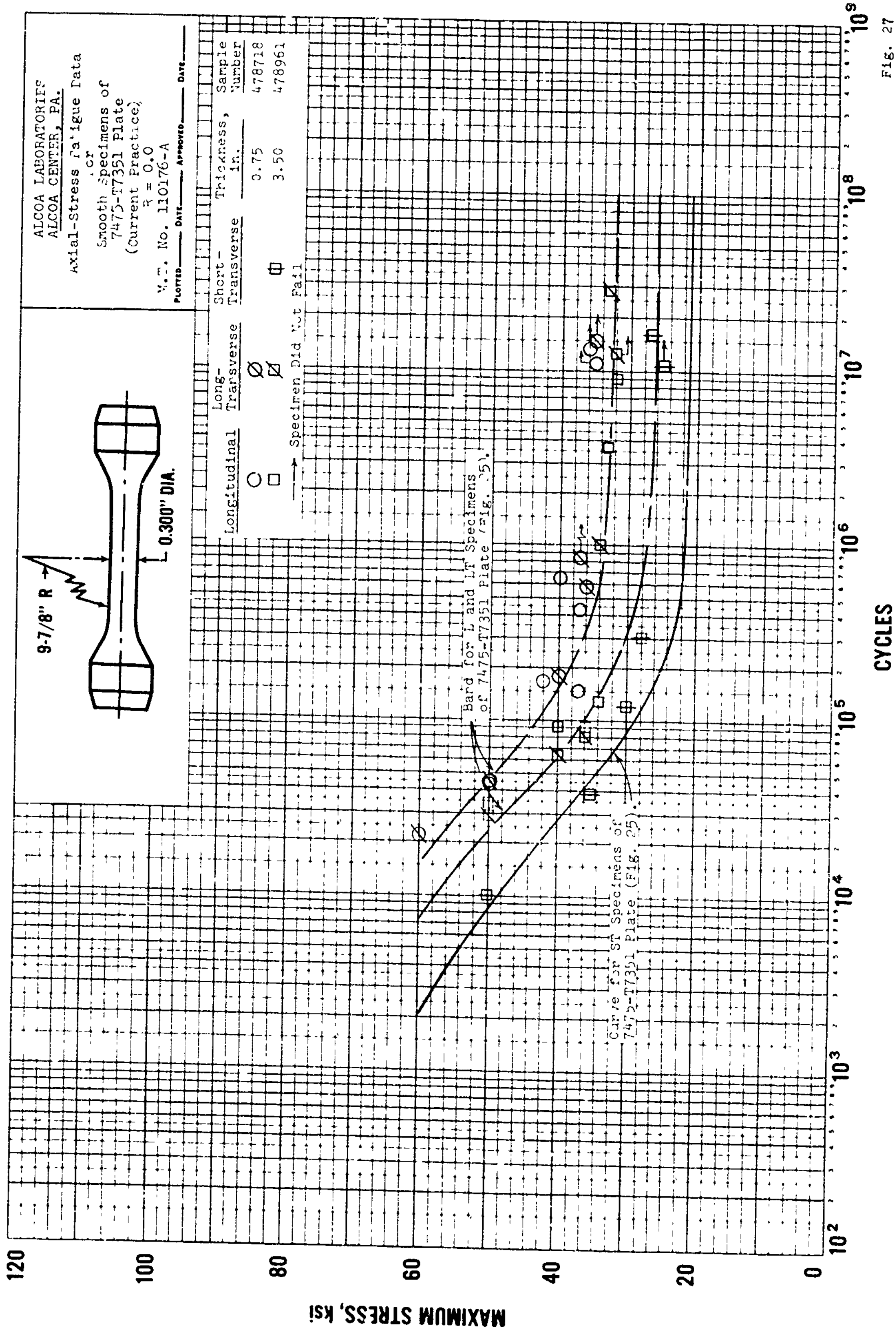
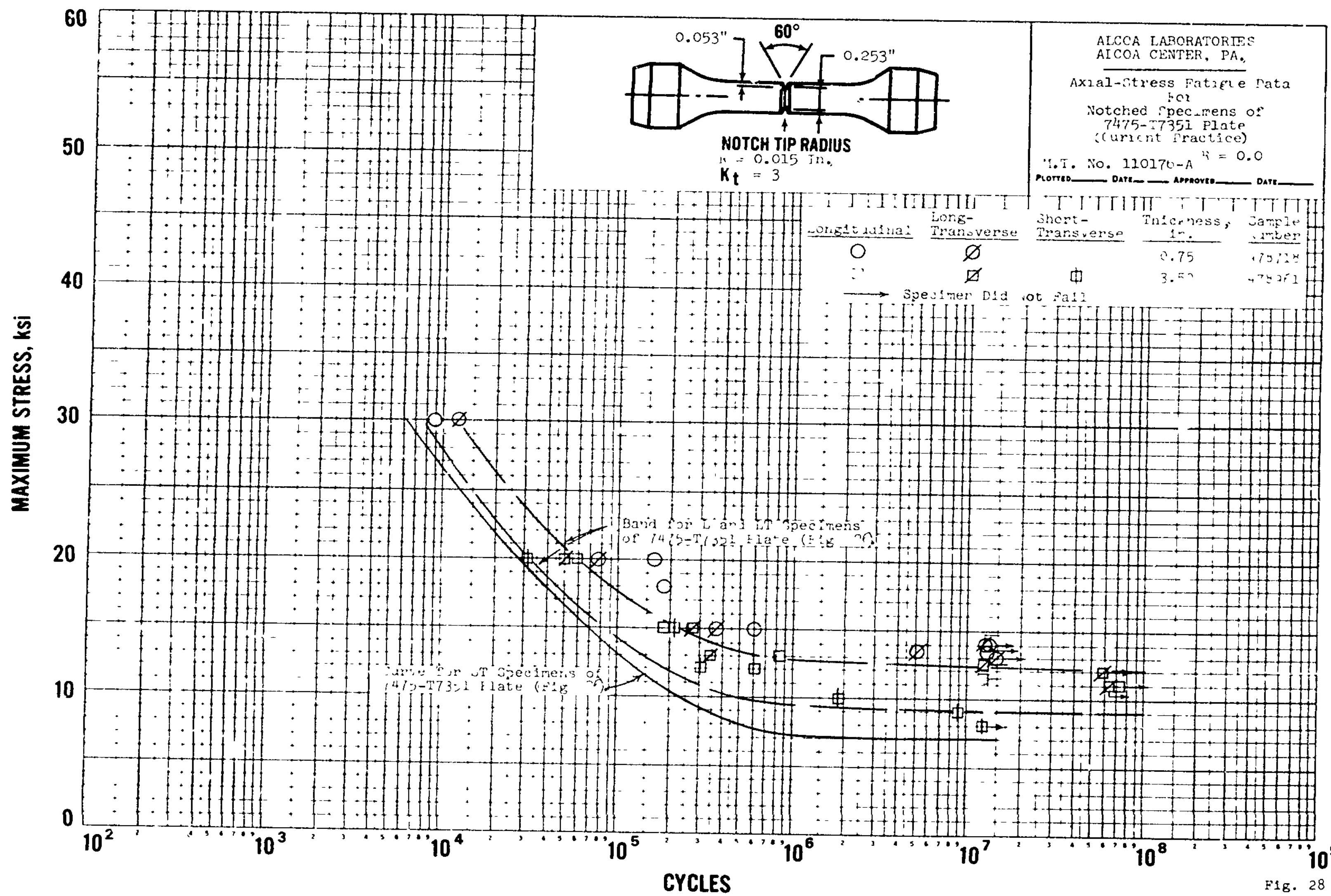

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data
for
Smooth Specimens of
7475-T7351 Plate
(Current Practice)
R = 0.0
W.O. No. 110176-A
9-7/8" R
0.300" DIA.
Longitudinal
Long-Transverse
Short-Transverse
Thickness, in.
Sample Number
0.75
3.50
478718
478961
Specimen Did Not Fail
Band for L and LT Specimens of 7475-T7351 Plate (Fig. 25)
Curve for ST Specimens of 7475-T7351 Plate (Fig. 25)
MAXIMUM STRESS, ksi
CYCLES
120
100
80
60
40
20
0
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9

Fig. 27



ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data
for
Notched Specimens of
7475-T7351 Plate
(Current Practice)
No. 110176-A R = 0.0
PLOTTED DATE APPROVED DATE
0.053"
60°
0.253"
NOTCH TIP RADIUS
R = 0.015 In.
Kt = 3
Longitudinal
Long-Transverse
Short-Transverse
Thickness, In.
Sample Number
0.75
Specimen Did Not Fail
Band for L and LT Specimens of 7475-T7351 Plate
MAXIMUM STRESS, ksi
CYCLES

Fig. 28

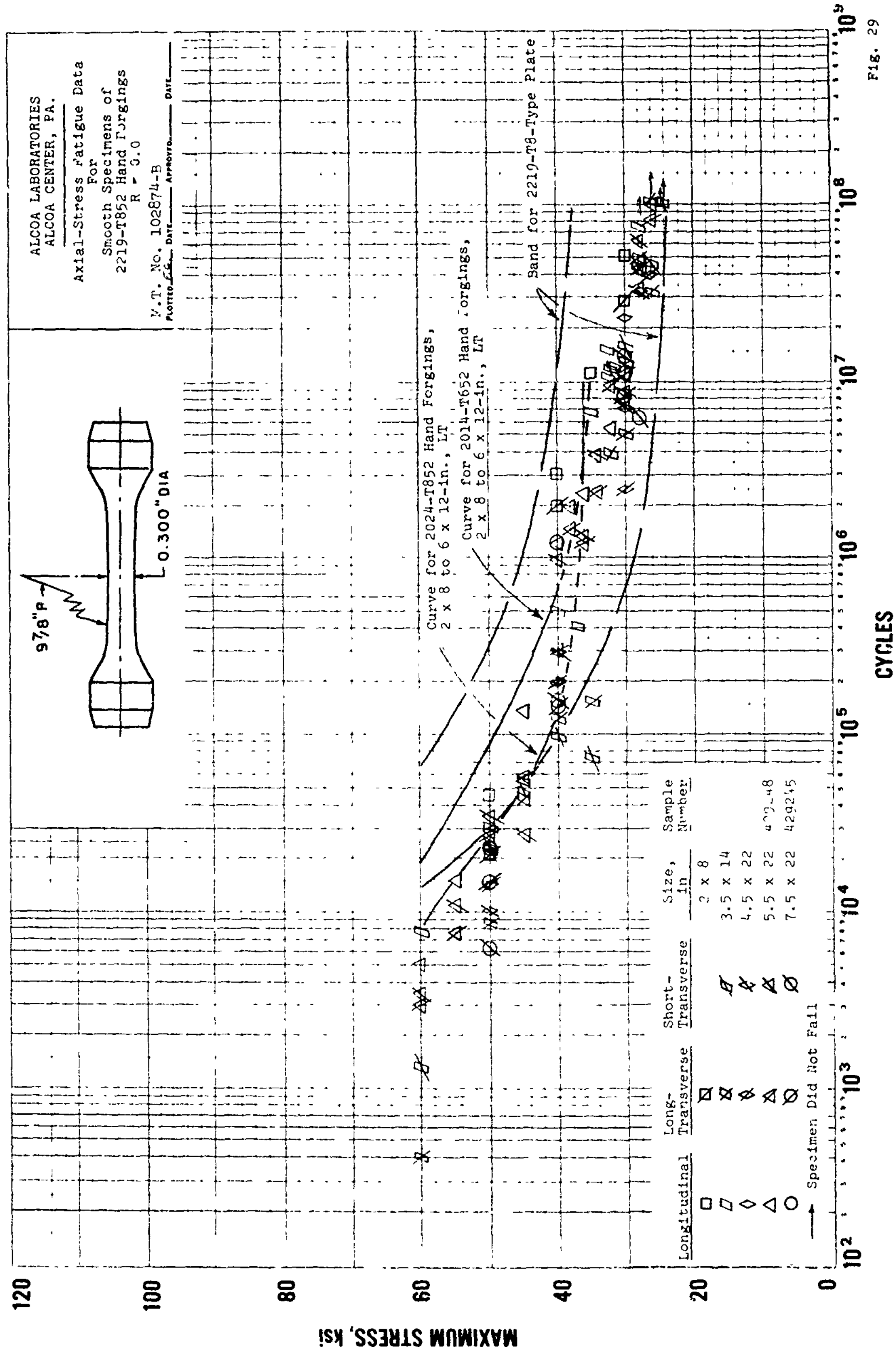

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data
For
Smooth Specimens of
2219-T852 Hand Forgings
R = 0.0
V.T. No. 102874-B
PLOTTED DATE APPROVED DATE
97/8"R
0.300"DIA
Curve for 2024-T852 Hand Forgings,
2 x 8 to 6 x 12-in., LT
Curve for 2014-T652 Hand Forgings,
2 x 8 to 6 x 12-in., LT
Band for 2219-T8-Type Plate
Longitudinal
Long-Transverse
Short-Transverse
Size, in
2 x 8
3.5 x 14
4.5 x 22
5.5 x 22
7.5 x 22
Sample Number
429245
Specimen Did Not Fail
MAXIMUM STRESS, ksi
CYCLES
0
20
40
60
80
100
120
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9

Fig. 29

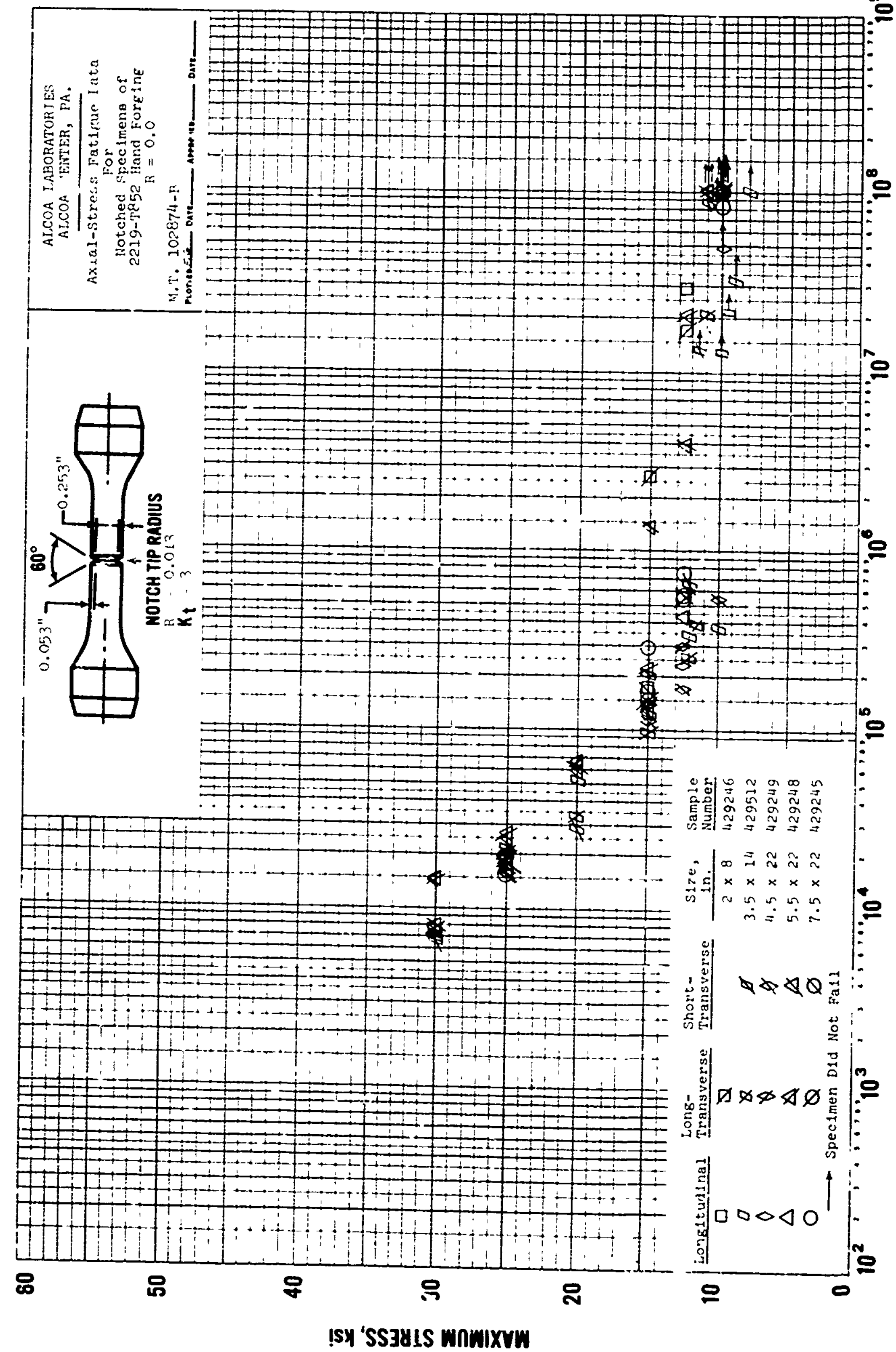

ALCOA LABORATORIES
ALCOA CENTER, PA.
Axial-Stress Fatigue Data
For
Notched Specimens of
2219-T852 Hand Forging
R = 0.0
M.T. 102874-R
0.053"
60°
0.253"
NOTCH TIP RADIUS
R = 0.013
Kt = 3
Longitudinal
Long-Transverse
Short-Transverse
Size, In.
Sample Number
2 x 8
429246
3.5 x 14
429512
4.5 x 22
429249
5.5 x 22
429248
7.5 x 22
429245
→ Specimen Did Not Fail
MAXIMUM STRESS, ksi
60
50
40
30
20
10
0
CYCLES
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9

Fig. 30

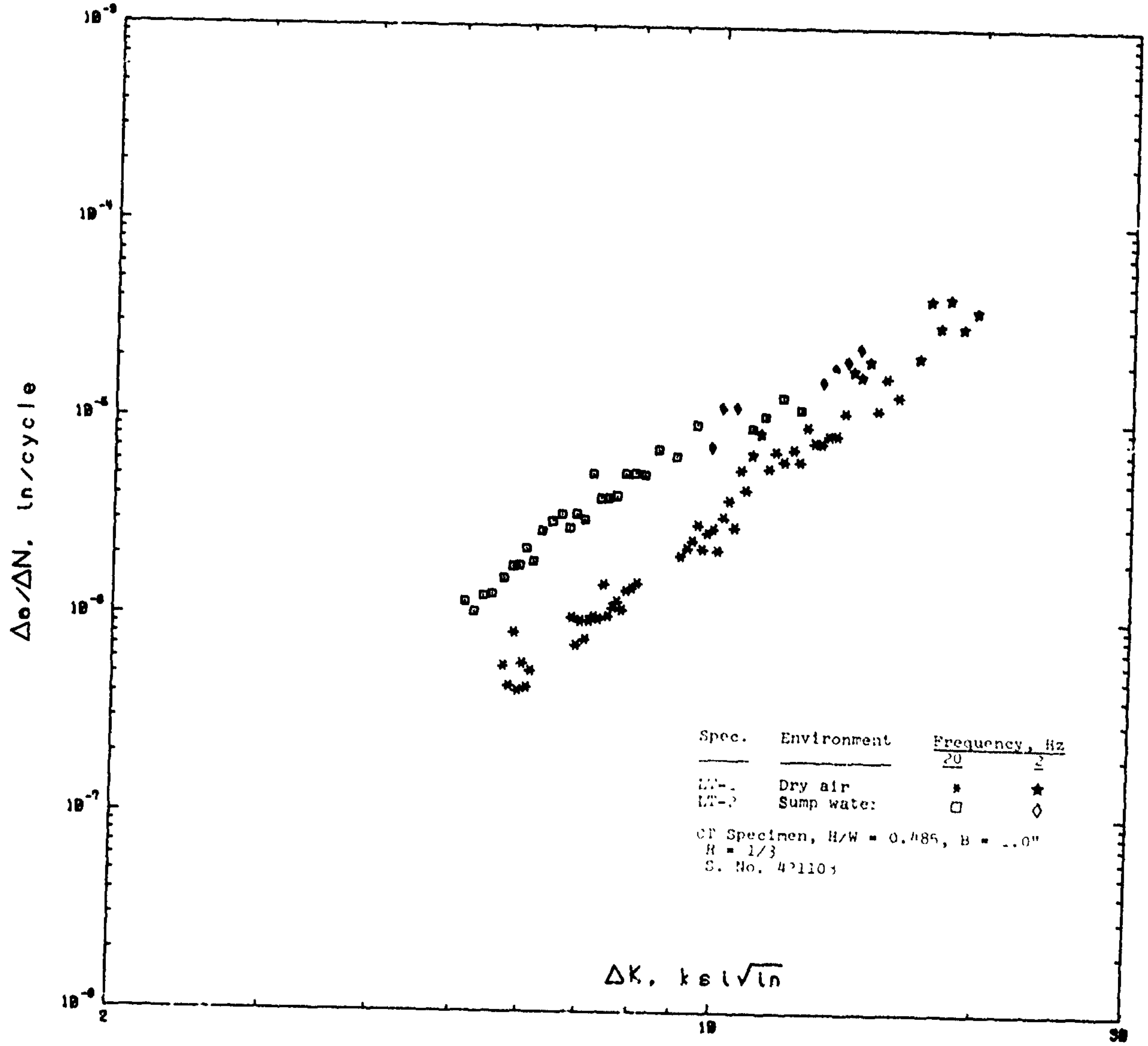


Fig. 31 Fatigue Crack Growth Data for 1-in. 2048-T851 Plate L-T Orientation

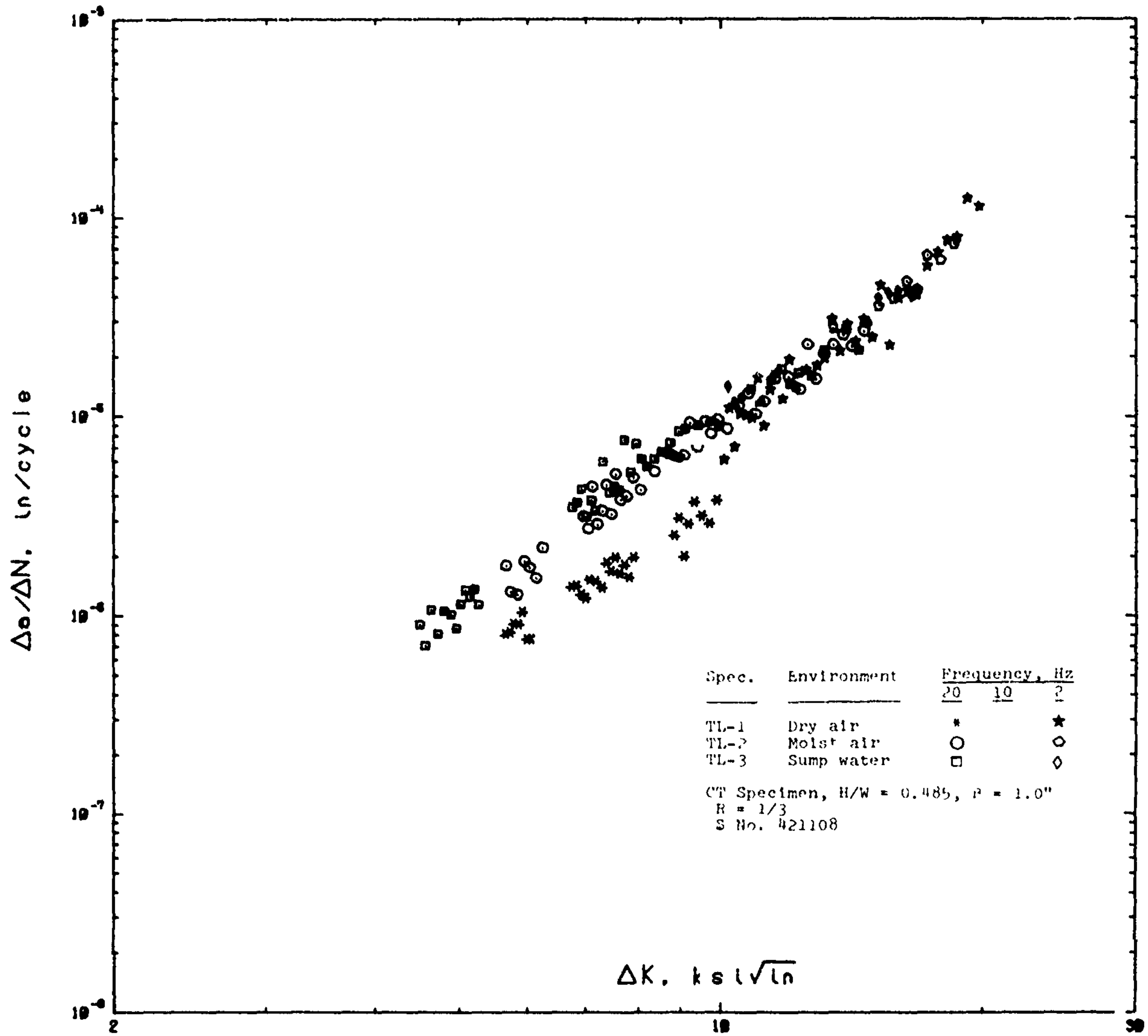


Fig. 32 Fatigue Crack-Growth Data for 1-in. 2048-T851 Plate T-L Orientation

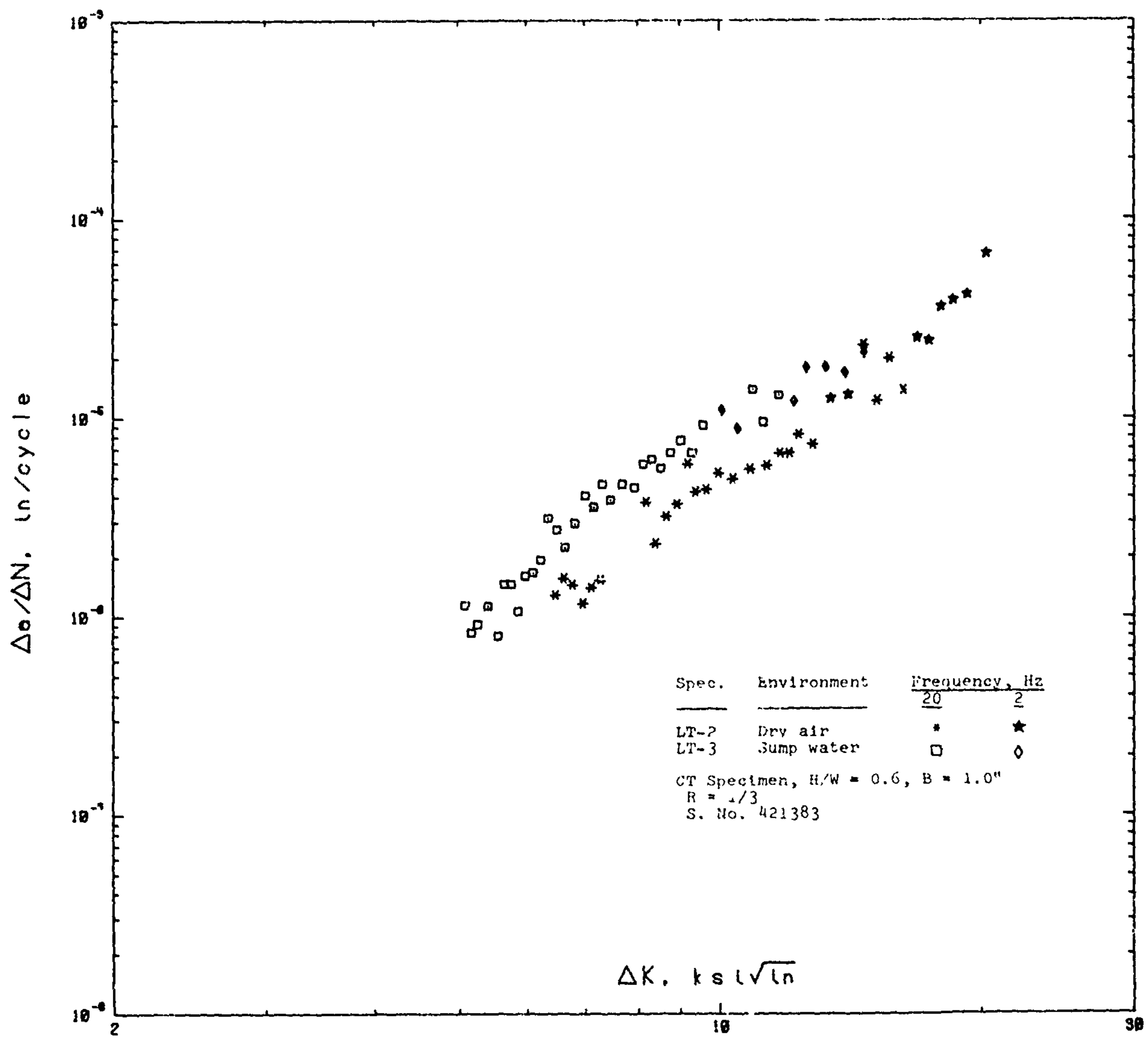


Fig. 33 Fatigue Crack-Growth Data for 4-in. 2048-T851 Plate L-T Orientation

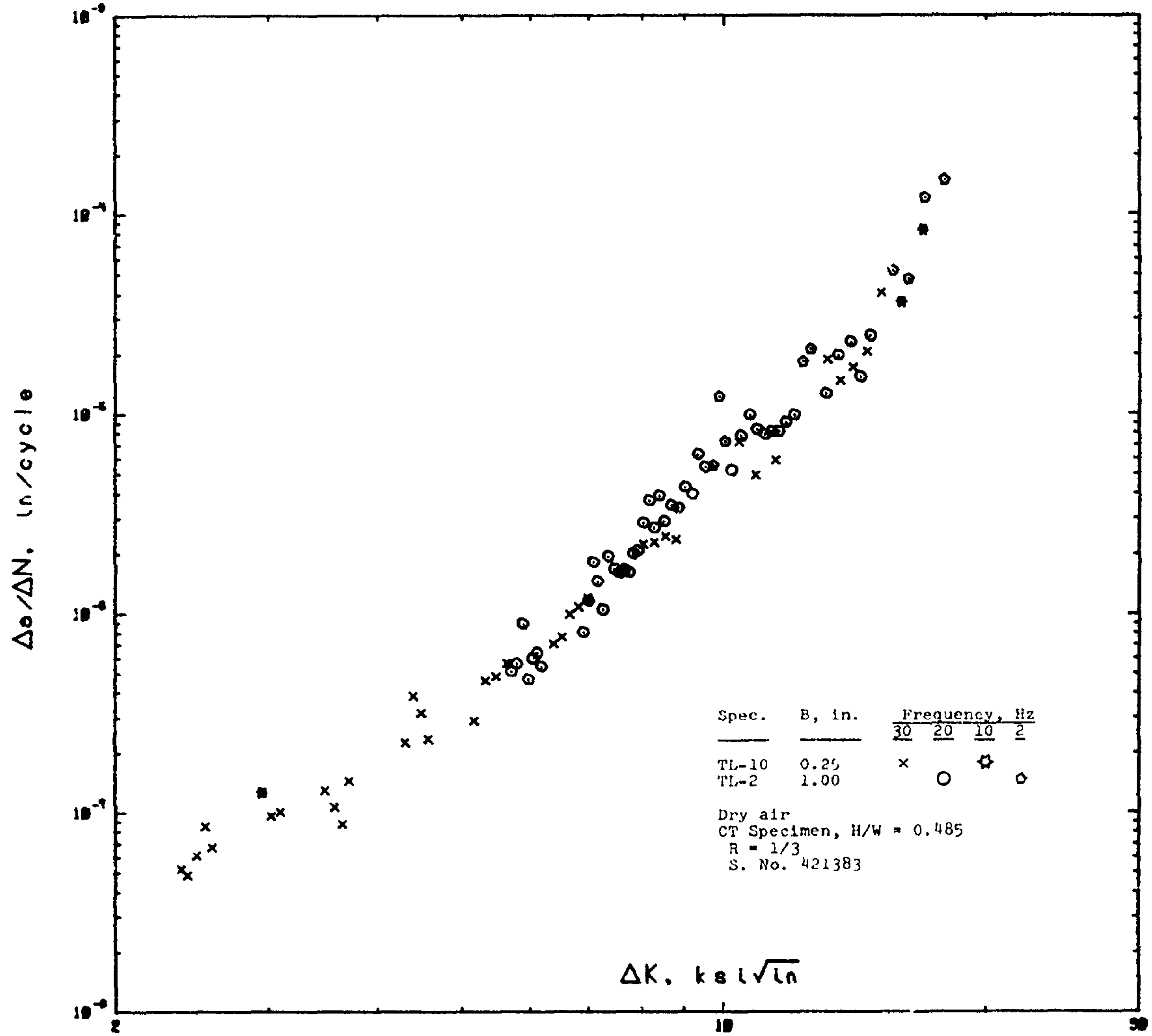


Fig. 34 Fatigue Crack-Growth Data for 4 in. 2048-T851 Plate T-L Orientation (dry air)

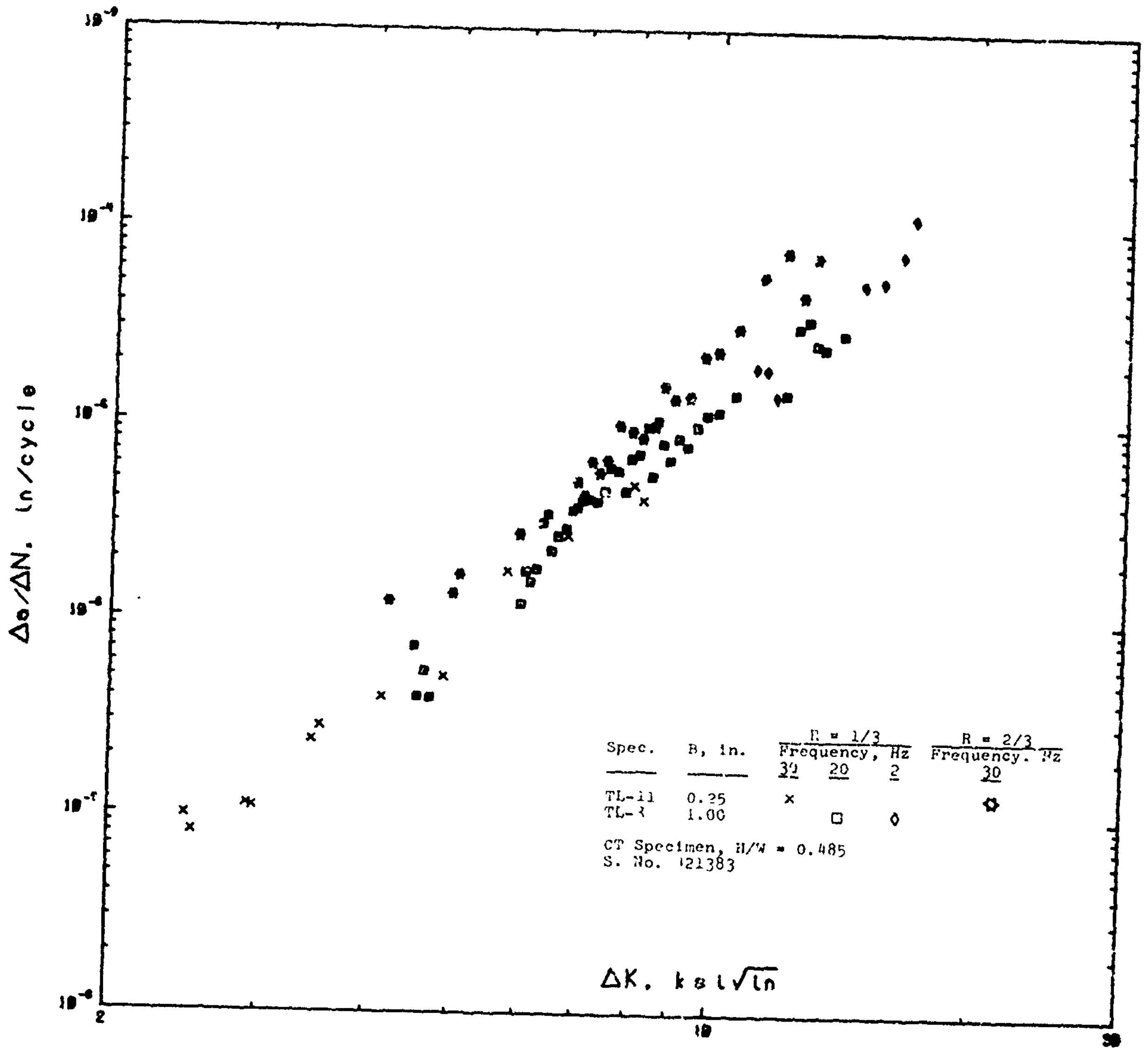


Fig. 35 Fatigue Crack-Growth Data for 4-in 2048-T851 Plate
T-L Orientation (sump water)

