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FATIGUE-CRACK-PROPAGATION AND FRACTURE-TOUGHNESS CHARACTERISTICS OF 7079 ALUMINUM-ALLOY SHEETS AND PLATES IN THREE AGED CONDITIONS

by S. H. Smith, T. R. Porter, and W. D. Sump

Prepared by
THE BOEING COMPANY
Renton, Wash.
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FOREWORD

This contractor report describes work accomplished under NASA Contract NAS 1-6474 by The Boeing Company during the contract time period of July 18, 1966, to July 18, 1967. Boeing personnel who participated in the investigation include Mr. J. P. Butler, program manager; Mr. S. H. Smith, project leader; and Mr. T. R. Porter, research engineer. Structural testing of specimens was conducted by Mr. W. D. Sump under the supervision of Mr. W. C. Larson. Structural-testing instrumentation support was provided by Mr. D. C. English, and aging and heat-treatment support was provided by Mr. M. V. Hyatt and Mr. J. C. McMillan. Computer programming support was provided by Mr. M. G. Hellborg.

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SUMMARY

This experimental research and development program was conducted to characterize the fatigue-crack-propagation behavior, residual strength, and fracture toughness of 7079 aluminum alloy in the underaged, peak-age (T6), and overaged conditions for thicknesses of 0.16, 0.25, 0.50, and 0.63 inch. Tensile-property, fatigue-crack-propagation, and fracture-toughness tests were conducted to determine the effects of aging temperature and time, material thickness, specimen width, and configuration and physical environments of dry air, liquid nitrogen (-65° F), and distilled water on these properties. The materials were available in 36- by 96-inch sheets or plates. Using centrally notched specimens, the crack-growth and fracture-toughness tests were performed on 36-, 12-, and 8-inch-wide panels with the latter two sizes of specimens being cut from the fractured halves of the large panels. Residual-strength characteristics were also determined with surface-flawed specimens in the 0.63-inch-thickness tests. Precracked Charpy impact-toughness tests also were conducted for the three aged conditions and for the four panel thicknesses. Aging conditions were determined from tensile tests and were verified by tensile specimens cut from the fracture-tested material.

The results of the test program showed that 7079 peak-age (T6) material has a faster rate of fatigue crack growth and a lower fracture toughness and residual strength than underaged and overaged materials. Underaged material exhibited the greatest fracture toughness and essentially the same rate of fatigue crack growth as that of overaged material. A slower fatigue-crack-growth rate was found for a decrease in plate thickness, an increase in panel width, a dry-air environment compared to distilled water, and a -65° F temperature compared to room temperature. Higher fracture-toughness and residual-strength values were found for a decrease in plate thickness, an increase in panel width, a longitudinal grain direction compared to transverse grain, and an increase in test temperature from -65° F to room temperature.

INTRODUCTION

Many material and structural failures occur from cracks or flaws that pre-exist or that originate in the material or structure. These failures can occur at applied tensile stress levels well below the tensile ultimate or yield strength of the material due to the unidentified presence of the flaw. Therefore, to ensure the fracture-safe design of a structure, knowledge of the residual-strength or fracture-toughness characteristics of structural materials in the presence of these flaws must be established. In addition, the growth rate of cracks or flaws in the material subjected to cyclic loading must be known to establish the required inspection time intervals for structure subjected to fatigue loading.

This investigation was undertaken to determine the fatigue-crack-propagation behavior, plane-strain and plane-stress fracture toughnesses, and residual strength of 7079 aluminum alloy in the underaged, peak-age (T6), and overaged conditions. Sheet and plate thicknesses of 0.16, 0.25, 0.50, and 0.63 inch were evaluated. The stress-intensity-factor method, or as it is sometimes referred to as linear elastic fracture mechanics, was applied in generating and presenting the fatigue-crack-propagation and fracture-toughness characteristics of 7079 aluminum alloy in the three aged conditions. Underaged and overaged transverse-yield-strength levels were 12.5 ± 2.5 percent below the peak transverse-yield-strength level. Tests were conducted at -65° F and room temperature. Cyclic fatigue-crack-propagation tests were conducted in a controlled dry-air environment and in distilled water.

A total of 363 tests were conducted in the program, including 204 tensile tests, 72 center-cracked-panel fatigue-crack-growth and fracture-toughness tests, 15 surface-flaw fatigue-crack-growth and fracture-toughness tests, and 72 precracked Charpy impact-toughness tests.