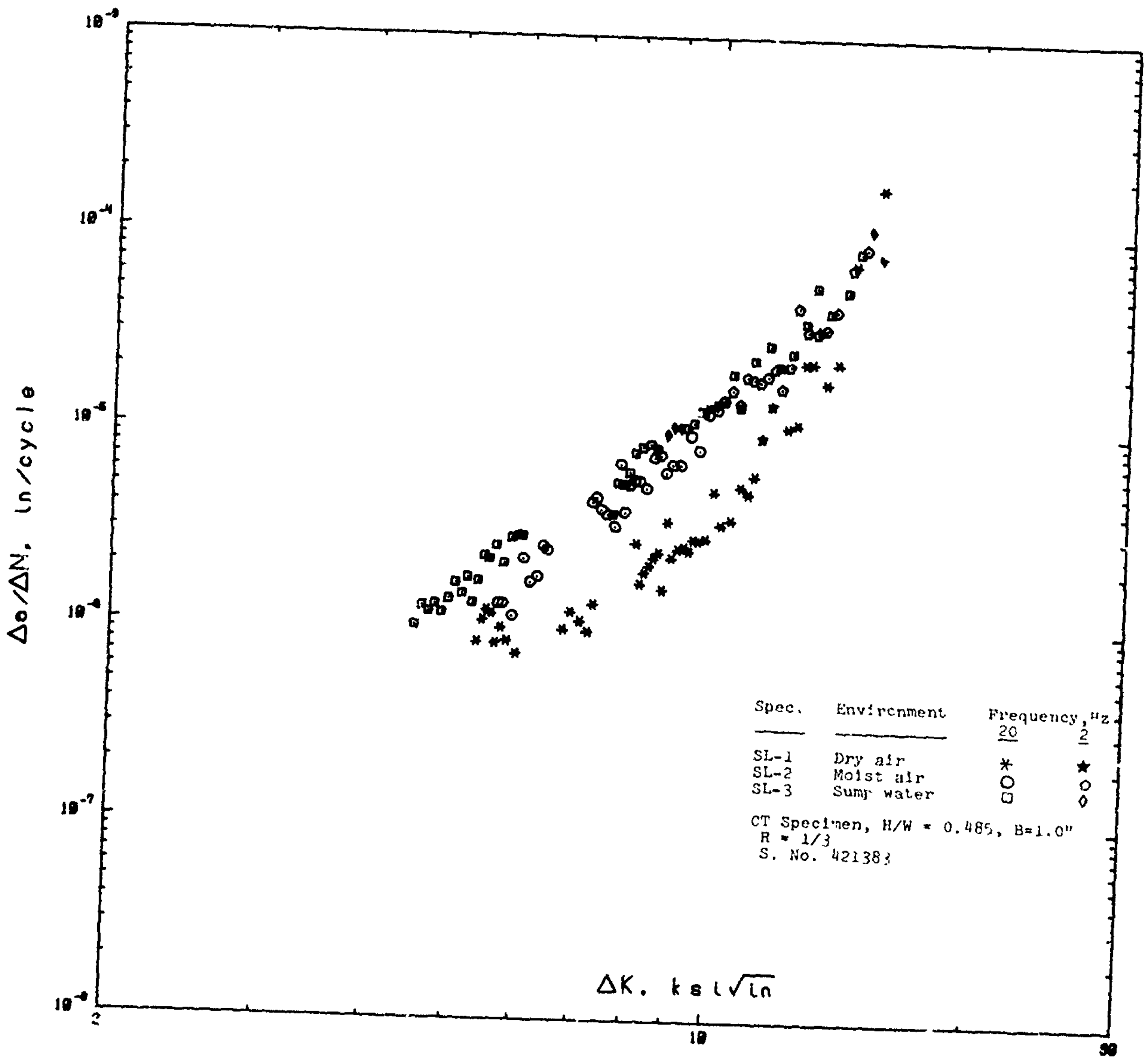


Fig. 36 Fatigue Crack-Growth Data for 4-in. 2049-T851 Plate S-L Orientation

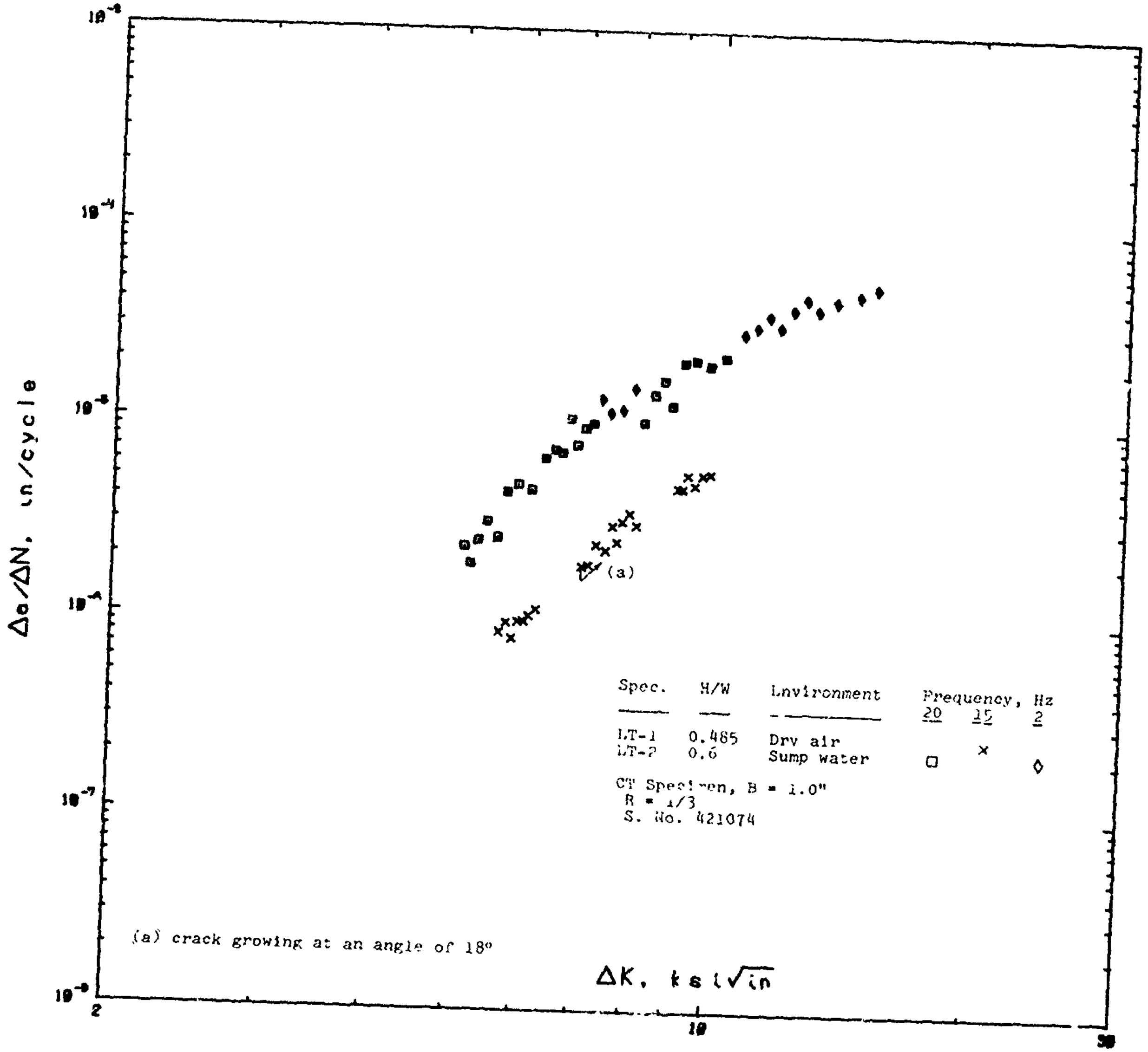


Fig. 37 Fatigue Crack-Growth Data for 2-in. 7050-T7351 Plate
L-T Orientation

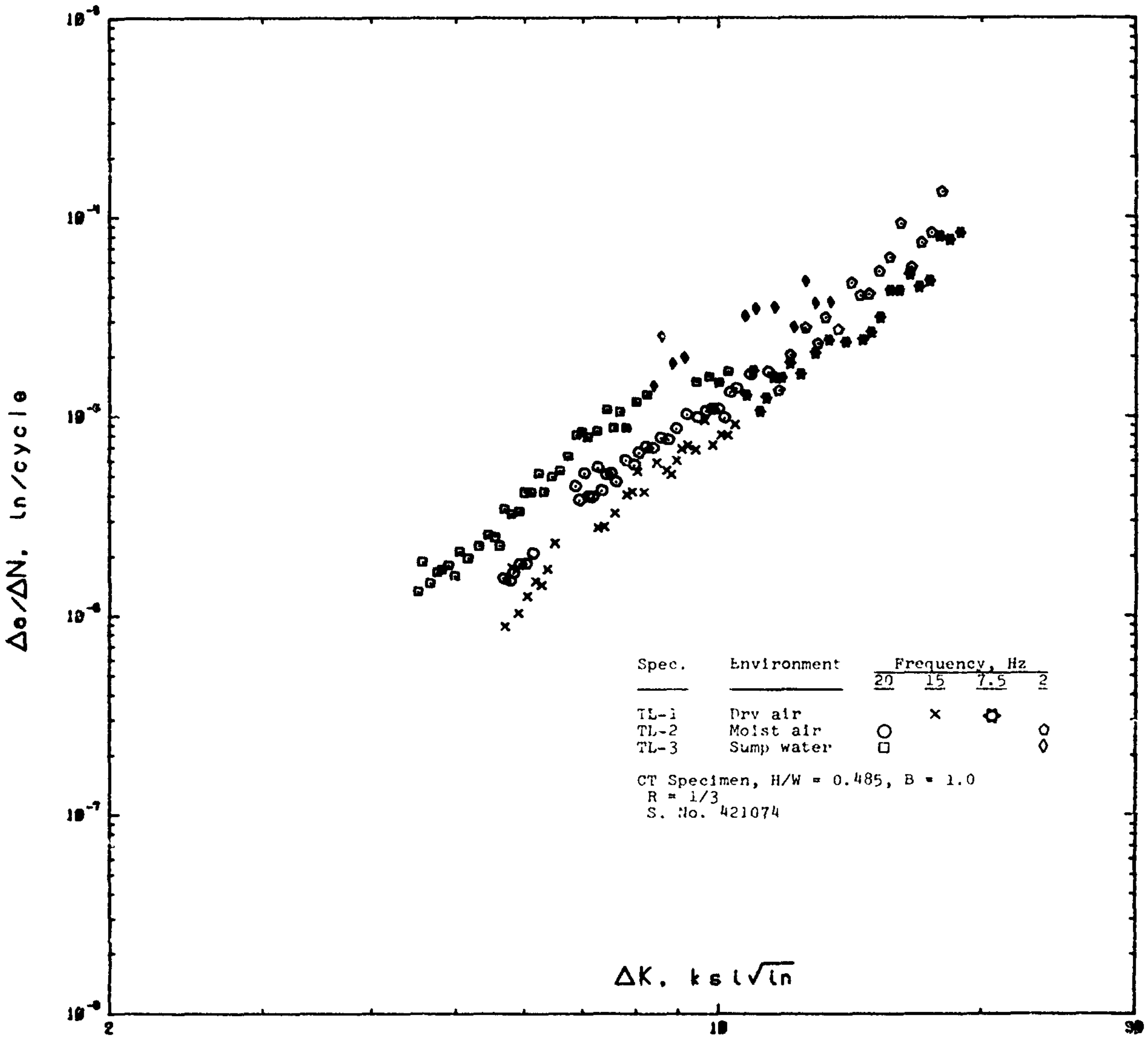


Fig. 38 Fatigue Crack-Growth Data for 2-in. 7050-T7351 Plate
T-L Orientation

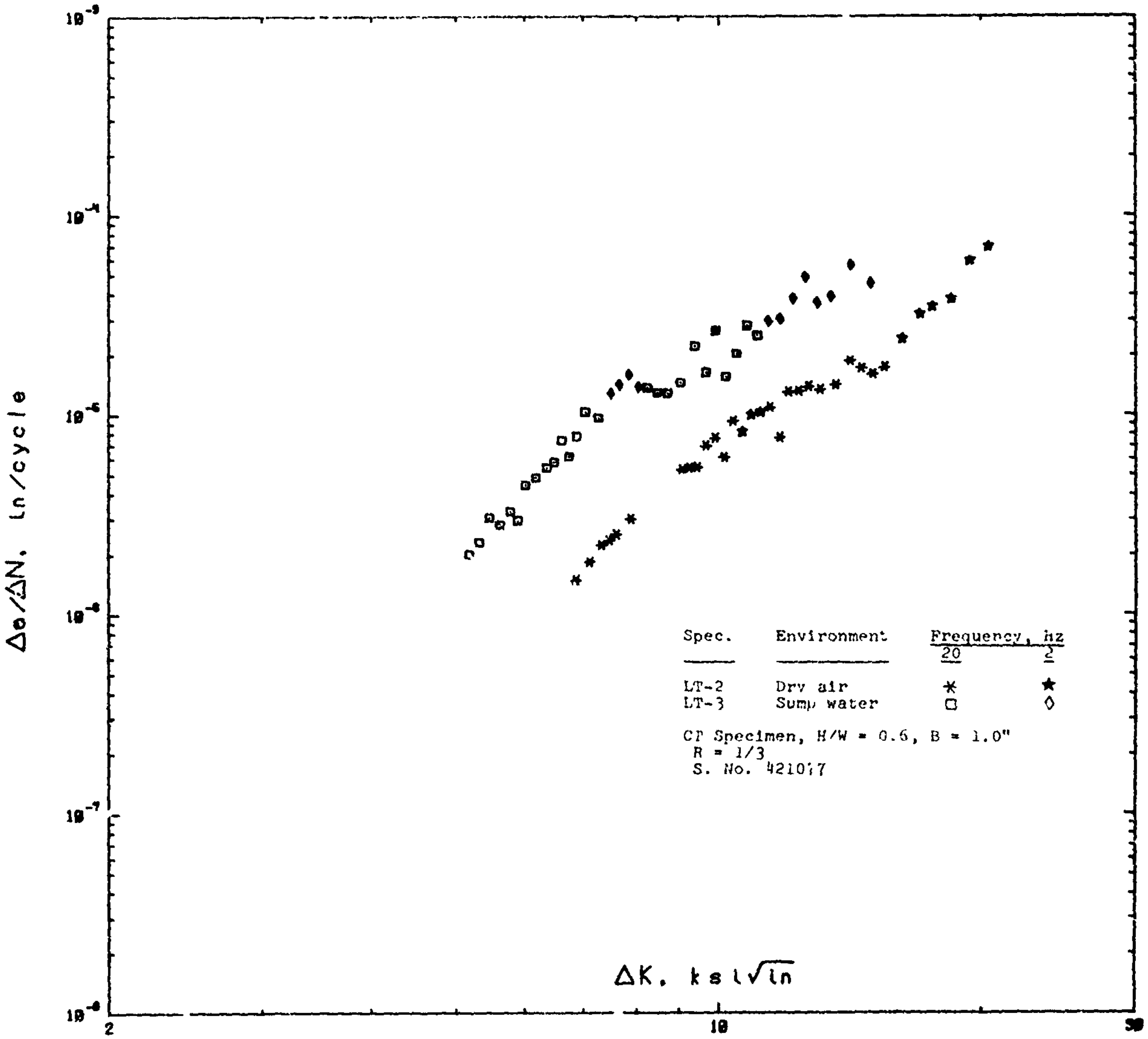


Fig. 39 Fatigue Crack-Growth Data for 4-in. 7050-T7 351 Plate
L-T Orientation

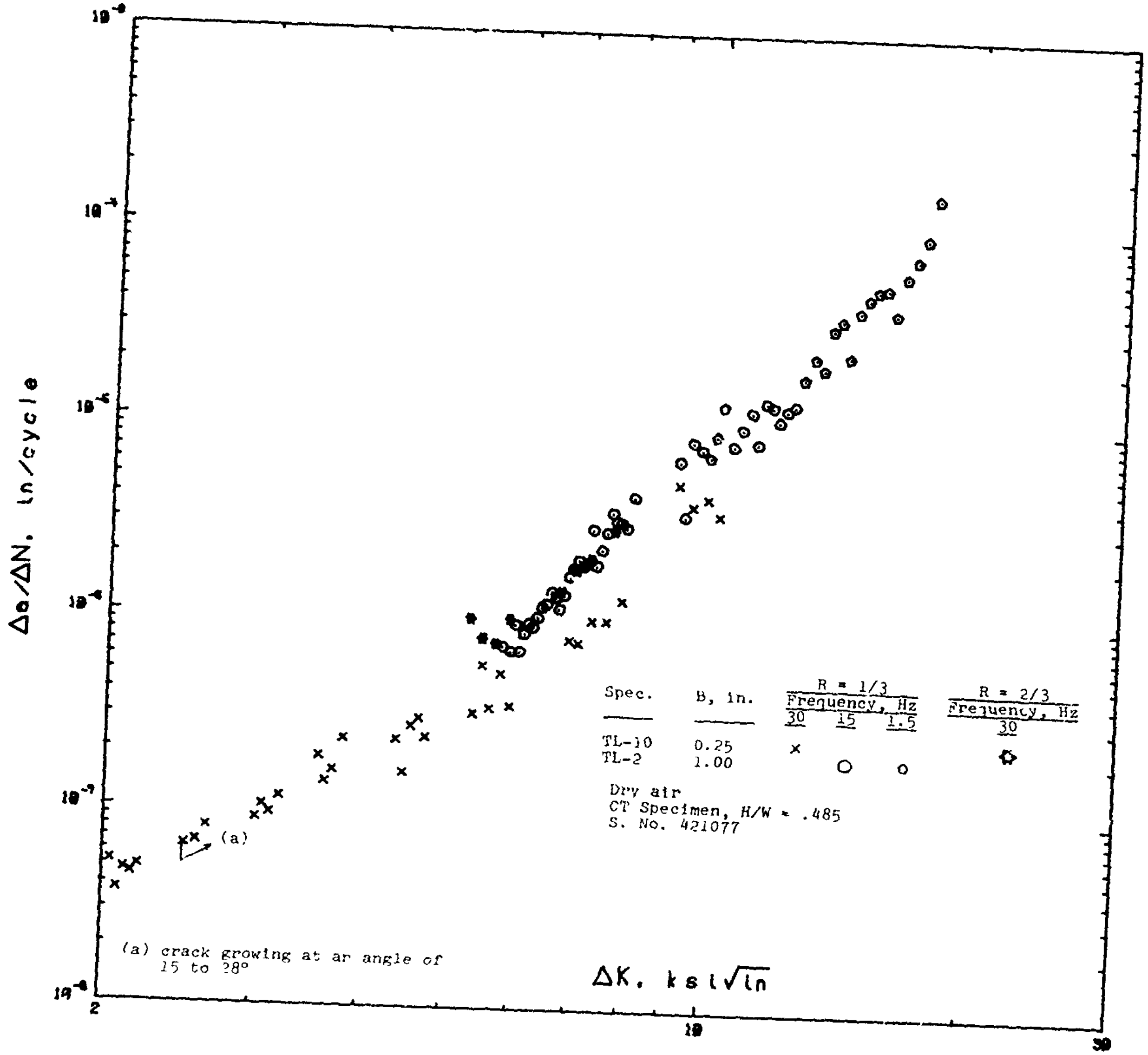


Fig. 40 Fatigue Crack-Growth Data for 4-in. 7050-T7351 Plate T-L Orientation (dry air)

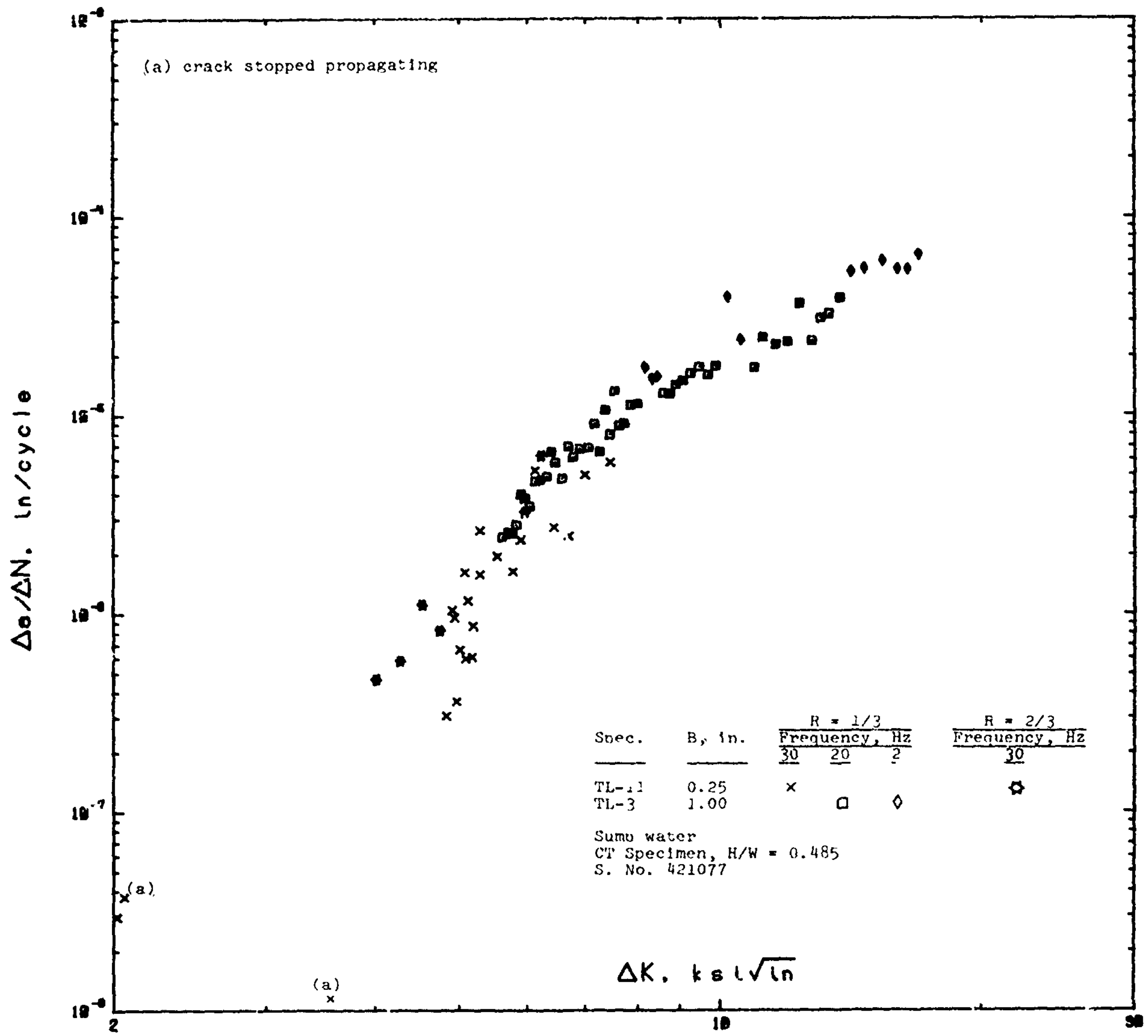


Fig. 41 Fatigue Crack-Growth Data for 4-in. 7050-T7351 Plate T-L Orientation (sump water)

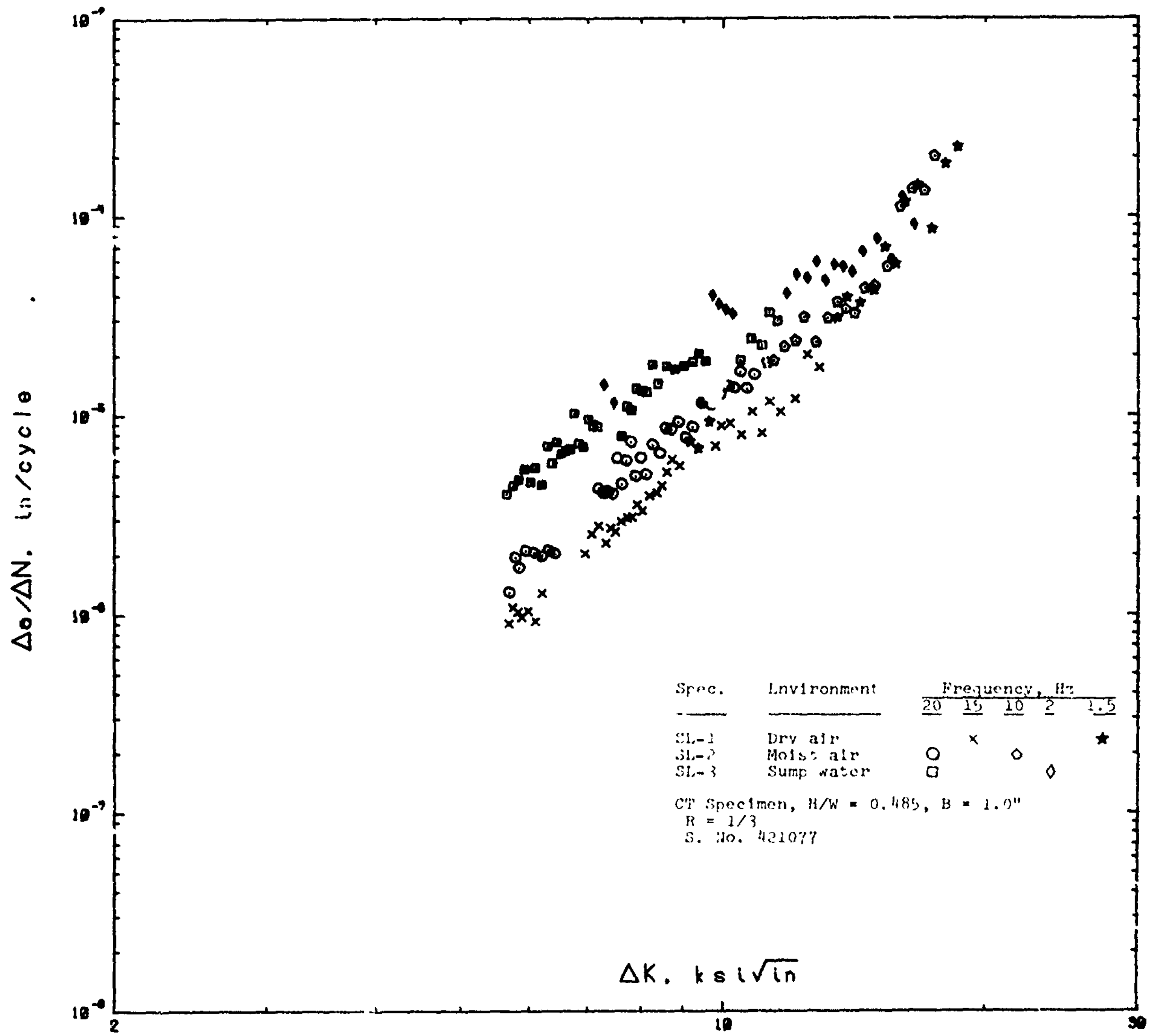


Fig. 42 Fatigue Crack-Growth Data for 4-in. 7050-T7351 Plate S-L Orientation

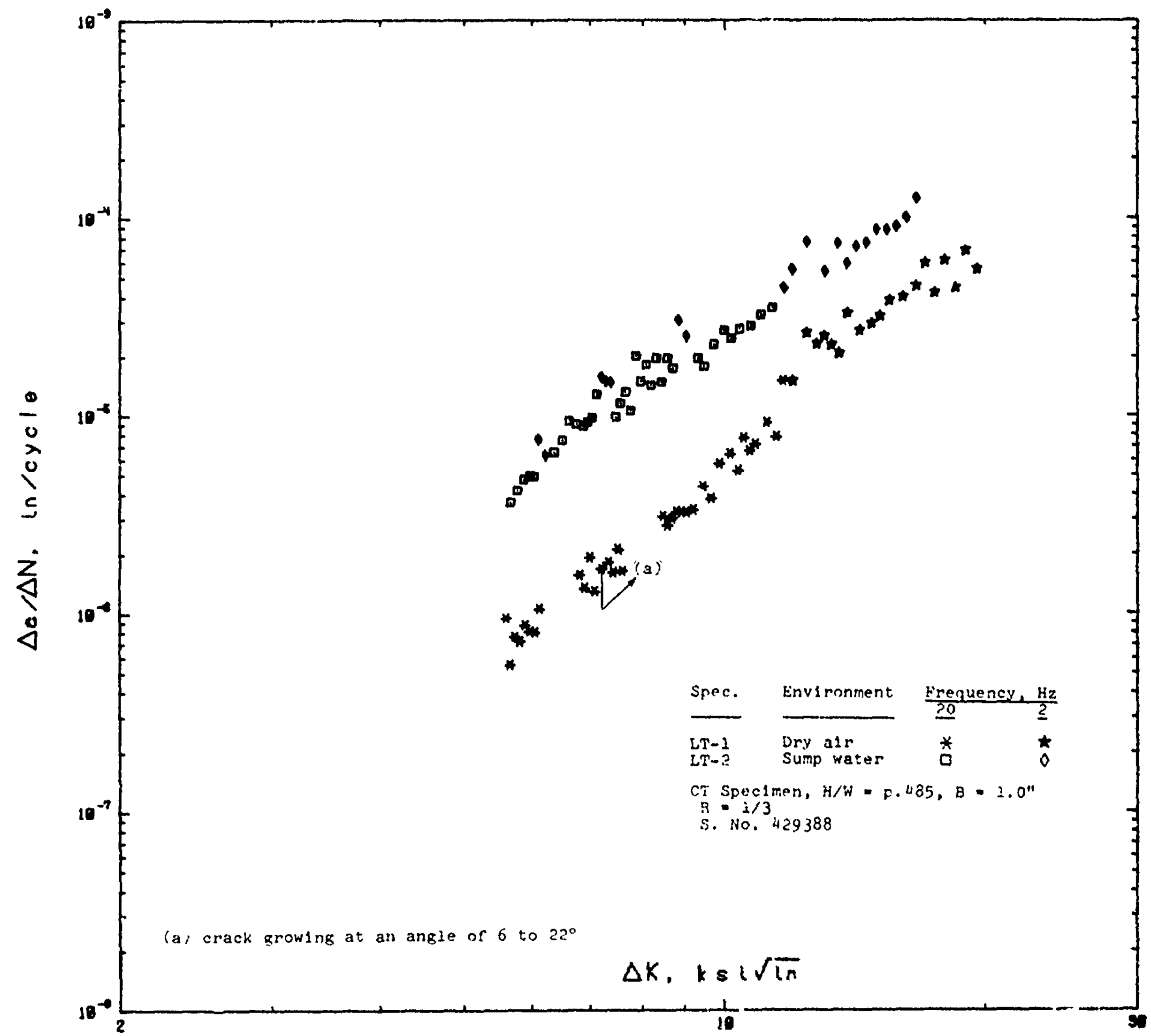


Fig. 43 Fatigue Crack-Growth Data for 1-in. 7475-T7351 Plate L-T Orientation

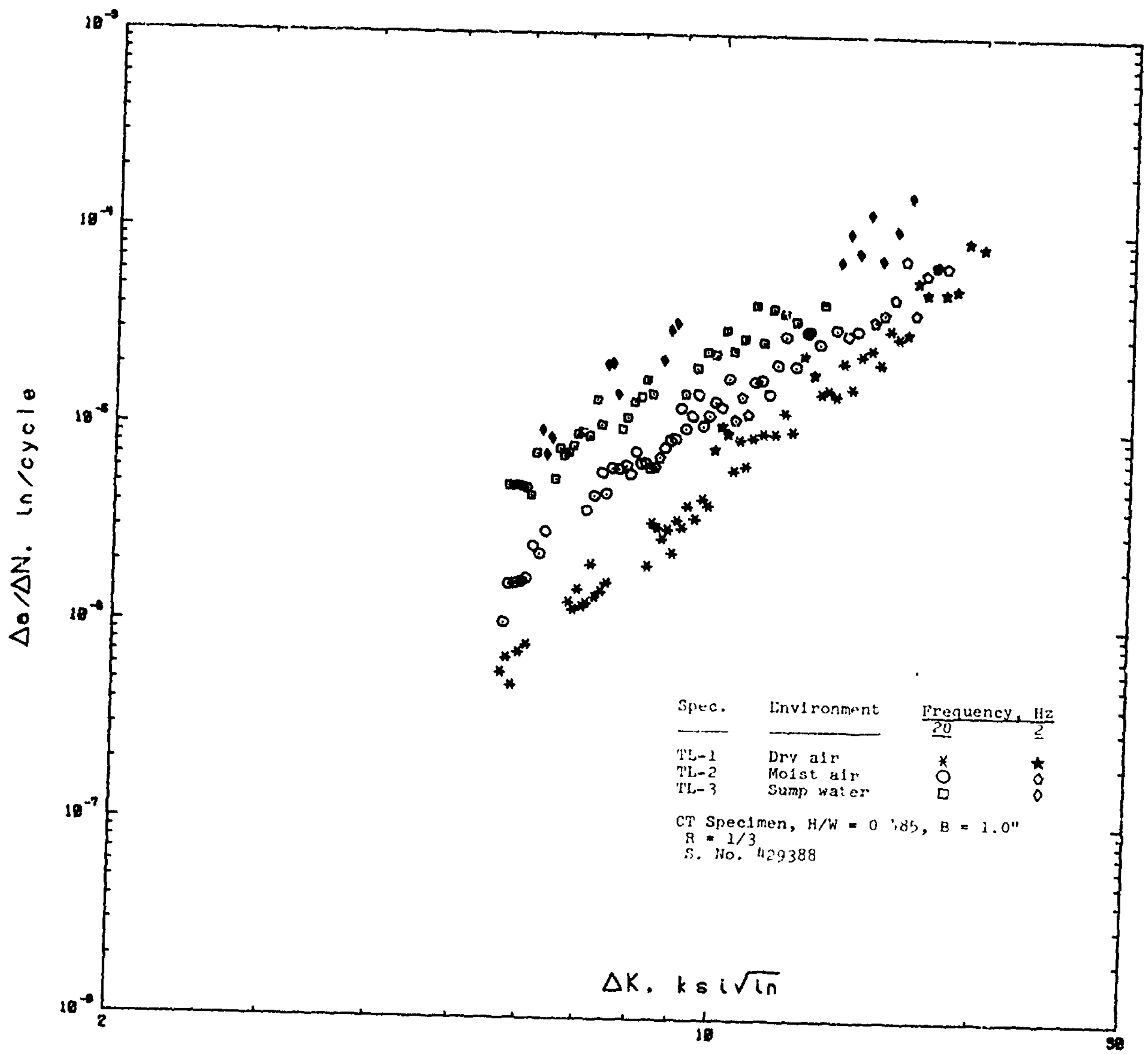


Fig. 44 Fatigue Crack-Growth Data for 1-in. 7475-T7351 Plate
T-L Orientation

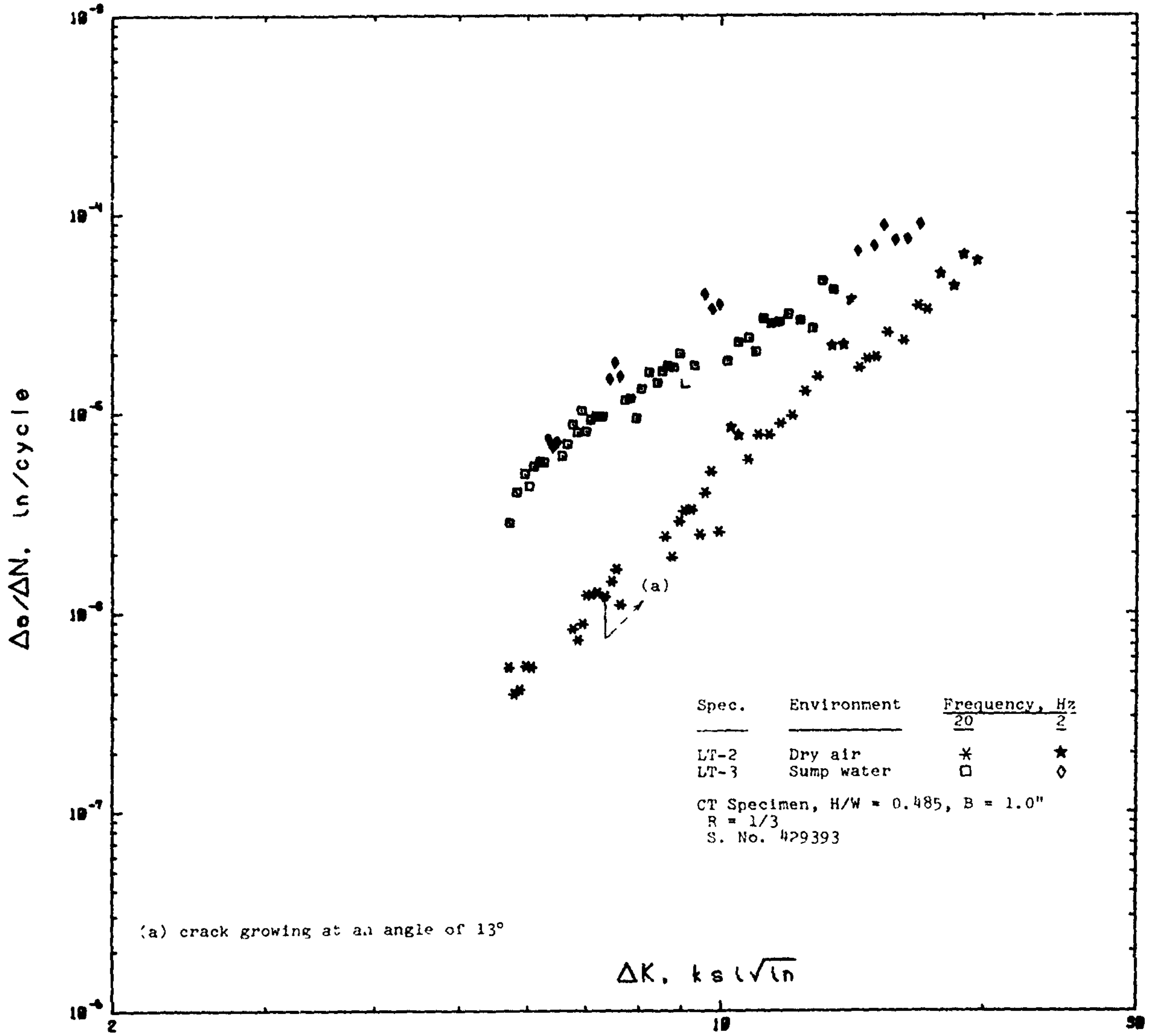


Fig. 45 Fatigue Crack-Growth Data for 4-in. 7475-T7351 Plate L-T Orientation

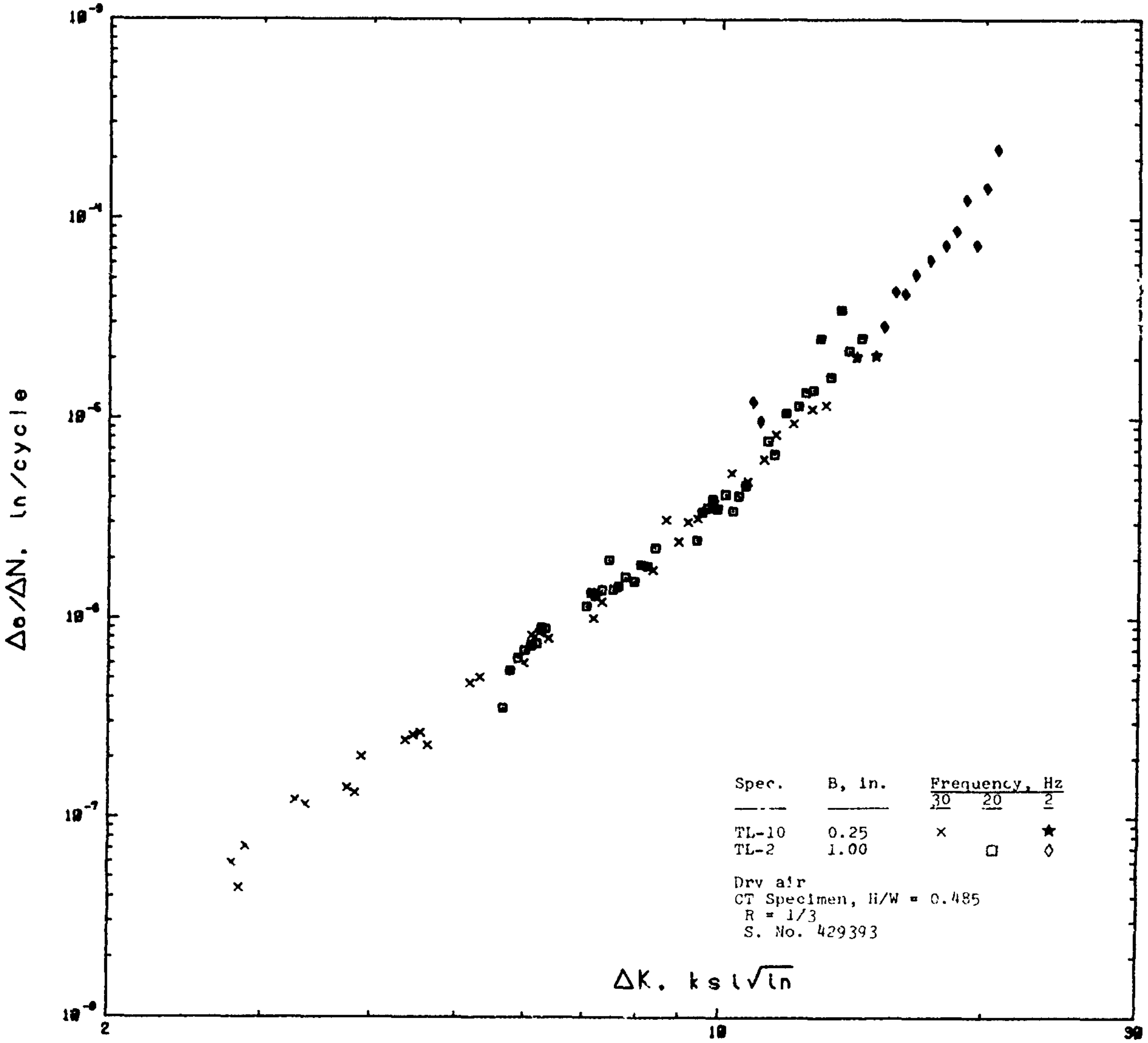


Fig. 46 Fatigue Crack-Growth Data for 4-in. 7475-T7351 Plate
T-L Orientation (dry air)

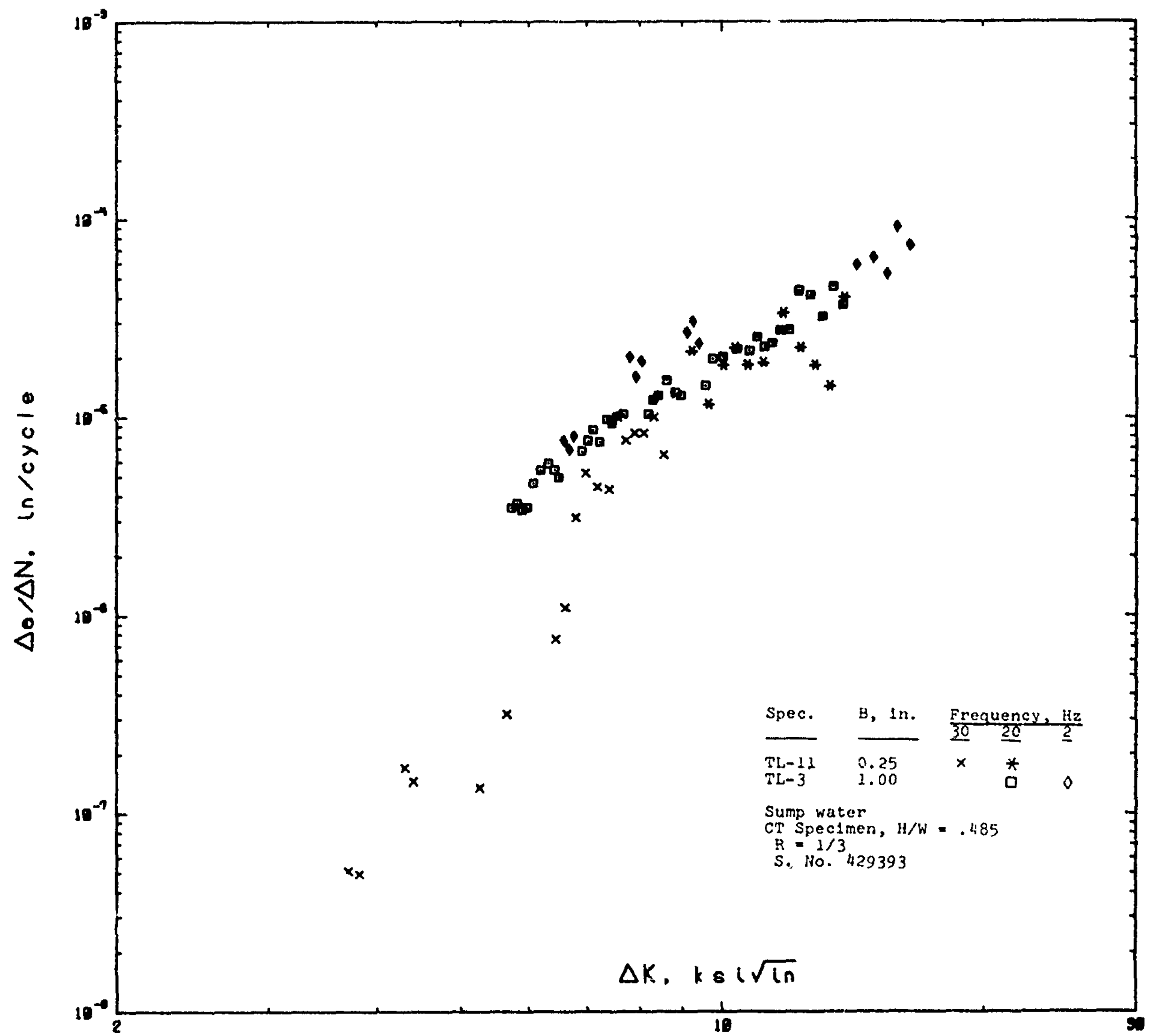


Fig. 47 Fatigue Crack-Growth Data for 4-in. 7475-T7351 Plate T-L Orientation (sump water)

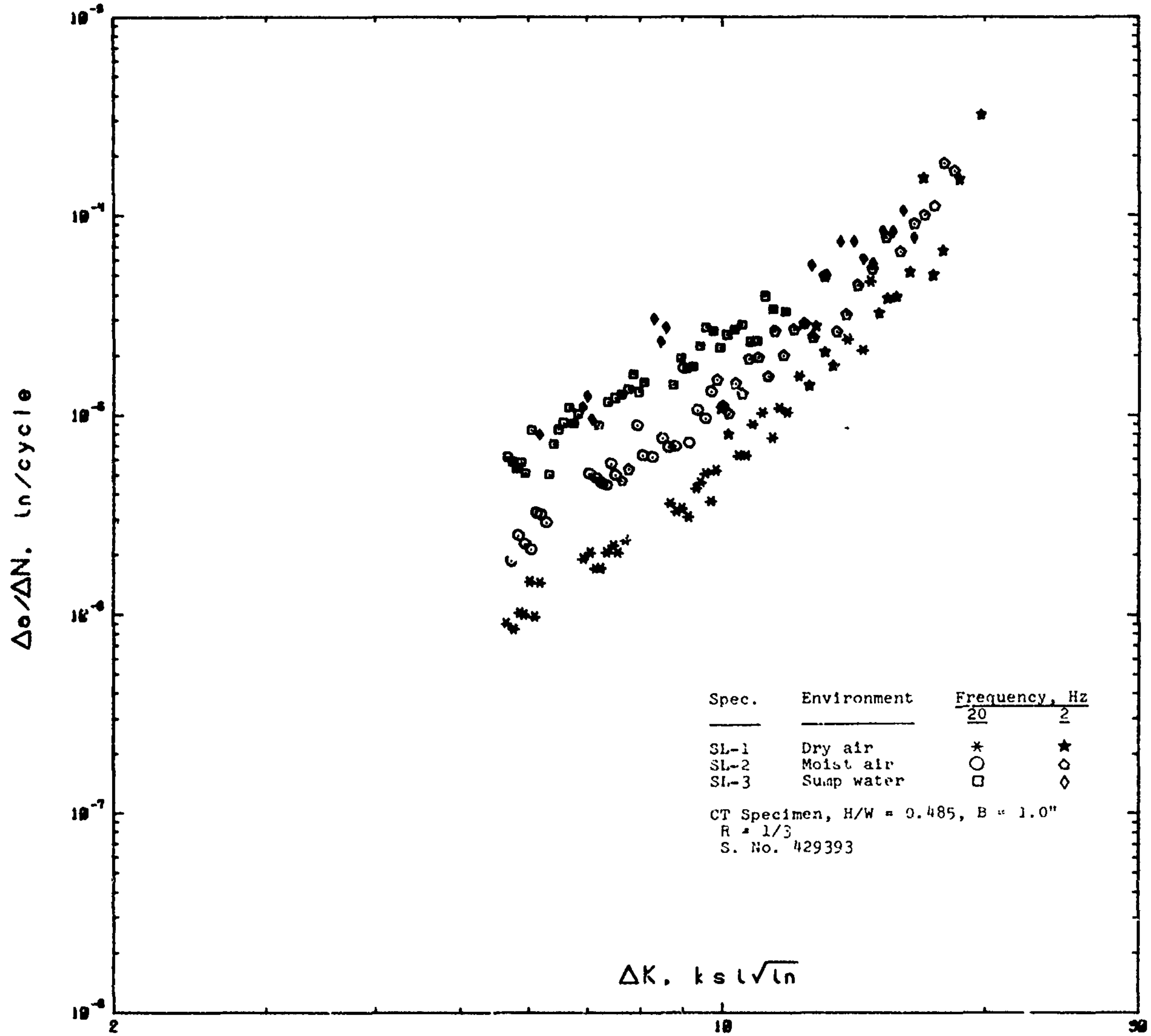


Fig. 48 Fatigue Crack-Growth Data for 4-in. 7475-T7351 Plate S-L Orientation

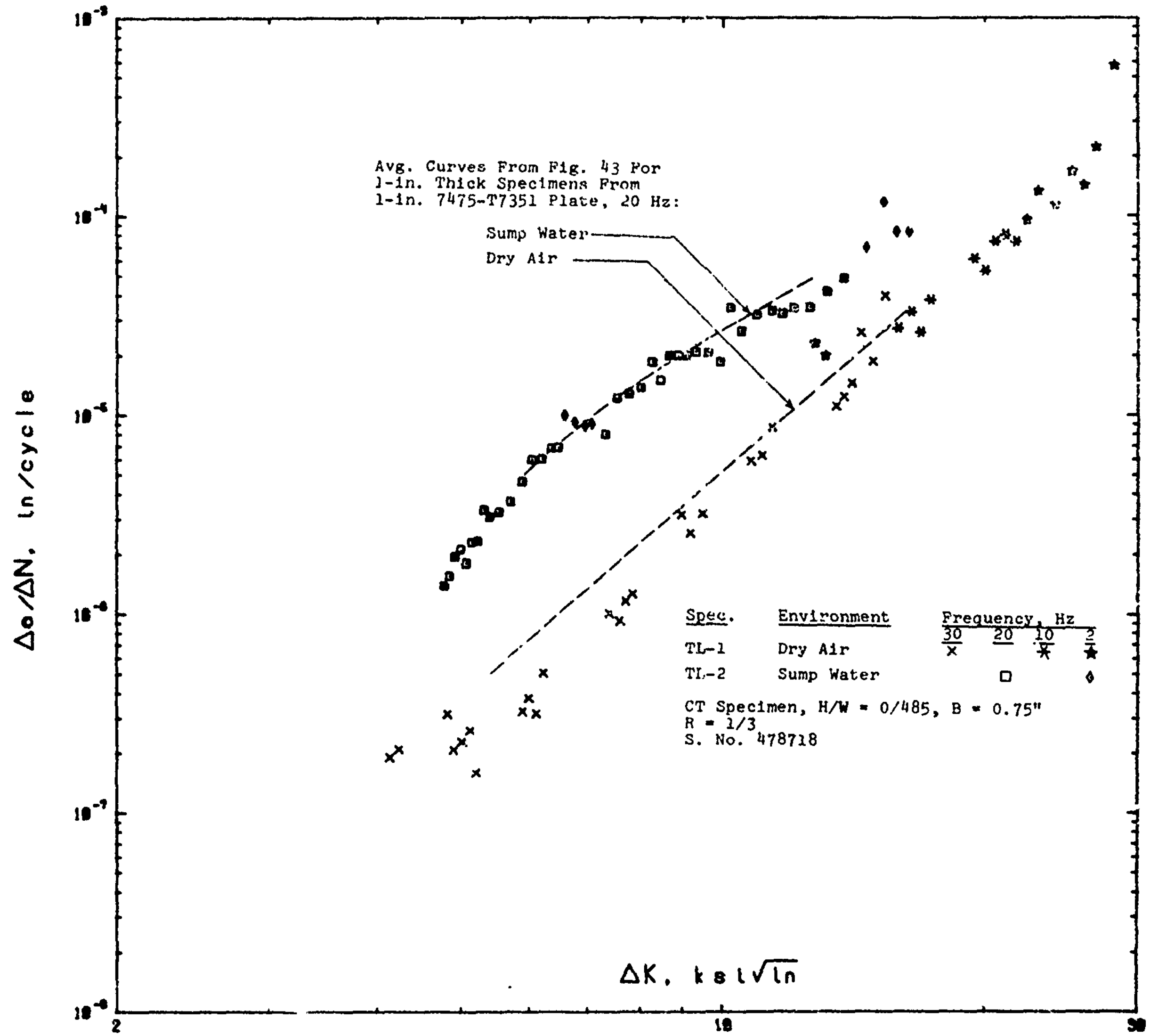


Fig. 49 Fatigue-Crack Growth Data for 3/4 in. 7475-T7351 Plate (Current Practice)
T-L Orientation

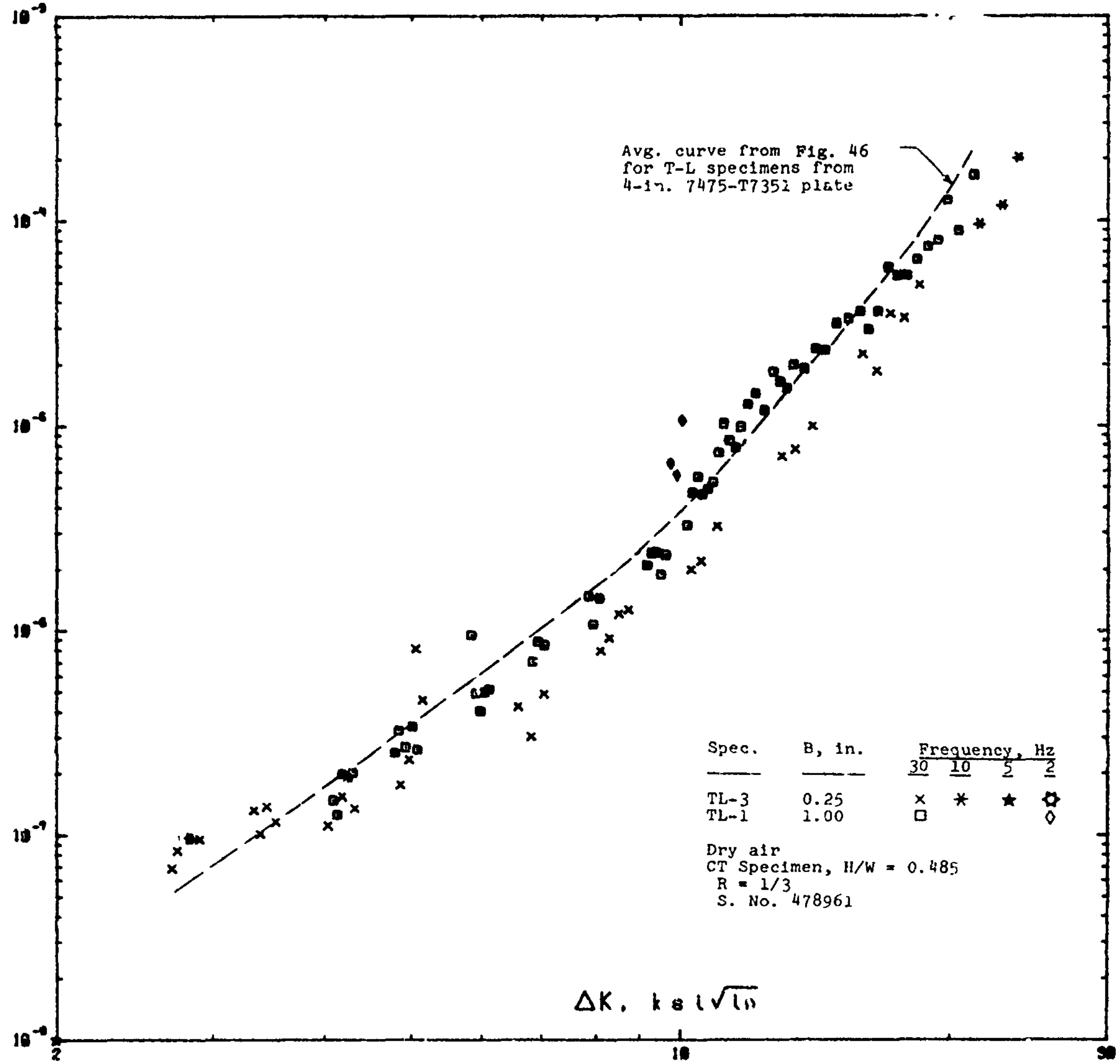


Fig. 50 Fatigue Crack-Growth Data for 3.5-in. 7475-T7351 Plate (Current Practice) T-L Orientation (dry air)

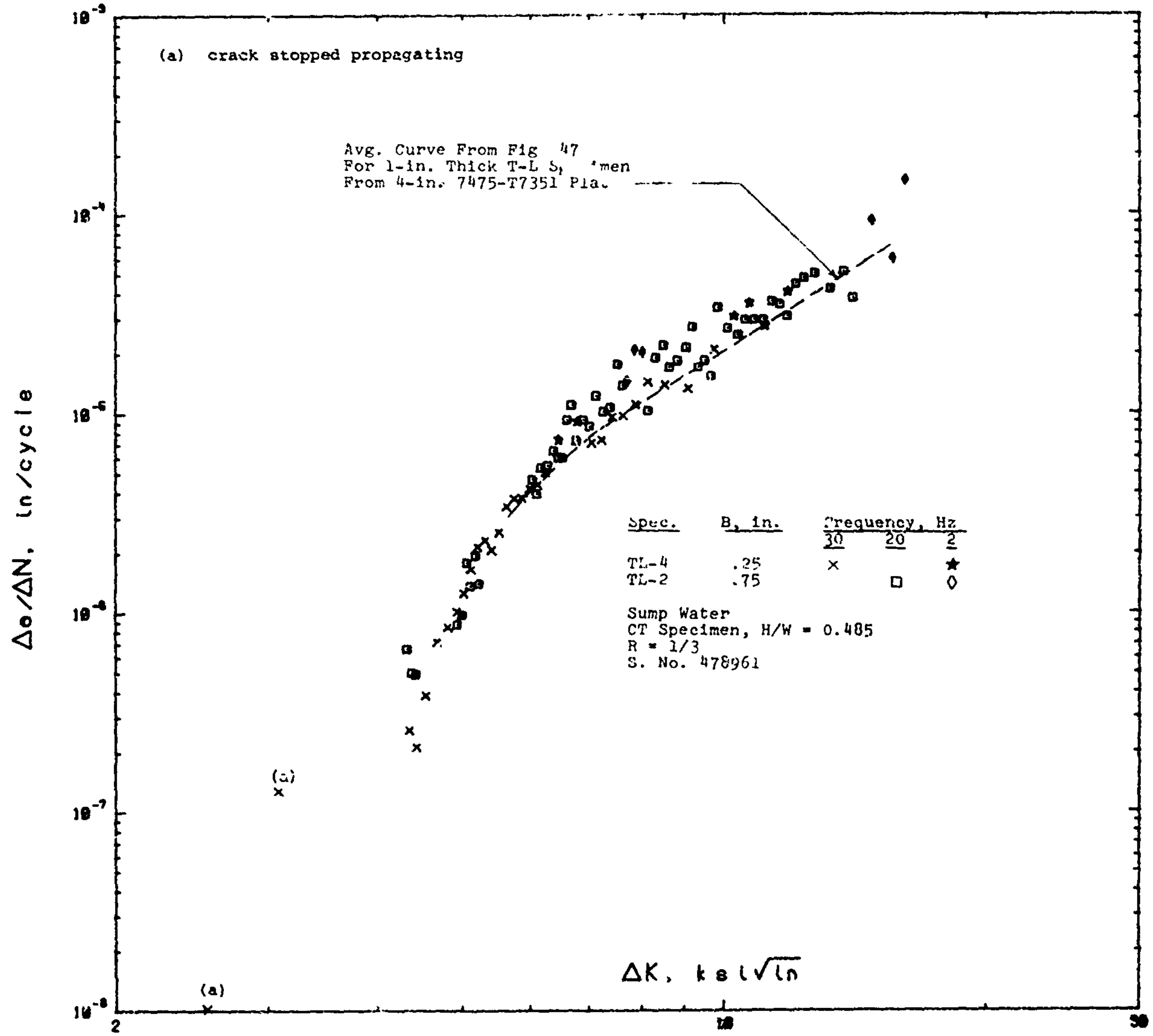


Fig. 51 Fatigue-Crack Growth Data for 3.5 in. 7475-T7351 Plate (Current Practice) T-L Orientation (Sump Water)

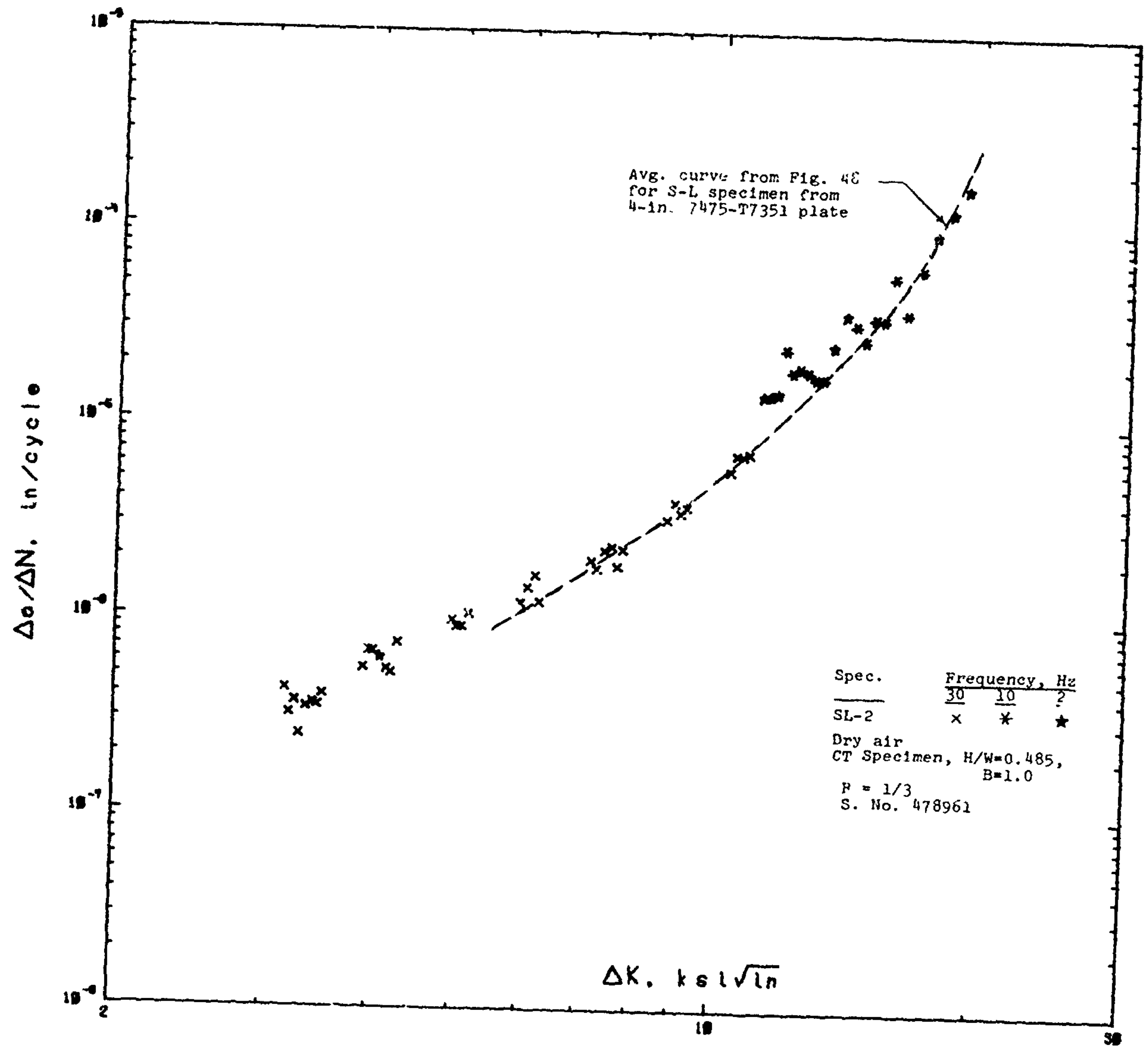


Fig. 52. Fatigue-Crack Growth Data for 3.5-in. 7475-T7351 Plate (Current Practice) S-L Orientation (dry air)

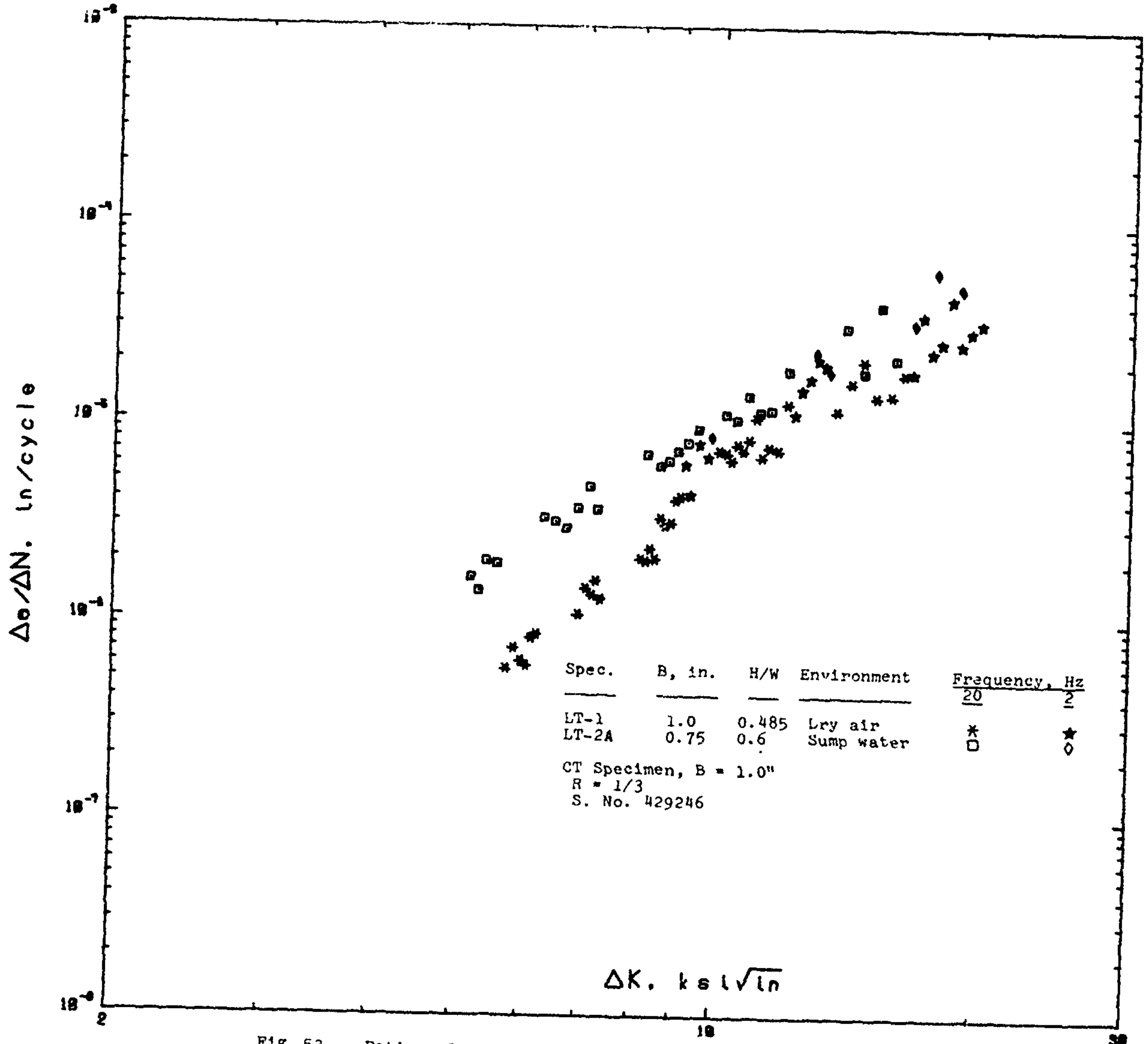


Fig. 53 Fatigue Crack-Growth Data for a 2 x 8-in. 2219-T852 Hand Forging L-T Orientation

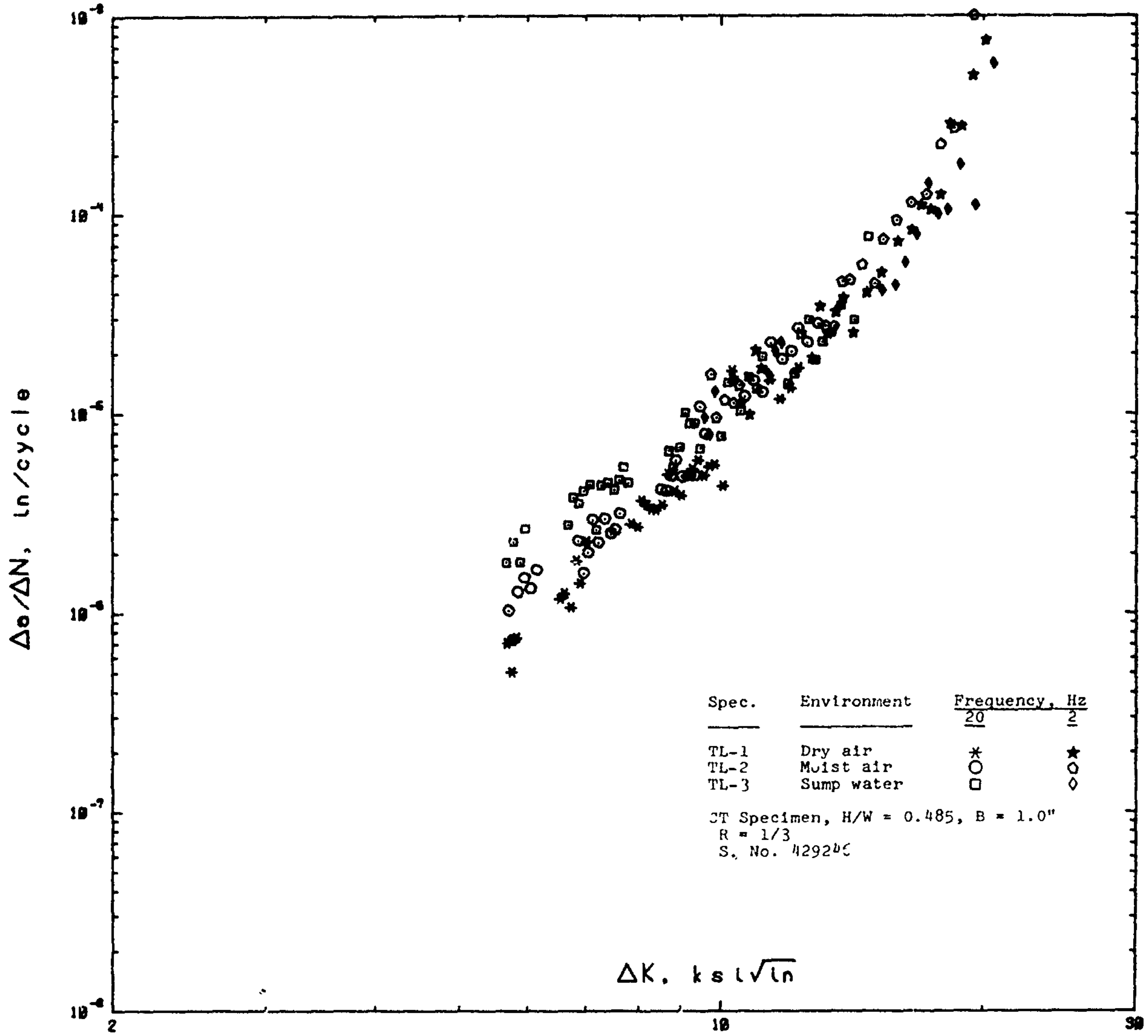


Fig. 54 Fatigue Crack-Growth Data for a 2 x 8-in. 2219-T852 Hand Forging T-L Orientation

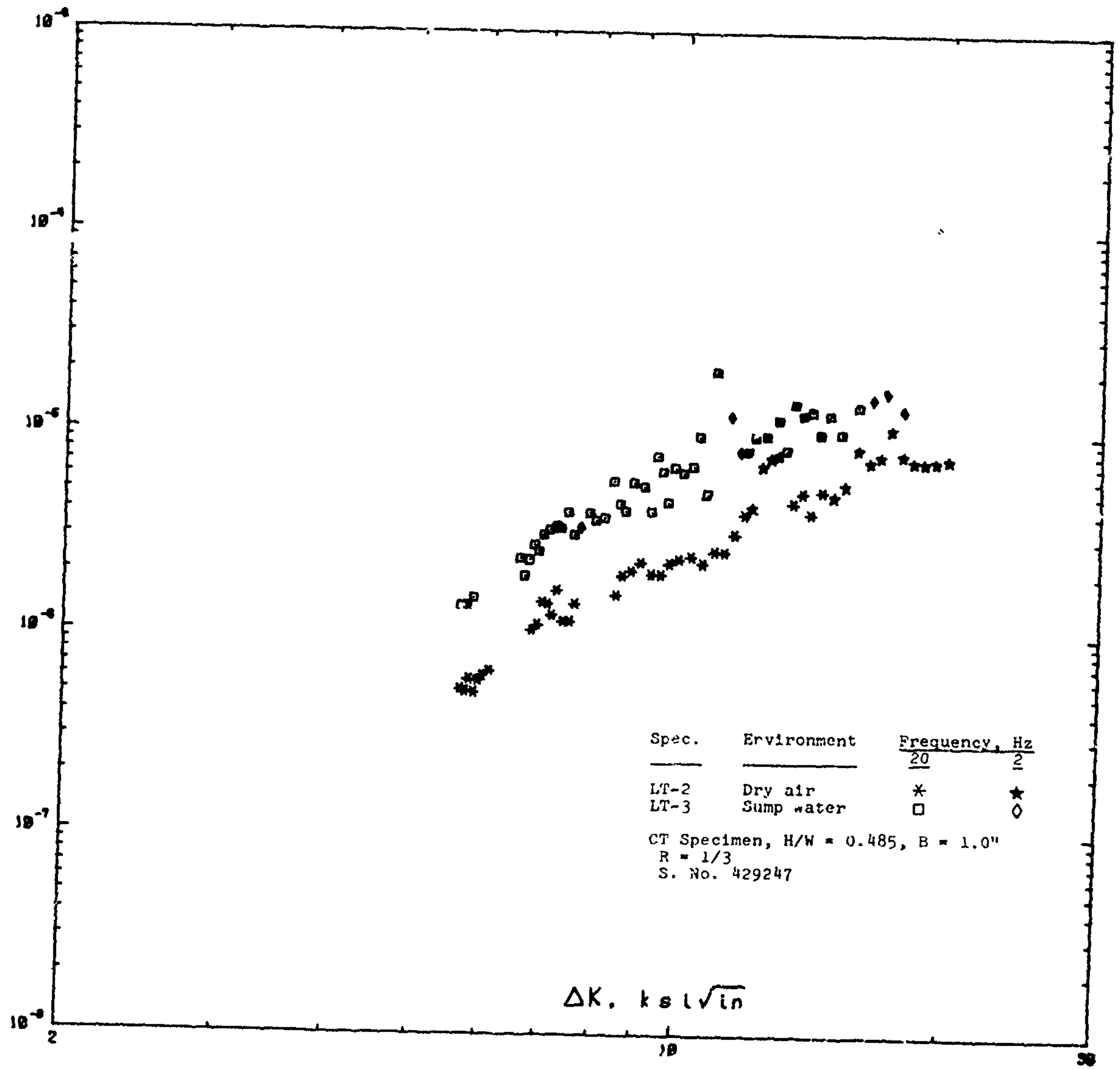


Fig. 55 Fatigue Crack-Growth Data for a 5.5 x 2?-in. 2219-T852 Hand Forging L-T Orientation

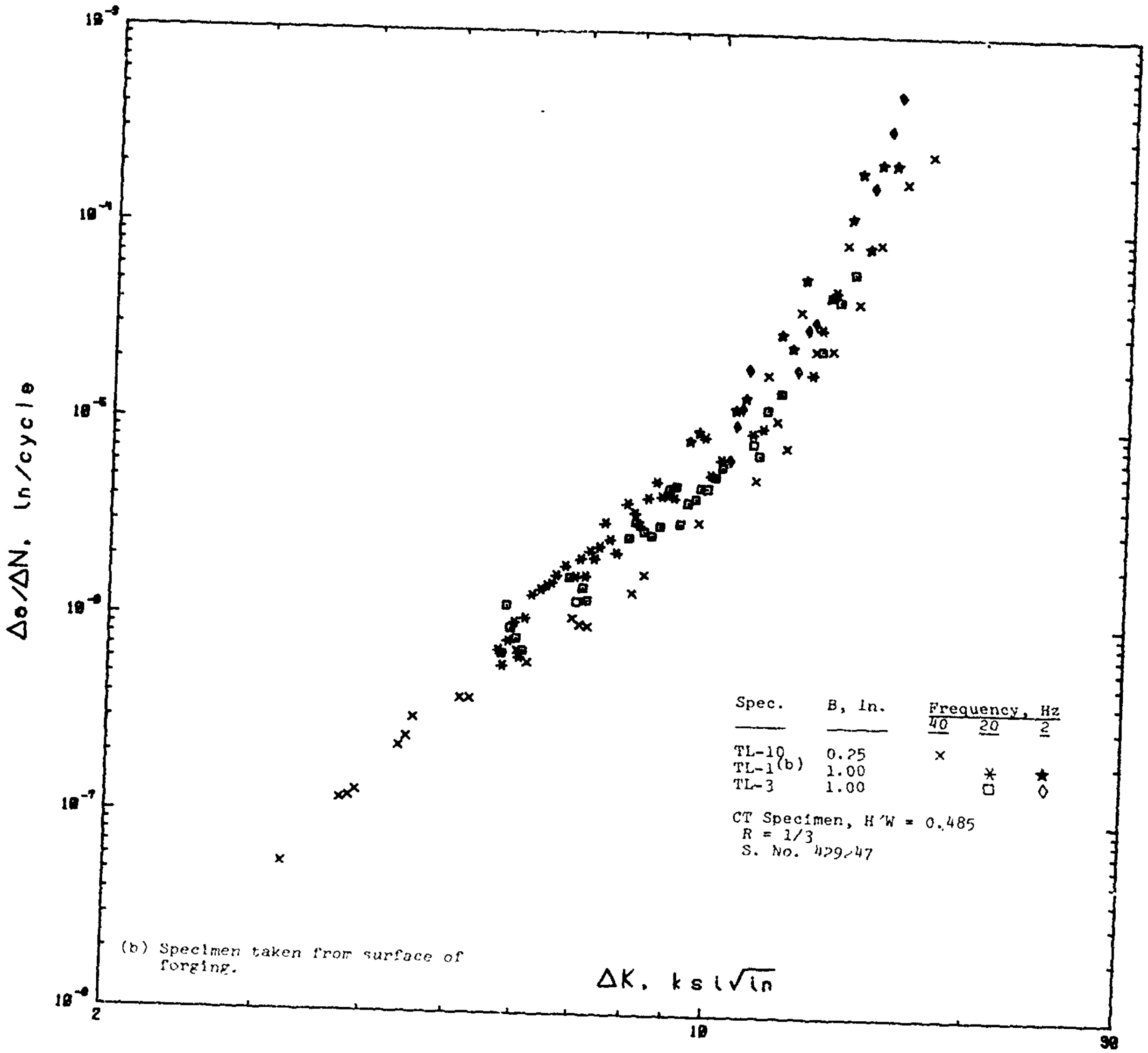


Fig. 56 Fatigue Crack-Growth Data for a 5.5 x 22-in. 2219-T852 Hand Forging T-L Orientation (dry air)

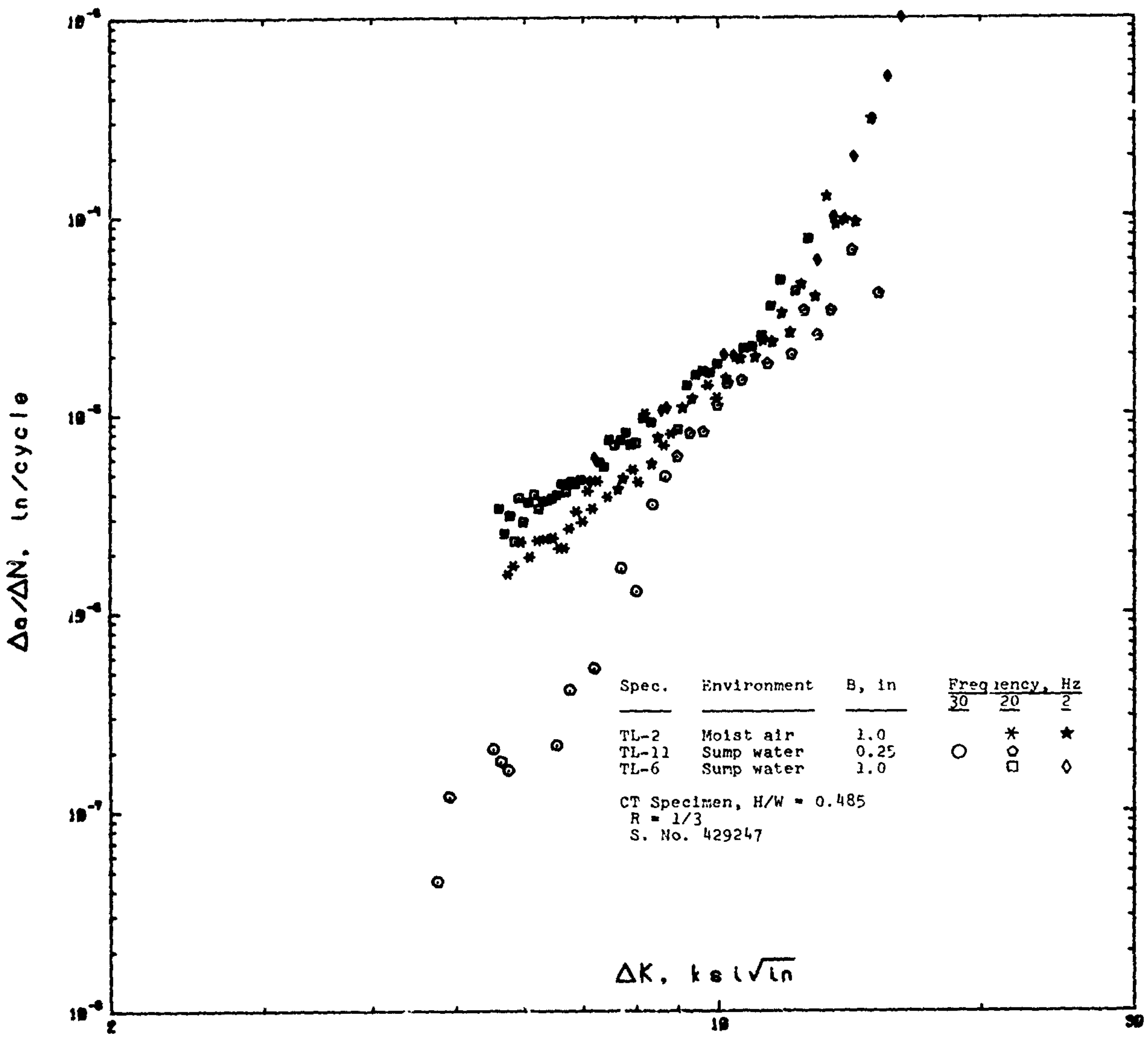


Fig. 57 Fatigue Crack-Growth Data for a 5.5 x 22-in. 2219-T852 Hand Forging T-L Orientation

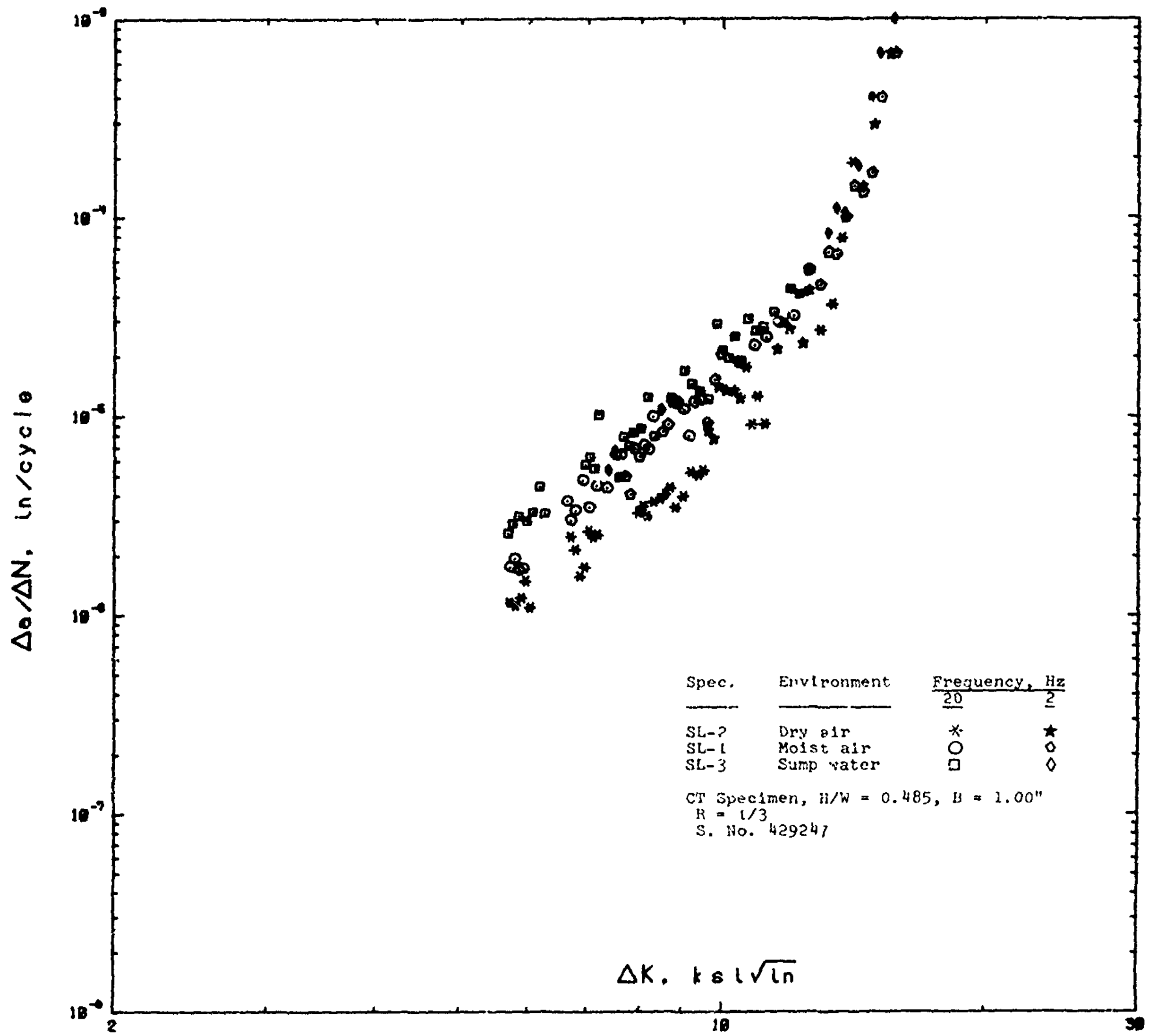


Fig. 58 Fatigue Crack-Growth Data for a 5.5 x 22-in. 2219-T952 Hand Forging S-L Orientation

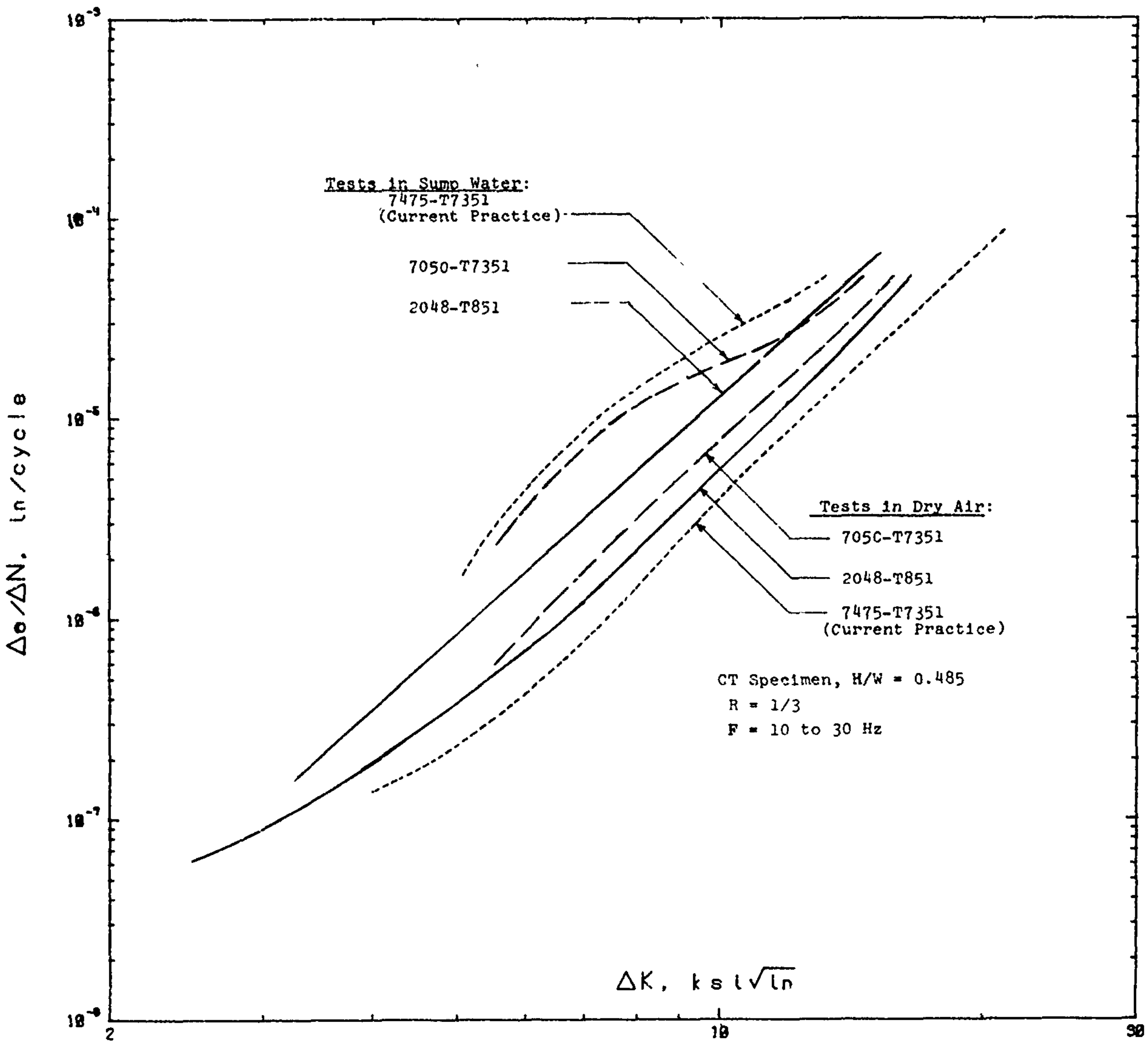
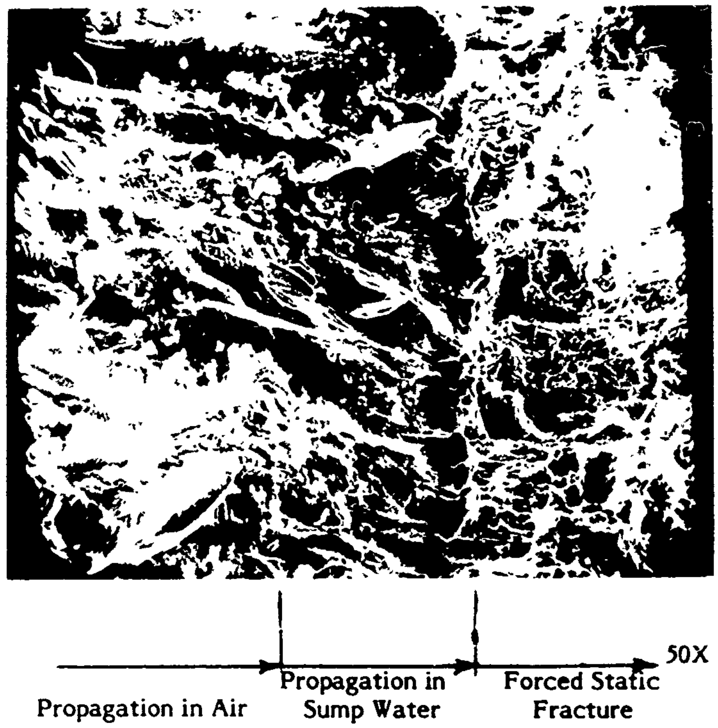
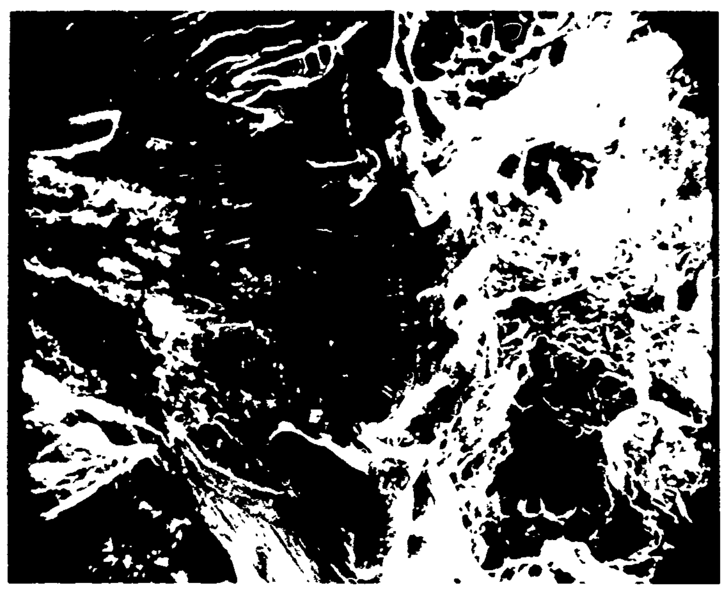


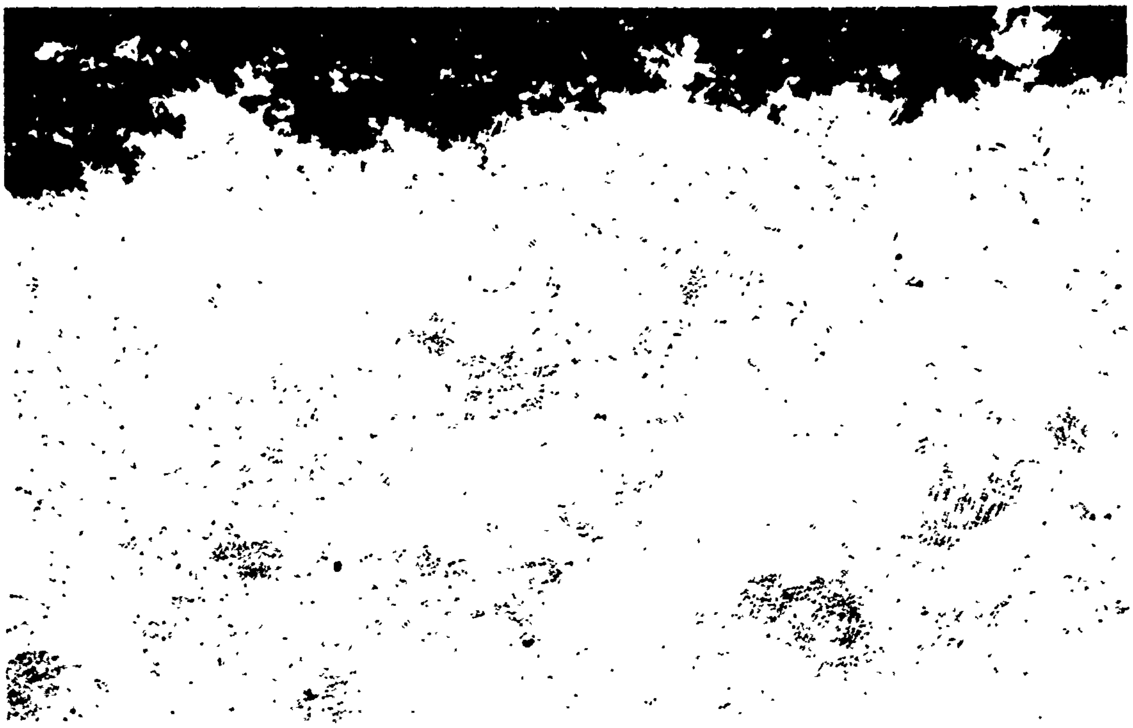
Fig. 59 Comparison of Fatigue-Crack Growth Rates for Thick Plate T-L Orientation





200X

Fig. 60 Sump Water Induced Arrest of Low Growth Rate Fatigue Crack in 7475-T7351 Plate (S.E.M.)



S. No. 478817-E2 Neg. 205122-A Mag: 100X

Fig. 61 Illustrates type of attack in center plane test panel from a 2.5-inch thick 2219-T852 alloy hand forging exposed to EXCO test.

S. No. 478817-E2 Neg. 205123 Mag: 500X

Fig. 62 View of Figure 61 at a higher magnification.

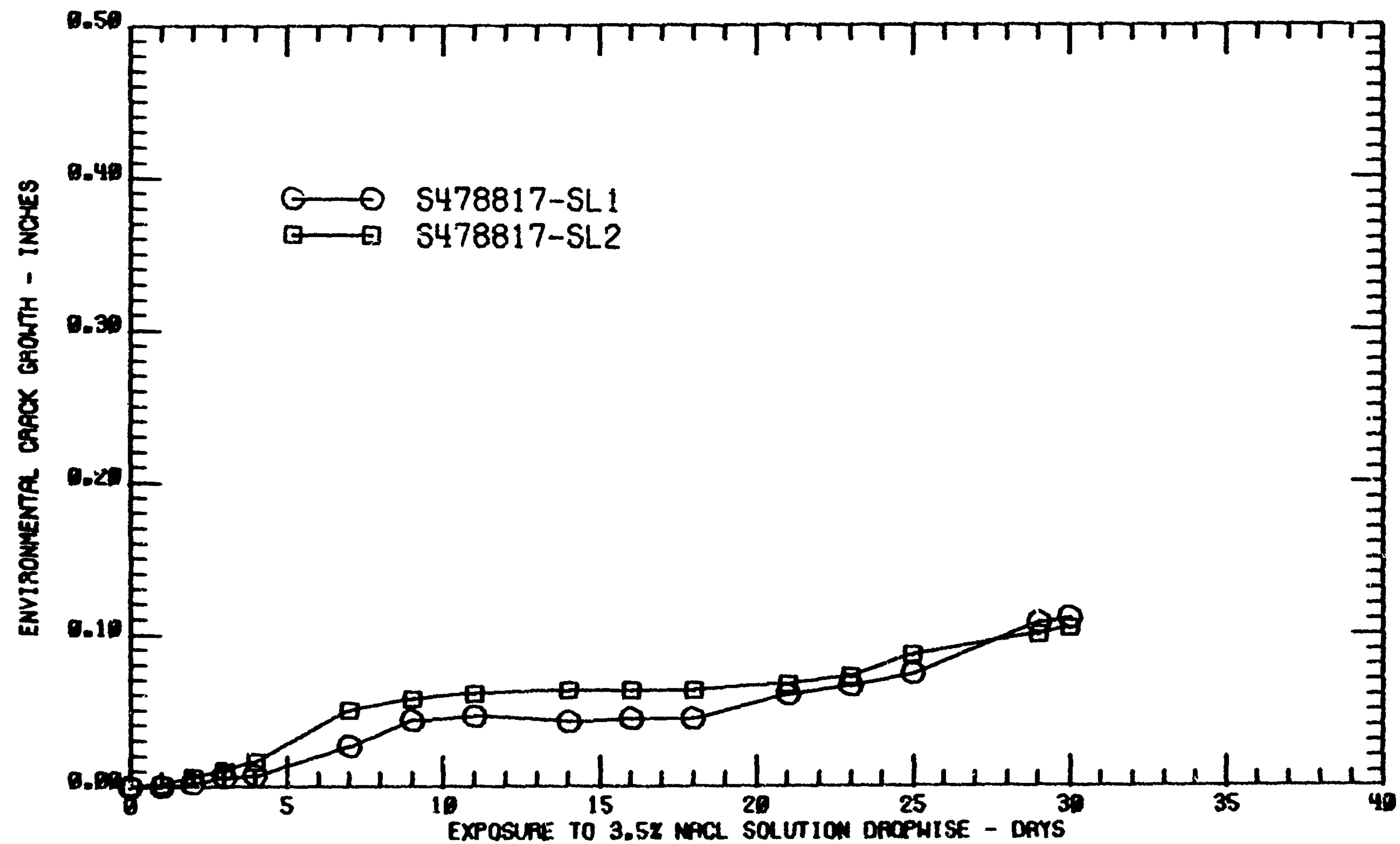


Fig. 63 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 2219-T852 ALLOY DCB SPECIMENS REMOVED FROM A 2.5-INCH THICK HAND FORGING.