SYMBOLS

A_o net area of precracked Charpy specimen, in.

b surface-flaw depth, in.

$\frac{d(2a)}{dN}$ fatigue-crack-growth rate, microinches/cycle

E Young's modulus of elasticity, ksi

F(U) ultimate tensile strength, ksi

F(Y) 0.2-percent offset yield strength, ksi

f cyclic frequency, cpm

G_c plane-stress fracture toughness, in.-lb/in.^{2}

$\overline{G}_c$ plastic-zone-corrected plane-stress fracture toughness, in.-lb/in.^{2}

G_{Ic} plastic-zone-corrected plane-strain fracture toughness, in.-lb/in.^{2}

K maximum-cyclic-stress-intensity factor, ksi$\sqrt{in.}$

K_c plane-stress critical-stress-intensity factor, ksi$\sqrt{in.}$

$\overline{K_c}$ plastic-zone-corrected plane-stress critical-stress-intensity factor, ksi$\sqrt{in.}$

K_I opening-mode stress-intensity factor, ksi$\sqrt{in.}$

K_{Ic} plane-strain critical-stress-intensity factor, ksi$\sqrt{in.}$

$\overline{K_{Ic}}$ plastic-zone-corrected plane-strain critical-stress-intensity factor, ksi$\sqrt{in.}$

K_{Ii} initial applied plane-strain stress-intensity level, ksi$\sqrt{in.}$

K_{max} maximum cyclic stress-intensity factor, ksi$\sqrt{in.}$

L center-cracked-panel length, in.

M constant in crack-growth-rate formula

N fatigue cycles, cycles

N_f surface-flaw cycles to failure, cycles

n exponent in crack-growth-rate formula

R ratio of minimum to maximum fatigue cyclic stress levels

RA reduction in area, percent

S percent shear lip observed on fracture surface

T thickness, in.

t thickness, in.

ULT ultimate tensile strength, ksi

UTS ultimate tensile strength, ksi

W center-cracked-panel width, in.

W_o precracked Charpy impact energy, in.-lb/in.^{2}

$\overline{w}$ plastic-zone width, in.

YS	0.2-percent offset yield strength, ksi
Θ	angle describing a point on the surface-crack front, degrees
μ	Poisson's ratio
σ_g	gross-area stress, ksi
$\dot{\sigma}_g$	gross-area-stress rate, ksi/sec
σ_{net}	net-area stress, ksi
σ_{ys}	0.2-percent offset yield strength, ksi
σ_o	gross-area stress level at pop-in, ksi
ϕ	complete elliptical integral of second kind
2A	fatigue crack length, in.
2a	fatigue crack length, in.
$2a_{cr}$	critical crack length, in.
2c	surface-flaw length, in.

FATIGUE-CRACK-PROPAGATION AND FRACTURE-TOUGHNESS ANALYSIS

The analysis methods used in investigating the fatigue crack propagation and fracture-toughness behaviors of 7079 aluminum alloys were based on linear elastic fracture mechanics or the stress-intensity-factor method. The stress-intensity-factor method of fracture mechanics has become a useful engineering tool in investigating the mechanics of subcritical crack growth and the final crack instability in metals due to static and fatigue loads, particularly where the material exhibits little net-section yielding. This method has been shown to be applicable in analyzing the subcritical fatigue-crack-growth behavior of surface or embedded flaws and through-the-thickness cracks in structure. Practical applications of the method are given in references 1, 2, and 3. Recently, the stress-intensity-factor method was used in determining the effects of humidity and liquid environments on the fatigue crack growth and sustained-load crack-growth behaviors of metals (refs. 4 through 7). The remainder of this discussion describes the stress-intensity-factor method and presents the stress-intensity-factor formulae for the specimen configurations and analysis used in this investigation. Additional analysis techniques used in analyzing the fatigue-crack-propagation and fracture-toughness data are also discussed.

Fatigue Crack Propagation

The stress-intensity-factor parameter K is a measure of the localized stress field around the tip of a crack and is a function of the remotely applied stress and crack size. For crack growth due to constant-amplitude fatigue loading, the maximum stress-intensity level and the fluctuation in stress-intensity level control the rate of fatigue crack growth (ref. 8). To compare the behavior of the rate of fatigue crack growth of different materials or to establish the effect of metallurgical, geometrical, or environmental variables on the rate of fatigue crack growth, identical levels of fatigue stress-intensity factors can be compared.