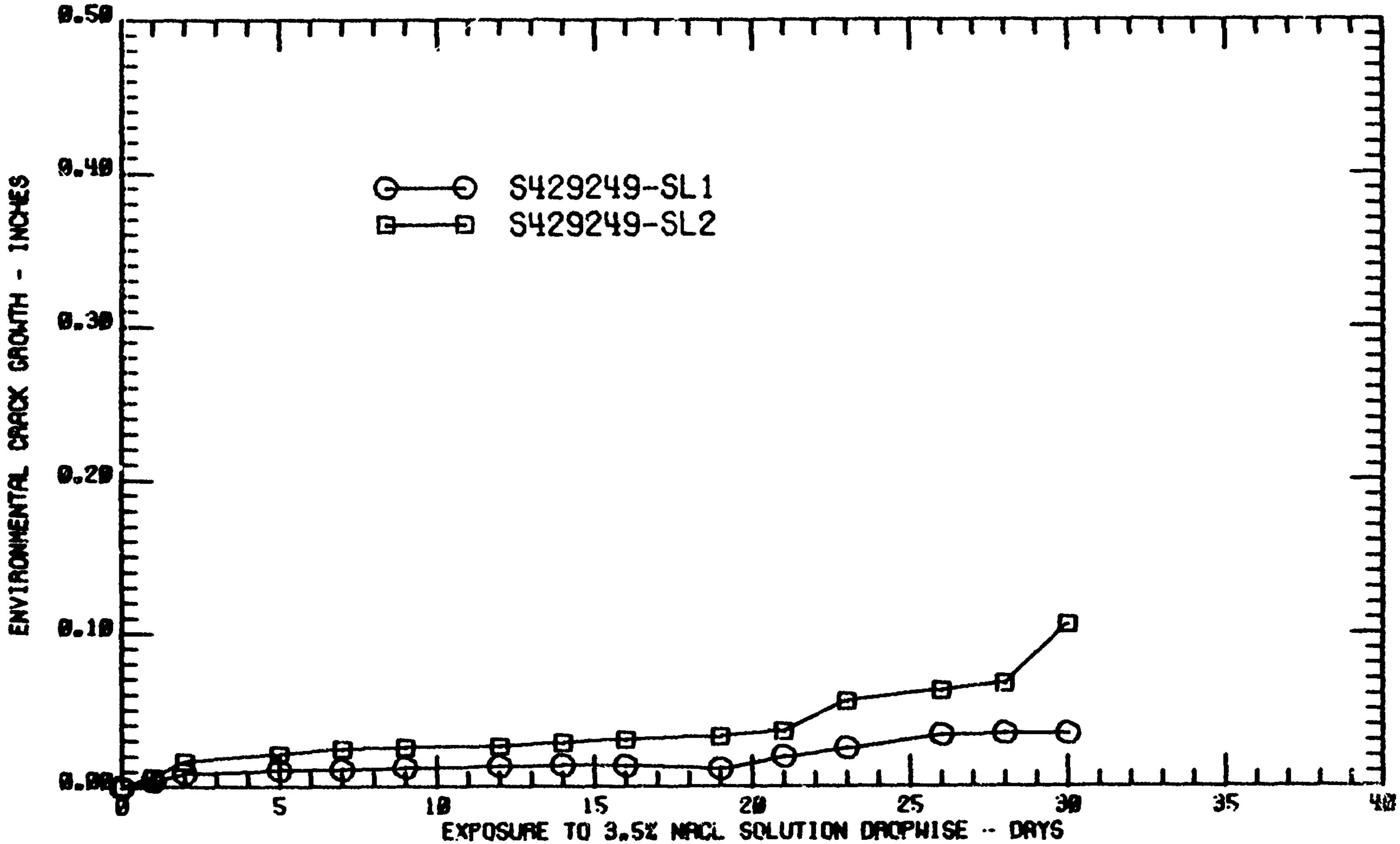


Fig. 64 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 2219-T852 ALLOY DCB SPECIMENS REMOVED FROM A 4.5-INCH THICK HAND FORGING.

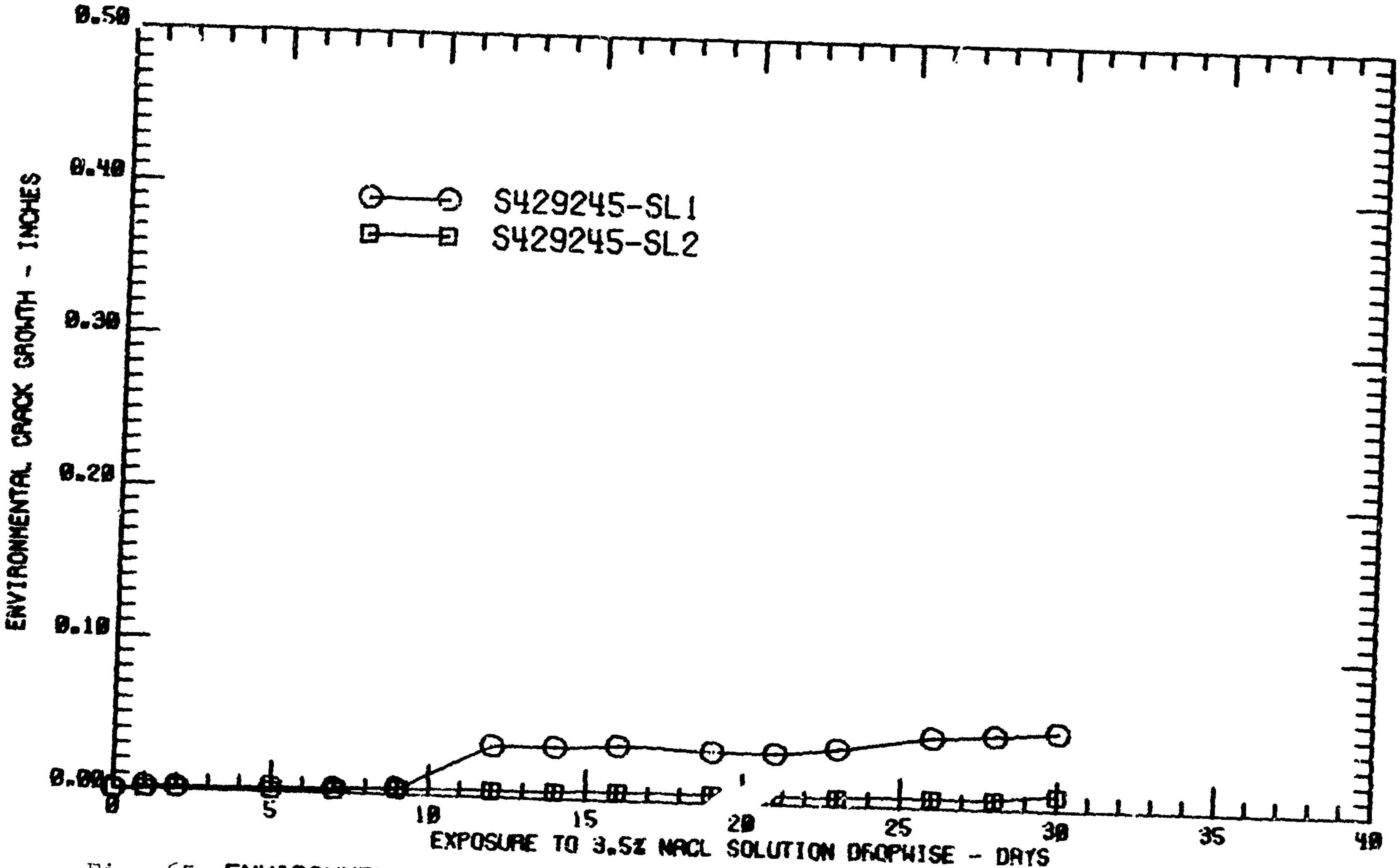


Fig. 65 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 2219-T852 ALLOY DCB SPECIMENS REMOVED FROM A 7.5-INCH THICK HAND FORGING.

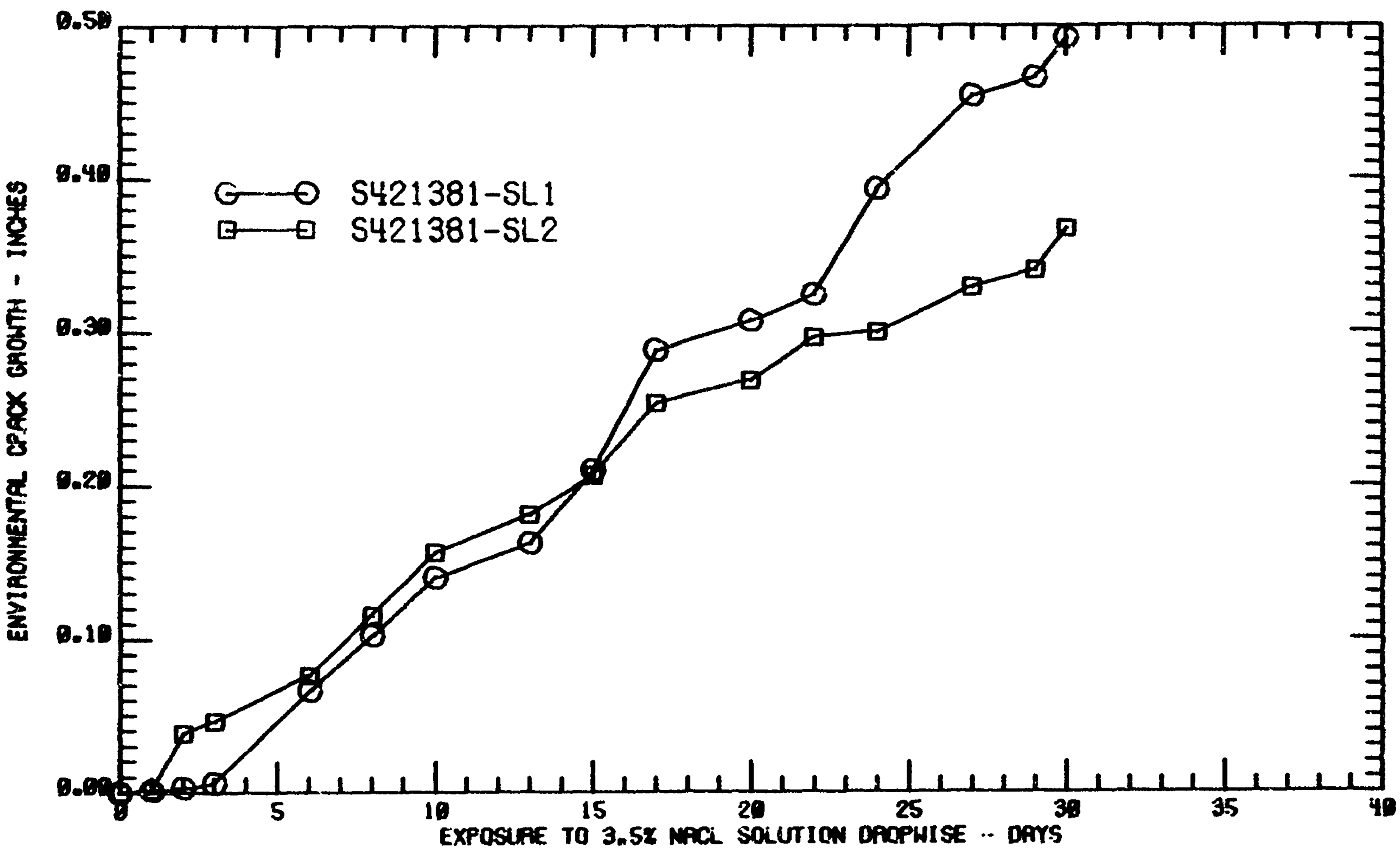


Fig. 66 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 2048-T851 ALLOY DCB SPECIMENS REMOVED FROM A 2-INCH THICK PLATE.

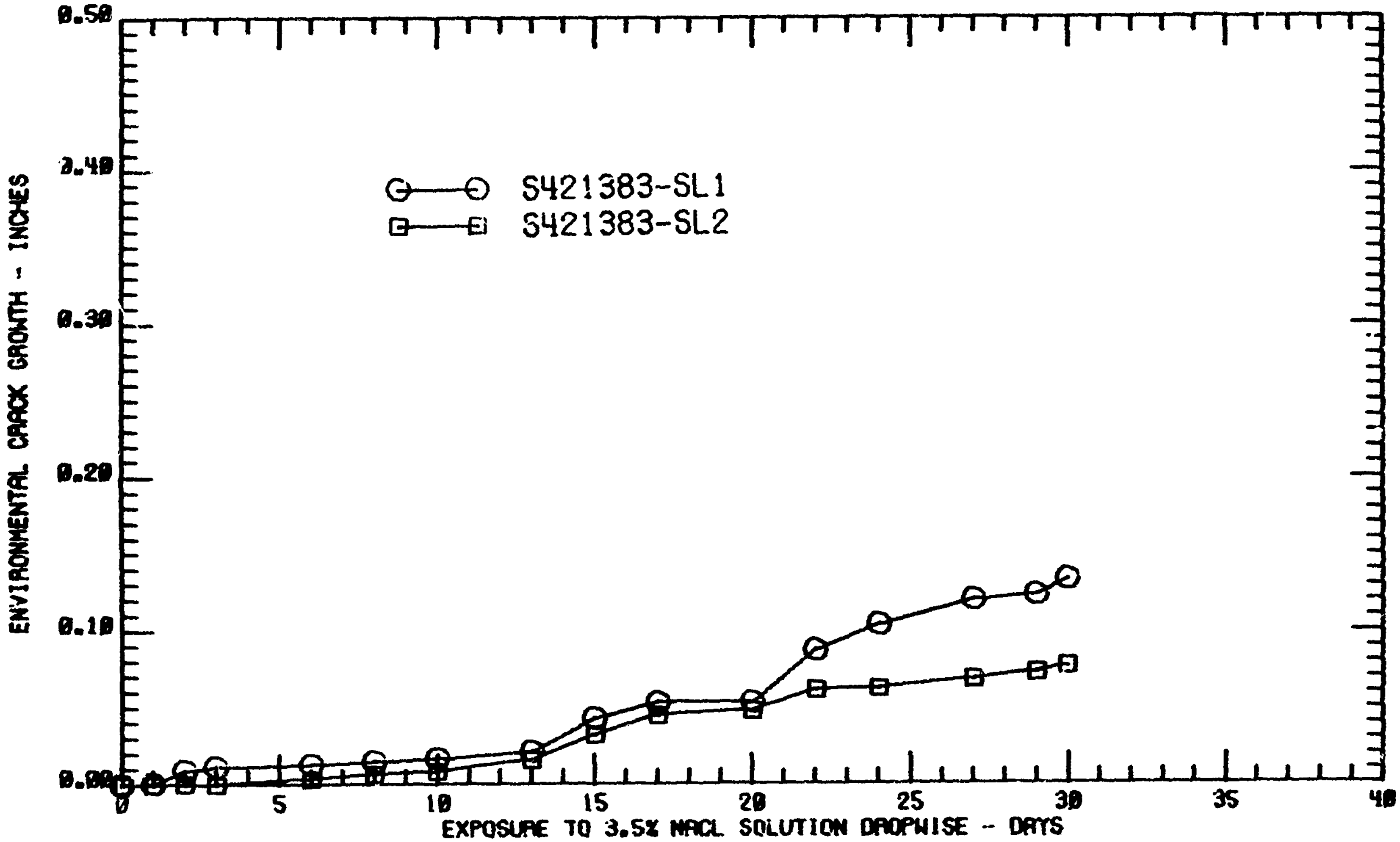


Fig. 67 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 2048-T851 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

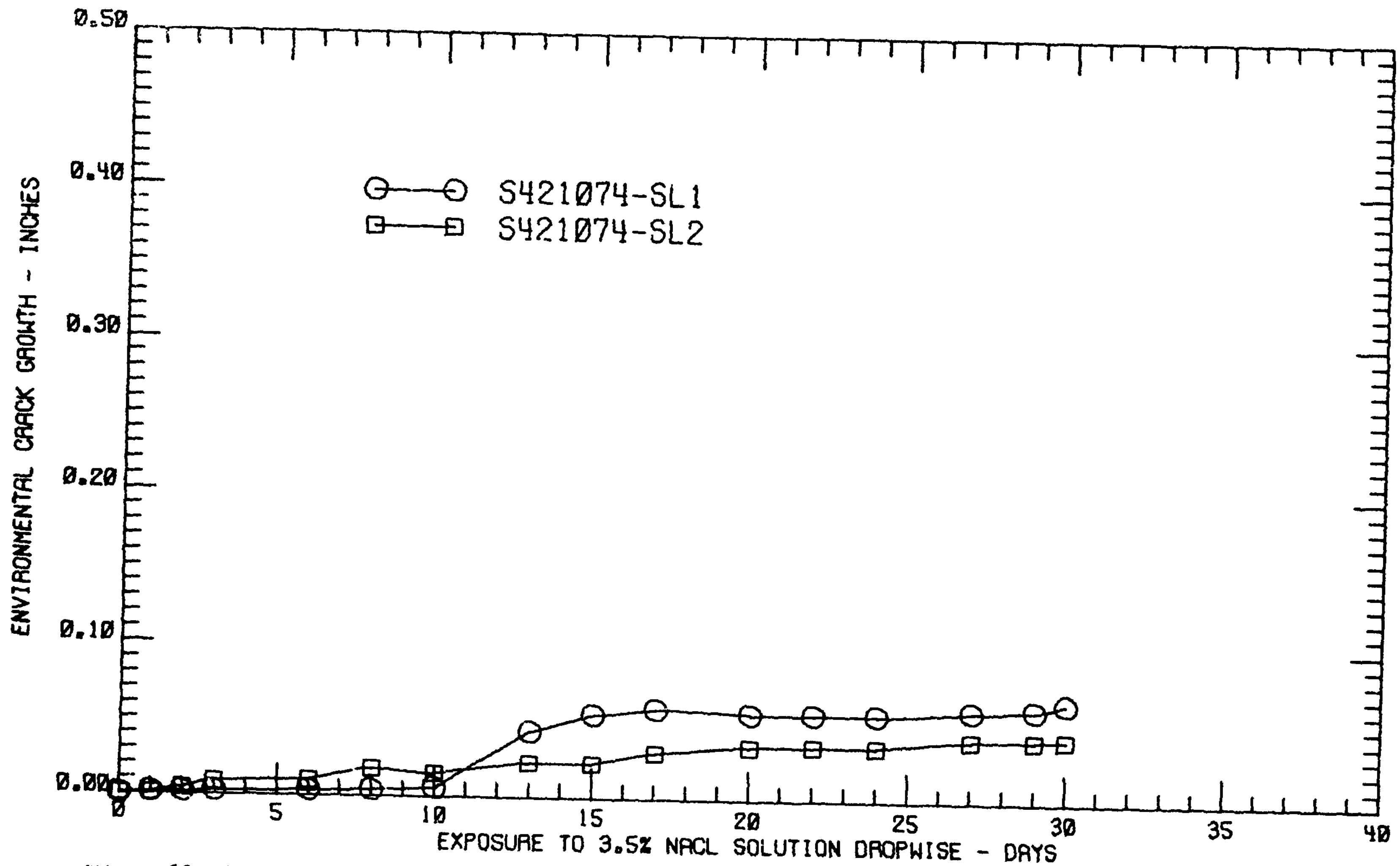


Fig. 68 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7050-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 2-INCH THICK PLATE.

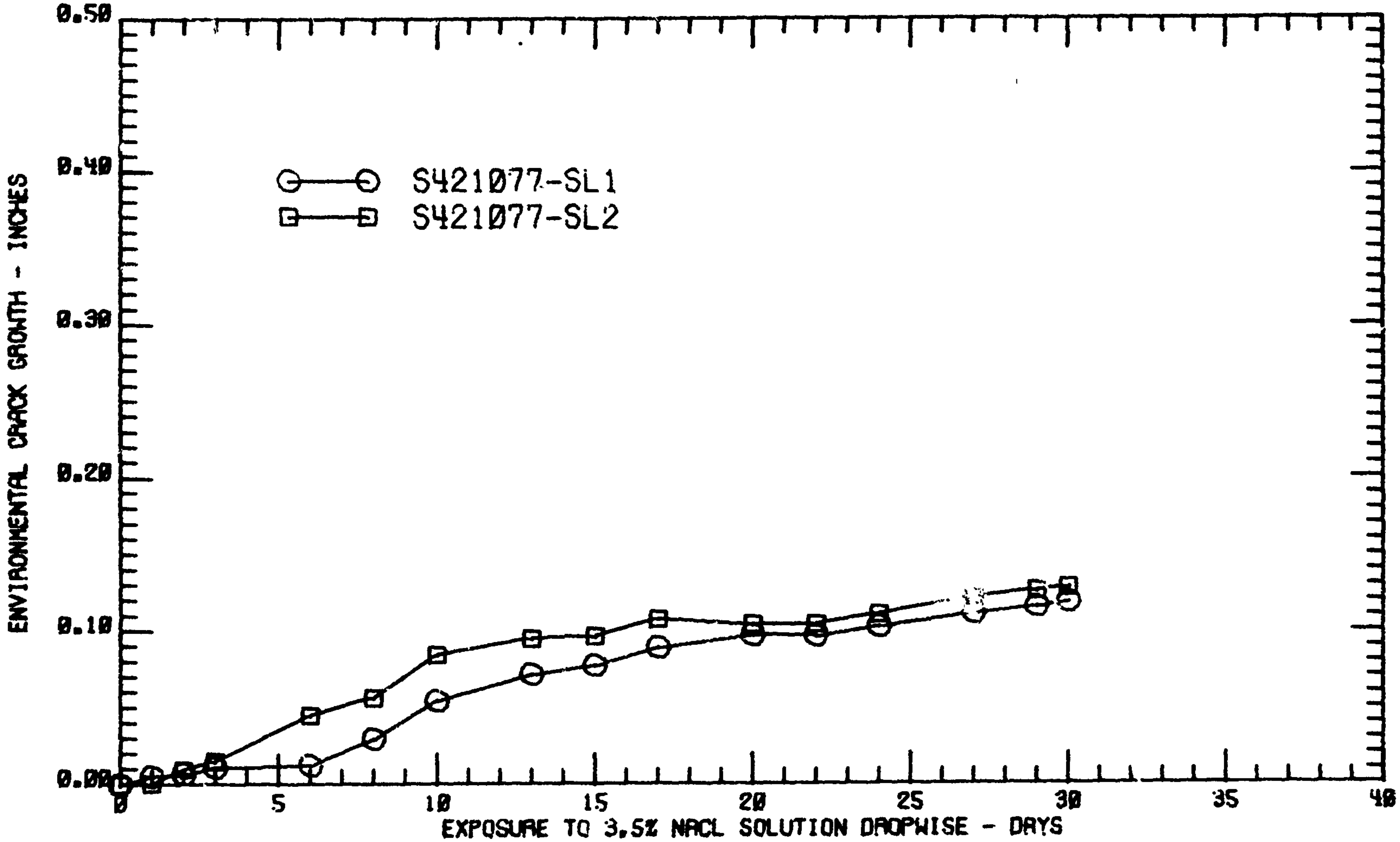


Fig. 69 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7050-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

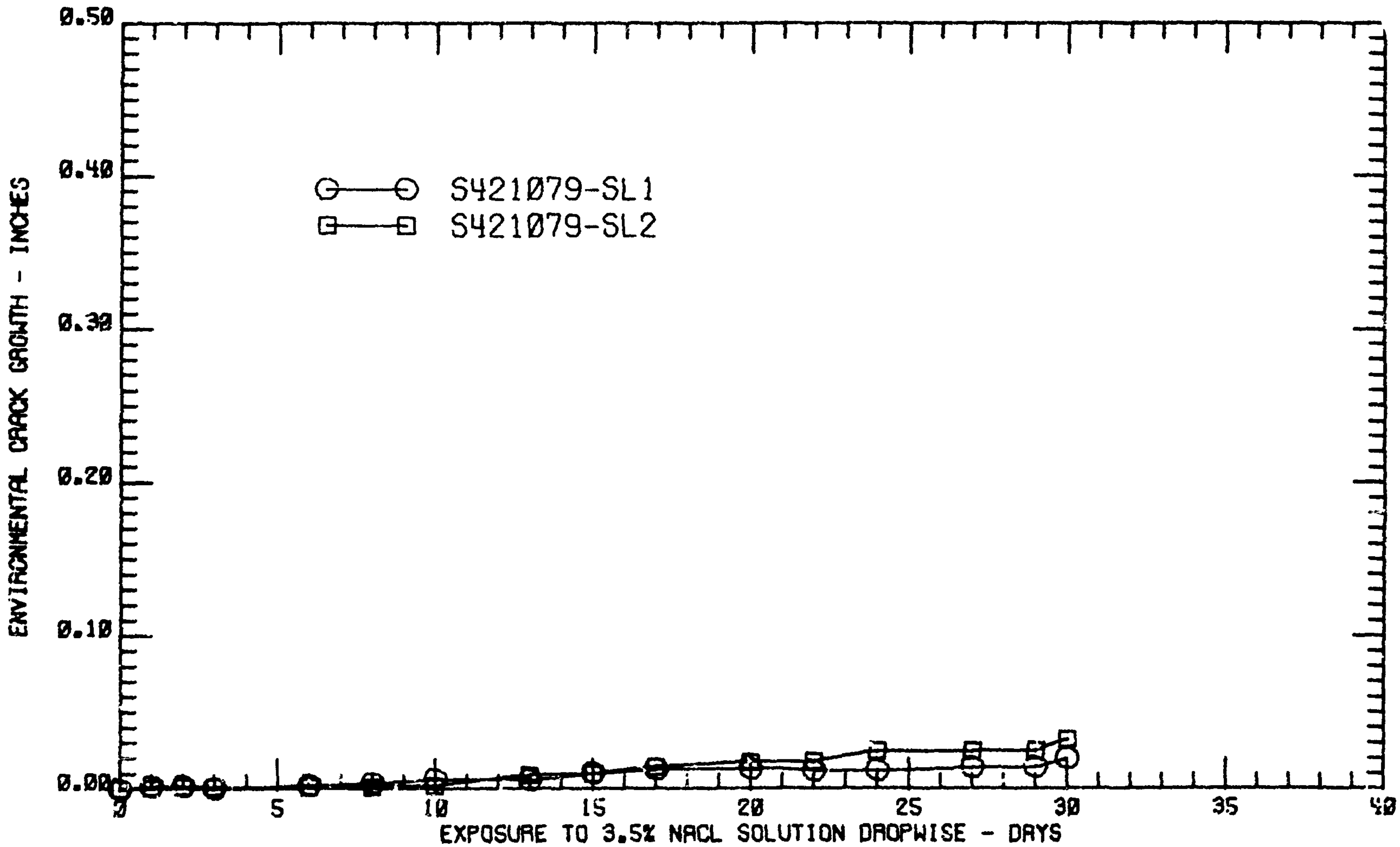


Fig. 70 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7050-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 6-INCH THICK PLATE.

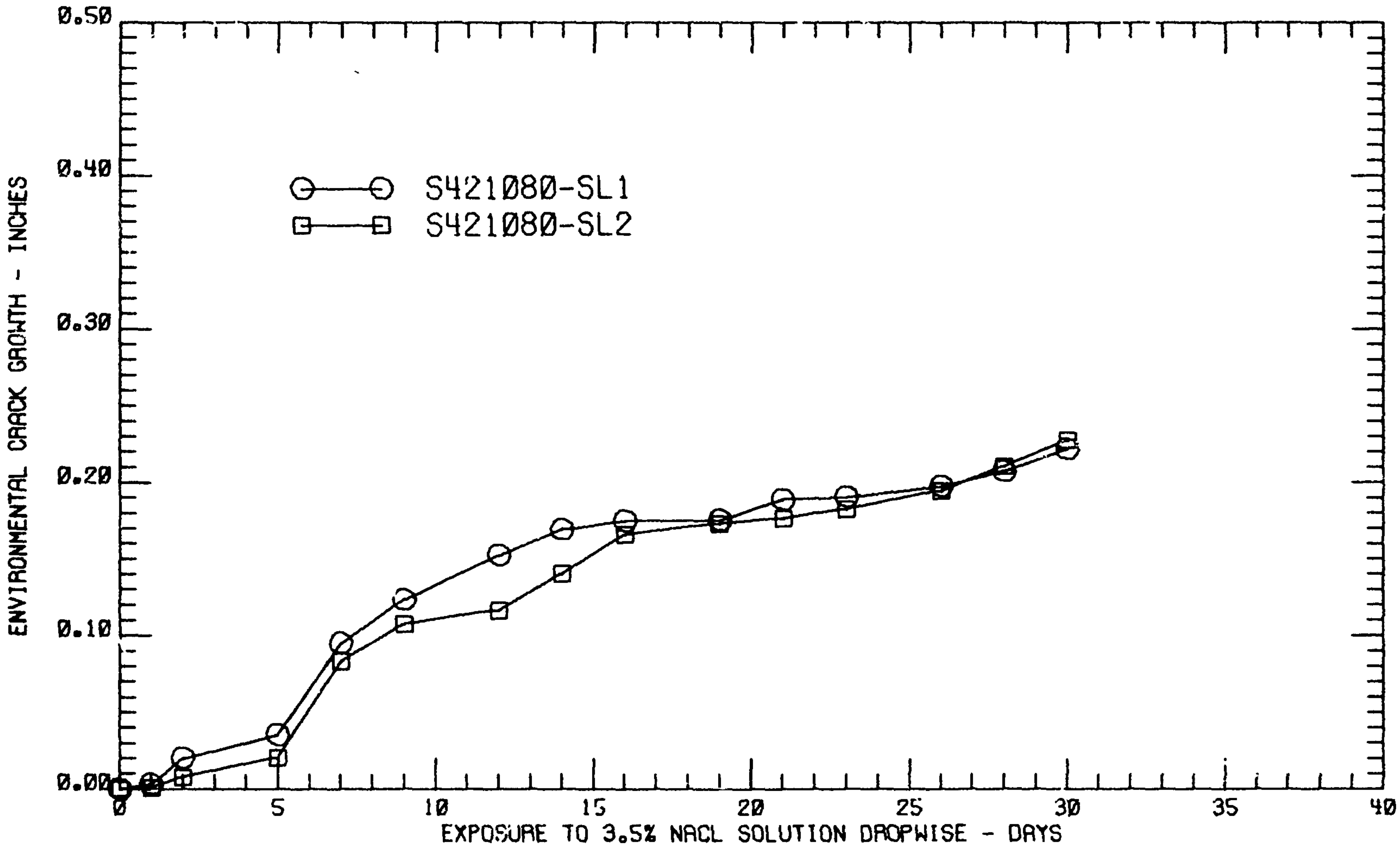


Fig. 71 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7050-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 6-INCH THICK PLATE.

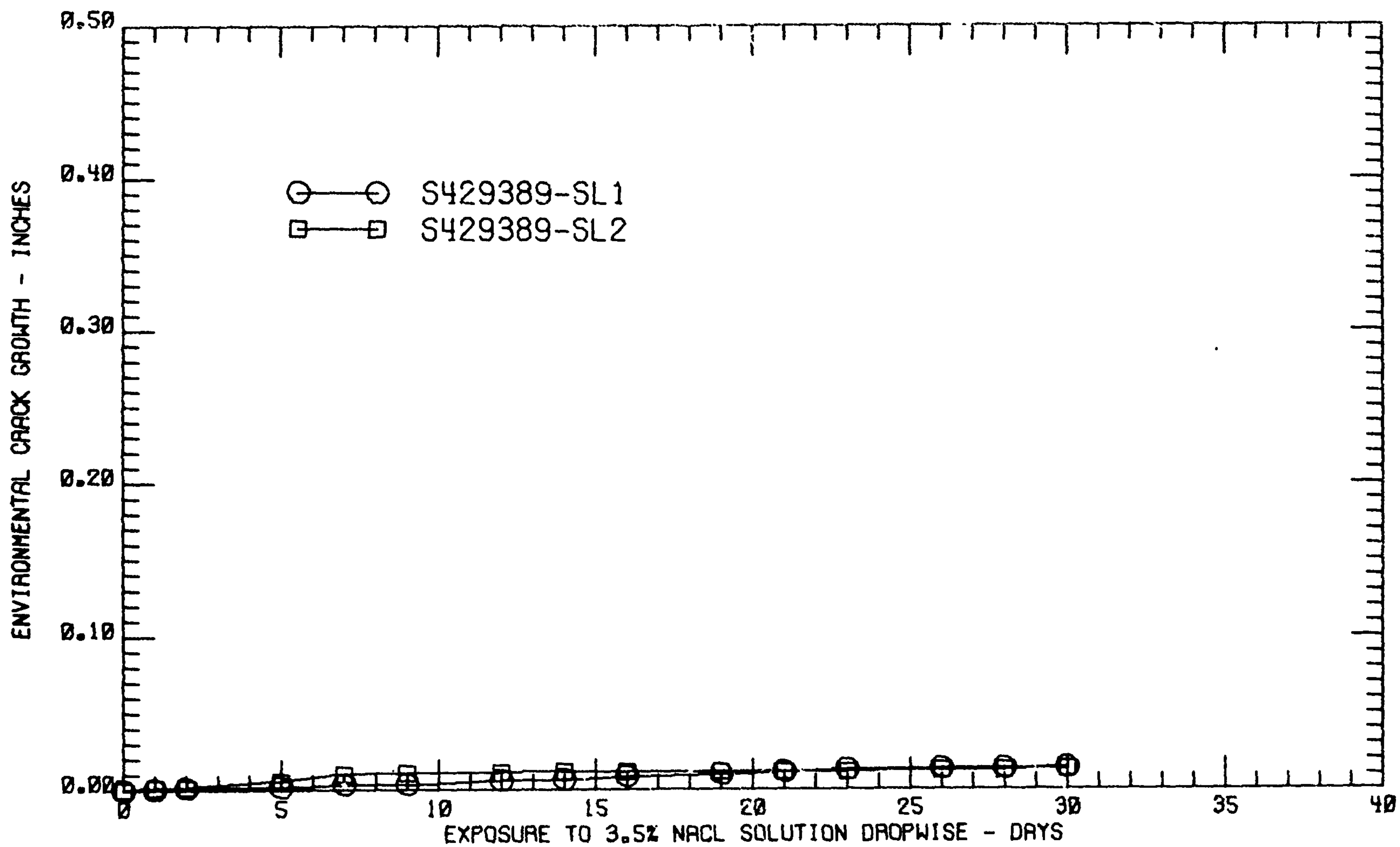


Fig. 72 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7475-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 2-INCH THICK PLATE.

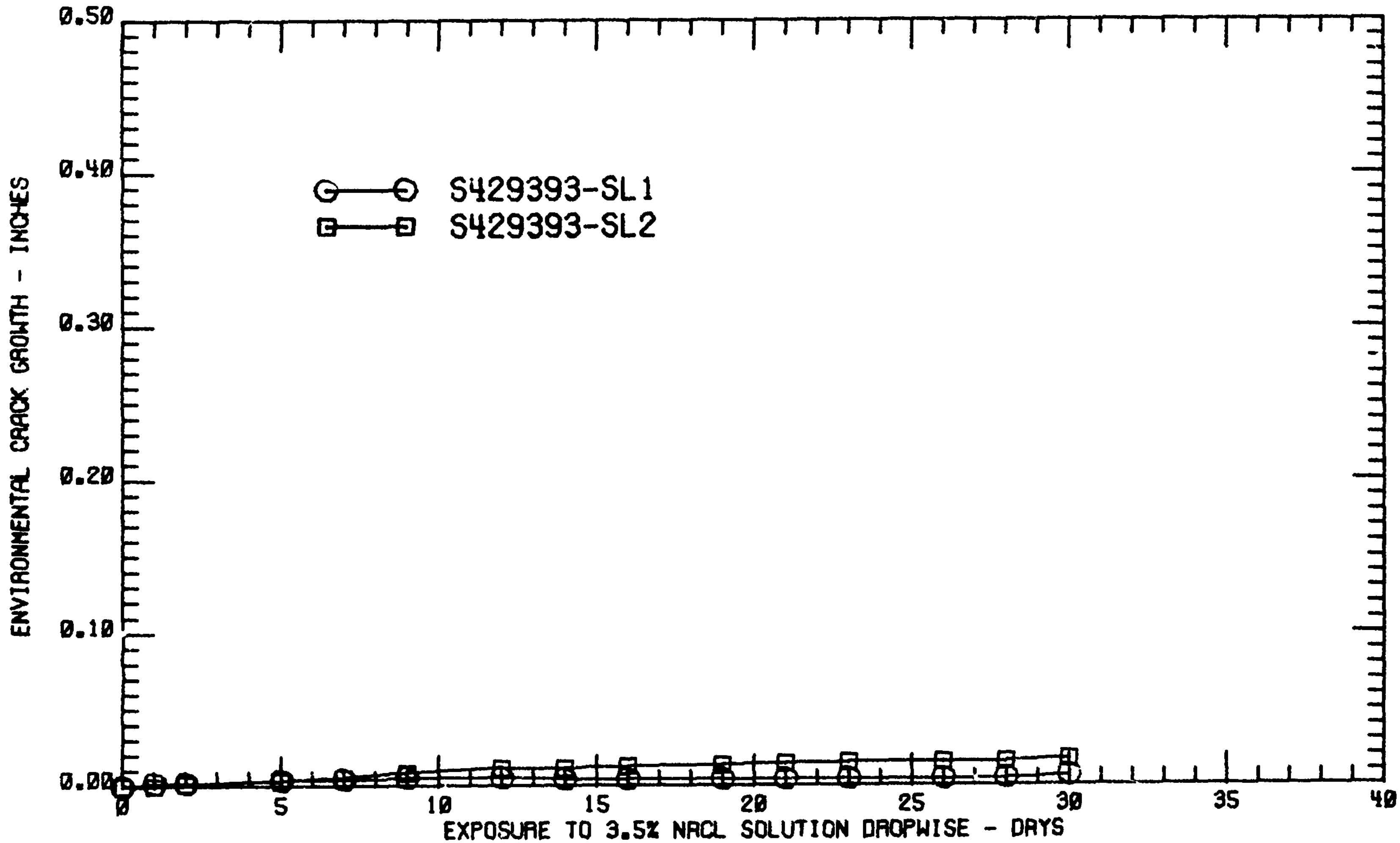


Fig. 73 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7475-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

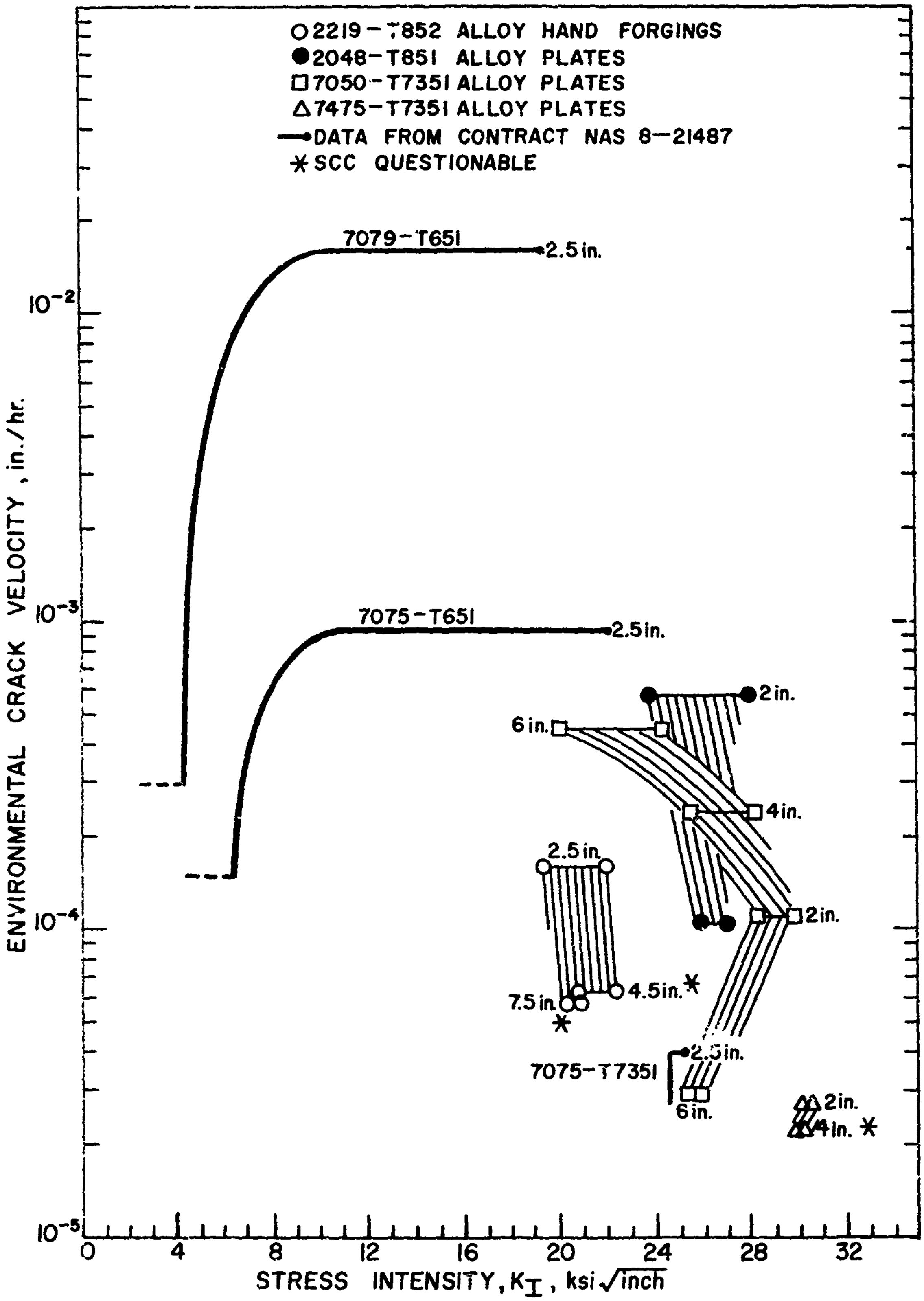


Fig. 74 K-Rate Comparisons of the Materials

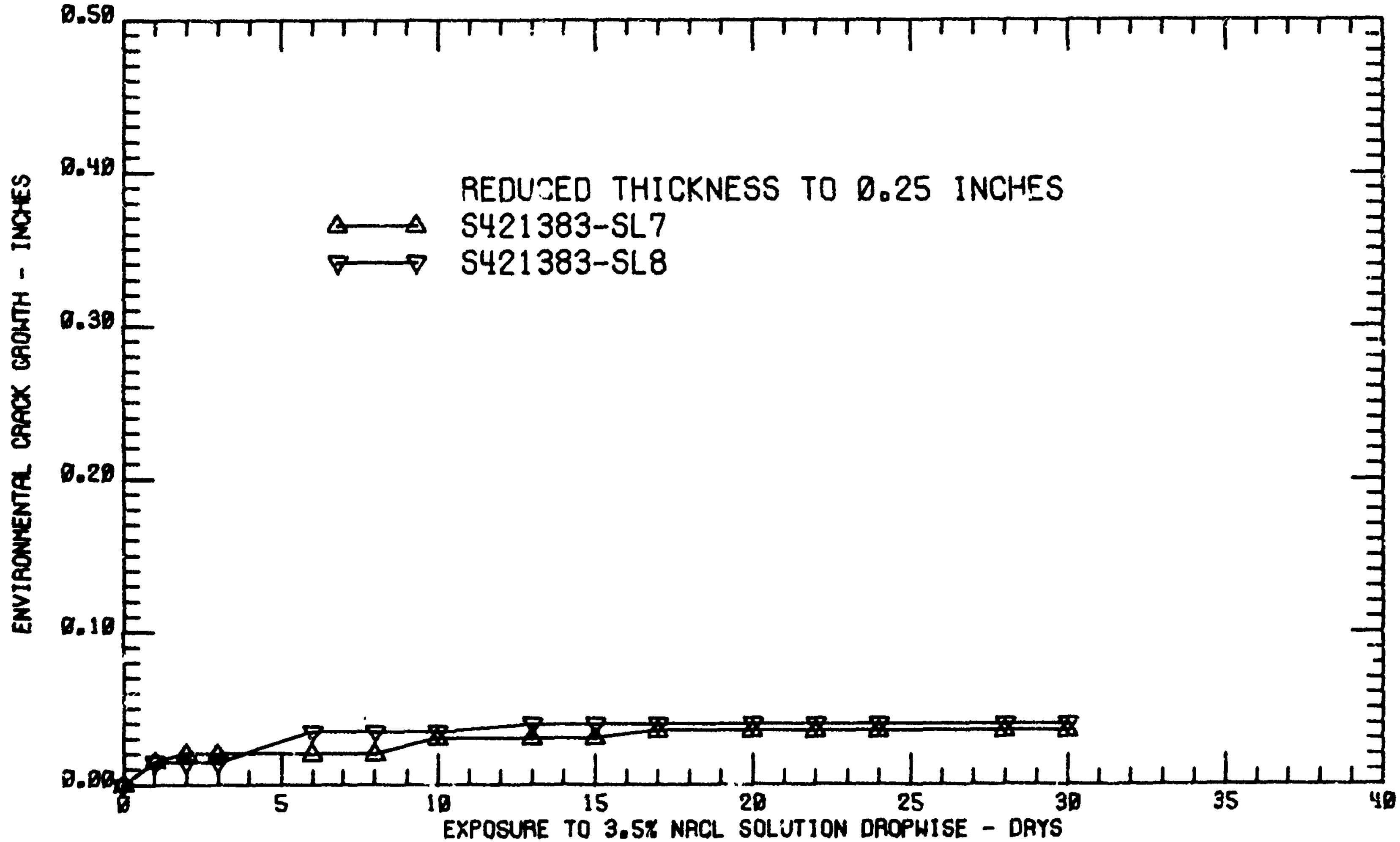


Fig. 75 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 2048-T851 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

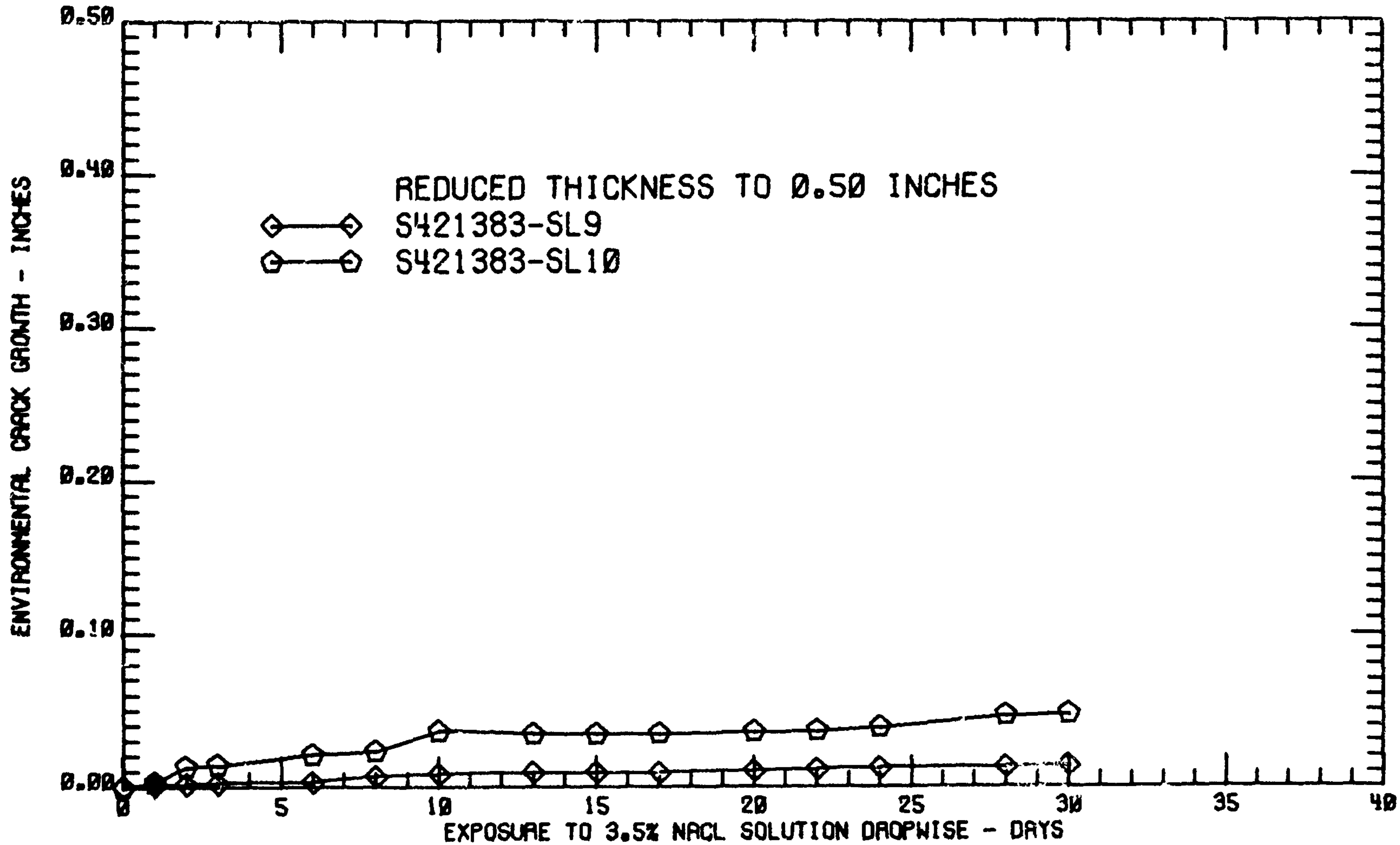


Fig. 76 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 2048-T851 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

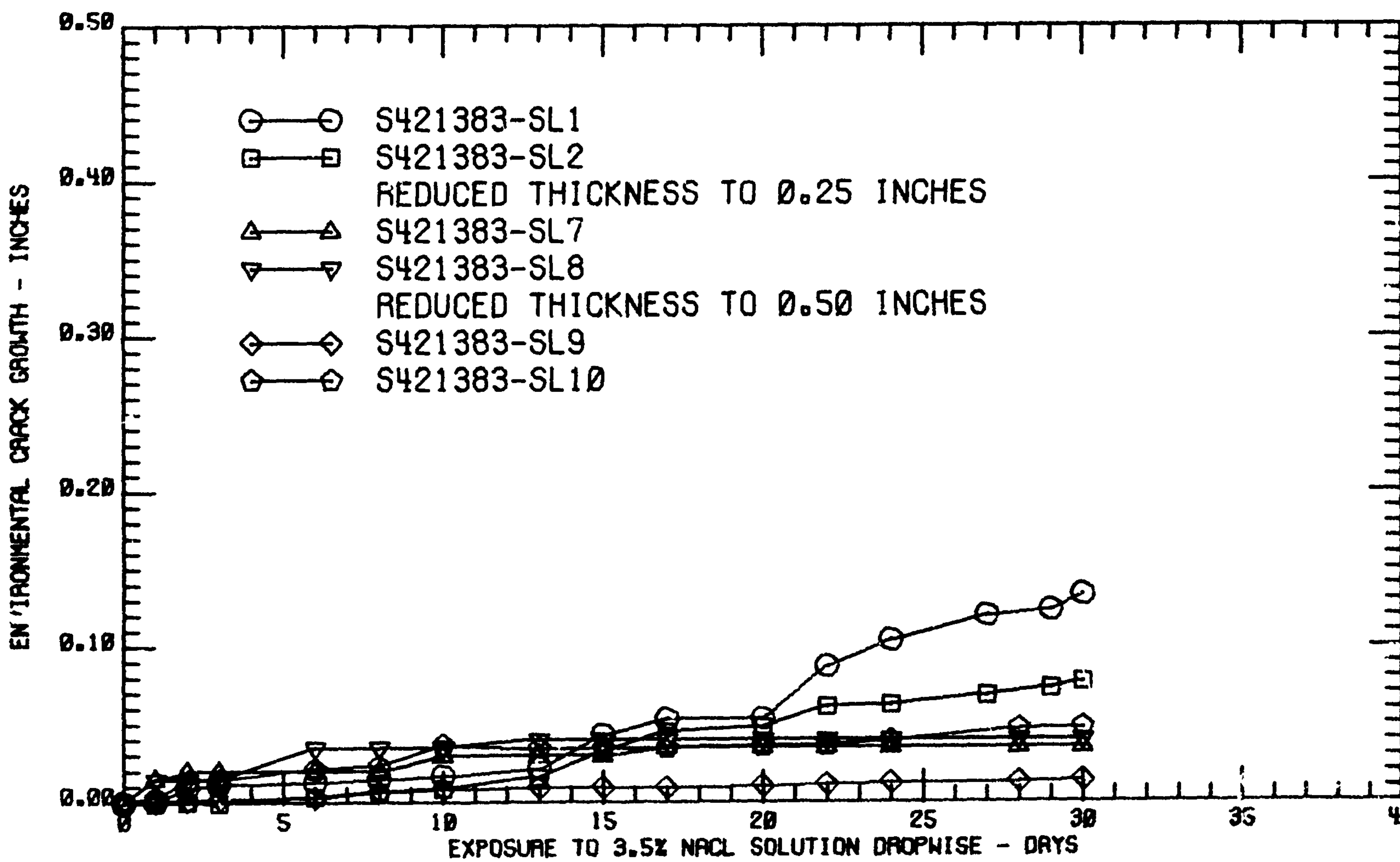


Fig. 77 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 2048-T851 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

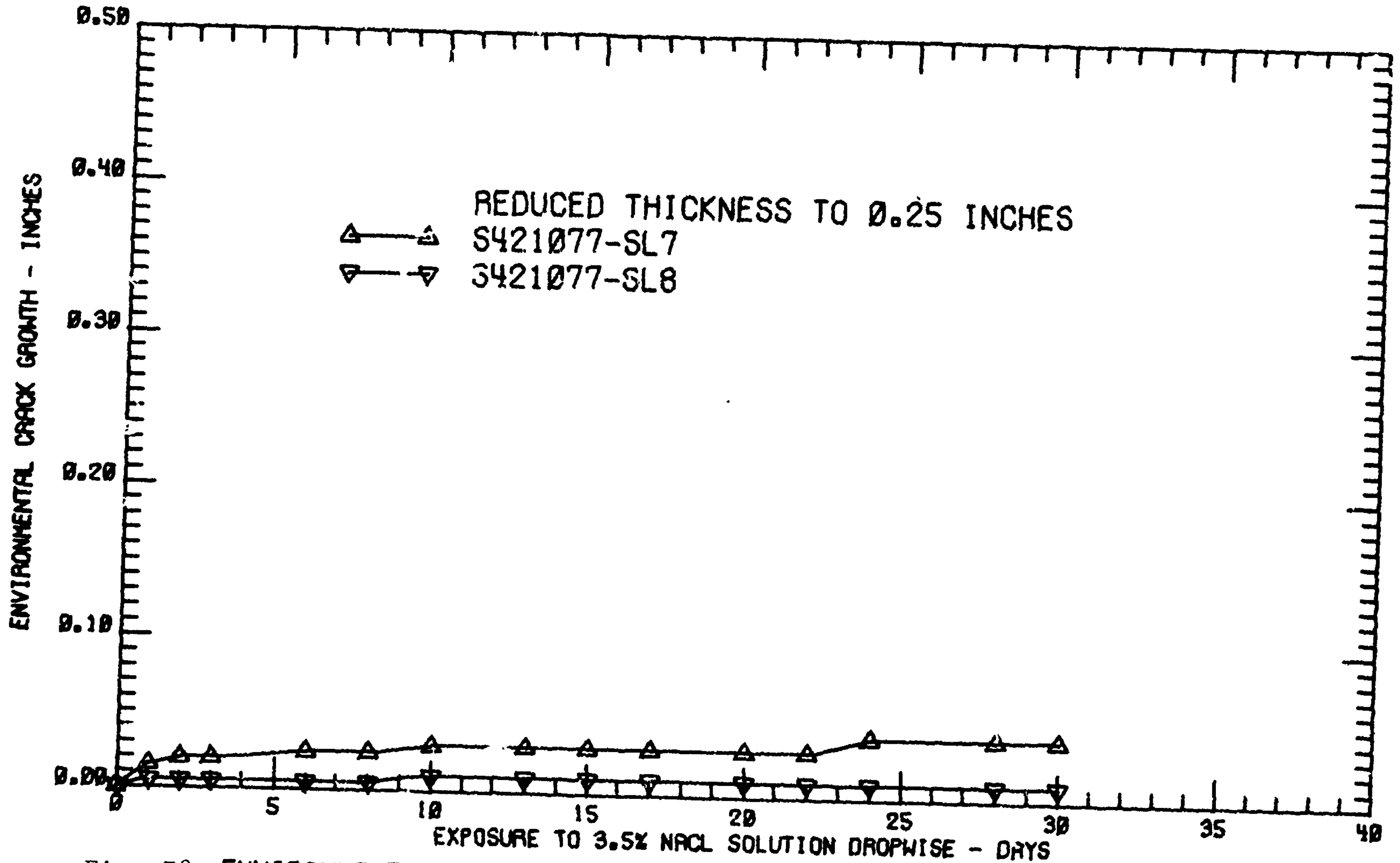


Fig. 78 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7050-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

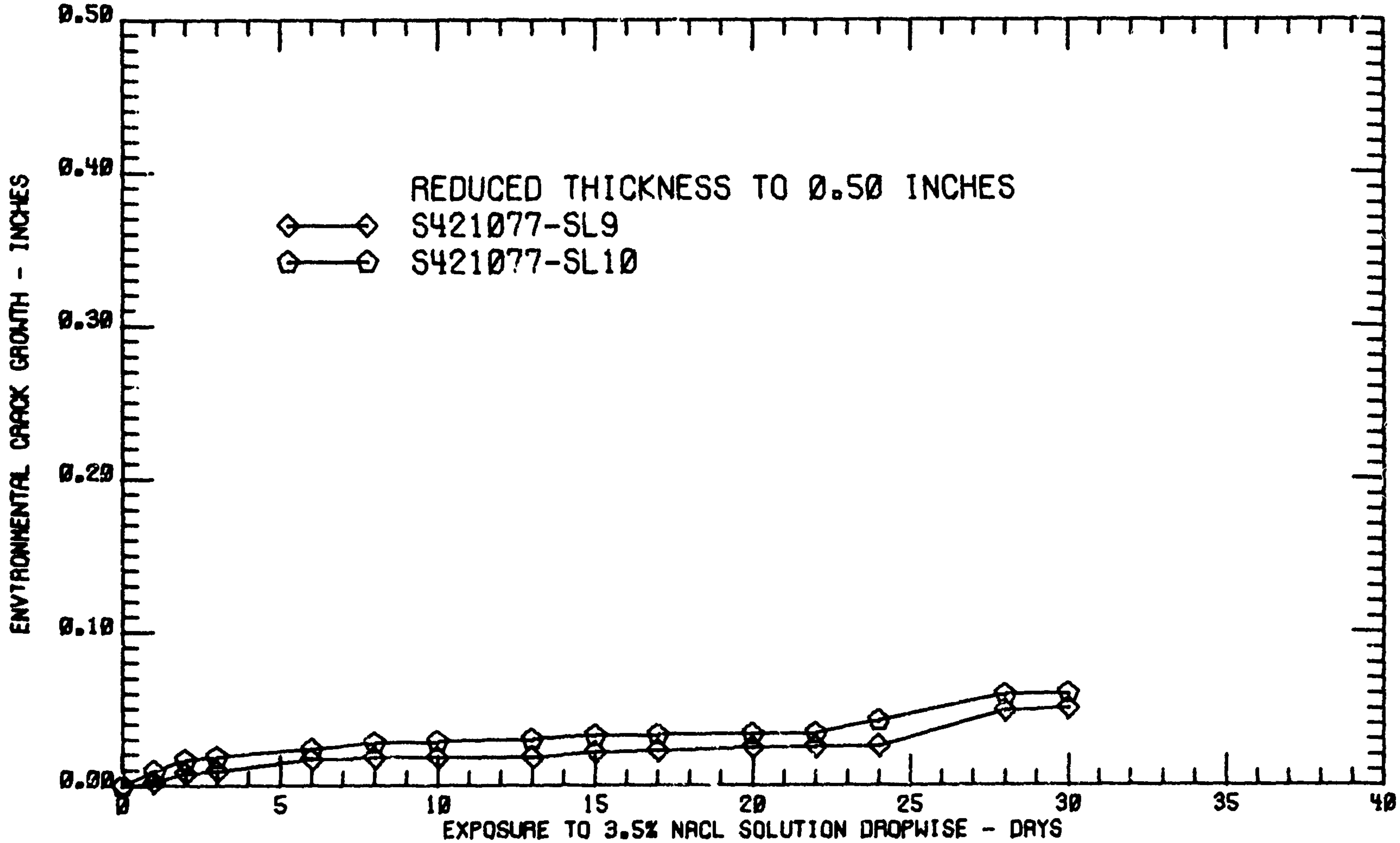


Fig. 79 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7050-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

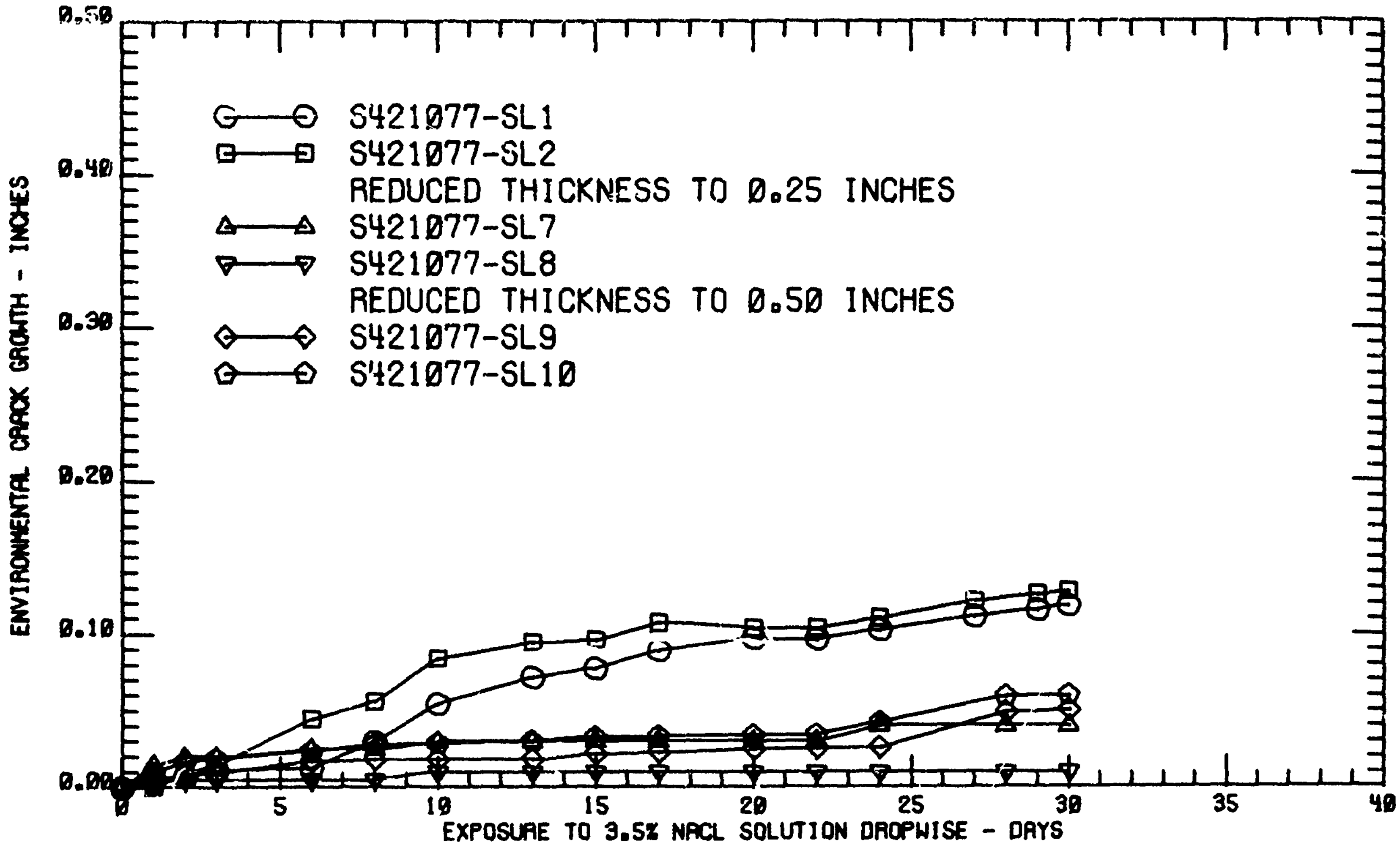


Fig. 80 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7050-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

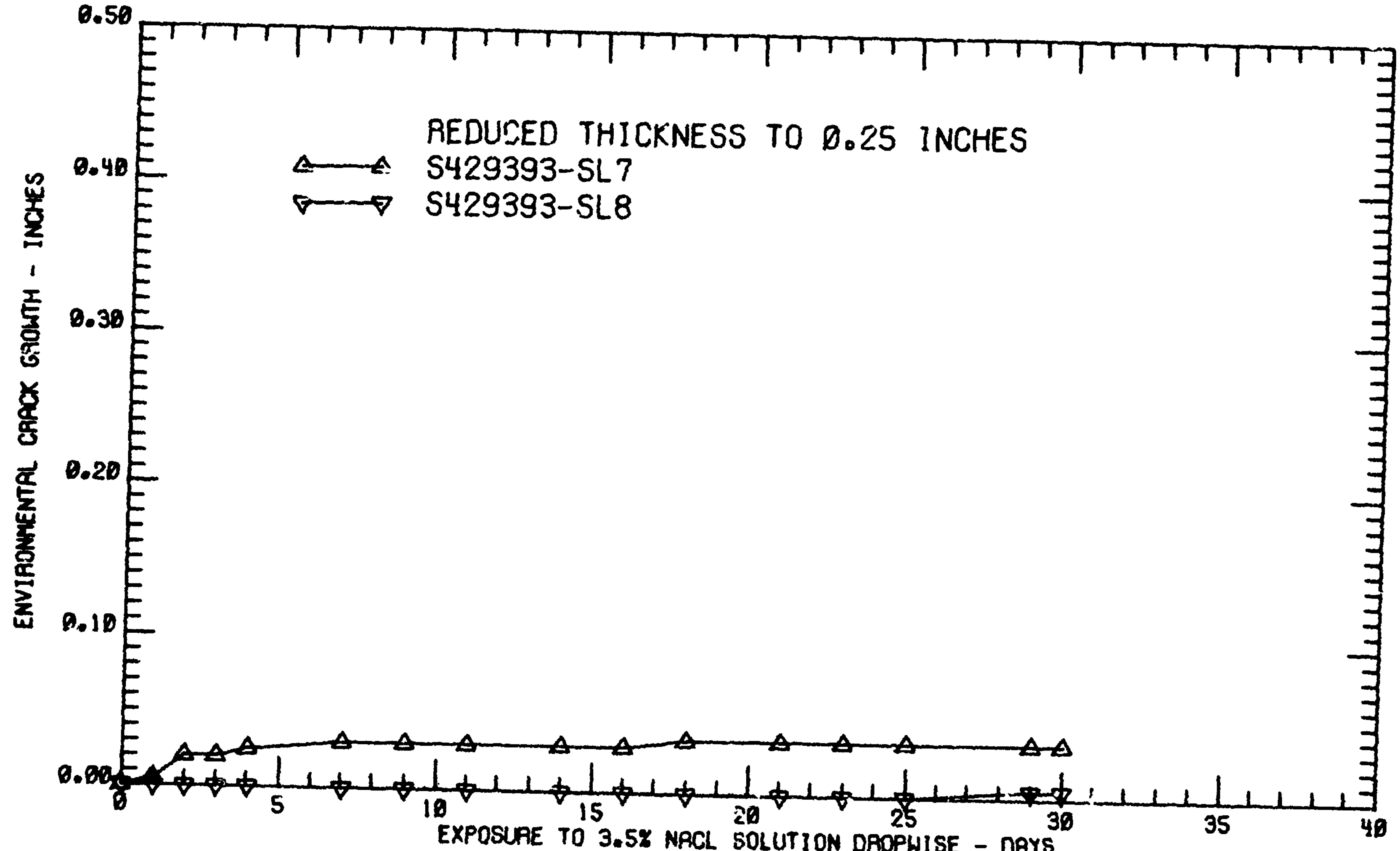


Fig. 81 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7475-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

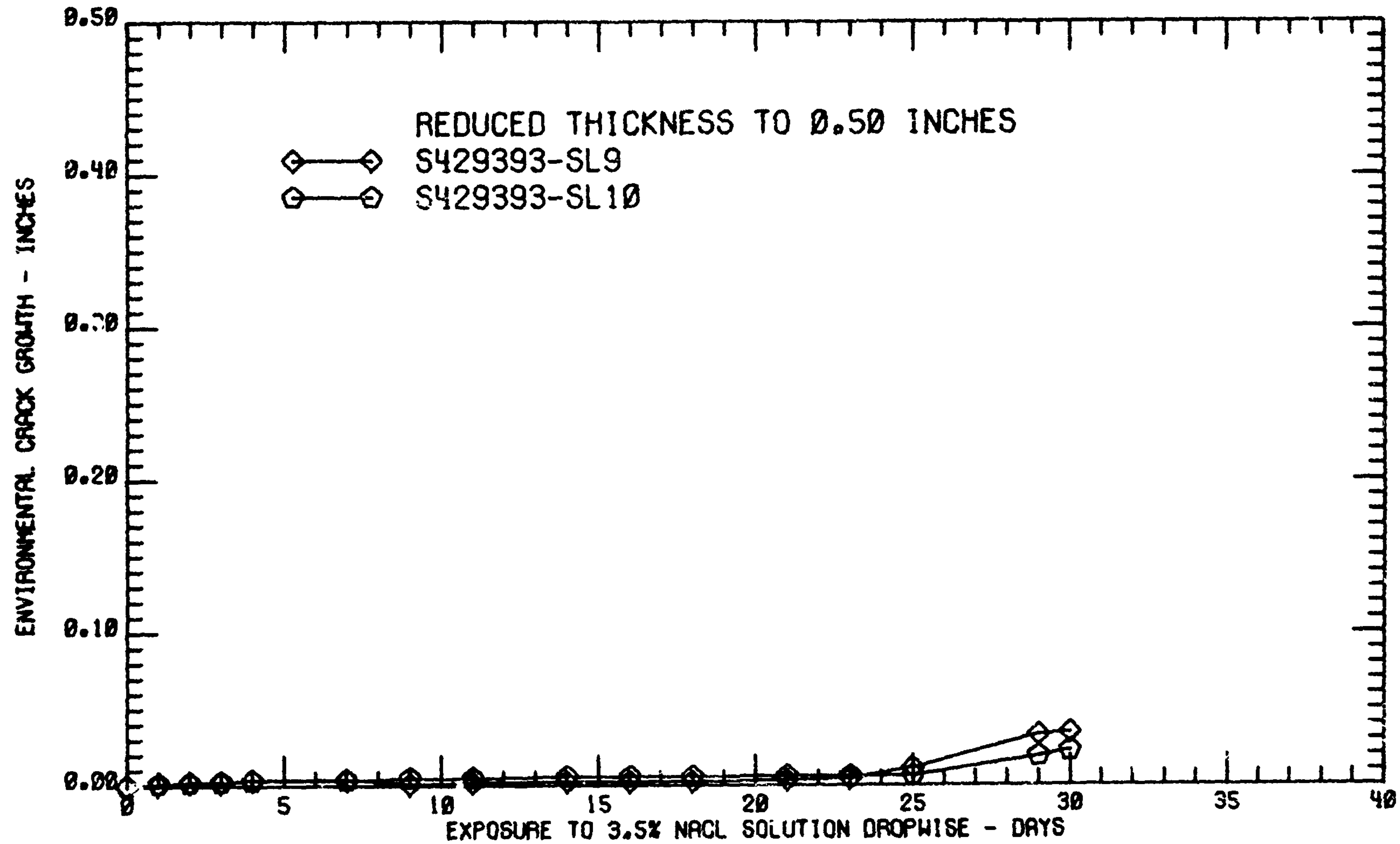


Fig. 82 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7475-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

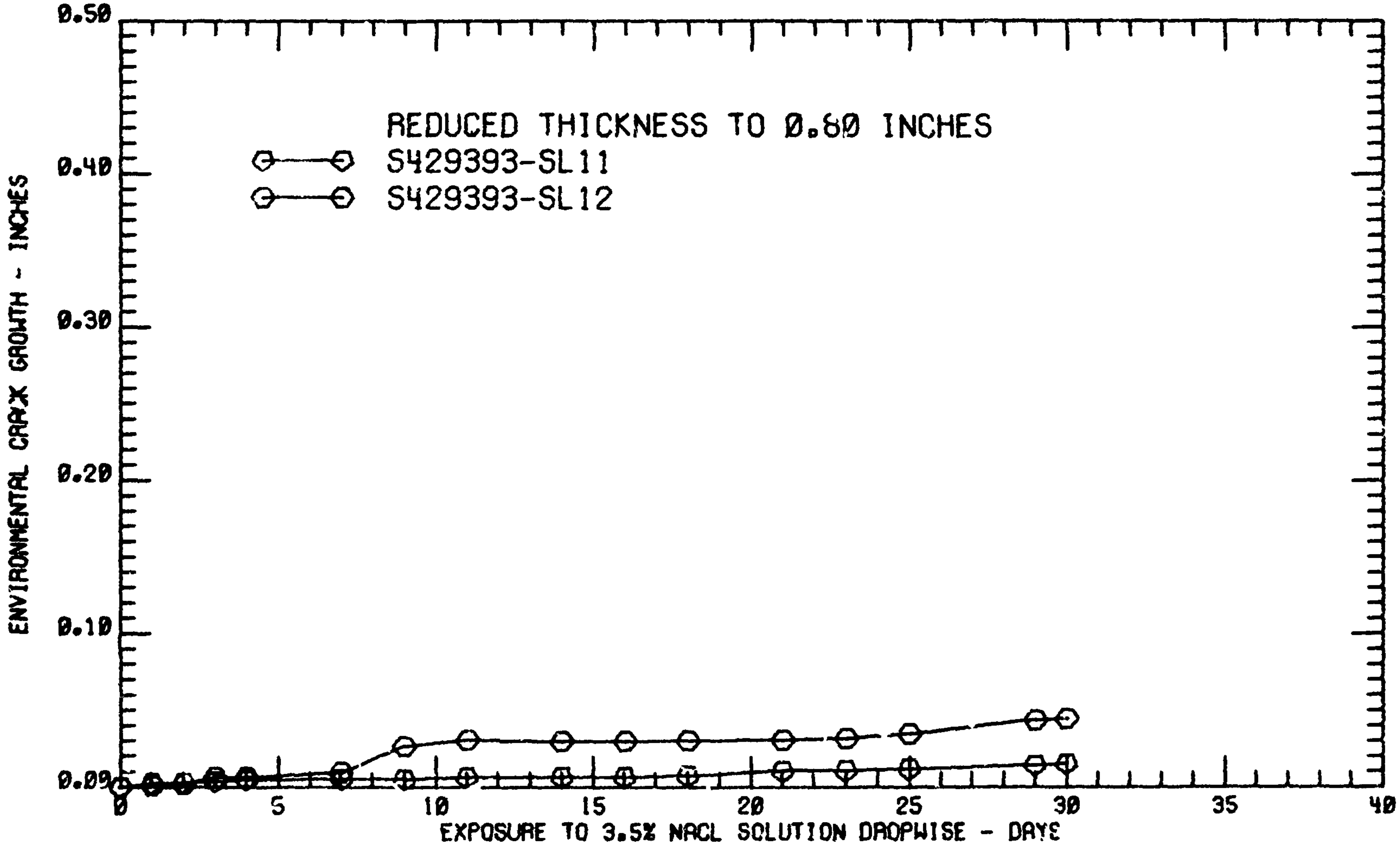


Fig. 83 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7475-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

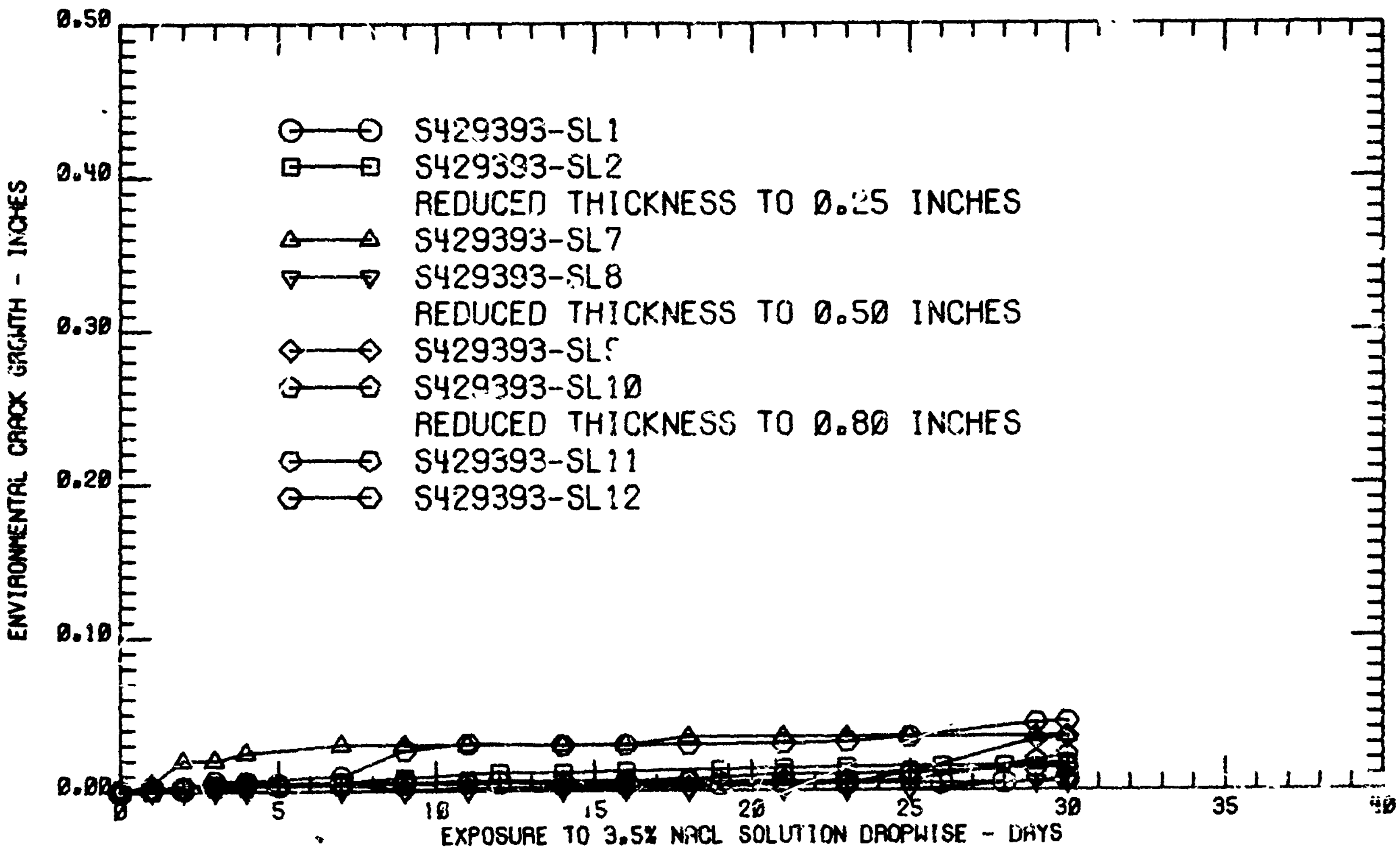


Fig. 84 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7475-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 4-INCH THICK PLATE.

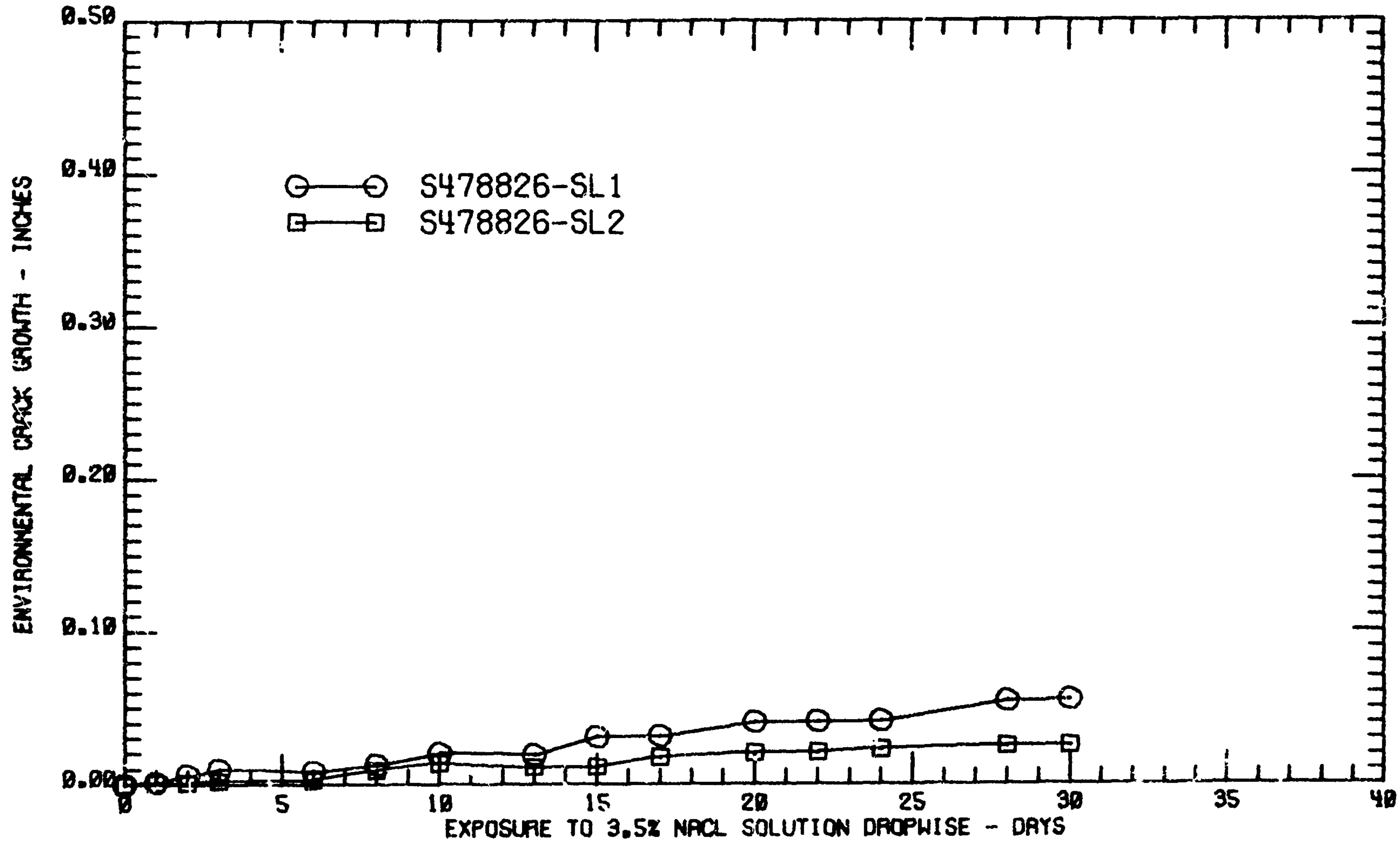


Fig. 85 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7475-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 2.25-INCH THICK PLATE.

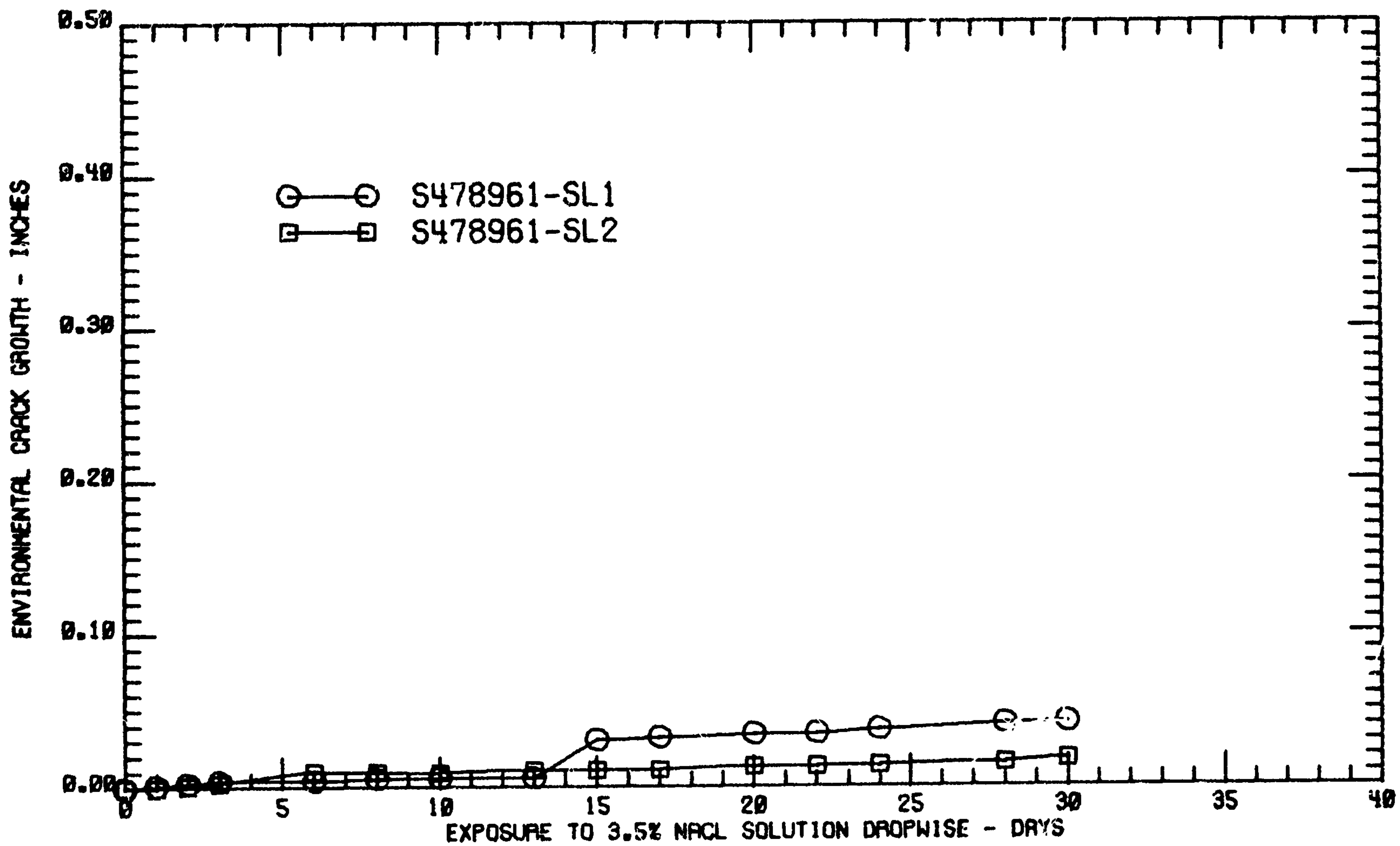


Fig. 86 ENVIRONMENTAL CRACK GROWTH OF SHORT TRANSVERSE 7475-T7351 ALLOY DCB SPECIMENS REMOVED FROM A 3.5 INCH THICK PLATE.

TABLE 1

CHEMICAL COMPOSITIONS OF 2048-T851 PLATE
(F33615-74-C-5089)

Sample[a] Thickness, in.	Sample[a] Number	Element, % Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
0.500	421378	0.05	0.13	3.12	0.40	1.34	0.00	0.05	0.01
0.500	421379	0.05	0.12	3.30	0.37	1.25	0.00	0.05	0.01
1.000	421108	0.05	0.12	3.74	0.37	1.38	0.00	0.06	0.01
1.000	421380	0.05	0.13	3.15	0.40	1.31	0.00	0.05	0.01
2.000	421381	0.05	0.13	3.21	0.40	1.29	0.00	0.05	0.01
2.000	421382	0.06	0.13	3.51	0.38	1.27	0.00	0.05	0.01
3.000	421083	0.08	0.15	3.24	0.34	1.25	0.00	0.02	0.01
3.000	421084	0.06	0.13	3.63	0.29	1.32	0.00	0.02	0.01
4.000	421383	0.05	0.13	3.19	0.40	1.35	0.00	0.05	0.01
4.000	421384	0.06	0.13	3.62	0.40	1.25	0.00	0.05	0.01
Limits[b] (Maximum unless range is shown)		0.15	0.20	2.8-3.8	0.20-0.6	1.2-1.8	--	0.25	0.10

(a) All samples fabricated by Reynolds Metals Co.

(b) Aluminum Association Alloy Designations and Chemical Composition Limits For Wrought Aluminum Alloys, revised September 1976.

TABLE 2

CHEMICAL COMPOSITIONS OF 7050-T7351 PLATE
(F33615-74-C-5089)

Sample[a]		Element, %								
Thickness, in.	Number	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
2.000	421074	0.04	0.07	2.31	0.00	2.24	0.00	6.05	0.04	0.11
2.000	421075	0.03	0.07	2.32	0.00	2.21	0.00	6.20	0.03	0.10
3.000	421076	0.03	0.07	2.41	0.00	2.27	0.00	6.07	0.02	0.11
3.000	421081	0.03	0.06	2.35	0.00	2.22	0.00	5.96	0.02	0.11
4.000	421077	0.03	0.07	2.48	0.00	2.27	0.00	6.45	0.02	0.11
4.000	421078	0.03	0.07	2.41	0.00	2.22	0.00	6.19	0.02	0.11
5.000	421073	0.04	0.07	2.36	0.00	2.23	0.00	6.18	0.03	0.10
5.118	421278	0.06	0.09	2.21	0.00	2.11	0.00	6.09	0.06	0.10
6.000	421079	0.04	0.08	2.34	0.00	2.13	0.00	6.27	0.04	0.11
6.000	421080	0.03	0.07	2.43	0.00	2.34	0.00	6.24	0.02	0.11
Limits[b] (Maximum unless range is shown)		0.12	0.15	2.0-2.6	0.10	1.9-2.6	0.04	5.7-6.7	0.06	0.08-0.15

(a) All samples fabricated by Alcoa.

(b) Aluminum Association Alloy Designations and Chemical Composition Limits For Wrought Aluminum Alloys, revised September 1976.

TABLE 3

CHEMICAL COMPOSITIONS OF 7475-T7351 PLATE
(F33615-74-C-5089)

Sample[a] Thickness, in.	Sample[a] Number	Element, % Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti
0.500	429422	0.03	0.10	1.47	0.00	2.19	0.19	0.00	5.46	0.02
0.500	429423	0.03	0.09	1.38	0.00	2.16	0.19	0.00	5.54	0.02
1.000	429387	0.03	0.10	1.55	0.00	2.18	0.20	0.00	5.48	0.02
1.000	429388	0.04	0.09	1.42	0.00	2.15	0.20	0.00	5.61	0.02
2.000	429389	0.03	0.10	1.60	0.00	2.22	0.20	0.00	5.56	0.02
2.000	429390	0.04	0.10	1.45	0.00	2.16	0.20	0.00	5.57	0.02
3.000	429391	0.04	0.10	1.48	0.00	2.20	0.20	0.00	5.67	0.02
3.000	429392	0.03	0.10	1.51	0.00	2.15	0.20	0.00	5.45	0.02
4.000	429393	0.04	0.11	1.48	0.00	2.19	0.20	0.00	5.69	0.02
4.000	429394	0.03	0.10	1.54	0.00	2.16	0.20	0.00	5.44	0.02
				Current Practice						
0.500	478717	0.05	0.07	1.55	0.00	2.19	0.20	0.00	5.60	0.02
0.750	478718	0.05	0.07	1.54	0.00	2.16	0.19	0.00	5.49	0.02
1.750	478824	0.06	0.09	1.61	0.00	2.38	0.21	0.01	5.91	0.02
1.750	478825	0.06	0.09	1.65	0.00	2.33	0.20	0.00	5.79	0.02
2.250	478826	0.06	0.09	1.63	0.00	2.27	0.20	0.00	5.74	0.02
2.250	478827	0.06	0.08	1.66	0.00	2.37	0.20	0.00	5.87	0.03
2.750	478828	0.06	0.08	1.57	0.00	2.24	0.20	0.00	5.60	0.02
2.750	478829	0.06	0.08	1.60	0.00	2.34	0.20	0.00	5.81	0.02
3.500	478830	0.06	0.09	1.62	0.00	2.30	0.20	0.00	5.73	0.02
3.500	478961	0.06	0.10	1.51	0.00	2.31	0.21	0.00	5.64	0.03
Limits[b]	(Maximum unless range is shown)	0.10	0.12	1.2-1.9	0.06	1.9-2.6	0.18-0.25	--	5.2-6.2	0.06

(a) All samples fabricated by Alcoa.