In this investigation, the center-notched panel configuration was used in generating the majority of the data on fatigue crack propagation The stress-intensity-factor formula for the center-notched panel is given by Irwin (ref. 9) as:

$$K = \sigma_g \sqrt{\pi a} \left(\frac{W}{\pi a} \tan \frac{\pi a}{W} \right)^{1/2}$$

Under fatigue cycling of a center-notched panel, a fatigue crack initiates at the notch tip and propagates at a steadily increasing rate for constant amplitude and maximum cyclic stress levels. The fatigue-crack-propagation data was recorded in the form of crack length at specific applied-load cycles until the fatigue crack propagated to a length of approximately 35 percent of the panel width.

A computer program was used to analyze the generated data on fatigue crack growth for growth-rate effects. The program computes the average maximum-cyclic-stress-intensity factor between measured crack-length-cycles data points and the corresponding average rate of fatigue crack growth. The application of a computerized curve-fitting process to the crack-length-cycles data to determine an analytical rate behavior was complicated by differences in the curves defined by the actual test points from the various test panels. A simple, single functional form for the crack-length-cycles data was not found to fit all the data. Hence, the crack-length-cycles curves were drawn through the actual measured data.

A regression analysis or a least-squares fit of the calculated values of stress-intensity factor and fatigue-crack-growth rate was performed with a computer program. This analysis fitted a straight line through a log-log plot of maximum-cyclic-stress-intensity factor versus fatigue-crack-growth rate. Such a regression analysis as this reflects a power law for the rate of fatigue crack growth. According to Paris (ref. 10), the rate of fatigue crack growth over many log cycles of rate can be expressed as:

$$\frac{d(2a)}{dN} = \frac{{K_{max}}^n}{M}$$

or in logarithmic terms, is a linear equation:

$$\log \frac{d2a}{dN} = n\log K_{max} - \log M$$

where n is suggested as 4.

Curves of crack length versus cycles and maximum cyclic stress-intensity factor versus the rate of fatigue crack growth were used to show the effects of heat treatment, material thickness, distilled water versus dry air, test temperature, and panel width on the behavior and rate of fatigue crack growth of the tested material.

The characteristics of low-cycle fatigue crack growth of thick plate were measured and analyzed by surface-flawed testing. The stress-intensity factor for a semi-elliptical surface crack in a plate is given by Irwin (ref. 11) as:

$$K_I = \frac{1.95\,\sigma_g \sqrt{b}}{\phi}$$

$$\phi = \int_0^{\frac{\pi}{2}} \left(1 - \frac{c^2 - b^2}{c^2} \sin^2\Theta\right)^{1/2} d\Theta$$

Values of ϕ for various ratios of $b/2c$ were found in standard mathematical tables.

The technique for evaluating the behavior of low-cycle fatigue crack growth by surface-flaw testing was developed by Tiffany (ref. 2). This technique was used in this investigation by fatigue cycling surface-flawed specimens. Baseline plane-strain critical-stress-intensity levels K_{Ic} were first established for the different aged conditions. Then initial stress-intensity levels, which were a specific percentage of K_{Ic}, were applied to various surface-flawed specimens and fatigue cycled to failure at maximum cyclic stress levels corresponding to desired stress-intensity levels. The behavior of fatigue crack growth was characterized by data plots of K_{Ii}/K_{Ic} versus fatigue cycles to failure, where K_{Ii} is the initial-applied-stress-intensity level.

Fracture-Toughness Analysis

Two typical types of failure modes can occur during material fracture and are described by the mechanics of crack growth. These two modes of failure are termed "plane stress" and "plane strain" and are a function of the three-dimensional stress field near a crack front.

For a through-the-thickness crack in a sheet or a plate, both plane-strain and plane-stress failure modes or mixed-mode failure can occur. If the material is ductile or if test conditions are such that the local stress acting normal to the plane of the sheet or plate is zero during fracture, the mode of failure is plane stress. This type of failure is characterized by extensive shear lips on the fracture surface. On the other hand, if the material is brittle or if the test conditions are such that the local strain acting normal to the sheet or plate is zero, the failure mode is plane strain. This mode of failure is characterized by the appearance of a flat fracture surface. Mixed modes of failure are characterized by flat areas and shear-lip areas on the fracture face and are plane stress with the degree of plane stress being dependent on thickness.