(b) Aluminum Association Alloy Designations and Chemical Composition Limits For Wrought Aluminum Alloys, revised September 1976.

TABLE 4

CHEMICAL COMPOSITIONS OF 2219-T852 HAND FORGINGS

(F33615-74-C-5089)

Sample[a]		Element, %								
Dimensions, in.	Number	Si	Fe	Cu	Mn	Mg	Zn	Ti	Zr	V
2.0x8	429246	0.08	0.19	6.33	0.28	0.00	0.00	0.07	0.12	0.08
2.5x22	478817	0.07	0.16	6.66	0.25	0.00	0.02	0.09	0.14	0.08
3.5x14	429512	0.08	0.18	6.35	0.26	0.00	0.01	0.08	0.11	0.09
3.5x22	429513	0.05	0.18	6.32	0.28	0.00	0.07	0.07	0.12	0.10
4.5x22	429249	0.07	0.13	6.04	0.29	0.00	0.01	0.10	0.12	0.09
4.5x22	429514	0.05	0.18	6.36	0.27	0.00	0.06	0.06	0.13	0.10
5.5x22	429247	0.05	0.19	6.40	0.30	0.00	0.07	0.06	0.12	0.09
5.5x22	429248	0.08	0.15	6.11	0.25	0.00	0.01	0.08	0.12	0.09
7.5x22	429244	0.08	0.15	6.11	0.25	0.00	0.01	0.09	0.12	0.10
7.5x22	429245	0.05	0.17	5.95	0.25	0.00	0.05	0.06	0.13	0.09
Limits[b] (Maximum unless range is shown)		0.20	0.30	5.8-6.8	0.20-0.40	0.02	0.10	0.02-0.10	0.10-0.25	0.05-0.15

(a) All samples fabricated by Alcoa.

(b) Aluminum Association Alloy Designations and Chemical Composition Limits for Wrought Aluminum Alloys, revised September 1976.

TABLE 5

MECHANICAL PROPERTIES OF 2048-T851 PLATE
(F33615-74-C-5089)

Sample Thickness, in.	Sample Number	Direction[b]	Tensile Ultimate Strength, ksi	Tensile Yield Strength,[a] ksi	Elongation in 4D, %	Reduction in Area, %	Compressive Yield Strength,[a] ksi	Shear Ultimate Strength, ksi	Bearing (Flatwise) Ultimate Strength, ksi e/D=1.5	Bearing (Flatwise) Ultimate Strength, ksi e/D=2.0	Bearing (Flatwise) Yield Strength,[c] ksi e/D=1.5	Bearing (Flatwise) Yield Strength,[c] ksi e/D=2.0
0.500	421378	L	66.1	62.2	12.0	39	63.4	38.8	100.3	132.0	87.6	100.8
		LT	66.3	61.5	12.0	38	63.4	39.1	102.3	132.9	92.3	101.4
0.500	421379	L	68.1	63.8	12.0	39	64.7	40.0	105.4	136.2	92.9	107.0
		LT	68.4	63.2	11.0	34	65.4	40.1	103.4	135.1	90.5	102.7
1.000	421108	L	71.4	67.5	9.5	27	66.5	40.7	101.4	131.8	89.6	101.6
		LT	70.5	65.4	8.5	20	66.5	39.8	102.3	134.4	90.5	103.2
1.000	421380	L	65.3	62.1	12.0	41	60.4	38.6	97.5	126.1	85.5	99.8
		LT	66.1	61.1	7.5	18	61.3	38.2	98.6	126.7	87.3	100.9
2.000	421381	L	67.3	63.7	11.5	36	62.3	38.0	99.7	129.5	87.4	100.4
		LT	67.1	62.6	7.0	10	63.3	39.2	100.6	131.1	90.7	101.2
		ST	64.0	59.3	5.4	10	64.4	--	--	--	--	--
2.000	421382	L	69.6	65.4	11.0	32	63.4	40.9	105.5	136.1	92.0	104.2
		LT	69.9	64.9	7.5	16	64.7	40.7	104.4	135.4	91.4	103.9
		ST	65.7	59.9	6.2	12	64.5	--	--	--	--	--
3.000	421083	L	67.9	64.2	8.5	20	60.9	38.6	101.1	131.5	38.6	104.0
		LT	68.0	62.9	7.0	16	63.0	38.6	96.7	130.9	87.1	102.1
		ST	63.6	58.5	4.0	8	62.9	33.1	--	--	--	--
3.000	421084	L	70.2	64.7	6.5	11	62.9	40.2	98.0	132.5	87.8	104.5
		LT	70.1	63.9	6.0	8	63.6	40.0	100.6	132.0	90.1	107.3
		ST	65.7	58.9	5.0	12	62.3	36.3	--	--	--	--
4.000	421383	L	64.4	59.1	9.0	22	55.9	37.4	95.1	122.9	81.2	94.9
		LT	63.7	57.3	7.5	12	56.6	37.4	96.6	125.4	82.6	96.8
		ST	62.5	56.0	4.3	8	59.5	34.2	--	--	--	--
4.000	421384	L	69.2	64.2	8.0	16	60.9	40.2	98.3	131.1	87.1	103.6
		LT	68.4	61.9	5.5	7	62.4	40.5	103.7	133.2	91.4	105.1
		ST	65.6	59.5	3.2	8	63.1	36.8	--	--	--	--
Tentative Minimum Properties												
2.001-3.000		L	62	56	6	--						
		LT	62	56	5	--						
		ST	60	54	2.5	--						
Typical Properties[d]												
0.500		LT	68	62	10	--						
1.000		LT	68	61	8	--						
2.000		LT	68	61	6	--						
3.000		LT	67	60	6	--						
4.000		LT	66	59	6	--						

(a) Offset equals 0.2 per cent.
(b) L-Longitudinal; LT-Long-Transverse; ST-Short-Transverse.
(c) Offset equals 2 per cent of pin diameter.
(d) Minimum properties expected 5 to 6 ksi below typical values; values supplied by Reynolds.

TABLE 6

MECHANICAL PROPERTIES OF 7050-T7351 PLATE

(F33615-74-C-5089)

Sample: Thickness, in.	Sample: Number	Direction (b)	Tensile: Ultimate Strength, ksi	Tensile: Yield Strength, (a) ksi	Tensile: Elongation in 4D, %	Tensile: Reduction in Area, %	Compressive Yield Strength, (a) ksi	Shear Ultimate Strength, ksi	Bearing (Flatwise): Ultimate Strength, ksi e/D=1.5	Bearing (Flatwise): Ultimate Strength, ksi e/D=2.0	Bearing (Flatwise): Yield Strength, (c) ksi e/D=1.5	Bearing (Flatwise): Yield Strength, (c) ksi e/D=2.0
2.000	421074	I	71.8	61.1	13.5	33	59.4	43.6	112.3(d)	141.5(d)	91.5(d)	108.0(d)
		LT	72.1	60.9	12.0	20	63.3	43.3	111.3	141.3	93.2	109.0
		ST	68.9	55.6	7.8	12	62.9	--	---	---	--	---
2.000	421075	I	71.3	60.4	14.0	35	59.0	43.6	110.4(e)	142.8(e)	90.1(e)	107.6(e)
		LT	71.6	60.4	12.0	29	62.6	43.2	109.2	142.5	90.3	109.0
		ST	69.0	55.3	8.6	16	62.4	--	---	---	--	---
3.000	421076	L	73.5	63.7	12.0	28	61.4	45.3	113.0	146.3	91.8	107.3
		LT	74.2	63.7	10.5	19	66.2	45.2	113.7	147.6	95.0	114.8
		ST	71.9	60.1	6.5	12	65.0	42.7	---	---	--	---
3.000	421081	L	73.4	63.9	12.5	29	61.7	45.6	114.4	147.6	93.9	111.3
		LT	74.7	64.2	10.5	21	66.6	45.1	112.8	146.5	92.9	112.0
		ST	72.4	61.4	6.5	12	65.6	43.2	---	---	--	---
4.000	421077	L	73.1	63.7	10.0	30	60.6	45.6	110.2	142.2	92.5	107.5
		LT	74.4	63.4	10.0	16	66.0	45.2	112.5	146.7	93.3	110.4
		ST	72.4	60.0	7.8	12	64.9	41.9	---	---	--	---
4.000	421078	L	72.9	63.7	11.5	24	60.5	45.5	113.6	145.9	94.6	111.3
		LT	74.2	63.4	10.0	16	65.7	45.3	115.8	145.9	97.8	111.2
		ST	71.6	59.0	5.7	8	64.3	41.7	---	---	--	---
5.000	421073	L	72.5	63.7	11.5	24	59.4	44.9	112.2(e)	142.3(d)	91.5(e)	113.8(d)
		LT	74.1	63.7	10.0	18	65.1	44.6	110.2	144.2(d)	90.4	110.0(d)
		ST	70.3	58.8	6.0	10	63.4	41.4	---	---	--	---
5.118	421278	L	71.9	63.2	11.0	22	59.8	44.6	109.6	141.8	91.3	107.2
		LT	72.4	61.4	9.0	15	64.9	44.5	111.4	142.7	91.4	109.0
		ST	69.5	58.6	7.0	10	62.5	42.2	---	---	--	---
6.000	421079	L	69.8	60.4	11.0	21	56.3	43.3	108.8	139.4(e)	89.0	107.5(e)
		LT	70.6	59.1	10.0	16	61.7	43.1	109.6	19.8	90.7	110.8
		ST	68.0	56.3	6.2	8	60.4	41.1	---	-	--	---
6.000	421080	L	71.8	62.2	10.5	19	57.7	44.9	113.2(d)	143.2(d)	91.0(d)	110.2(d)
		LT	72.9	60.9	9.0	13	63.8	44.7	111.4	143.4(d)	93.0	106.6(d)
		ST	68.5	58.1	4.0	6	62.7	41.4	---	---	--	---
Tentative Minimum Properties												
≤ 2.000		L	67	58	10							
		LT	68	58	7							
2.001-3.000		L	67	59	10							
		LT	68	59	7							
		ST	64	55	2.5							
3.001-4.000		L	66	57	10							
		LT	67	57	7							
		ST	63	53	2.5							
4.001-5.000		L	64	55	10							
		LT	65	55	6							
		ST	61	51	2.5							
5.001-6.000		L	62	53	9							
		LT	63	53	5							
		ST	59	49	2.5							

(a) Offset equals 0.2 per cent.
(b) L - Longitudinal, LT - Long-Transverse; ST - Short-Transverse; Specification test location at T/4.
(c) Offset equals 2 per cent of pin diameter.
(d) Retest value; original test result questionable.
(e) Average of original test and retest values.

NOTE: All samples fabricated by Alcoa

TABLE 7

MECHANICAL PROPERTIES OF 7475-T7351 PLATE

(F33615-74-C-5089)

Sample Thickness, in.	Sample Number	Direction(b)	Tensile Ultimate Strength, ksi	Tensile Yield Strength,(a) ksi	Tensile Elongation in 4D, %	Tensile Reduction in Area, %	Compressive Yield(a) Strength, ksi	Shear Ultimate Strength, ksi	Bearing (Flatwise) Ultimate Strength, ksi e/D=1.5	Bearing (Flatwise) Ultimate Strength, ksi e/D=2.0	Bearing (Flatwise) Yield Strength,(c) ksi e/D=1.5	Bearing (Flatwise) Yield Strength,(c) ksi e/D=2.0
0.500	429422	L	72.8	62.4	16.0	41	62.5	44.6	106.0	137.4	86.2	102.7
		L(d)	71.1	61.6	16.0	39	--	--	105.3	138.1	86.4	107.7
		LT	73.7	63.2	13.5	33	65.2	43.5	105.8	138.2	85.5	106.1
		LT(d)	72.8	62.8	14.0	27	--	--	105.7	139.4	86.4	102.7
0.500	429423	L	72.2	62.3	16.0	42	63.4	45.1	106.9	138.8	91.0	104.7
		L(d)	71.1	61.9	17.0	43	--	--	108.5	141.9	90.4	107.6
		LT	74.0	63.9	14.0	35	64.8	44.4	106.8	138.8	84.0	101.3
		LT(d)	73.3	63.1	14.0	27	--	--	110.0	143.3	97.0	109.6
1.000	429387	L	72.5	62.3	14.2	39	61.6	42.8	103.3	133.8	83.6	101.4
		LT	71.6	61.2	13.2	32	62.7	42.3	103.9	133.7	83.8	100.6
1.000	429388	L	70.0	59.6	15.0	41	58.3	42.1	102.0	130.4	81.9	98.2
		LT	70.0	59.4	13.5	32	61.1	41.6	102.4	132.8	82.6	99.3
2.000	429389	L	68.0	57.0	15.2	41	56.0	(e)	106.1	137.3	85.2	98.3
		L(d)	68.7	57.8	14.5	35	--	42.5	106.5	138.2	85.7	102.0
		LT	69.2	57.7	12.2	28	60.3	(e)	106.8	140.0	86.9	106.4
		LT(d)	69.3	58.1	13.0	27	--	42.9	108.6	139.3	89.3	105.3
		ST	65.5	57.0	6.2	16	59.8	--	---	---	--	---
2.000	429390	L	68.7	57.7	15.0	39	57.1	(e)	107.3	139.0	87.3	103.9
		L(d)	68.7	57.6	15.5	38	--	43.0	106.2	137.9	87.6	101.2
		LT	69.6	58.3	12.5	27	60.1	(e)	107.5	137.6	87.4	98.3
		LT(d)	69.2	58.3	13.0	27	--	42.2	107.1	138.3	88.1	101.4
		ST	66.6	58.2	7.8	17	60.7	--	---	---	--	---
3.000	429391	L	65.7	54.9	15.7	42	54.3	43.2	104.9	136.4	83.8	98.7
		LT	67.8	55.7	11.7	27	58.9	43.0	106.1	136.5	85.2	99.3
		ST	67.0	54.4	8.0	17	58.3	40.5	---	---	--	---
3.000	429392	L	65.8	55.0	15.5	41	54.0	43.2	104.5	135.3	84.3	98.7
		LT	68.2	56.4	11.2	20	58.8	43.2	105.3	135.6	85.2	98.3
		ST	66.2	54.0	7.0	11	58.3	40.0	---	---	--	---
4.000	429393	L	63.8	52.6	5.2	41	51.2	41.9	100.3	131.+	80.5	93.1
		LT	66.0	54.2	11.0	21	56.0	41.4	100.1	129.9	81.4	94.2
		ST	65.0	52.5	8.2	13	56.3	39.1	---	---	--	---
4.000	429394	L	64.1	52.7	15.2	41	50.9	41.9	100.9	129.2	80.5	94.0
		LT	65.8	53.1	10.7	19	55.3	41.6	99.9	129.4	80.5	92.7
		ST	64.6	51.6	7.5	10	55.8	38.9	---	---	--	---
Tentative Minimum Properties												
0.500-1.000		L	68	57	10							
		LT	68	57	9							
1.501-2.000		L	67	55	10							
		LT	67	55	8							
		ST	64	52	4							
2.501-3.000		L	65	53	10							
		LT	65	53	8							
		ST	62	50	3							
3.501-4.000		L	61	48	9							
		LT	61	48	7							
		ST	59	46	3							

(a) Offset equals 0.2 per cent.
(b) L - Longitudinal; LT - Long-Transverse, ST - Short-Transverse. Specification test location T/2 for 0.500 and 1.000-in. thick plate and T/4 for all other thicknesses.
(c) Offset equals 2 per cent of pin diameter.
(d) Retests.
(e) Original values questionable. Ratios in Table 12 based on shear and tensile retest values.

NOTE 1 In Table 12, compressive and shear ratios based on original LT tensile tests except as noted in (e). Where a bearing retest is indicated, ratio is based on average of original test and retest bearing and tensile properties.

NOTE 2 All samples fabricated by Alcoa.

TABLE 8

MECHANICAL PROPERTIES OF 7475-T7351 PLATE (CURRENT PRACTICE)

(M.T. NO. 110176-A)

Sample			Tensile					Compressive		Shear	Bearing (Flatwise)			
Thickness, in.	Number	Direction[b]	Ultimate Strength, ksi	Yield Strength,[a] ksi	Elongation in 4D, %	Reduction in Area, %	Modulus, 10^3ksi	Yield Strength,[a] ksi	Modulus, 10^3ksi	Ultimate Strength, ksi	Ultimate Strength, ksi e/D=1.5	Ultimate Strength, ksi e/D=2.0	Yield Strength,[c] ksi e/D=1.5	Yield Strength,[c] ksi e/D=2.0
0.500	478717	L	71.0	62.3	18.0	45	---	62.3	---	43.9	112.6	145.7	91.1	114.8
		LT	73.4	63.8	14.0	29	---	66.6	---	43.6	114.2	143.7	95.2	112.5
0.750	478718	L	72.8	63.8	16.0	46	10.32	63.4	10.69	42.6	107.7	140.3	88.5	108.3
		LT	73.2	63.7	14.0	37	10.41	56.6	10.81	42.1	108.2	136.3	89.6	104.2
1.750	478824	L	72.9	61.9	15.5	41	---	--	---	--	---	---	---	---
		LT	72.9	61.9	13.0	33	---	--	---	--	---	---	---	---
		ST	71.4	58.4	9.4	23	---	--	---	--	---	---	---	---
1.750	478825	L	72.4	61.8	15.0	41	---	--	---	--	---	---	---	---
		LT	72.8	61.9	13.5	33	---	--	---	--	---	---	---	---
		ST	70.2	57.7	9.4	22	---	--	---	--	---	---	---	---
2.250	478826	L	71.1	60.4	15.5	42	---	--	---	--	---	---	---	---
		LT	72.2	61.1	12.5	29	---	--	---	--	---	---	---	---
		ST	70.8	58.7	8.0	18	---	--	---	--	---	---	---	---
2.250	478827	L	70.1	59.0	15.5	40	---	--	---	--	---	---	---	---
		LT	71.0	59.3	12.0	28	---	--	---	--	---	---	---	---
		ST	68.7	55.7	8.0	18	---	--	---	--	---	---	---	---
2.750	478828	L	69.0	58.3	14.5	39	---	--	---	--	---	---	---	---
		LT	69.9	58.3	12.0	28	---	--	---	--	---	---	---	---
		ST	68.1	55.3	10.0	20	---	--	---	--	---	---	---	---
2.750	478829	L	68.7	58.1	15.0	48	---	--	---	--	---	---	---	---
		LT	70.8	59.3	11.5	24	---	--	---	--	---	---	---	---
		ST	68.8	54.3	10.0	18	---	--	---	--	---	---	---	---
3.500	478830	L	67.0	56.0	15.0	41	---	--	---	--	---	---	---	---
		LT	68.4	56.3	12.0	24	---	--	---	--	---	---	---	--
		ST	67.7	54.4	10.0	16	---	--	---	--	---	---	---	---
3.500	478961	L	66.6	55.2	15.0	39	10.13	53.8	10.48	42.5	105.9	139.6	84.3	100.4
		LT	68.0	55.6	11.0	29	10.34	58.3	10.80	41.8	109.2	136.7	90.8	101.5
		ST	67.5	54.1	6.6	16	10.23	58.8	10.60	37.5	---	---	---	---
Tentative Minimum Properties														
0.500-1.000		L	68	57	10									
		LT	68	57	9									
1.501-2.000		L	67	55	10									
		LT	67	55	8									
		ST	64	52	4									
2.001-2.500		L	66	54	10									
		LT	66	54	8									
		ST	64	52	4									
2.501-3.000		L	65	53	10									
		LT	65	53	8									
		ST	62	50	3									
3.001-3.500		L	63	51	10									
		LT	63	51	8									
		ST	61	48	3									

(a) Offset equals 0.2 per cent.
(b) L - Longitudinal, LT - Long-Transverse, ST - Short-Transverse.
(c) Offset equals 2 per cent of pin diameter.

TABLE 9

MECHANICAL PROPERTIES OF 2219-T852 HAND FORGINGS

(F33615-74-C-5089)

Sample Dimensions, in.	Sample Number	Direction[b]	Tensile Ultimate Strength, ksi	Tensile Yield Strength,[a] ksi	Tensile Elongation in 4D, %	Tensile Reduction in Area, %	Compressive Yield Strength,[a] ksi	Shear Ultimate Strength, ksi	Bearing (Edgewise) Ultimate Strength, ksi e/D = 1.5	Bearing (Edgewise) Ultimate Strength, ksi e/D = 2.0	Bearing (Edgewise) Yield Strength,[c] ksi e/D = 1.5	Bearing (Edgewise) Yield Strength,[c] ksi e/D = 2.0
2.0x8	429246	L	63.0	50.7	10.5	26	52.5	41.4	82.7	116.2	81.5	96.8
		LT	66.5	50.6	9.0	14	53.3	41.6	92.2	120.6	84.9	97.0
		ST	66.6	51.5	9.4	12	53.6	--	--	--	--	--
2.5x22	478817	L	64.9	50.4	13.0	32	50.5	39.8	81.5	112.5	76.2	93.8
		LT	65.7	49.9	10.0	17	52.5	39.4	85.0	118.2	78.4	96.6
		ST	65.9	51.1	8.0	14	52.7	35.2	--	--	--	--
3.5x14	429512	L	65.0	50.3	11.0	26	47.8	41.9	92.2	124.3	78.3	90.1
		LT	64.4	49.8	8.0	12	48.1	38.9	89.6	117.9	76.7	88.9
		ST	64.9	49.7	8.0	11	48.1	37.7	--	--	--	--
3.5x22	429513	L	65.6	51.2	10.5	24	47.5	42.1	84.0	117.0	77.1	89.6
		LT	56.1	50.2	8.0	12	48.1	40.5	81.9	113.1	77.1	88.9
		ST	66.7	51.1	9.0	11	47.6	36.4	--	--	--	--
4.5x22	429249	L	59.0	45.2	12.0	28	42.3	39.4	81.8	106.2	72.3	85.5
		LT	58.3	45.7	5.0	7	44.8	38.4	84.0	114.2	72.9	93.9
		ST	60.0	47.0	5.0	6	45.6	36.4	--	--	--	--
4.5x22	429514	L	64.1	50.2	12.5	29	46.8	42.8	87.1	121.8	79.1	91.2
		LT	66.1	50.6	8.0	12	47.1	41.4	89.1	119.3	80.0	93.1
		ST	66.6	51.2	7.9	12	48.6	38.7	--	--	--	--
5.5x22	429247	L	62.5	49.2	11.0	25	46.8	40.0	88.2	116.4	75.9	91.0
		LT	61.6	46.4	8.5	13	48.7	39.6	90.2	117.6	78.2	91.1
		ST	62.3	47.2	7.1	9	47.2	37.3	--	--	--	--
5.5x22	429248	L	60.6	44.6	14.5	22	45.9	41.2	86.9	114.2	75.7	86.3
		LT	60.0	43.1	11.8	16	46.9	40.7	90.0	116.4	75.8	[illegible]
		ST	65.8	50.8	8.6	8	44.0	37.9	--	--	--	--
7.5x22	429244	L	54.7	41.9	12.0	26	41.4	36.4	81.1	107.0	67.4	78.2
		LT	55.8	43.8	5.0	7	40.6	36.8	81.7	108.2	67.7	79.8
		ST	56.7	42.4	6.5	9	42.2	36.2	--	--	--	--
7.5x22	429245	L	57.4	43.4	11.0	26	43.8	39.1	87.4	116.7	71.9	83.6
		LT	58.2	44.2	8.0	11	42.1	39.1	87.6	114.0	74.0	86.3
		ST	58.3	44.1	7.5	13	43.6	38.4	--	--	--	--
Minimum Properties												
Up to 4.000[d]		L	62	50	6							
		LT	62	49	4							
		ST	60	46	3							
4.001-6.000[e]		L	56	43	6							
		LT	56	42	4							
		ST	54	39	3							
6.001-8.000[e]		L	53	40	6							
		LT	53	39	4							
		ST	51	36	3							

(a) Offset equals 0.2%.
(b) L-Longitudinal; LT-Long-Transverse; ST-Short-Transverse.
(c) Offset equals 2% of pin diameter.
(d) Federal Specification QQ-A-367g; AMDT. 1, dated May 23, 1968.
(e) Tentative

TABLE 10

RATIOS AMONG THE TENSILE, COMPRESSIVE, SHEAR, AND BEARING PROPERTIES OF 2048-T851 PLATE
(F33615-74-C-5089)

Sample		Compressive			Shear			Bearing (Flatwise)							
Thickness, in.	Number	CYS(L)/TYS(LT)	CYS(LT)/TYS(LT)	CYS(ST)/TYS(LT)	SU(L)/TUS(LT)	SU(LT)/TUS(LT)	SU(ST)/TUS(LT)	BUS(L)/TUS(LT) e/D=1.5	BUS(L)/TUS(LT) e/D=2.0	BYS(L)/TYS(LT) e/D=1.5	BYS(L)/TYS(LT) e/D=2.0	BUS(LT)/TUS(LT) e/D=1.5	BUS(LT)/TUS(LT) e/D=2.0	BYS(LT)/TYS(LT) e/D=1.5	BYS(LT)/TYS(LT) e/D=2.0
0.500	421378	1.031	1.031	---	0.585	0.590	---	1.513	1.991	1.424	1.639	1.543	2.005	1.501	1.649
0.500	421379	1.024	1.035	---	0.585	0.586	---	1.541	1.991	1.470	1.693	1.512	1.975	1.432	1.625
1.000	421108	1.017	1.017	---	0.577	0.565	---	1.438	1.870	1.370	1.554	1.451	1.906	1.384	1.578
1.000	421380	0.989	1.003	---	0.584	0.578	---	1.475	1.908	1.399	1.633	1.492	1.917	1.429	1.651
2.000	421381	0.995	1.011	1.029	0.566	0.584	---	1.486	1.930	1.396	1.604	1.499	1.954	1.449	1.617
2.000	421382	0.977	0.997	0.994	0.585	0.582	---	1.509	1.947	1.418	1.606	1.494	1.937	1.408	1.601
3.000	421083	0.968	1.002	1.000	0.568	0.568	0.487	1.487	1.934	1.409	1.653	1.422	1.925	1.385	1.623
3.000	421084	0.984	0.995	0.975	0.573	0.571	0.518	1.398	1.890	1.374	1.635	1.435	1.883	1.410	1.679
4.000	421383	0.976	0.988	1.038	0.587	0.587	0.537	1.493	1.929	1.417	1.656	1.516	1.969	1.442	1.689
4.000	421384	0.984	1.008	1.019	0.588	0.592	0.538	1.437	1.917	1.407	1.674	1.516	1.947	1.477	1.668

TABLE 11

RATIOS AMONG THE TENSILE, COMPRESSIVE, SHEAR AND BEARING PROPERTIES OF 7050-T7351 PLATE

(F33615-74-C-5089)

Sample Thickness, in.	Sample Number	Compressive CYS(L)/TYS(LT)	Compressive CYS(LT)/TYS(LT)	Compressive CYS(ST)/TYS(LT)	Shear SUS(L)/TUS(LT)	Shear SUS(LT)/TUS(LT)	Shear SUS(ST)/TUS(LT)	Bearing (Flatwise) BUS(L)/TUS(LT) e/D=1.5	BUS(L)/TUS(LT) e/D=2.0	BYS(L)/TYS(LT) e/D=1.5	BYS(L)/TYS(LT) e/D=2.0	BUS(LT)/TUS(LT) e/D=1.5	BUS(LT)/TUS(LT) e/D=2.0	BYS(LT)/TYS(LT) e/D=1.5	BYS(LT)/TYS(LT) e/D=2.0
2.000	421074	0.975	1.039	1.033	0.605	0.501	---	1.558	1.963	1.502	1.773	1.544	1.960	1.530	1.790
2.000	421075	0.977	1.036	1.033	0.609	0.603	---	1.542	1.994	1.492	1.781	1.535	1.990	1.495	1.805
3.000	421076	0.964	1.039	1.020	0.611	0.609	0.575	1.523	1.972	1.441	1.684	1.532	1.989	1.491	1.802
3.000	421081	0.961	1.037	1.022	0.610	0.504	0.578	1.531	1.976	1.463	1.734	1.510	1.961	1.447	1.745
4.000	421077	0.956	1.041	1.024	0.613	0.608	0.563	1.481	1.911	1.459	1.696	1.512	1.972	1.472	1.741
4.000	421078	0.954	1.036	1.041	0.613	0.611	0.562	1.531	1.966	1.492	1.756	1.561	1.966	1.543	1.754
5.000	421073	0.932	1.022	0.995	0.606	0.602	0.559	1.514	1.920	1.436	1.786	1.487	1.946	1.419	1.727
5.118	421278	0.974	1.057	1.024	0.616	0.615	0.583	1.514	1.959	1.487	1.746	1.539	1.971	1.489	1.775
6.000	421079	0.953	1.044	1.022	0.613	0.610	0.582	1.541	1.975	1.506	1.819	1.552	1.980	1.535	1.875
6.000	421080	0.947	1.048	1.030	0.616	0.613	0.568	1.553	1.964	1.494	1.810	1.528	1.96[illegible]	1.527	1.750

NOTE: See Table 6 for basis of ratio determinations.

TABLE 12

RATIOS AMONG THE TENSILE, COMPRESSIVE, SHEAR AND BEARING PROPERTIES OF 7475-T7351 PLATE

(F33615-74-C-5089)

Sample		Compressive			Shear			Bearing (Flatwise)							
								BUS(L)/TUS(LT)		BYS(L)/TYS(LT)		BUS(LT)/TUS(LT)		BYS(LT)/TYS(LT)	
Thickness, in.	Number	CYS(L)/TYS(LT)	CYS(LT)/TYS(LT)	CYS(ST)/TYS(LT)	SUS(L)/TUS(LT)	SUS(LT)/TUS(LT)	SUS(ST)/TUS(LT)	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0
0.500	429422	0.989	1.032	---	0.605	0.590	---	1.442	1.881	1.370	1.670	1.444	1.895	1.364	1.657
0.500	429423	0.992	1.014	---	0.609	0.600	---	1.462	1.906	1.428	1.672	1.472	1.915	1.425	1.661
1.000	429387	1.007	1.024	---	0.598	0.591	---	1.443	1.869	1.366	.657	1.451	1.867	1.369	1.644
1.000	429388	0.981	1.029	---	0.601	0.594	---	1.457	1.863	1.379	1.653	1.463	1.897	1.391	1.672
2.000	429389	0.971	1.045	1.036	0.613	0.619	---	1.535	1.989	1.476	1.730	1.555	2.017	1.522	1.828
2.000	429390	0.979	1.031	1.041	0.621	0.610	---	1.538	1.995	1.500	1.759	1.546	1.986	1.505	1.713
3.000	429391	0.975	1.057	1.047	0.637	0.634	0.597	1.547	2.012	1.504	1.772	1.565	[illegible]	1.530	1.783
3.000	429392	0.957	1.043	1.034	0.633	0.633	0.587	1.532	1.984	1.495	1.750	1.544	1.998	1.511	1.743
4.000	429393	0.945	1.033	1.039	0.635	0.627	0.592	1.520	1.991	1.485	1.718	1.517	1.968	1.502	1.738
4.000	429394	0.959	1.041	1.051	0.637	0.632	0.591	1.533	1.964	1.516	1.770	1.518	1.967	1.516	1.746

NOTE: See Table 7 for basis of ratio determinations.

TABLE 13

RATIOS AMONG TENSILE, COMPRESSIVE, SHEAR AND BEARING PROPERTIES
OF 7475-T7351 PLATE (CURRENT PRACTICE)

Sample		Compressive			Shear			Bearing (Flatwise)							
								BUS(L)/TUS(LT)		BYS(L)/TYS(LT)		BUS(LT)/TUS(LT)		BYS(LT)/TYS(LT)	
Thickness, in.	Number	CYS(L)/TYS(LT)	CYS(LT)/TYS(LT)	CYS(ST)/TYS(LT)	SUS(L)/TUS(LT)	SUS(LT)/TUS(LT)	SUS(ST)/TUS(LT)	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0
0.500	478717	0.976	1.044	---	0.598	0.594	---	1.524	1.985	1.428	1.799	1.556	1.958	1.492	1.76?
0.750	478718	0.995	1.046	---	0.582	0.575	---	1.473	1.917	1.389	1.700	1.478	1.889	1.407	1.636
3.500	478961	0.968	1.049	1.058	0.625	0.615	0.551	1.557	2.053	1.516	1.806	1.606	2.010	1.633	1.326

TABLE 14

RATIOS AMONG THE TENSILE, COMPRESSIVE, SHEAR, AND BEARING PROPERTIES OF 2219-T852 HAND FORGINGS
(F33615-74-C-5089)

Sample		Compressive			Shear			Bearing (Edgewise)							
Dimensions, in.	Number	CYS(L)/TYS(LT)	CYS(LT)/TYS(LT)	CYS(ST)/TYS(LT)	SU(L)/TUS(LT)	SU(LT)/TUS(LT)	SU(ST)/TUS(LT)	BUS(L)/TUS(LT)		BYS(L)/TYS(LT)		BUS(LT)/TUS(LT)		BYS(LT)/TYS(LT)	
								e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0
2.0x8	429246	1.038	1.053	1.059	0.623	0.626	--	1.244	1.747	1.611	1.913	1.386	1.814	1.678	1.917
2.5x22	478817	1.012	1.052	1.056	0.607	0.600	0.536	1.240	1.712	1.527	1.880	1.294	1.799	1.571	1.936
3.5x14	429512	0.950	0.966	0.966	0.651	0.604	0.585	1.432	1.930	1.572	1.809	1.391	1.831	1.540	1.785
3.5x22	429513	0.946	0.958	0.948	0.637	0.613	0.551	1.271	1.770	1.536	1.785	1.239	1.711	1.536	1.771
4.5x22	429249	0.926	0.980	0.998	0.676	0.659	0.624	1.403	1.822	1.582	1.871	1.441	1.959	1.595	2.055
4.5x22	429514	0.925	0.931	0.960	0.648	0.626	0.585	1.318	1.843	1.563	1.802	1.348	1.805	1.581	1.849
5.5x22	429247	1.009	1.050	1.017	0.649	0.642	0.606	1.432	1.890	1.635	1.961	1.464	1.909	1.685	1.963
5.5x22	429248	1.064	1.088	1.021	0.687	0.678	0.632	1.448	1.903	1.756	2.002	1.500	1.940	1.759	2.021
7.5x22	429244	0.945	0.927	0.963	0.652	0.659	0.649	1.453	1.918	1.539	1.785	1.464	1.939	1.546	1.822
7.5x22	429245	0.991	0.952	0.986	0.672	0.672	0.660	1.502	2.005	1.627	1.891	1.505	1.959	1.674	1.952

TABLE 15

RESULTS OF TENSILE AND COMPRESSIVE MODULUS OF ELASTICITY TESTS OF 2048-T851, 7050-T7351 AND 7475-T7351 PLATE AND 2219-T852 HAND FORGING

(F33615-74-C-5089)

Alloy and Temper	Product	Sample Thickness, in.	Sample Number	Longitudinal Tensile, 10^3 ksi	Longitudinal Compressive, 10^3 ksi	Long-Transverse Tensile, 10^3 ksi	Long-Transverse Compressive, 10^3 ksi	Short-Transverse Tensile, 10^3 ksi	Short-Transverse Compressive, 10^3 ksi	Nominal E, 10^3 ksi	Nominal E_c, 10^3 ksi	Nominal G, 10^3 ksi
2048-T851	Plate	1.5	421378	10.36	10.83	10.53	10.88	---	---			
		2.0	421381	10.33	10.68	10.41	10.71	10.22	10.70			
		3.0	421083	10.36	10.76	10.44	10.91	10.22	10.65			
		4.0	421384	10.44	10.75	10.45	10.80	10.37	10.70			
	Average			10.37	10.76	10.46	10.82	10.27	10.68	10.4	10.7	3.95
7050-T7351	Plate	2.0	421074	10.27	10.52	10.37	10.74	10.15	10.59			
		3.0	421076	10.25	10.61	10.41	10.70	10.16	10.71			
		4.0	421077	10.22	10.56	10.30	10.80	10.21	10.73			
		5.1	421278	10.22	10.52	10.30	10.63	10.19	10.50			
		6.0	421079	10.24	10.51	10.32	10.61	10.25	10.57			
	Average			10.24	10.54	10.34	10.70	10.19	10.62	10.3	10.6	3.9
7475-T7351	Plate	0.5	429402	10.40	10.75	10.52	10.94	---	---			
		2.0	429389	10.23	10.57	10.35	10.72	10.21	10.70			
		3.0	429391	10.19	10.48	10.27	10.70	10.22	10.62			
		4.0	429394	10.26	10.58	10.31	10.61	10.22	10.61			
	Average			10.27	10.60	10.36	10.74	10.22	10.64	10.3	10.6	3.9
2219-T852	Hand Forging	2.0	429246	10.42	10.58	10.45	10.65	10.05	10.41			
		3.5	429512	10.31	10.44	10.14	10.30	10.06	10.08			
		4.5	429249	10.29	10.66	10.40	10.67	10.37	10.50			
		5.5	429248	10.39	10.57	10.36	10.52	10.04	10.20			
		7.5	429245	10.13	10.20	10.21	10.30	9.98	10.10			
	Average			10.31	10.40	10.31	10.49	10.10	10.26	10.2	10.4	3.85

TABLE 16

TYPICAL STRESS-STRAIN DATA FOR 2048-T851 PLATE

(F33615-74-C-5089)

Strain Departure u in./in.	Tension (Modulus: 10.4 x 10^3 ksi) Longitudinal[a] Stress, ksi (% TYS)	Strain, u in./in.	Long-Transverse[a] Stress, ksi (% TYS)	Strain, u in./in.	Short-Transverse[b] Stress, ksi (% TYS)	Strain u in./in.	Compression (Modulus: 10.7 x 10^3 ksi) Longitudinal[a] Stress, ksi (% CYS)	Strain, u in./in.	Long-Transverse[a] Stress, ksi (% CYS)	Strain, u in./in.	Short-Transverse[b] Stress, ksi (% CYS)	Strain, u in./in.
0	25.1 (40.5)	2414	24.5 (40.2)	2359	23.3 (40.9)	2245	44.4 (72.8)	4150	43.4 (70.0)	4096	42.9 (70.3)	4012
20	34.0 (54.8)	3286	34.1 (55.9)	3302	31.7 (55.6)	3069	47.7 (78.2)	4481	48.0 (77.4)	4503	47.0 (77.0)	4411
40	40.0 (64.5)	3890	39.5 (64.8)	3841	37.1 (65.1)	3612	49.2 (80.7)	4638	49.6 (80.0)	4680	48.5 (79.5)	4571
60	44.1 (71.0)	4300	42.6 (69.8)	4156	39.6 (69.5)	3871	50.1 (82.2)	4745	50.8 (82.0)	4811	49.7 (81.5)	4706
80	46.9 (75.6)	4586	44.8 (73.4)	4385	41.4 (72.6)	4056	50.9 (83.5)	4838	51.7 (83.4)	4915	50.7 (83.1)	4816
100	49.1 (79.2)	4816	46.3 (75.9)	4554	42.6 (74.7)	4197	51.6 (84.6)	4919	52.[illegible] (84.5)	5001	51.4 (84.3)	4905
150	52.4 (84.5)	5187	49.0 (80.3)	4860	45.0 (78.9)	4474	52.8 (86.5)	5080	53.8 (86.8)	5181	52.8 (86.6)	5082
200	54.4 (87.7)	5430	50.8 (83.2)	5080	46.4 (81.4)	4664	53.7 (88.0)	5219	54.8 (88.4)	5320	53.9 (88.4)	5234
250	55.7 (89.9)	5609	52.1 (85.4)	5256	47.6 (83.5)	4830	54.4 (89.2)	5336	55.6 (89.7)	5449	54.7 (89.7)	5358
300	56.7 (91.5)	5755	53.1 (87.1)	5407	48.5 (85.1)	4968	55.0 (90.2)	5442	56.3 (90.8)	5564	55.3 (90.7)	5473
350	57.4 (92.6)	5874	54.0 (88.5)	5538	49.3 (86.5)	5092	55.6 (91.1)	5543	56.8 (91.6)	5662	55.[illegible] (91.6)	5575
400	58.1 (93.1)	5983	54.7 (89.6)	5657	50.0 (87.7)	5204	56.0 (91.8)	5634	57.3 (92.4)	5755	56.4 (92.4)	5666
500	59.0 (95.1)	6170	55.8 (91.5)	5869	51.0 (89.5)	54.8	56.7 (93.0)	5803	58.1 (93.7)	5928	57.2 (93.8)	5844
600	59.6 (96.2)	6334	56.7 (93.0)	6054	51.9 (91.1)	5592	57.4 (94.1)	5961	58.7 (94.7)	6088	57.8 (94.8)	6002
800	60.5 (97.6)	6616	58.0 (95.1)	6376	53.3 (93.5)	5924	58.3 (95.6)	6249	59.6 (96.1)	6373	58.7 (96.2)	6282
1000	61.0 (98.4)	6867	58.9 (96.5)	6662	54.3 (95.2)	6219	59.0 (96.7)	6514	60.3 (97.3)	6632	59.3 (97.2)	6543
1500	61.7 (99.5)	7432	60.2 (98.7)	7292	56.0 (98.2)	6880	60.2 (98.7)	7124	61.3 (98.9)	7230	60.4 (99.0)	7143
2000 YS	62.0 (100.0)	7962	61.0 (100.0)	7965	57.0 (100.0)	7481	61.0 (100.0)	7701	62.0 (100.0)	7794	61.0 (100.0)	7701
2200	62.1 (100.2)	8171	61.2 (100.4)	8087	57.3 (100.6)	7715	61.2 (100.4)	7922	6212 (100.3)	8013	61.2 (100.3)	7920
2300	---	--	61.3 (100.5)	8196	57.5 (100.9)	7830	61.4 (100.6)	8034	62.3 (100.5)	8123	61.3 (100.5)	8029
2400	---	--	61.4 (100.7)	8305	57.6 (101.1)	7943	61.5 (100.8)	8146	62.4 (100.6)	8231	---	--
2500	---	--	61.5 (100.8)	8413	57.8 (101.4)	8056	---	--	62.5 (100.8)	8340	---	--

(a) Data based on tests of four samples, 0.5, 2. 3.0 and 4.0-in. thick.
(b) Data based on tests of three samples, 2.0, 3." and 4.0-in. thick.

TABLE 17

TYPICAL STRESS-STRAIN DATA FOR 7050-T7351 PLATE

(F33615-74-C-5089)

Strain Departure, μ in./in.	Tension (Modulus, 10.3 x 10³ ksi) Longitudinal[a] Stress, ksi (% TYS)	Strain, μ in./in.	Long-Transverse[a] Stress, ksi (% TYS)	Strain, μ in./in.	Short-Transverse[a] Stress, ksi (% TYS)	Strain, μ in./in.	Compression (Modulus, 10.6 x 10³ ksi) Longitudinal[a] Stress, ksi (% CYS)	Strain, μ in./in.	Long-Transverse[a] Stress, ksi (% CYS)	Strain, μ in./in.	Short-Transverse[a] Stress, ksi (% CYS)	Strain, μ in./in.
0	24.0 (38.7)	2327	24.1 (38.9)	2340	22.3 (36.5)	2167	39.0 (65.0)	3682	43.8 (68.5)	4135	43.4 (68.9)	40[illegible]7
20	31.8 (51.3)	3108	32.2 (51.3)	3140	30.8 (51.3)	2911	43.5 (72.4)	4120	47.8 (74.6)	4525	47.6 (75.5)	4509
40	37.[illegible] (60.0)	3650	37.1 (59.8)	3630	34.3 (59.1)	3369	45.5 (75.8)	4332	49.7 (77.6)	4727	49.5 ([illegible])	4707
60	40.8 (65.8)	40[illegible]	40.2 (64.8)	3966	37.3 (64.3)	3678	46.[illegible] (78.[illegible])	4488	51.0 (79.6)	4868	50.8 (80.[illegible])	4853
80	43.4 (70.0)	4299	42.6 (68.7)	4216	39.5 (68.[illegible])	[illegible]18	47.8 (79.7)	4593	51.9 (81.1)	4980	51.8 (82.2)	4962
100	45.7 (73.7)	4535	44.3 (71.5)	4402	41.1 (70.9)	4093	48.8 (81.3)	4700	52.7 (82.3)	5069	52.5 (83.4)	5057
150	49.5 (79.8)	4958	47.3 (76.3)	4741	44.0 (75.8)	[illegible]	50.2 (83.7)	4890	54.3 (84.8)	5272	54.0 (85.7)	5244
200	51.9 (83.7)	5241	49.4 (79.7)	4995	45.8 (79.0)	4651	51.3 (81.5)	5043	55.4 (86.6)	5430	55.1 (87.4)	5397
250	53.7 (86.6)	5463	51.0 (82.2)	5197	47.3 (81.5)	4841	52.2 (87.0)	5177	56.3 (88.0)	5565	55.9 (88.7)	5525
300	55.0 (88.7)	5639	52.2 (84.2)	5363	48.4 (83.5)	4999	52.9 (88.2)	[illegible]	57.1 (89.2)	5686	56.6 (89.8)	5639
350	56.0 (90.3)	5790	53.2 (85.8)	5513	49.3 (85.0)	5135	53.5 (89.2)	5399	57.7 (90.2)	5796	57.2 (90.7)	5742
400	5[illegible].8 (91.6)	5[illegible]17	54.0 (87.1)	5645	50.1 (86.3)	5201	54.1 (90.1)	5499	58.3 (91.1)	5898	57.6 (91.5)	5838
500	58.0 (93.6)	6134	55.4 (89.4)	587[illegible]	51.3 (88.4)	5479	54.9 (91.5)	5679	59.2 (92.5)	6082	58.5 (92.8)	6016
600	58.9 (95.0)	631[illegible]	56.5 (91.1)	6083	52.2 (90.1)	5672	55.6 (92.7)	5845	59.9 (93.6)	6251	59.1 (93.8)	6178
800	60.0 (96.8)	6625	58.0 (93.6)	6436	53.7 (9[illegible].6)	6016	56.7 (94.5)	6147	61.0 (95.3)	6554	60.9 (96.6)	6474
1000	60.7 (97.9)	6891	59.2 (95.5)	6744	54.8 (9[illegible].5)	6323	57.5 (95.8)	64[illegible]	61.8 (96.5)	68[illegible]	61.6 (97.8)	6741
1500	61.[illegible] (99.3)	7477	60.9 (98.3)	7417	56.7 (97.8)	7007	59.0 (98.3)	7063	63.1 (98.7)	7457	62.6 (99.4)	7362
2000(Y)	62.[illegible] (100.0)	8019	62.0 (100.0)	8019	58.0 (100.0)	7631	60.0 (100.0)	7060	64.0 (100.0)	8038	63.0 (100.0)	7943
2200	62.1 (100.2)	8231	62.3 (100.5)	8249	58.4 (100.7)	787[illegible]	60.4 (100.6)	7894	64.3 (100.4)	8264	63.3 (100.5)	8170
2300	62.2 (100.3)	8337	62.[illegible] (100.7)	83[illegible]3	58.6 (101.0)	7990	60.5 (100.8)	8008	64.4 (100.6)	8376	63.4 (100.6)	8281
2400	62.2 (100.4)	8441	62.6 (100.9)	847[illegible]	58.8 (101.4)	8108	---	--	---	--	63.5 (100.8)	8392
2500	62.3 (100.4)	8546	6[illegible] (101.1)	8[illegible]88	59.0 (101.7)	8226	---	--	---	--	---	--

(a) Data based on tests of five samples, 2.0, 3.0, 4.0, 5.0 and 6.0-in. thick.