The fracture-toughness values of plane-strain and plane-stress fracture modes are determined by the critical-stress-intensity levels K_{Ic} and K_c as measured during the static pull of the center-cracked panel. During the slow-loading pull of the fatigue-cracked panel, the first possible mode of failure is that of plane strain K_{Ic} , and a pop-in or a local discontinuity in the load strain curve, often associated with an audible click, may occur. Slow crack growth follows pop-in, and the onset of rapid fracture is a plane-stress failure mode and is measured as K_c . If no pop-in is detected and slow crack growth is absent, the onset of rapid fracture is a plane-strain failure mode.

Plane-strain pop-in K_{Ic} and plastic-zone-corrected K_{Ic} values were determined from the following equations, respectively (ref. 12):

$$K_{Ic} = \sigma_o \left(W \tan \frac{\pi a}{W}\right)^{1/2}$$

$$\overline{K_{Ic}} = \sigma_o \left[W \tan \frac{\pi}{W} \left(a + \frac{K_{Ic}^2}{6\pi\sigma_{ys}^2}\right)\right]^{1/2}$$

Plane stress K_c and plastic-zone-corrected K_c values were determined from the following equations:

For plane stress,

$$K_c = \sigma_g \left(W \tan \frac{\pi a_{cr}}{W}\right)^{1/2}$$

For plastic-zone-corrected,

$$\overline{K_c} = \sigma_g \left[W \tan \frac{\pi}{W} \left(a_{cr} + \frac{K_c^2}{2\pi\sigma_{ys}^2}\right)\right]^{1/2}$$

The plastic-zone widths were computed using the following equations:

For plane strain,

$$\overline{w} = \frac{K_{Ic}^2}{6\pi\sigma_{ys}^2}$$

For plane stress,

$$\bar{w} = \frac{K_c^{\,2}}{2\pi\sigma_{ys}^{\,2}}$$

Plane-strain and plane-stress fracture-toughness values were computed using the following equations:

For plane strain,

$$G_{Ic} = \left(1 - \mu^2\right) \frac{K_{Ic}^{\,2}}{E}$$

$$\overline{G_{Ic}} = \left(1 - \mu^2\right) \frac{\overline{K_{Ic}}^{\,2}}{E}$$

For plane stress,

$$G_c = \frac{K_c^{\,2}}{E}$$

$$\overline{G_c} = \frac{\overline{K_c}^{\,2}}{E}$$

For a surface crack in a plate, the stress state in the periphery of the crack is that of plane strain, thus resulting in a plane-strain failure mode.

The plane-strain critical-stress-intensity factor was computed from the following equation:

$$K_{Ic} = \frac{1.95\,\sigma_g \sqrt{b}}{\phi}$$

The plastic-zone-corrected K_{Ic} value was computed from the following equation:

$$\overline{K_{Ic}} = \frac{1.95\,\sigma_g \sqrt{b}}{\left[\phi^2 - 0.212\left(\frac{\sigma_g}{\sigma_{ys}}\right)^2\right]^{1/2}}$$

Another measurement of material toughness is by a precracked Charpy impact test. The parameter W_o/A_o is impact toughness, where W_o is the impact energy in inch-pounds and A_o is the net fracture area. The different failure modes of plane strain and plane stress cannot be separated by this type of test; therefore, the test is used only as a qualitative measurement of fracture toughness.

EXPERIMENTAL PROGRAM AND SPECIMENS

This experimental research and development program was designed to characterize the fatigue-crack-propagation behavior, fracture toughness, and residual-strength properties of 7079 aluminum alloy in the underaged, peak-age (T6), and overaged conditions. The effects of aging temperature and time, material thickness, specimen configuration, and the physical environments of dry air, liquid nitrogen (-65° F), and distilled water on these properties were evaluated.

The 7079 aluminum alloy used in this investigation was furnished by the Government. Twelve sheets or plates of 36- by 96-inch 7079 alloy materials in the underaged condition and aged for 4 hours at 245 to 255°F were received in nominal thicknesses of 0.16, 0.25, 0.50, and 0.63 inch for testing. As-received mechanical properties and chemical composition as reported by the manufacturer are given in table I.

The experimental program consisted of two phases. The first phase was an aging and heat-treatment study to determine the time at temperature required to produce underaged and overaged tensile yield strengths 12.5 ± 2.5 percent below the peak-age (T6) condition. The second phase consisted of a study of fatigue crack propagation, residual strength, and fracture toughness utilizing center-notched, surface-flawed, and precracked Charpy impact specimens and associated testing techniques. Flow charts showing the detailed testing performed in this program are shown in figure 1.

The objective of the first phase of this program was to determine the time required at 250 and 290°F to age each thickness of material to the following conditions:

(1) Peak transverse yield strength (T6) using 250° F aging temperature

(2) Underage to 12.5 ± 2.5 percent below peak transverse tensile yield strength using 250° F aging temperature

(3) Overaged to 12.5 ± 2.5 percent below peak transverse tensile yield strength using 290° F aging temperature

Considering the manufacturer's tensile-property data and aging curves, mechanical properties were determined for an aging temperature of 250° F and total aging times of 5, 6, 48, 72, and 120 hours. Likewise, mechanical properties were checked for an aging temperature of 290° F and aging times of 17, 40, 50, 70, 90, 120, and 160 hours. In materials of certain thicknesses, some different aging times were used to develop only that portion of the aging curves that was of primary interest.

The material for the aging study was taken from a 4- by 36-inch strip from one end of one panel of each thickness. The specimens were fabricated in the transverse grain direction after aging. The sheet and round tensile used in this phase are shown in figure 2. The sheet specimen was used for panel thicknesses of 0.16 and 0.25 inch and the round specimen for panel thicknesses of 0.50 and 0.63 inch. All tensile testing for this phase was conducted at room temperature.

Fabricated tensile specimens not used in developing aging curves were heat treated with the 36-inch-wide plates for additional verification of heat treatment.

After aging data and curves were obtained, aging times were selected to give the three desired strength levels. The four reduced-size 36- by 92-inch panels, from which the aging-mechanical-properties study was made, were used for the underaged condition. The remaining 36- by 96-inch panels were aged to peak strength and overaged conditions. Material tensile properties of each panel were determined to verify heat treatment. This was done by obtaining longitudinal and transverse tensile properties from every 36- by 96-inch and 36- by 92-inch panel following testing of the large panels for fatigue-crack-growth rate and residual strength.

The evaluation of the effect of material thickness and heat treatment on fracture toughness, residual strength, and fatigue-crack-propagation behavior of 7079 aluminum alloy was based mainly on center-notched panels. Variables studied include thickness, panel width, grain direction, temperature, and wet and dry environments. In addition. some surface-flawed specimens and configurations fabricated only from 0.63-inch-thick material were tested by fatigue cycling to determine the behavior of surface-flawed crack growth and to provide further residual-strength and fracture-toughness data. Figure 3 shows the specimen layout.

Room-temperature and dry-air fatigue-crack-propagation behaviors of each heat treatment and thickness were determined by fatigue cycling the 36- by 96- or 92-inch, 12- by 36-inch, and 8- by 24-inch center-notched panels of longitudinal grain direction. Dry air is an air environment with a relative humidity of less than 10 percent.

The effect of reduced temperature on the behavior of fatigue crack propagation was investigated at -65° F. Center-notched 12- by 36-inch panels of longitudinal grain direction were fatigue cycled at -65° F and the crack-growth data were compared with the 12- by 36-inch-panel data obtained at room temperature.

The effects of a wet environment on the behavior of fatigue crack propagation was investigated for each thickness and heat treatment. This behavior was established by fatigue cycling center-notched panels (12 by 36 inches) of transverse grain direction. The behavior of fatigue crack growth in distilled water (complete immersion) was measured and compared with its behavior in dry air.

The behavior of the low-cycle fatigue crack growth of each heat treatment in dry air was determined by fatigue cycling surface-flawed specimens. Baseline plane-strain fracture toughness was established by fracture testing one of these specimens from each heat treatment. These specimens contained an initial machined flaw depth of 0.290 inch and a flaw length of 1.450 inches. The remainder of the surface-flawed specimens with an initial machined flaw depth of 0.100 inch and length of 0.400 inch were fatigue cycled to failure at constant cyclic gross-area stress levels corresponding to initial maximum stress-intensity levels of 45, 50, 55, and 60 percent of baseline plane-strain critical-stress-intensity levels.

Hole patterns for grip attachments in all specimens were drilled in each end by a programmed tape-controlled automatic drill press to ensure uniformity among all specimens. All specimens were center-notched by first drilling a small hole in the center of the panel and then inserting a saw through the hole to saw the initial notch. Surface flaws were produced by an electrical-discharge machining process.