TABLE 18

TYPICAL STRESS-STRAIN DATA FOR 7475-T7351 PLATE

(F33615-74-C-5089)

Strain Departure µ in./in.	Tension (Modulus, 10.3 x 10^3 ksi)						Compression (Modulus, 10.6 x 10^3 ksi)					
	Longitudinal[a]		Long-Transverse[a]		Short-Transverse[b]		Longitudinal[a]		Long-Transverse[a]		Short-Transverse[b]	
	Stress, ksi (% TYS)	Strain, µ in./in.	Stress, ksi (% TYS)	Strain, µ in./in.	Stress, ksi (% TYS)	Strain, µ in./in.	Stress, ksi (% CYS)	Strain, µ in./in.	Stress, ksi (% CYS)	Strain, µ in./in.	Stress, ksi (% CYS)	Strain, µ in./in.
0	21.6 (36.1)	2102	23.4 (39.1)	2276	23.0 (40.3)	2231	42.0 (71.2)	3961	43.[illegible] (70.5)	4126	44.0 (72.1)	4154
20	30.5 (50.8)	2980	32.1 (53.7)	3145	31.0 (54.3)	3025	46.5 (78.9)	4411	48.7 (78.6)	4618	47.6 (78.0)	4514
40	36.0 (59.9)	3530	38.0 (63.3)	3729	36.4 (63.8)	3570	48.2 (81.7)	4592	50.3 (81.1)	4784	49.2 (80.7)	4681
60	39.8 (66.4)	3925	41.3 (68.9)	4072	39.7 (69.7)	3919	49.3 (83.5)	4709	51.4 (82.9)	4913	50.3 (82.5)	4810
80	42.5 (71.0)	4218	43.7 (72.8)	4319	42.0 (73.7)	4159	50.1 (84.9)	4809	52.2 (84.2)	5006	51.1 (83.8)	4904
100	44.9 (74.9)	4461	45.6 (75.9)	4523	43.5 (76.4)	4326	50.7 (85.9)	4883	52.9 (85.3)	5091	51.8 (84.9)	4985
150	48.8 (81.3)	4889	48.5 (80.8)	4859	45.9 (80.5)	4606	51.9 (87.9)	5042	54.2 (87.4)	5263	53.0 (86.9)	5146
200	51.3 (85.5)	5178	50.4 (83.9)	5090	47.4 (83.1)	4799	52.7 (89.3)	5169	55.2 (89.0)	5405	53.9 (88.3)	5281
250	52.9 (88.2)	5386	51.7 (86.2)	5269	48.4 (85.0)	4951	53.3 (90.4)	5282	55.9 (90.2)	5524	54.6 (89.5)	5400
300	54.2 (90.3)	5558	52.7 (87.9)	5421	49.2 (86.4)	5079	53.8 (91.2)	5379	56.6 (91.3)	5636	55.2 (90.5)	5505
350	55.0 (91.7)	5693	53.6 (89.3)	5550	49.9 (87.5)	5191	54.3 (92.0)	5474	57.1 (92.1)	5735	55.6 (91.1)	5596
400	55.7 (92.9)	5810	54.3 (90.5)	5669	50.5 (88.1)	5298	54.7 (92.7)	5559	57.5 (92.7)	5825	56.0 (91.8)	5684
500	56.8 (94.7)	6014	55.[illegible] (92.3)	5874	51.4 (90.2)	5489	55.3 (93.7)	5718	58.2 (93.9)	5995	56.7 (93.0)	5853
600	57.5 (95.8)	6182	56.2 (93.6)	6054	52.1 (91.4)	5660	55.8 (94.6)	5867	58.8 (94.8)	6148	57.3 (93.9)	6003
800	58.4 (97.3)	6470	57.4 (95.6)	6369	53.3 (93.4)	6072	56.6 (95.9)	6140	59.7 (96.3)	6428	58.1 (95.2)	6286
1000	58.9 (98.2)	67[illegible]3	58.1 (96.9)	6644	54.2 (95.0)	6259	57.2 (96.9)	6397	60.3 (97.3)	6688	58.8 (96.4)	6550
1500	59.6 (99.4)	7291	59.4 (98.8)	7258	55.8 (97.9)	6917	58.2 (98.6)	6993	61.3 (98.9)	7284	60.1 (98.5)	7168
2000(YS)	60.0 (100.0)	7825	60.0 (100.0)	7825	57.0 (100.0)	7534	59.0 (100.0)	7566	62.0 (100.0)	7849	61.0 (100.0)	7755
2200	60.1 (100.2)	8036	60.2 (100.3)	8045	57.4 (100.7)	7775	59.3 (100.5)	7790	62.2 (100.3)	8071	61.3 (100.5)	7982
2400	---	--	---	--	57.8 (101.4)	8013	---	--	62.4 (100.6)	8291	61.6 (101.0)	8208
2500	60.2 (100.4)	8348	60.5 (100.8)	8370	58.0 (101.8)	8131	---	--	---	--	61.7 (101.1)	8320

(a) Data based on tests of four samples, 0.5, 2.0, 3.0 and 4.0-in. thick.
(b) Data based on tests of three samples, 2.9, 3.0 and 4.0-in. thick.

TABLE 19

DATA FOR ESTABLISHING TYPICAL STRESS-STRAIN CURVES FOR 2219-T852 HAND FORGINGS

(F33615-74-C-5089)

Strain Departure u in./in.	Percentage of Yield Stress[a]					
	Tension (Modulus 10.2 x 10^3 ksi)			Compression (Modulus 10.4 x 10^3 ksi)		
	Longitudinal	Long-Transverse	Short-Transverse	Longitudinal	Long-Transverse	Short-Transverse
0	47.8	51.2	44.3	65.2	63.7	57.9
20	61.3	63.5	56.0	74.1	75.9	67.1
40	68.3	70.4	62.9	77.8	79.4	72.9
60	73.3	74.5	67.1	80.4	82.0	75.9
80	76.9	77.4	70.2	82.2	83.6	78.2
100	79.6	79.7	73.2	83.7	84.8	80.1
150	84.1	83.4	78.0	86.3	87.2	83.4
200	86.9	85.9	81.4	88.0	88.8	85.8
250	88.9	87.7	84.0	89.3	90.0	87.5
300	90.4	89.1	86.0	90.5	91.0	88.9
350	91.5	90.3	87.5	91.3	91.8	90.0
400	92.4	91.2	88.8	92.1	92.5	91.0
500	93.8	92.7	90.8	93.3	93.6	92.5
600	94.9	93.8	92.4	94.3	94.5	93.7
800	96.3	95.5	94.6	95.7	95.9	95.4
1000	97.3	96.7	96.1	96.7	96.9	96.6
1250	98.2	97.8	97.5	97.8	97.9	97.8
1500	98.9	98.7	98.5	98.6	98.7	98.6
1750	99.5	99.4	99.3	99.4	99.4	99.4
2000(YS)	100.0	100.0	100.0	100.0	100.0	100.0
2100	100.2	100.2	100.2	100.3	100.2	100.2
2200	100.4	100.4	100.5	100.5	100.5	100.4
2300	100.5	---	100.7	100.7	100.7	100.7
2400	100.7	---	100.9	100.9	100.9	---
2500	100.7	---	101.1	101.2	100.9	---

(a) Data based on tests of four samples, 2.0, 3.5, 4.5 and 5.5-in. thick.

TABLE 20

DATA FOR TYPICAL COMPRESSIVE TANGENT-MODULUS CURVES FOR 2048-T851, 7050-T7351 AND 7475-T7351 PLATE

(F33615-74-C-5089)

Modulus,	Stress, ksi								
	2048-T851			7050-T7351			7475-T7351		
	Longitudinal	Long-Transverse	Short-Transverse	Longitudinal	Long-Transverse	Short-Transverse	Longitudinal	Long-Transverse	Short-Transverse
10.7	44.4	43.4	42.9	---	---	---	---	---	---
10.6	--	--	--	39.0	43.8	43.4	42.0	43.7	44.0
10.5	45.3	44.4	43.7	39.8	44.1	44.2	42.4	44.3	44.3
10.2	46.0	45.5	44.9	41.7	45.6	45.8	43.9	46.0	45.3
10.0	46.8	46.8	45.7	42.8	46.6	46.7	44.8	47.1	46.1
9.7	47.7	48.0	46.8	44.2	48.0	48.0	46.1	48.3	47.2
9.3	48.7	49.5	48.3	45.8	49.6	49.4	47.6	49.8	48.4
9.0	49.3	50.4	49.3	46.8	50.5	50.3	48.5	50.6	49.2
8.5	50.4	51.7	50.7	49.3	52.0	51.7	49.6	51.8	50.5
8.0	51.3	52.7	51.7	49.4	53.3	52.8	50.5	52.8	51.6
7.0	52.9	54.5	53.5	51.1	55.4	54.6	51.7	54.5	53.2
6.0	54.2	55.8	55.0	52.6	57.1	56.2	52.9	55.8	54.4
5.0	55.6	57.1	56.2	54.1	58.6	57.5	53.9	57.0	55.5
4.0	56.9	58.2	57.3	55.5	59.9	58.8	55.0	58.2	56.5
3.0	58.0	59.2	58.5	57.0	61.2	60.1	56.0	59.2	57.9
2.5	58.7	59.9	59.0	57.9	61.9	60.8	56.5	59.9	58.7
2.0	59.5	60.4	59.6	58.8	62.6	61.6	57.2	60.4	59.5
1.5	60.4	61.1	60.1	60.1	63.5	62.5	58.1	61.0	60.7
1.3	60.8	61.4	60.3	60.6	63.9	62.8	58.7	61.4	61.1
1.1	61.4	61.7	60.7	--	64.4	63.2	59.4	61.9	61.6
0.7	--	62.5	--	--	--	--	--	62.6	--

TABLE 21

RESULTS OF FRACTURE-TOUGHNESS TESTS OF 2048-T851 PLATE

(F33615-74-C-5089)

L-T Orientation

Sample Thickness, in.	Sample Number		Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in.}$	Valid
0.500	421378		62.2	L1	0.49	1.03	0.91	37.6	No(b,c)
				L2	0.49	1.08	0.97	38.8	No(b,c)
				L3	0.49	1.02	0.98	39.0	No(b,c)
		Avg.						--	
0.500	421379		63.8	L1	0.49	1.00	0.83	36.0	No(b,c)
				L2	0.49	1.05	0.86	37.4	No(b,c)
				L3	0.49	1.02	0.76	35.2	No(b,c)
		Avg						--	
1.000	421108		67.5	L1	1.00	1.04	0.70	35.7	Yes
				L2	1.00	1.04	0.70	35.7	Yes
				L3	1.00	1.02	0.70	35.2	Yes
		Avg.						35.5	
1.000	421380		62.1	L1	1.00	1.02	0.95	38.2	No(d)
				L2	1.00	1.03	0.97	38.7	Yes
				L3	1.00	1.03	0.90	37.3	No(d)
		Avg.(a)						38.7	
2.000	421381		62.9	L1	1.98	2.07	0.99	39.6	Yes
				L2	1.98	2.06	1.13	42.4	Yes
				L3	1.98	2.05	1.07	41.2	Yes
		Avg						41.0	
2.000	421382		63.4	L1	1.98	2.06	0.94	38.9	Yes
				L2	1.98	2.04	0.96	39.4	Yes
				L3	1.98	2.04	0.96	39.3	Yes
		Avg.						39.2	
3.000	421083		60.4	L1	3.00	3.14	0.95	37.2	Yes
				L2	3.00	3.12	0.94	37.0	Yes
				L3	3.00	3.12	0.91	36.[illegible]	Yes
		Avg.						36.9	
3.000	421084		60.1	L1	3.00	3.06	1.03	38.5	Yes
				L2	3.00	3.07	1.04	38.8	Yes
				L3	3.00	3.08	0.98	37.6	Yes
		Avg.						38.3	
4.000	421383		59.1	L1	2.00	2.00	1.07	38.[illegible]	Yes
				L2	2.00	2.04	1.05	38.4	Yes
				L3	2.00	2.02	1.00	37.4	Yes
		Avg.						38.1	
4.000	421384		61.2	L1	2.00	2.01	0.7[illegible]	35.2	Yes
				L2	2.00	2.02	0.80	36.2	Yes
				L3	2.00	2.02	0.80	36.4	Yes
		Avg.						35.9	

T-L Orientation

Sample Thickness, in.	Sample Number		Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in.}$	Valid
0.500	421378		61.5	T1	0.49	1.02	0.80	34.8	No(b,c)
				T2	0.49	1.02	0.73	33.2	No(b,c)
				T3	0.49	1.03	0.80	34.8	No(b,c)
		Avg.						--	
0.500	421379		63.2	T1	0.49	1.02	0.68	32.9	No(b,c)
				T2	0.49	1.04	0.62	31.4	No(b,c)
				T3	0.49	1.03	0.68	32.9	No(b,c)
		Avg						--	
1.000	421108		65.4	T1	1.00	1.05	0.55	30.7	Yes
				T2	1.00	1.06	0.55	30.9	Yes
				T3	1.00	1.05	0.56	31.0	Yes
		Avg.						30.9	
1.000	421380		61.1	T1	1.00	1.04	0.68	31.8	Yes
				T2	1.00	1.03	0.67	31.7	Yes
				T3	1.00	1.03	0.67	31.7	Yes
		Avg.(a)						31.7	
2.000	421381		61.6	T1	1.98	2.05	0.59	30.0	Yes
				T2	1.98	2.06	0.57	29.4	Yes
				T3	1.98	2.09	0.58	29.7	
		Avg						29.7	
2.000	421382		62.4	T1	1.98	2.09	0.56	29.5	Yes
				T2	1.98	2.05	0.58	29.9	Yes
				T3	1.98	2.07	0.59	30.4	
		Avg.						29.9	
3.000	421083		60.4	T1	3.00	3.07	0.77	33.6	Yes
				T2	3.00	3.14	0.79	33.9	Yes
				T3	3.00	3.10	0.76	33.3	
		Avg.						33.6	
3.000	421084		60.5	T1	3.00	3.24	0.78	33.7	Yes
				T2	3.00	3.24	0.81	34.5	Yes
				T3	3.00	3.28	0.80	34.3	Yes
		Avg.						34.[illegible]	
4.000	421383		57.3	T1	2.00	2.06	0.61	28.3	Yes
				T2	2.00	2.02	0.61	28.4	Yes
				T3	2.00	2.03	0.60	28.0	Yes
		Avg.						28.2	
4.000	421384		61.9	T1	2.00	2.03	0.45	26.2	Yes
				T2	2.00	2.04	0.47	27.0	Yes
				T3	2.00	2.06	0.46	26.6	Yes
		Avg.						26.6	

S-L Orientation

Sample Thickness, in.	Sample Number		Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in.}$	Valid
0.500	421378		--	--	--	--	--	--	--
			--	--	--	--	--	--	--
			--	--	--	--	--	--	--
		Avg.							
0.500	421379		--	--	--	--	--	--	--
			--	--	--	--	--	--	--
			--	--	--	--	--	--	--
		Avg							
1.000	421108		--	--	--	--	--	--	--
			--	--	--	--	--	--	--
			--	--	--	--	--	--	--
		Avg.							
1.000	421380		--	--	--	--	--	--	--
			--	--	--	--	--	--	--
			--	--	--	--	--	--	--
		Avg.(a)							
2.000	421381		59.3	N1	0.75	0.77	0.43	24.7	Yes
				N2	0.75	0.77	0.43	24.7	Yes
				N3	0.75	0.78	0.45	25.3	Yes
		Avg						24.9	
2.000	421382		59.9	N1	0.75	0.78	0.47	26.0	Yes
				N2	0.75	0.78	0.48	26.2	Yes
				N3	0.75	0.78	0.48	26.2	Yes
		Avg.						26.1	
3.000	421083		58.5	N1	1.25	1.28	0.38	22.8	Yes
				N2	1.25	1.28	0.41	23.7	Yes
				N3	1.25	1.28	0.38	22.9	Yes
		Avg.						23.1	
3.000	421084		58.9	N1	1.25	1.30	0.52	26.8	Yes
				N2	1.25	1.29	0.60	28.8	Yes
				N3	1.25	1.29	0.65	30.0	Yes
		Avg.						28.5	
4.000	421383		56.0	N1	1.50	1.53	0.52	25.6	Yes
				N2	1.50	1.53	0.55	26.2	Yes
				N3	1.50	1.53	0.48	24.0	Yes
		Avg.						25.5	
4.000	421384		59.5	N1	1.50	1.52	0.42	24.3	Yes
				N2	1.50	1.52	0.40	23.9	Yes
				N3	1.50	1.52	0.43	24.5	Yes
		Avg.						24.[illegible]	

(a) Valid value only.
(b) Insufficient specimen thickness, $B < 2.5\left(\frac{K_Q}{\sigma_{ys}}\right)^2$.
(c) $\frac{P_{max}}{P_Q} > 1.1$, where P_Q and P_{max} are 5 per cent secant load and peak load, respectively.
(d) Same as (c). However, P_{max}/P_5 is in meaningful range of 1.105 to 1.200.

TABLE 22

RESULTS OF FRACTURE TOUGHNESS TESTS OF 7050-T7351 PLATE

(F33615-74-C-5089)

L-T Orientation

Sample Thickness, in.	Sample Number		Tensile Yield Strength ksi	Specimen Number	Specimen Thickness in	Crack Length, in.	$5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q ksi√in.	Valid
2 000	421074		61.0	L1	2.00	2.03	1.04	39.3	Yes
				L2	2.00	2.03	1.04	39.3	Yes
				L3	2.00	2.02	1.05	39.5	Yes
		Avg						39.4	
[illegible] 000	421075		60.5	L1	2.00	2.01	1.26	43.0	Yes
				L2	2.00	2.01	1.18	41.5	Yes
				L3	2.00	2.02	1.28	43.4	Yes
		Avg						42.6	
3 000	421076		63.7	L1	1.50	1.56	0.72	34.3	Yes
				L2	1.50	1.56	0.76	35.0	Yes
				L3	1.50	1.56	0.75	34.8	Yes
		Avg						34.7	
3 000	421081		63.9	L1	1.50	1.57	0.73	34.5	Yes
				L2	1.50	1.57	0.75	35.1	Yes
				L3	1.50	1.57	0.79	35.9	Yes
		Avg.						35.1	
4 000	421077		63.7	L1	2.00	2.06	0.82	36.5	Yes
				L2	2.00	2.05	0.77	35.5	Yes
				L3	2.00	2.09	0.82	36.4	Yes
		Avg.						36.1	
4 000	421078		63.7	L1	2.00	2.06	0.72	34.2	Yes
				L2	2.00	2.05	0.71	34.0	Yes
				L3	2.00	2.08	0.72	34.3	Yes
		Avg.						34.1	
5.000	421073		63.7	L1	2.00	2.06	0.72	34.3	Yes
				L2	2.00	2.03	0.69	33.4	Yes
				L3	2.00	2.05	0.68	33.3	Yes
		Avg						33.7	
[illegible].118	421278		63.2	L1	2.00	2.00	0.54	29.3	Yes
				L2	1.98	2.00	0.53	29.1	Yes
				L3	2.00	2.00	0.55	29.7	Yes
		Avg.						29.4	
[illegible] 000	421079		60.4	L1	2.00	2.06	0.77	33.6	Yes
				L2	2.00	2.04	0.77	33.5	Yes
				L3	2.00	2.05	0.77	33.6	Yes
		Avg						33.6	
[illegible] 000	421080		62.2	L1	2.00	2.01	0.55	29.1	Yes
				L2	2.00	2.04	0.54	28.9	Yes
				L3	2.00	2.02	0.53	28.6	Yes
		Avg						28.9	

T-L Orientation

Sample Number	Tensile Yield Strength ksi	Specimen Number	Specimen Thickness, in	Crack Length, in.	$> 5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q ksi√in.	Valid
421074	60.6	T1	2.00	2.07	0.73	32.6	Yes
		T2	2.00	2.05	0.71	32.2	Yes
		T3	2.00	2.07	0.71	32.4	Yes
Avg						32.4	
421075	60.0	T1	2.00	2.07	0.83	34.6	Yes
		T2	2.00	2.06	0.83	34.5	Yes
		T3	2.00	2.06	0.88	35.6	Yes
Avg						34.9	
421076	63.7	T1	1.50	1.58	0.55	30.0	Yes
		T2	1.50	1.56	0.57	30.3	Yes
		T3	1.50	1.58	0.55	29.9	Yes
Avg						30.1	
421081	64.2	T1	1.50	1.59	0.55	30.1	Yes
		T2	1.50	1.60	0.57	30.6	Yes
		T3	1.50	1.59	0.56	30.4	Yes
Avg						30.4	
421077	63.4	T1	2.00	2.10	0.58	30.5	Yes
		T2	2.00	2.09	0.59	30.6	Yes
		T3	2.00	2.10	0.58	30.6	Yes
Avg						30.6	
421078	63.4	T1	2.00	2.04	0.54	29.4	Yes
		T2	2.00	2.08	0.54	29.4	Yes
		T3	2.00	2.09	0.51	28.6	Yes
Avg						29.1	
421073	63.7	T1	2.00	2.10	0.53	29.4	Yes
		T2	2.00	2.11	0.54	29.7	Yes
		T3	2.00	2.12	0.53	29.4	Yes
Avg						29.5	
421278	61.4	T1	2.00	2.06	0.41	24.9	No[b]
		T2	2.00	2.02	0.41	24.9	Yes
		T3	2.00	2.05	0.41	25.0	Yes
Avg						25.0	
421079	59.1	T1	2.00	2.09	0.66	30.3	Yes
		T2	2.00	2.07	0.63	29.8	Yes
		[illegible]	2.00	2.08	0.63	29.6	Yes
Avg						29.9	
421080	60.9	T1	2.00	2.05	0.48	26.7	Yes
		T2	2.00	2.05	0.47	26.3	Yes
		T3	2.00	2.08	0.48	26.6	Yes
Avg						26.5	

S-L Orientation

Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in.	$5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q ksi√in.	Valid
421074	55.6	N1	0.75	0.78	0.62	27.7	Yes
		N2	0.75	0.77	0.61	27.5	Yes
		N3	0.75	0.77	0.55	26.0	Yes
Avg						27.0	
421075	55.3	N1	0.75	0.77	0.73	29.9	Yes
		N2	0.75	0.77	0.73	29.9	Yes
		N3	0.75	0.77	0.68	28.8	Yes
Avg						29.5	
421076	60.1	N1	1.25	1.27	0.54	27.8	Yes
		N2	1.25	1.28	0.51	27.0	Yes
		N3	1.25	1.28	0.51	27.2	Yes
Avg						27.3	
421081	61.4	N1	1.25	1.27	0.48	27.0	Yes
		N2	1.25	1.27	0.53	28.3	Yes
		N3	1.25	1.28	0.54	28.4	Yes
Avg						27.9	
421077	60.0	N1	1.50	1.54	0.59	29.2	Yes
		N2	1.50	1.53	0.59	29.1	Yes
		N3	1.50	1.54	0.58	28.9	Yes
Avg						29.0	
421078	59.0	N1	1.50	1.53	0.55	27.7	Yes
		N2	1.50	1.53	0.59	28.5	Yes
		N3	1.50	1.53	0.62	29.4	Yes
Avg						28.5	
421073	58.8	N1	1.50	1.53	0.56	27.9	Yes
		N2	1.50	1.54	0.60	28.9	Yes
		N3	1.50	1.52	0.57	28.2	Yes
Avg						28.3	
421278	58.6	N1	1.50	1.52	0.50	26.2	Yes
		N2	1.50	1.50	0.47	25.5	Yes
		N3	1.50	1.53	0.49	26.0	Yes
Avg						25.9	
421079	56.3	N1	1.50	1.52	0.66	[illegible]8.9	Yes
		N2	1.50	1.52	0.70	[illegible].7	Yes
		N3	1.50	1.51	0.69	29.5	Yes
Avg						29.4	
421080	58.1	N1	1.50	1.55	0.53	26.3	Yes
		N2	1.50	1.54	0.53	26.7	Yes
		N3	1.50	1.53	0.51	26.1	Yes
Avg						26.5	

(a) Average of valid K_{Ic} values.

(b) K_f greater than 0.6 K_Q for the last step of fatigue cracking. However, K_f/K_Q is in meaningful range of 0.601 to 0.700.

TABLE 23

RESULTS OF FRACTURE TESTS OF 7475-T7351 PLATE

(F33615-74-C-5089)

L-T Orientation

Sample Dimensions, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in	Crack Length, in.	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in}$	Valid
0.50	429422	62.4	L1	0.50	0.51	0.74	33.9	No(a)(b)(c)
			L2	0.50	0.51	[illegible]	37.4	No(a)(b)
			L3	0.50	0.54	0.39	37.1	No(a)(b)
0.50	429423	62.3	L1	0.49	0.52	0.86	36.5	No(a)(b)(c)
			L2	0.49	0.52	0.87	36.6	No(a)(b)
			L3	0.49	0.52	0.87	36.7	No(a)(b)
1.00	[illegible]	62.3	L1	1.00	1.02	1.13	42.0	No(a)(b)
			L2	1.00	1.03	1.13	41.4	No(a)(b)
			L3	1.00	1.03	1.11	41.4	No(a)(b)
	Avg.							
1.00	429388	59.6	L1	1.00	1.01	1.31	43.2	No(a)(b)
			L2	1.00	1.02	1.37	44.1	No(a)(b)
			L3	1.00	1.02	1.25	41.9	No(a)(b)
	Avg.							
2.00	[illegible]	57.0	L1	1.97	2.11	1.37	42.2	Yes
			L2	1.97	2.09	1.37	42.2	Yes
			L3	1.97	2.09	1.42	42.9	Yes
	Avg.						42.4	
2.00	429330	57.7	L1	1.97	2.09	1.43	43.6	Yes
			L2	1.97	2.07	1.41	43.3	Yes
			L3	1.97	2.11	1.47	42.2	Yes
	Avg.						43.7	
3.00	429391	54.9	L1	2.86	3.15	1.81	46.8	Yes
			L2	2.85	3.14	1.90	47.8	Yes
			L3	2.85	3.12	1.89	47.7	Yes
	Avg.						47.4	
3.00	429392	55.0	L1	2.82	3.14	1.83	47.0	Yes
			L2	2.84	3.16	1.80	46.7	Yes
			L3	2.82	3.12	1.86	47.4	Yes
	Avg.						47.0	
4.00	429393	52.6	L1	3.00	3.15	1.86	45.4	Yes
			L2	2.97	3.17	1.87	45.5	Yes
			L3	3.00	3.17	1.88	45.6	Yes
	Avg.						45.5	
4.00	429394	52.7	L1	3.00	3.18	1.75	[illegible]	Yes
			L2	2.98	3.23	1.84	45.3	Yes
			L3	2.97	3.19	1.76	44.3	Yes
							44.6	

T-L Orientation

Sample Dimensions, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in	Crack Length, in.	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in}$	Valid
0.50	429422	63.2	T1	0.50	0.50	0.70	33.3	No(a)(b)
			T	0.50	0.52	0.61	31.3	No(a)(b)
				0.50	0.53	0.69	33.2	No(a)(b)
0.50	429423	63.9	T1	0.49	0.53	0.66	32.9	No(a)(b)
			T2	0.49	0.54	0.67	33.0	No(a)(b)
			T3	0.49	0.51	0.66	32.7	No(a)(b)
1.00	[illegible]	61.4	T1	1.00	1.02	0.83	35.4	Yes
			T2	1.00	1.02	0.78	34.1	Yes
			T3	1.00	1.02	0.81	34.8	Yes
	Avg.						34.8	
1.00	429388	59.4	T1	1.00	1.03	0.88	35.3	Yes
			T2	1.00	1.03	0.90	35.7	Yes
			T3	1.00	1.01	0.90	35.7	Yes
	Avg.						35.6	
2.00	[illegible]	57.7	T1	1.97	2.12	0.82	33.0	Yes
			T2	1.97	2.12	0.79	32.5	Yes
			T3	1.97	2.13	0.80	32.7	Yes
	Avg.						32.8	
2.00	429330	58.3	T1	1.97	2.10	0.75	32.0	Yes
			T2	1.97	2.10	0.77	32.4	Yes
			T3	1.97	2.12	0.79	32.7	Yes
	Avg.						32.3	
3.00	429391	55.7	T1	1.99	2.06	0.90	33.5	Yes
			T2	2.00	2.07	0.88	33.0	Yes
			T3	1.99	2.06	0.86	32.7	Yes
	Avg.						33.1	
3.00	429392	56.4	T1	1.99	2.11	0.82	32.3	Yes
			T2	1.98	2.07	0.82	32.3	Yes
			T3	2.00	2.04	0.77	31.3	Yes
	Avg.						32.0	
4.00	429393	54.2	T1	1.99	2.04	0.89	32.4	Yes
			T2	1.98	2.05	0.96	33.6	Yes
			T3	1.99	2.05	0.92	32.9	Yes
	Avg.						32.9	
4.00	429394	53.1	T1	1.99	2.06	0.95	32.8	Yes
			T2	1.99	2.12	0.94	32.5	Yes
			T3	1.98	2.12	0.98	33.2	Yes
							32.8	

S-L Orientation

Sample Dimensions, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in	Crack Length, in	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in}$	Valid
0.50	429422	--	--	--	--	--	--	--
		--	--	--	--	--	--	--
		--	--	--	--	--	--	--
0.50	429423	--	--	--	--	--	--	--
		--	--	--	--	--	--	--
		--	--	--	--	--	--	--
1.00	[illegible]	--	--	--	--	--	--	--
		--	--	--	--	--	--	--
		--	--	--	--	--	--	--
1.00	429388	--	--	--	--	--	--	--
		--	--	--	--	--	--	--
		--	--	--	--	--	--	--
2.00	[illegible]	57.0	N1	0.75	0.76	0.58	27.4	Yes
			N2	0.75	0.78	0.67	29.6	Yes
			N3	0.75	0.77	0.65	29.1	Yes
	Avg.						28.7	
2.00	429330	58.2	N1	0.75	0.77	0.69	30.6	Yes
			N2	.75	0.78	0.67	30.0	Yes
			N3	.75	0.77	0.65	28.9	Yes
	Avg.						29.8	
3.00	429391	54.4	N1	0.96	1.01	0.82	31.2	Yes
			N2	1.00	1.02	0.77	30.3	Yes
			N3	1.00	1.01	0.76	30.1	Yes
	Avg.						30.5	
3.00	429392	54.0	N1	1.00	1.00	0.73	29.1	Yes
			N2	1.00	1.01	0.64	27.3	Yes
			N3	1.00	1.00	0.70	28.5	Yes
	Avg.						28.3	
4.00	429393	52.5	N1	1.50	1.53	0.93	32.1	Yes
			N2	1.50	1.56	0.86	30.7	Yes
			N3	1.50	1.54	0.83	30.3	Yes
	Avg.						31.0	
4.00	429394	51.6	N1	1.50	1.54	0.81	29.4	Yes
			N2	1.50	1.52	0.81	29.3	Yes
			N3	1.50	1.54	0.84	29.8	Yes
							29.5	

(a) Insufficient specimen thickness, $B < 2.5 (\frac{K_Q}{\sigma_{ys}})^2$

(b) Fatigue crack is too short, $2.5 (\frac{K_Q}{\sigma_{ys}})^2 > a$ (crack length)

(c) $\frac{P_{max}}{P_Q} > 1$ [illegible] where P_Q and P_{max} are 5 percent secant load and peak load, respectively.

TABLE 24

RESULTS OF FRACTURE TOUGHNESS TESTS OF 7475-T7351 PLATE (CURRENT PRACTICE)

(M.T. NO. 110176-A)

L-T Orientation

Sample Thickness, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in.	$2.5\left(\frac{K_Q}{\sigma_{ys}}\right)^2$	K_Q, ksi$\sqrt{in.}$	Valid
0.500	478717	62.3	L1	0.49	2.99	2.19	58.4	No(a,c)
			L2	0.49	2.99	2.44	61.7	No(a,c)
							--	
0.750	478718	63.8	L1	0.76	3.03	2.20	59.9	No(a,c)
			L2	0.76	2.99	2.05	57.9	No(a,c)
							--	
1.750	478824	63.7	L1	1.74	3.00	1.89	55.4	No(a)
			L2	1.74	3.00	1.72	52.[illegible]	No(c,d)
Average							52.9	
1.750	478825	63.0	L1	1.75	3.03	1.83	53.9	No(a,d)
			L2	1.74	3.01	1.83	53.9	No(a,d)
Average							53.9	
2.250	478826	61.9	L1	2.26	2.99	1.52	48.3	Yes
			L2	2.26	3.00	1.54	48.7	Yes
Average							48.5	
2.250	478827	59.2	L1	2.25	3.01	1.72	49.2	Yes
			L2	2.25	3.02	1.69	48.8	Yes
Average							49.0	
2.750	478828	57.9	L1	2.75	2.99	1.87	50.2	Yes
			L2	2.75	2.99	1.83	49.6	Yes
Average							49.9	
2.750	478829	60.4	L1	2.74	3.00	1.51	47.0	Yes
			L2	2.73	3.01	1.49	46.7	Yes
Average							46.9	
3.500	478830	59.1	L1	3.00	3.15	1.83	50.7	Yes
			L2	3.00	3.12	1.87	51.2	Yes
Average							50.9	
3.500	478961	58.8	L1	3.00	3.10	1.75	49.2	Yes
			L2	3.00	3.12	1.78	49.7	Yes
Average							49.5	

T-L Orientation

Sample Thickness, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in.	$2.5\left(\frac{K_Q}{\sigma_{ys}}\right)^2$	K_Q, ksi$\sqrt{in.}$	Valid
0.500	478717	3.8	T1	0.49	1.99	1.11	42.6	No(a,c)
			T2	0.49	2.00	1.11	42.6	No(a,c)
							--	
0.750	478718	6[illegible].7	T1	0.76	2.01	1.15	43.3	No(a,c)
			T2	0.76	2.01	1.19	44.1	No(a,c)

1.750	478824	62.0	T1	1.75	3.0[illegible]	1.02	39.7	Yes
			T2	1.75	3.0[illegible]	1.05	40.2	Yes
Average							40.0	
1.750	478825	61.2	T1	1.76	3.02	0.99	38.6	Yes(c,d)
			T2	1.76	3.03	0.98	38.5	No(c,d)
Average							38.5	
2.250	478826	60.9	T1	2.26	3.06	0.95	37.6	Yes
			T2	2.26	3.08	0.97	38.1	Yes
Average							37.8	
2.250	478827	59.0	T1	2.25	3.07	0.95	36.5	Yes
			T2	2.24	3.10	0.96	36.6	Yes
Average							36.6	
2.750	478828	57.6	T1	2.75	3.08	1.05	37.5	Yes
			T2	2.75	3.08	1.05	37.4	Yes
Average							37.4	
2.750	478829	58.7	T1	2.72	3.14	0.89	35.0	Yes
			T2	2.74	3.08	0.88	35.0	Yes
Average							35.0	
3.500	478830	57.0	T1	2.99	3.20	1.07	37.4	Yes
			T2	3.00	3.19	1.09	37.7	Yes
Average							37.6	
3.500	478961	57.0	T1	3.00	3.17	1.04	36.8	Yes
			T2	3.00	3.16	1.00	36.2	Yes
Average							36.5	

S-L Orientation

Sample Thickness, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in.	$2.5\left(\frac{K_Q}{\sigma_{ys}}\right)^2$	K_Q, ksi$\sqrt{in.}$	Valid
0.500	478717	---	---	---	---	---	---	---
		---	---	---	---	---	---	---
0.750	478718	---	---	---	---	---	---	---
		---	---	---	---	---	---	---
1.750	478824	58.4	N1	0.75	0.77	1.04	37.8	No(a,b)
			N2	0.75	0.77	0.94	35.8	No(a,b)
Average							--	
1.750	478825	57.7	N1	0.75	0.77	0.85	33.8	No(a,b)
			N2	0.75	0.76	0.86	33.9	No(a,b)
Average							--	
2.250	478826	58.7	N1	0.75	0.76	0.79	33.0	No(a,b)
			N2	0.75	0.75	0.79	33.2	No(a,b)
Average							--	
2.250	478827	55.7	N1	0.75	0.76	0.87	33.0	No(a,b)
			N2	0.75	0.76	0.91	33.7	No(a,b)
Average							--	
2.750	478828	55.3	N1	1.00	1.00	0.99	35.0	Yes
			N2	1.00	1.01	0.99	34.9	Yes
Average							34.9	
2.750	478829	[illegible]4.3	N1	1.00	1.01	0.63	31.3	Yes
			N2	1.00	1.00	0.87	[illegible]	Yes
Average							[illegible].7	
3.500	478830	54.4	N1	1.25	1.25	0.95	33.5	Yes
			N2	1.24	1.25	0.89	32.5	Yes
Average							33.0	
3.500	478961	54.2	N1	1.25	1.26	0.85	31.7	Yes
			N2	1.25	1.26	0.88	32.2	Yes
Average							32.0	

(a) Insufficient specimen thickness, $B < 2.5\ (K_Q/\sigma_{ys})^2$.
(b) Insufficient crack length, $A < 2.5\ (K_Q/\sigma_{ys})^2$.
(c) $P_{max}/P_Q > 1.1$.
(d) Values considered meaningful.

TABLE 25

RESULTS OF FRACTURE-TOUGHNESS TESTS OF 2219-T852 HAND FORGINGS

(F33615-74-C-5089)

(L-T) Orientation

Sample Dimensions, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in.	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in.}$	Valid
2.0x8	429246	50.7	L-1	1.50	1.57	1.48	39.0	Yes
			L-2	1.50	1.51	1.89	44.1	No(b)(c)
			L-3	1.50	1.55	1.54	39.8	No(b)
	Avg.(a)						39.0	
2.5x22	478817	51.1	L-1	2.49	2.53	1.49	-	Yes
			L-2	2.49	2.54	1.33	36.8	Yes
			L-3	2.50	2.45	1.35	37.0	Yes
	Avg.(a)						37.6	
3.5x14	429512	50.3	L-1	2.50	2.57	1.67	41.1	Yes
			L-2	2.50	2.56	1.78	42.4	Yes
			L-3	2.50	2.65	1.97	44.7	Yes
	Avg.(a)						42.7	
3.5x22	429513	51.2	L-1	2.50	2.62	1.59	40.8	Yes
			L-2	2.50	2.51	1.56	40.4	Yes
			L-3	2.50	2.58	1.69	42.1	Yes
	Avg.(a)						41.1	
4.5x22	429249	45.2	L-1	2.50	2.55	1.50	35.1	Yes
			L-2	2.50	2.58	1.68	37.0	Yes
			L-3	2.50	2.56	1.63	36.5	Yes
	Avg.(a)						36.2	
4.5x22	429514	50.2	L-1	2.50	2.60	1.69	41.3	Yes
			L-2	2.50	2.56	1.96	44.5	No(f)
			L-3	2.50	2.56	2.16	46.7	Yes
	Avg.(a)						44.0	
5.5x22	429247	49.2	L-1	2.50	2.53	1.83	42.1	Yes
			L-2	2.50	2.61	1.56	38.9	Yes
			L-3	2.50	2.55	1.58	39.1	Yes
	Avg.(a)						40.0	
5.5x22	429248	44.6	L-1	2.50	2.52	1.91	39.0	Yes
			L-2	2.50	2.52	1.82	38.0	Yes
			L-3	2.50	2.55	2.08	40.7	Yes
	Avg.(a)						39.2	
7.5x22	429244	41.9	L-1	2.50	2.58	1.73	34.8	Yes
			L-2	2.50	2.57	1.85	35.5	Yes
			L-3	2.50	2.55	1.55	33.0	Yes
	Avg.(a)						34.5	
7.5x22	429245	43.4	L-1	2.50	2.56	1.97	38.6	Yes
			L-2	2.50	2.61	2.00	38.8	No(f)
			L-3	2.50	2.61	2.03	39.1	No(f)
	Avg.(a)						38.6	

(T-L) Orientation

Sample Dimensions, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in.	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in.}$	Valid
2.0x8	429246	50.6	T-1	1.50	1.56	0.79	28.5	Yes
			T-2	1.50	1.51	0.84	29.4	Yes
			T-3	1.50	1.56	0.84	29.2	Yes
	Avg.(a)						29.0	
2.5x22	478817	49.9	T-1	2.49	2.51	0.66	26.1	Yes
			T-2	2.50	2.56	0.93	30.6	Yes
			T-3	2.49	2.57	0.67	26.0	Yes
	Avg.(a)						27.6	
3.5x14	429512	49.8	T-1	2.50	2.56	0.80	28.1	Yes
			T-2	2.50	2.58	0.80	28.2	Yes
			T-3	2.50	2.56	0.83	28.7	Yes
	Avg.(a)						28.3	
3.5x22	429513	50.2	T-1	2.50	2.50	0.62	24.9	Yes
			T-2	2.50	2.52	0.67	26.0	Yes
			T-3	2.50	2.53	0.68	26.2	Yes
	Avg.(a)						25.7	
4.5x22	429249	45.7	T-1	2.50	2.53	0.97	28.4	Yes
			T-2	2.50	2.54	0.94	28.1	Yes
			T-3	2.50	2.50	0.71	24.3	No(d)
	Avg.(a)						28.2	
4.5x22	429514	50.6	T-1	2.50	2.51	0.86	29.8	Yes
			T-2	2.50	2.51	0.74	27.5	Yes
			T-3	2.50	2.57	0.83	29.1	Yes
	Avg.(a)						28.8	
5.5x22	429247	46.4	T-1	2.50	2.52	0.74	25.2	Yes
			T-2	2.50	2.54	0.65	23.7	No(d)
			T-3	2.50	2.64	0.55	21.8	No(e)
	Avg.(a)						25.2	
5.5x22	429248	43.1	T-1	2.50	2.57	1.10	28.6	Yes
			T-2	2.50	2.62	1.07	28.2	Yes
			T-3	2.50	2.58	0.73	23.3	No(d)
	Avg.(a)						25.4	
7.5x22	429244	43.9	T-1	2.50	2.60	0.85	25.7	No(d)
			T-2	2.50	2.60	0.85	25.6	No(d)
			T-3	2.50	2.62	0.67	22.8	No(e)
	Avg.(a)						--	
7.5x22	429245	44.2	T-1	2.50	2.62	0.73	23.9	No(d)
			T-2	2.50	2.62	0.77	24.6	No(d)
			T-3	2.50	2.56	0.78	24.6	No(d)
			T-4(h)	1.50	1.53	0.70	23.3	Yes
			T-5(h)	1.50	1.54	0.81	25.1	Yes
	Avg.(a)						24.2	

(S-L) Orientation

Sample Dimensions, in.	Sample Number	Tensile Yield Strength, ksi	Specimen Number	Specimen Thickness, in.	Crack Length, in.	$2.5(\frac{K_Q}{\sigma_{ys}})^2$	K_Q, ksi$\sqrt{in.}$	Valid
2.0x8	429246	51.5	N-1	0.75	0.80	0.75	28.3	No(b)
			N-2	0.75	0.79	0.85	30.1	No(b)(c)
			N-3	0.75	0.80	0.62	25.6	Yes
	Avg.(a)						25.6	
2.5x22	478817	50.4	N-1	1.00	1.01	0.48	22.6	Yes
			N-2	1.00	1.01	0.43	21.2	Yes
			N-3	1.00	1.01	0.43	21.4	Yes
	Avg.(a)						21.7	
3.5x14	429512	49.7	N-1	1.00	1.02	0.67	25.8	Yes
			N-2	1.00	1.03	0.65	25.3	Yes
			N-3	1.00	1.04	0.64	25.1	Yes
	Avg.(a)						25.4	
3.5x22	429513	51.1	N-1	1.00	1.01	0.54	23.8	Yes
			N-2	1.00	1.04	0.62	25.5	Yes
			N-3	1.00	1.02	0.61	25.2	Yes
	Avg.(a)						24.8	
4.5x22	429249	47.0	N-1	1.50	1.55	0.68	24.4	Yes
			N-2	1.50	1.53	0.67	24.3	Yes
			N-3	1.50	1.51	0.56	22.2	Yes
	Avg.(a)						23.7	
4.5x22	429514	51.2	N-1	1.50	1.53	0.68	26.7	Yes
			N-2	1.50	1.57	0.52	23.4	Yes
			N-3	1.50	1.57	0.63	25.7	Yes
	Avg.(a)						25.3	
5.5x22	429247	47.2	N-1	2.00	2.08	0.53	21.7	No(d)
			N-2	2.00	2.16	0.44	19.8	No(g)
			N-3	2.00	2.07	0.53	21.7	No(d)
			N-4(h)	1.00	1.03	0.61	23.4	Yes
			N-5(h)	1.00	1.03	0.63	23.6	Yes
	Avg.(a)						23.5	
5.5x22	429248	50.8	N-1	2.00	2.05	0.68	26.6	Yes
			N-2	2.00	2.04	0.60	24.9	Yes
			N-3	2.00	2.04	0.59	24.7	Yes
	Avg.(a)						25.4	
7.5x22	429244	42.4	N-1	2.00	2.03	0.69	22.3	No(d)
			N-2	2.00	2.06	0.71	22.6	No(d)
			N-3	2.00	2.05	0.81	24.2	No(d)
	Avg.(a)						--	
7.5x22	429245	44.1	N-1	2.00	2.02	0.87	26.0	Yes
			N-2	2.00	2.70	0.97	27.4	No(e)(g)
			N-3	2.00	2.05	0.88	26.1	Yes
	Avg.(a)						26.1	

(a) Average of valid K_{Ic} values.

(b) Specimen not thick enough $[2.5(K_Q/\sigma_{ys})^2 > \text{thickness}]$

(c) Fatigue crack too short. $[2.5(K_Q/\sigma_{ys})^2 > \text{crack length}]$

(d) K_f greater than 0.6 K_Q for the last step of fatigue cracking. However, K_f/K_Q is in meaningful range of 0.601 to 0.700.

(e) K_f greater than 0.7 K_Q for the last step of fatigue cracking.

(f) Ratio of maximum load to 5% secant load greater than 1.1. However, P_{max}/P_5 is in meaningful range of 1.105 to 1.200.

(g) Crack length to specimen width ratio not between 0.45 and 0.55.

(h) Retest results.

TABLE 26

Rates of Fatigue-Crack Propagation(a)

Alloy	Product	Thickness or Size(in.)	Sample No.	Orientation	Fig.	Δa/ΔN at Indicated ΔK(b), micro-in/cycle: Dry Air 4	Dry Air 7	Dry Air 12	Moist Air 4	Moist Air 7	Moist Air 12	Sump Water 4	Sump Water 7	Sump Water 12
2048-T851	Plate	1	421108	L-T	31		0.9	7					4.2	13
		4	421383	T-L	32		1.4	13		3.0	16	.6	4.4	17
				L-T	33		1.4	6.5					3.3	15
				T-L	34, 35	.19	1.2	12				.36	3.2	26
				S-L	36		1.3	11		5.2	25		4.2	30
7050-T7351	Plate	2	421074	L-T	37		1.8						9.0	35
		4		T-L	38		2.4	15		3.6	19	0.85	7.2	38
				L-T	39		1.6	12					8.0	32
				T-L	40, 41		1.7	16					7.0	26
				S-L	42		2.0	14		3.2	22		10.0	36
7475-T7351	Plate	1	429338	L-T	43		1.4	12					9.5	40
		4	429383	T-L	44		1.4	11		4.0	22		9.5	41
				L-T	45		1.0	10					8.2	31
				T-L	46, 47	.18	1.1	10				0.8	7.2	41
				S-L	48		1.6	12		4.2	25		10.0	39
7475-T7351 (Current Practice)	Plate	3/4	478718	T-L	49	.16	0.7	9					9.0	35
		3-1/2	478961	T-L	50, 51	.14	0.8	9					9.0	38
				S-L	52	.56	1.8	14						
2219-T852	Hand Forging	2x3	429246	L-T	53		1.2	10					3.6	16
				T-L	54		1.5	16		2.3	22		3.7	21
		5-1/2x22	429247	L-T	55		1.2	3.5					2.9	10
				T-L	56, 57	.15	1.3	15		3.0	28		4.7	42
				S-L	58		2.1	18		3.8	33		5.5	41
Reference Material														
7050-T73651	Plate	1		T-L	(c)		1.8	19		4.2	24			
		6		L-T	(c)		1.2	14		2.6	20			
				T-L	(c)		1.4	14		2.6	23			
				S-L	(c)		1.5	11		2.6	28			
2124-T851	Plate	4-1/2		T-L	(d)		2.5	12		4.0	25			
7050-T73652	Hand Forging	2-1/2x22		T-L	(c)		1.9	19		1.5	26			
		7-1/2x22		L-T	(c)		[illegible]	5		3.8	10			
				T-L	(c)		2.8	100		4.4	140			
				S-L	(c)		1.9	>200		5.0	>300			
7175-T736	Hand Forging	5x20		T-L	(d)		3.5	24		7.0	40			

(a) Average rates for tests at about 20 Hz.
(b) ksi√in.
(c) Ref. 10
(d) Ref. 9

TABLE 27

RESULTS OF TESTS TO EVALUATE THE RESISTANCE TO EXFOLIATION OF SAMPLES OF 2219-T852
HAND FORGINGS
(F33615-74-C-5089)

Dimensions Inches	Number	EXCO (a) T/10	EXCO (a) T/2	MASTMAASIS (b) T/10	MASTMAASIS (b) T/2	Point Judith T/10	Point Judith T/2
2.0 x 8	429246	E-A	E-A	---	---	---	---
2.5 x 22	478817	E-D(e)	E-D(e)	P	P	(d)	(d)
3.5 x 14	429512	P	E-A	---	---	---	---
3.5 x 22	429513	E-A	E-A	---	---	---	---
4.5 x 22	429249	E-A	E-A	P	P	(c)	(c)
4.5 x 22	429514	E-A	E-A	---	---	---	---
5.5 x 22	429247	E-A	P	---	---	---	---
5.5 x 22	429248	E-A	E-A	---	---	---	---
7.5 x 22	429244	E-A	E-A	---	---	---	---
7.5 x 22	429245	P	P	P	P	(c)	(c)

Notes: (a) Total immersion for 144 hours in an acidified chloride-nitrate solution (4 N NaCl + 0.5 N KNO_3 + 0.1 N HNO_3 at pH 0.4) ASTM G34-72.

(b) Exposed for 4 weeks in acidified salt spray test MIL-A-8978, 8979, and 8980.

(c) Exposed to the seacoast atmosphere at Point Judith, Rhode Island, 8/20/75.

(d) Exposed to the seacoast atmosphere at Point Judith, Rhode Island, 3/28/77.

(e) Total immersion of 48 hours in acidified chloride-nitrate solution (4 N NaCl + 0.5 N HNO_3 + 0.1 N HNO_3 at 0.4) ASTM G34-72.

TABLE 28

RESULTS OF TESTS TO EVALUATE THE RESISTANCE TO EXFOLIATION OF SAMPLES OF 7050-T7351 ALLOY PLATE

Thickness Inches	Sample Number	EXCO (a) T/10 Electrical Conductivity (% IACS)	EXCO (a) T/10 Results	EXCO (a) T/2 Electrical Conductivity (% IACS)	EXCO (a) T/2 Results	MASTMAASIS (b) T/10	MASTMAASIS (b) T/2	Point Judith T/10	Point Judith T/2
2.000	421074	41.9	P	42.7	P	P	P	(c)	(c)
2.000	421075	42.2	P	43.0	P	---	---	---	---
3.000	421076	41.5	P	42.5	P	---	---	---	---
3.000	421081	41.6	P	42.5	P	---	---	---	---
4.000	421077	41.5	P	42.6	P	P	P	(c)	(c)
4.000	421078	41.6	P	42.6	P	---	---	---	---
5.118	421278	40.5	P	41.7	P	P	P	(c)	(c)
5.000	421073	41.4	P	42.6	P	---	---	---	---
6.000	421079	41.7	P	42.4	P	P	P	(c)	(c)
6.000	421080	41.3	P	42.4	P	---	---	---	---

(a) Total immersion for 96 hours in an acidified chloride-nitrate solution (4 N NaCl + 0.5 N KNO_3 + 0.1 N HNO_3 at pH 0.4) ASTM G34-72.

(b) Exposed for 4 weeks in acidified salt spray test MIL-A-8978, 8979, and 8980.

(c) Exposed to the seacoast atmosphere at Point Judith, Rhode Island 5/14/76.

TABLE 29

RESULTS OF TESTS TO EVALUATE THE RESISTANCE TO EXFOLIATION OF SAMPLES OF 2048-T851 ALLOY PLATE

Thickness Inches	Sample Number	EXCO (a) T/10 Electrical Conductivity (% IACS)	EXCO (a) T/10 Results	EXCO (a) T/2 Electrical Conductivity (% IACS)	EXCO (a) T/2 Results	MASTMAASIS (b) T/10	MASTMAASIS (b) T/2	Point Judith T/10	Point Judith T/2
0.500	421378	40.6	P	40.8	P	---	---	---	---
0.500	421379	41.0	P	41.4	P	---	---	---	---
1.000	421380	40.5	P	41.0	P	P	P	(c)	(c)
1.000	421108	41.0	P	41.2	P	---	---	---	---
2.000	421381	41.0	P	41.3	P	P	P	(c)	(c)
2.000	421382	41.0	P	41.3	P	---	---	---	---
3.000	421083	41.6	P	41.8	P	---	---	---	---
3.000	421084	42.0	P	42.2	P	---	---	---	---
4.000	421383	41.2	P	41.6	P	P	P	(c)	(c)
4.000	421384	41.4	P	41.7	P	---	---	---	---

(a) Total immersion for 96 hours in an acidified chloride-nitrate solution (4 N NaCl + 0.5 KNO_3 + 0.1 N HNO_3 at pH 0.4) ASTM G34-72.

(b) Exposed for 4 weeks in acidified salt spray test MIL-A-8978, 8978, and 8980.

(c) Exposed to the seacoast atmosphere at Point Judith, Rhode Island 5/14/76.

TABLE 30

RESULTS OF TESTS TO EVALUATE THE RESISTANCE TO EXFOLIATION OF SAMPLES OF 7475-T7351 ALLOY PLATE

		EXCO (a)				MASTMAASIS (b)		Point Judith	
		T/10		T/2					
Thickness Inches	Sample Number	Elect. Cond. % IACS	Results	Elect. Cond. % IACS	Results	T/10	T/2	T/10	T/2
0.500	429422	41.3	P	42.1	E-A	---	---	---	---
0.500	429423	41.3	P	41.8	E-A	---	---	---	---
1.000	429387	41.9	P	42.8	E-A	---	---	---	---
1.000	429388	41.6	P	42.6	E-A	P	P	(c)	(c)
2.000	429389	41.9	P	42.8	E-A	P	P	(c)	(c)
2.000	429390	41.7	P	42.9	E-A	---	---	---	---
3.000	429391	41.5	P	42.7	E-A	---	---	---	---
3.000	429392	41.9	P	42.8	E-A	---	---	---	---
4.000	429393	41.6	P	42.7	E-A	P	P	(c)	(c)
4.000	429394	41.8	P	42.7	E-A	---	---	---	---

Notes (a) Total immersion for 96 hours in an acidified chloride-nitrate solution (4N NaCl + 0.5N KNO_3 + 0.1N HNO_3 at pH 0.4) ASTM G34-72.

(b) Exposed for 4 weeks in acidified salt spray test MIL-A-8978, 8979, and 8980.

(c) Exposed to seacoast atmosphere at Point Judith, Rhode Island on July 11, 1975.

TABLE 31

RESULTS OF STRESS-CORROSION TESTING OF 0.125-INCH DIAMETER TENSION SPECIMENS OF 2219-T852 ALLOY HAND FORGINGS BY ALTERNATE IMMERSION IN A 3.5% SODIUM CHLORIDE SOLUTION FOR 84 DAYS (ASTM G44-75)

Hand Forgings Dimensions Inches	Sample Number	Longitudinal Tension Specimens: Applied Stress ksi	Longitudinal: Failure Data F/N (a)	Longitudinal: Failure Data Days to Failure (b)	Longitudinal: Average % Loss in Tensile Properties of Unfailed Specimens Yield	Longitudinal: Ult.	Longitudinal: El.	Long-Transverse Tension Specimens: Applied Stress ksi	Long-Transverse: Failure Data F/N (a)	Long-Transverse: Failure Data Days to Failure (b)	Long-Transverse: Average % Loss in Tensile Properties of Unfailed Specimens Yield	Long-Transverse: Ult.	Long-Transverse: El.	Short-Transverse Tension Specimens: Applied Stress ksi	Short-Transverse: Failure Data F/N (a)	Short-Transverse: Failure Data Days to Failure (b)	Short-Transverse: Average % Loss in Tensile Properties of Unfailed Specimens Yield	Short-Transverse: Ult.	Short-Transverse: El.
2.0 x 8	429246	0	0/2	**	15	19	50	0	0/2	**	17	20	33	0	0/2	**	29	34	57
2.0 x 8	429246	37	0/3	***	18	20	43	37	0/3	***	18	33	78	25	0/3	***	20	37	80
2.0 x 8	429246													37	0/3	***	22	28	57
2.5 x 22	478817	0	0/2	**	17	19	69	0	0/2	**	22	24	60	0	0/2	**	26	31	75
2.5 x 22	478817	37	0/3	***	17	19	48	37	0/3	***	14	13	20	25	0/3	***	21	29	75
2.5 x 22	478817													37	0/3	***	17	27	75
3.5 x 14	429512													0	0/2	*+	30	45	75
3.5 x 14	429512													25	0/3	***	23	26	50
3.5 x 14	429512													37	0/3	***	22	25	50
3.5 x 22	429513													0	0/2	*+	(c)	60	100
3.5 x 22	429513													25	0/3	***	27	30	56
3.5 x 22	429513													37	1/3	52 *+	27	40	56
4.5 x 22	429249													0	0/2	**	29	45	60
4.5 x 22	429249													21	0/3	** +	24	26	40
4.5 x 22	429249													32	0/3	***	27	34	60
4.5 x 22	429514													0	0/2	**	40	60	75
4.5 x 22	429514													21	0/3	***	30	34	49
4.5 x 22	429514													32	0/3	***	31	41	49
5.5 x 22	429247													0	0/2	**	34	46	72
5.5 x 22	429247													21	0/3	***	21	26	15
5.5 x 22	429247													32	0/3	***	22	28	44
5.5 x 22	429248													0	0/2	**	36	43	53
5.5 x 22	429248													21	0/3	***	24	30	77
5.5 x 22	429248													32	0/3	***	24	33	77
7.5 x 22	429244	0		**	17	17	33	0	0/2	**	27	34	20	0	0/2	**	30	41	69
7.5 x 22	429244	29		**	14	14	33	29	0/3	***	21	21	0	20	0/3	***	24	32	38
7.5 x 22	429244													29	0/3	***	23	31	59
7.5 x 22	429245	0		**	16	20	27	0	0/2	**	18	21	0	0	0/2	**	24	31	33
7.5 x 22	429245	29	0/3	***	9	14	27	29	0/3	***	13	15	0	20	0/3	***	22	28	47
7.5 x 22	429245													29	0/3	** +	16	24	47

Notes: (a) F/N denotes number of failures over total number of specimens tested.
(b) For day to failure

* Indicates that the specimen did not fail during the 84 day test
\+ Indicates that the specimen completed the 84 day test but suffered mechanical type failure during removal from the testing fixture.

(c) Specimen failed in tensile test prior to reaching 0.2% offset.

TABLE 32

RESULTS OF STRESS-CORROSION TESTING OF 0.125-INCH DIAMETER TENSION SPECIMENS OF 7050-T7351 ALLOY PLATE BY ALTERNATE IMMERSION IN 3.5% SODIUM CHLORIDE SOLUTION FOR 84 DAYS (ASTM G44-75)

		Longitudinal Tension Specimens					Long-Transverse Tension Specimens					Short-Transverse Tension Specimens				
					Average % Loss in Tensile Properties of Unfailed Specimens					Average % Loss in Tensile Properties of Unfailed Specimens					Average % Loss in Tensile Properties of Unfailed Specimens	
Plate Thick. In.	Sample Number	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.
2.000	421074											0	0/2	**	33	37
2.000	421074											32	0/3	***	51	50
2.000	421074											47	0/3	***	47	56
2.000	421075											0	0/2	**	32	40
2.000	421075											32	0/3	***	34	44
2.000	421075											47	1/3	84,**	>44(c)	63
3.000	421076											0	0/2	**	28	32
3.000	421076											32	0/3	***	>47(d)	54
3.000	421076											47	0/3	***	>67(d)	63
3.000	421081											0	0/2	**	33	35
3.000	421081											32	0/3	***	49	54
3.000	421081											47	0/3	***	53	59
4.000	421077	0	0/2	**	20	20	0	0/2	**	24	29	0	0/2	**	30	34
4.000	421077	46	0/3	***	30	34	45	0/3	***	38	43	31	0/3	***	40	46
4.000	421077											46	0/3	***	49	56
4.000	421078	0	0/2	**	25	27	0	0/2	**	28	28	0	0/2	**	28	34
4.000	421078	46	0/3	***	36	39	46	0/3	***	42	47	31	0/3	***	46	51
4.000	421078											46	3/3	76,78,84	---	---
5.000	421073	0	0/2	**	25	25	0	0/2	**	28	31	0	0/2	**	30	34
5.000	421073	44	0/3	***	33	36	44	0/3	***	>41(c)	49	30	0/3	***	38	47
5.000	421073											44	1/3	84,**	(d)	57
5.118	421278	0	0/2	**	31	31	0	0/2	**	32	32	0	0/2	**	32	37
5.118	421278	43	0/3	***	38	45	43	0/3	***	42	48	29	0/3	***	38	41
5.118	421278											43	0/3	***	46	53
6.000	421079											0	0/2	**	32	39
6.000	421079											29	0/3	***	36	41
6.000	421079											43	0/3	***	45	53
6.000	421080											0	0/2	**	33	35
6.000	421080											29	0/3	***	36	43
6.000	421080											43	1/3	64,**	47	54

Notes: (a) F/N denotes number of failures over total number of specimens tested.
(b) For day to failure, * indicates that the specimen did not fail during the 84 day test.
(c) One specimen failed in tension test prior to reaching 0.2% offset.
(d) Two specimens failed in tension test prior to reaching 0.2% offset.

TABLE 33

RESULTS OF STRESS-CORROSION TESTING OF 0.125-INCH DIAMETER TENSION SPECIMENS OF 2048-T851 ALLOY PLATE BY ALTERNATE IMMERSION IN A 3.5% SODIUM CHLORIDE SOLUTION FOR 84 DAYS (ASTM G44-75)

		Longitudinal Tension Specimens					Long-Transverse Tension Specimens					Short-Transverse Tension Specimens				
					Average % Loss in Tensile Properties of Unfailed Specimens					Average % Loss in Tensile Properties of Unfailed Specimens					Average % Loss in Tensile Properties of Unfailed Specimens	
Plate Thick. In.	Sample Number	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.
1.000	421108	0	0/2	**	17	16	0	0/2	**	17	17					
1.000	421108	42	0/3	***	15	14	42	0/3	***	14	14					
1.000	421380	0	0/2	**	17	17	0	0/2	**	16	16					
1.000	421380	42	0/3	***	16	15	42	0/3	***	14	15					
2.000	421381											0	0/2	**	17	17
2.000	421381											28	0/3	***	17	18
2.000	421381											42	2/3	26(c), 47,*	---	54
2.000	421382											0	0/2	**	18	22
2.000	421382											28	0/3	***	19	21
2.000	421382											42	3/3	9(c),33, 63	--	---
3.000	421083											0	0/2	**	20	33
3.000	421083											28	2/3	46,84,*	---	17
3.000	421083											41	3/3	29,76(c) 84	---	---
3.000	421084											0	0/2	**	20	21
3.000	421084											28	0/3	***	19	20
3.000	421084											41	2/3	77,84,*	20	21
4.000	421383	0	0/2	**	19	17	0	0/2	**	19	20	0	0/2	**	20	22
4.000	421383	41	0/3	***	17	16	41	0/3	***	17	19	28	0/3	***	18	20
4.000	421383											41	1/3	68,**	29	36
4.000	421384	0	0/2	**	23	21	0	0/2	**	19	20	0	0/2	**	19	21
4.000	421384	41	0/3	***	23	21	41	0/3	***	18	19	28	0/3	***	18	18
4.000	421384											41	1/3	53(c),**	29	35

Notes: (a) F/N denotes number of failures over total number of specimens tested.
(b) For day to failure, * indicates that the specimen did not fail during the 84 day test.
(c) Metallographically examined.

TABLE 34

RESULTS OF STRESS-CORROSION TESTING OF 0.125-INCH DIAMETER TENSION SPECIMENS OF 7475-T7351 ALLOY PLATE BY ALTERNATE IMMERSION IN A 3.5% SODIUM CHLORIDE SOLUTION FOR 84 DAYS (ASTM G44-75)

		Longitudinal						Long-Transverse						Short-Transverse					
			Failure Data		Average % Loss in Tensile Properties of Unfailed Specimens				Failure Data		Average % Loss in Tensile Properties of Unfailed Specimens				Failure Data		Average % Loss in Tensile Properties of Unfailed Specimens		
Plate Thick. Inch	Sample Number	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.	El.	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.	El.	Applied Stress ksi	F/N (a)	Days to Failure (b)	Yield	Ult.	El.
1.000	429387	0	0/2	**	13	12	44	0	0/2	**	16	16	70						
1.000	429387	43	0/3	***	15	15	37	43	0/3	***	16	18	64						
1.000	429388	0	0/2	**	13	11	27	0	0/2	**	15	14	48						
1.000	429388	43	0/3	***	13	14	51	43	0/3	***	14	15	56						
2.000	429389													0	0/2	**	19	18	35
2.000	429389													28	0/3	***	24	28	68
2.000	429389													42	0/3	***	36	43	68
2.000	429390													0	0/2	**	21	19	49
2.000	429390													28	0/3	***	24	26	74
2.000	429390													42	0/3	**+	40	49	74
3.000	429391													0	0/2	**	15	18	50
3.000	429391													26	0/3	***	16	19	50
3.000	429391													39	0/3	***	20	28	75
3.000	429392													0	0/2	**	19	21	50
3.000	429392													26	0/3	***	17	21	50
3.000	429392													39	0/3	**+	21	37	100
4.000	429393	0	0/2	**	6	7	47	0	0/2	**	13	13	45	0	0/2	*+	25	22	51
4.000	429393	36	0/3	***	6	7	56	36	0/3	***	14	15	45	24	0/3	**+	20	17	51
4.000	429393													36	0/3	***	18	24	51
4.000	429394	0	0/2	**	9	10	61	0	0/2	**	14	16	44	0	0/2	**	18	22	47
4.000	429394	36	0/3	***	8	10	61	36	0/3	***	15	20	44	24	0/3	***	16	22	47
4.000	429394													36	0/3	***	18	26	73

Notes: (a) F/N denotes number of failures over total number of specimens tested.

(b) For day to failure

* indicates that the specimen did not fail during the 84 day test.

+ indicates that the specimen completed the 84 day test but fractured during removal from the testing fixture.

TABLE 35

RESULTS OF STRESS-CORROSION TESTS OF 0.125-INCH DIAMETER SHORT-TRANSVERSE TENSION SPECIMENS OF 2219-T852 ALLOY HAND FORGINGS IN OUTDOOR ATMOSPHERES

Size Inches	Sample Number	Applied Stress ksi	Point Judith Seacoast Atmos.		ATC Industrial Atmos.	
			F/N(a)	Days to Failure	F/N(a)	Days to Failure
2.0 x 8	429246	0	0/2	OK 492 days	0/2	OK 496 days
		25	0/3	OK 492 days	0/3	OK 496 days
		37	0/3	OK 492 dyas	0/3	OK 496 days
2.5 x 22	478817	0	0/2	(b)	0/2	OK 24 days
		25	0/3	(b)	0/3	OK 24 days
		37	0/3	(b)	0/3	OK 24 days
3.5 x 14	429512	0	0/2	OK 492 days	0/2	OK 496 days
		25	0/3	OK 492 days	0/3	OK 496 days
		37	0/3	OK 492 days	0/3	OK 496 days
3.5 x 22	429513	0	0/2	OK 492 days	0/2	OK 496 days
		25	0/3	OK 492 days	0/3	OK 496 days
		37	0/3	OK 492 days	0/3	OK 496 days
4.5 x 22	429249	0	0/2	OK 492 dyas	0/2	OK 496 days
		21	0/3	OK 492 days	0/3	OK 496 days
		32	0/3	OK 492 days	0/3	OK 496 days
4.5 x 22	429514	0	0/2	OK 492 days	0/2	OK 496 days
		21	0/3	OK 492 days	0/3	OK 496 days
		32	0/3	OK 492 days	0/3	OK 496 days
5.5 x 22	429247	0	0/2	OK 492 dyas	0/2	OK 496 days
		21	0/3	OK 492 dyas	0/3	OK 496 days
		32	0/3	OK 492 dyas	0/3	OK 496 days
5.5 x 22	429248	0	0/2	OK 492 days	0/2	OK 496 days
		21	0/3	OK 492 days	0/3	OK 496 days
		32	0/3	OK 492 days	0/3	OK 496 days
7.5 x 22	429244	0	0/2	OK 492 days	0/2	OK 496 days
		20	0/3	OK 492 days	0/3	OK 496 days
		29	0/3	OK 492 days	0/3	OK 496 days
7.5 x 22	429245	0	0/2	OK 492 dyas	0/2	OK 496 days
		20	0/3	OK 492 dyas	0/3	OK 496 dyas
		29	0/3	OK 492 dyas	0/3	OK 496 days

(a) F/N denotes number of failures over total number of specimens exposed.
(b) Exposed to the seacoast atmosphere at Point Judith, Rhode Island, 3/28/77.

TABLE 36

RESULTS OF STRESS-CORROSION TESTS OF 0.125-INCH DIAMETER SHORT-TRANSVERSE TENSION SPECIMENS OF 7050-T7351 ALLOY PLATES IN OUTDOOR ATMOSPHERES

Thickness Inches	Sample Number	Applied Stress ksi	Point Judith Seacoast Atmos. F/N(a)	Point Judith Seacoast Atmos. Days to Failure	ATC Industrial Atmos. F/N(a)	ATC Industrial Atmos. Days to Failure
2.0	421074	0	0/2	OK 288 days	0/2	OK 322 days
		32	0/3	OK 288 days	0/3	OK 322 days
		47	0/3	OK 288 days	0/3	OK 322 days
2.0	421075	0	0/2	OK 288 days	0/2	OK 322 days
		32	0/3	OK 288 days	0/3	OK 322 days
		47	0/3	OK 288 days	0/3	OK 322 days
3.0	421076	0	0/2	OK 288 days	0/2	OK 322 days
		32	0/3	OK 288 days	0/3	OK 322 days
		47	0/3	OK 288 days	0/3	OK 322 days
3.0	421081	0	0/2	OK 288 days	0/2	OK 322 days
		32	0/3	OK 288 days	0/3	OK 322 days
		47	0/3	OK 283 days	0/3	OK 322 days
4.0	421077	0	0/2	OK 288 days	0/2	OK 322 days
		31	0/3	OK 288 days	0/3	OK 322 days
		46	0/3	OK 288 days	0/3	OK 322 days
4.0	421078	0	0/2	OK 288 days	0/2	OK 322 days
		31	0/3	OK 288 days	0/3	OK 322 days
		46	0/3	OK 288 days	0/3	OK 322 days
5.0	421073	0	0/2	OK 288 days	0/2	OK 322 days
		30	0/3	OK 288 days	0/3	OK 322 days
		44	0/3	OK 288 days	0/3	OK 322 days
5.118	421278	0	0/2	OK 288 days	0/2	OK 322 days
		29	0/3	OK 288 days	0/3	OK 322 days
		43	0/3	OK 288 days	0/3	OK 322 days
6.0	421079	0	0/2	OK 288 days	0/2	OK 322 days
		29	0/3	OK 288 days	0/3	OK 322 days
		43	0/3	OK 288 days	0/3	OK 322 days
6.0	421080	0	0/2	OK 288 days	0/2	OK 322 days
		29	0/3	OK 288 days	0/3	OK 322 days
		43	0/3	OK 288 days	0/3	OK 322 days

(a) F/N denotes number of failures over total number of specimens exposed.

TABLE 37

RESULTS OF STRESS-CORROSION TESTS OF 0.125-INCH DIAMETER SHORT-TRANSVERSE TENSION SPECIMENS OF 2048-T851 ALLOY PLATES IN OUTDOOR ATMOSPHERES

Thickness Inches	Sample Number	Applied Stress ksi	Point Judith Seacoast Atmos. F/N(2)	Point Judith Seacoast Atmos. Days to Failure	ATC Industrial Atmos. F/N(a)	ATC Industrial Atmos. Days to Failure
2.0	421381	0	0/2	OK 288 Days	0/2	OK 260 Days
		28	0/3	OK 288 Days	0/3	OK 260 Days
		42	2/3	71, 128, OK 288 Days	0/3	OK 260 Days
2.0	421382	0	0/2	OK 288 days	0/2	OK 260 days
		28	0/3	OK 288 days	0/3	OK 260 days
		42	1/3	71, 2 OK 288 days	0/3	OK 260 days
3.0	421083	0	0/2	OK 288 days	0/2	OK 260 days
		28	0/3	OK 288 days	0/3	OK 260 days
		41	2/3	73, 128, 1 OK 288 days	0/3	OK 260 days
3.0	421084	0	0/2	OK 288 days	0/2	OK 260 days
		28	0/3	OK 288 days	0/3	OK 260 days
		41	0/3	OK 288 days	0/3	OK 260 days
4.0	421383	0	0/2	OK 288 days	0/2	OK 260 days
		28	0/3	OK 288 days	0/3	OK 260 days
		41	0/3	OK 288 days	0/3	OK 260 days
4.0	421384	0	0/2	OK 288 days	0/2	OK 260 days
		28	0/3	OK 288 days	0/3	OK 260 days
		41	0/3	OK 288 days	0/3	OK 260 days

(a) F/N denotes number of failure over total number of specimens tested.

TABLE 38

RESULTS OF STRESS-CORROSION TESTS OF 0.125-INCH DIAMETER SHORT-TRANSVERSE TENSION SPECIMENS OF 7475-T7351 ALLOY PLATES IN OUTDOOR ATMOSPHERES

Thickness Inches	Sample Number	Applied Stress ksi	Point Judith Seacoast Atmos. F/N(a)	Point Judith Seacoast Atmos. Days to Failure	ATC Industrial Atmos. F/N(a)	ATC Industrial Atmos. Days to Failure
2.0	429389	0	0/2	OK 617 days	0/2	OK 622 days
		28	0/3	OK 617 days	0/3	OK 622 days
		42	0/3	OK 617 days	0/3	OK 622 days
2.0	429390	0	0/2	OK 617 days	0/2	OK 622 days
		28	0/3	OK 617 days	0/3	OK 622 days
		42	0/3	OK 617 days	0/3	OK 622 days
3.0	429391	0	0/2	OK 617 days	0/2	OK 622 days
		26	0/3	OK 617 days	0/3	OK 622 days
		39	0/3	OK 617 days	0/3	OK 622 days
3.0	429392	0	0/2	OK 617 days	0/2	OK 622 days
		26	0/3	OK 617 days	0/3	OK 622 days
		39	0/3	OK 617 days	0/3	OK 622 days
4.0	429393	0	0/2	OK 617 days	0/2	OK 622 days
		24	0/3	OK 617 days	0/3	OK 622 dyas
		36	0/3	OK 617 days	0/3	OK 622 days
4.0	429394	0	0/2	OK 617 days	0/2	OK 622 days
		24	0/3	OK 617 days	0/3	OK 622 days
		36	0/3	OK 617 days	0/3	OK 622 days

(a) F/N denotes number of failures over total number of specimens exposed.

TABLE 39

RESULTS OF INITIAL STRESS INTENSITY, K_{Ii}, LOADS OF DOUBLE CANTILEVER BEAM SPECIMENS

Alloy & Temper	Sample Thick. In.	Sample Number	S-L (a) K_{Ic} ksi $\sqrt{In.}$	Product	3 1/2% NaCl Solution-Dropwise: Dash Number	Crack Length In.	Total V(c) In.	S-L K_{Ii} (b) ksi $\sqrt{In.}$	Point Judith Seacoast Atmos.: Dash Number	Crack Length In.	Total V (c) In.	S-L K_{Ii} (b) ksi $\sqrt{In.}$	ATC Industrial Atmos.: Dash Number	Crack Length In.	Total V (c) In.	S-L K_{Ii} (b) ksi $\sqrt{In.}$
2048-T851	2	421381	24.9	Plate	1	1.332	0.055	30.7	5	1.260	0.044	26.5	3	1.319	0.042	23.8
					2	1.339	0.052	28.8	6	1.282	0.043	25.8	4	1.348	0.045	24.4
2048-T851	4	421383	25.5	Plate	1	1.363	0.053	28.3	5	1.272	0.043	25.5	3	1.304	0.043	24.0
					2	1.405	0.050	25.7	6	1.276	0.044	25.9	4	1.298	0.043	25.0
7050-T7351	2	421074	27.0	Plate	1	1.366	0.059	31.4	5	1.224	0.043	27.1	3	1.309	0.045	25.3
					2	1.362	0.052	27.8	6	1.217	0.046	29.5	4	1.258	0.041	24.8
7050-T7351	4	421077	29.0	Plate	1	1.302	0.049	28.1	5	1.147	0.043	29.8	3	1.161	0.038	25.9
					2	1.261	0.047	28.3	6	1.190	0.043	28.6	4	1.170	0.041	27.3
7050-T7351	6	421079	29.4	Plate	1	1.315	0.044	25.1	5	1.146	0.041	28.1	3	1.292	0.045	26.1
					2	1.231	0.042	26.3	6	1.134	0.037	26.2	4	1.156	0.039	26.8
7050-T7351	6	421083	26.5	Plate	1	1.196	0.036	23.5	5	1.170	0.036	24.3	3	1.276	0.039	23.0
					2	1.203	0.039	25.2	6	1.196	0.035	22.5	4	1.123	0.038	24.3
7475-T7351	2	429389	28.7	Plate	1	1.345	0.055	29.9	5	1.315	0.048	27.1	3	1.284	0.047	27.5
					2	1.292	0.053	31.0	6	1.303	0.048	27.4	4	1.320	0.047	26.3
7475-T7351	4	429393	31.0	Plate	1	1.373	0.056	29.3	5	1.283	0.055	32.2	3	1.297	0.054	31.1
					2	1.266	0.052	31.1	6	1.285	0.056	32.8	4	1.289	0.056	32.3
2219-T852	2.5	478817	21.7	Hand	1	1.331	0.038	20.6	5	1.327	0.039	21.5	3	1.300	0.040	22.7
				Forging	2	1.272	0.036	21.2	6	1.324	0.038	20.7	4	1.338	0.041	22.0
2219-T852	4.5	429249	23.7	Hand	1	1.284	0.038	22.0	5	1.362	0.041	21.6	3	1.263	0.045	26.7
				Forging	2	1.283	0.039	22.3	6	1.393	0.046	23.7	4	1.305	0.046	26.0
2219-T852	7.5	429245	26.1	Hand	1	1.406	0.040	20.4	5	1.337	0.043	23.4	3	1.350	0.038	20.6
				Forging	2	1.387	0.041	21.3	6	1.263	0.041	24.1	4	1.386	0.042	21.4

(a) Average short-transverse plane strain fracture toughness tests.
(b) Short-transverse initial stressed intensity calculations.
(c) Total crack opening displacement - V.

TABLE 40

AVERAGE CRACK GROWTH VELOCITIES FOR DOUBLE CANTILEVER BEAM SPECIMENS EXPOSED TO 3.5% NaCl SOLUTION DROPWISE FOR 30 DAYS

Alloy & Temper	Number	Dash	Product	Thickness In.	K_{I_i} $Ksi\sqrt{In.}$	K_I 15 Da. $Ksi\sqrt{In.}$	K_I 20 Da. $Ksi\sqrt{In.}$	Avg. 15 Day Velocity In/Hr (a)	Mean Velocity In/Hr (a)	K_{Ith} (EST) $Ksi\sqrt{In.}$	K_{Ith} (EST) % K_{Ii}
2219-T852	478817	SL1	Hand Forging	2.5	20.6	19.6	19.1	1.19×10^{-4}	1.6×10^{-4}	19.4	93
2219-T852	478817	SL2	Hand Forging	2.5	21.2	19.7	19.6	1.75×10^{-4}			
2219-T852	429249	SL1	Hand Forging	4.5	22.0	21.7	19.6	3.89×10^{-5} (b)	6.1×10^{-5} (b)	20.5(b)	93(b)
2219-T852	429249	SL2	Hand Forging	4.5	22.3	21.6	21.4	8.3×10^{-5} (b)			
2219-T852	429245	SL1	Hand Forging	7.5	20.4	19.6	19.6	9.72×10^{-5} (b)	5.6×10^{-5} (b)	20.4(b)	98(b)
2219-T852	429245	SL2	Hand Forging	7.5	21.3	21.2	21.2	1.39×10^{-5} (b)			
2048-T851	421381	SL1	Plate	2	30.7	24.4	22.1	5.83×10^{-4}	5.8×10^{-4}	21.8	73
2048-T851	421381	SL2	Plate	2	28.8	22.9	21.5	5.73×10^{-4}			
2048-T851	421383	SL1	Plate	4	28.3	27.0	26.7	1.19×10^{-4}	1.0×10^{-4}	25.6	95
2048-T851	421383	SL2	Plate	4	25.7	24.8	24.4	8.97×10^{-5}			
7050-T7351	421074	SL1	Plate	2	31.4	29.5	29.5	1.53×10^{-4}	3.9×10^{-4}	28.1	95
7050-T7351	421074	SL2	Plate	2	27.8	27.1	26.7	6.19×10^{-5}			
7050-T7351	421077	SL1	Plate	4	28.1	25.7	25.1	2.15×10^{-4}	2.4×10^{-4}	25.1	89
7050-T7351	421077	SL2	Plate	4	28.3	25.2	25.0	2.68×10^{-4}			
7050-T7351	421079	SL1	Plate	6	25.1	24.8	24.7	2.97×10^{-5}	2.9×10^{-5}	25.2	98
7050-T7351	421079	SL2	Plate	6	26.3	25.9	25.7	2.78×10^{-5}			
7050-T7351	421080	SL1	Plate	6	23.5	19.1	18.9	4.78×10^{-4}	4.5×10^{-4}	19.7	81
7050-T7351	421080	SL2	Plate	6	25.2	21.0	20.5	4.26×10^{-4}			
7475-T7351	429389	SL1	Plate	2	30.0	29.7	29.6	2.14×10^{-5}	2.7×10^{-5}	30.1	99
7475-T7351	429389	SL2	Plate	2	31.0	30.6	30.6	3.29×10^{-5}			
7475-T7351	429393	SL1	Plate	4	29.3	29.2	29.2	1.19×10^{-5} (b)	2.2×10^{-5} (b)	29.9(b)	99(b)
7475-T7351	429393	SL2	Plate	4	31.1	30.7	30.6	3.28×10^{-5} (b)			

(a) Overall average velocity for the first 15 day [illegible] posure.

(b) Presence of actual SCC is questionable based on [illegible] sual examination.

TABLE 41

AVERAGE CRACK GROWTH VELOCITIES OF REDUCED THICKNESS DCB SPECIMENS EXPOSED TO 3.5% NaCl SOLUTION DROPWISE FOR 30 DAYS

Alloy & Temper	Specimen Number	Specimen Dash	Specimen Thick. In.	K_{Ii} Ksi$\sqrt{In.}$	K_I 15 Da. Ksi$\sqrt{In.}$	K_I 20 Da. Ksi$\sqrt{In.}$	Avg. 15 Day Velocity In/Hr (b)	Mean Velocity In/Hr (b)	K_{Ith} (EST) Ksi$\sqrt{In.}$	K_{Ith} (EST) % K_{Ii}
2048-T851	421383	SL7(a)	0.25	37.3	35.8	35.6	8.33×10^{-5}	9.7×10^{-5}	36.5	95
2048-T851	421383	SL8(a)	0.25	39.3	37.3	37.3	1.11×10^{-4}			
2048-T851	421383	SL9	0.50	28.5	28.2	28.1	2.58×10^{-5}	6.3×10^{-5}	27.4	97
2048-T851	421383	SL10	0.50	27.9	26.7	26.7	1.01×10^{-4}			
7050-T7351	421077	SL7(a)	0.25	38.8	37.3	37.3	8.33×10^{-5}	5.6×10^{-5}	37.9	97
7050-T7351	421077	SL8(a)	0.25	39.0	38.4	38.4	2.78×10^{-5}			
7050-T7351	421077	SL9	0.50	28.3	27.6	27.5	6.11×10^{-5}	7.5×10^{-5}	27.1	97
7050-T7351	421077	SL10	0.50	27.7	26.6	26.6	8.97×10^{-5}			
7475-T7351	429393	SL7(a)	0.25	50.0	48.0	47.6	8.33×10^{-5}	4.2×10^{-5}	50.4	98
7475-T7351	429393	SL8(a)	0.25	53.2	53.2	53.2	0			
7475-T7351	429393	SL9	0.50	33.4	33.3	33.3	6.94×10^{-6}	1.08×10^{-5}	34.4	99
7475-T7351	429393	SL10	0.50	35.8	35.5	35.5	1.47×10^{-5}			
7475-T7351	429393	SL11	0.80	29.7	29.5	29.3	1.75×10^{-5}	5.0×10^{-5}	30.1	98
7475-T7351	429393	SL12	0.80	31.9	30.8	30.8	8.25×10^{-5}			

(a) Results based on surface measurements only.

(b) Overall average velocity for the first 15 days of exposure.

TABLE 42

RESULTS OF STRESS-CORROSION TESTING OF 0.125-INCH DIAMETER SHORT-TRANSVERSE TENSION SPECIMENS OF 7475-T7351 ALLOY PLATE BY ALTERNATE IMMERSION IN A 3.5% SODIUM CHLORIDE SOLUTION FOR 84 DAYS (ASTM G44-75)

Thickness Inches	Sample Number	Applied Stress ksi	F/N (a)	Days to Failure (b)	Average % Loss in Tensile Properties of Unfailed Specimens		
					Yield	Ult.	El.
2.25	478826	0	0/2	**	18	19	50
		28	0/3	***	26	33	75
		41	0/3	***	35	46	75
3.5	478961	0	0/2	**	21	23	58
		25	0/3	***	21	27	65
		38	0/3	***	27	35	79

(a) F/N denotes number of failures over total number of specimens exposed.

(b) For day to failure

* Indicates that the specimen did not fail during the 84 day test.

TABLE 43

RESULTS OF STRESS-CORROSION TESTS OF 0.125-INCH DIAMETER SHORT-TRANSVERSE TENSION SPECIMENS OF 7475-T7351 ALLOY PLATES IN OUTDOOR ATMOSPHERES

Thickness Inches	Sample Number	Applied Stress ksi	Point Judith Seacoast Atmos. F/N(a)	Point Judith Seacoast Atmos. Days to Failure	ATC Industrisl Atmos. F/N(a)	ATC Industrisl Atmos. Days to Failure
2.25	478826	0	/2	(b)	0/2	OK 24 Days
		28	/3	(b)	0/3	OK 24 Days
		41	/3	(b)	0/3	OK 24 Days
3.5	478961	0	/2	(b)	0/2	OK 24 Days
		24	/3	(b)	0/3	OK 24 Days
		38	/3	(b)	0/3	OK 24 Days

(a) F/N denotes number of failures over total number of specimens exposed.

(b) Exposed to the seacoast atmosphere at Point Judith, Rhode Island, 3/28/77.

TABLE 44

RESULTS OF INITIAL STRESS INTENSITY, K_{Ii}, LOAD OF DOUBLE CANTILEVER BEAM SPECIMENS

Alloy & Temper	Thick. In.	Number	S-L(a) K_{Ic} ksi$\sqrt{In.}$	Product	3 1/2% NaCl Solution-Dropwise				Point Judith Seacoast Atmos.				ATC Industrial Atmos.			
					Dash Number	Crack Length In.	Total V(c) In.	S-L K_{Ii} (b) ksi$\sqrt{In.}$	Dash Number	Crack Length In.	Total V(c) In.	S-L K_{Ii} (b) ksi$\sqrt{In.}$	Dash Number	Crack Length In.	Total V(c) In.	S-L K_{Ii} (b) ksi$\sqrt{In.}$
7475-T7351	2.25	478826	33.1	Plate	1	1.2270	0.051	31.7	5	1.3063	0.057	32.7	3	1.2570	0.058	35.1
					2	1.3123	0.054	30.6	6	1.2710	0.056	33.0	4	1.2297	0.054	33.4
7475-T7351	3.5	478961	32.0	Plate	1	1.2453	0.057	35.0	5	1.2230	0.052	32.8	3	1.3300	0.065	36.0
					2	1.2760	0.056	32.9	6	1.2603	0.057	34.6	4	1.2773	0.059	34.8

(a) Average short-transverse plain strain fracture toughness tests.

(b) Short-transverse initial stress intensity calculations.

(c) Total crack opening displacements - V.

TABLE 45

AVERAGE CRACK VELOCITIES FOR DOUBLE CANTILEVER BEAM SPECIMENS FROM 7475-T7351 ALLOY PLATES AND EXPOSED TO 3.5% NaCl SOLUTION DROPWISE

Specimen Number	Specimen Dash	Plate Thick. In.	K_{Ii} Ksi$\sqrt{In.}$	K_I 15 Day Ksi$\sqrt{In.}$	K_I 20 Day Ksi$\sqrt{In.}$	Average 15 Day Velocity In/Hr (a)	Mean Velocity In/Hr.	K_{Ith} (EST) Ksi$\sqrt{In.}$	K_{Ith} (EST) % K_{Ii}
478826	SL1	2.25	31.7	30.5	30.2	8.61×10^{-5}	5.9×10^{-5}	30.0	96
	SL2	2.25	30.6	30.2	29.8	3.14×10^{-5}			
478961	SL1	3.50	35.0	33.7	33.6	[illegible].31 $\times 10^{-5}$	5.9×10^{-5}	33.0	9[illegible]
	SL2	3.50	32.9	32.4	32.3	3.14×10^{-5}			

(a) Overall average velocity for the first 15 days of exposure.

☆U.S.Government Printing Office: 1978 — 757-080/296