After fracture testing, the mechanical properties and complete curves of stress-strain to failure for each heat treatment and thickness of material were determined. The large-sheet tensile specimen used for thicknesses of 0.16 and 0.25 inch and the round tensile specimen used for thicknesses of 0.50 and 0.63 inch are shown in figure 2.

Longitudinal and transverse precracked Charpy impact toughnesses were determined for each thickness and heat treatment. A 0.16-inch-thick specimen was used, and, for thicknesses greater than 0.16 inch, the specimens were fabricated at the surface of the material. The precracked Charpy specimen is shown in figure 2.

TESTING MACHINES AND PROCEDURES

The following paragraphs discuss the tensile, center-cracked-panel, surface-flaw, and Charpy impact-testing techniques and equipment used in this investigation.

The tensile specimens of the aging study were tested at room temperature, and the verification tensile specimens were tested at room temperature and -65° F. All specimens were tested in a 20-kip universal testing machine. Aged tensile specimens were tested at an applied strain rate of 0.005 in./in./min. Stress-strain curves were only developed past the 0.2-percent offset yield stress level. Complete curves of stress-strain to failure were developed in the verification tensile testing, and an applied strain rate of 0.005 in./in./min was used past the 0.2-percent offset yield strength and 0.100 or 0.020 in./in./min was used to failure. A cold box using nitrogen gas released from a liquid-nitrogen tank was used for -65° F tensile testing.

Fatigue cycling and fracture testing were performed in servovalve-controlled hydraulic test machines. Five hydraulic machines were used having static load capacities of 125, 180, 250, 300, and 1000 kips. The 1000-kip hydraulic machine is shown in figure 4; all 36-inch-wide panels were tested in this machine. The 180-, 250-, and 300-kip hydraulic load machines are shown in figure 4. All 12- and 8-inch-wide panels were tested in these machines.

Pin-ended loading grips, which ensured axial loading, were bolted to the ends of the specimens in preparing them for fatigue cracking. The surface area adjacent to the initial saw cut and along the line of expected crack extension was polished for easy visualization and measuring of the fatigue crack growth.

Uniform applied gross-area stresses were applied hydraulically to the panels during fatigue cycling and were controlled by single-channel electronic load-control units. The maximum cyclic gross-area-stress levels applied to the panels was 12 ksi, except for one 36-inch-wide panel in which a stress level of 8 ksi was applied. The ratio of minimum to maximum cyclic gross-area stresses R was 0.05, except for the 12-inch-wide transverse panels tested in distilled water and dry air and in which R was 0.67. The cycling frequency varied from 35 to 120 cpm, depending on the panel thickness and hydraulic machine utilized. All 36-inch-wide panels were buckling restrained by aluminum channel sections to prevent buckling in and out of the plane. Only the 0.16- and 0.25-inch-thick, 8- and 12-inch-wide panels were buckling restrained. No 8-inch-wide panels were restrained during fracture testing because of the small panel width. Figure 5 shows a sketch of the buckling restraints used for each panel width.

The dry-air environment with its relative humidity of less than 10 percent was maintained by passing bottled room air through a desiccating column and then into a plastic chamber mounted on the specimen around the crack area. The plastic chamber acted as an additional buckling restraint. Nitrogen gas from a liquid-nitrogen tank was used as a cooling media for -65° F testing. Like the dry-air environment, the nitrogen gas was passed into plastic chambers mounted onto the panel. Temperature control was maintained by monitoring thermocouples mounted on the panels.

The fatigue-crack lengths in the 36-inch-wide panels were measured to the nearest thousandths of an inch using a surveyor's transit and a steel scale mounted on the panel. The lengths of the fatigue cracks in the 12- and 8-inch-wide panels were measured with a calibrated 50-power microscope. Fatigue cycling was interrupted to record crack lengths, and the static mean load level was maintained on the panels.

During the accumulation of fatigue-crack-growth data, a maximum allowable rate of fatigue crack growth of approximately 500 microinches per cycle was imposed in the testing so that panel failure during fatigue cycling would not occur. If this rate level was reached prior to completion of the test, the maximum cyclic stress level was reduced in steps to maintain a rate less than 500 microinches per cycle.

Plane-strain and plane-stress fracture toughnesses were determined by static loading the panels to failure at a gross-area stress rate of 1000 psi/sec following fatigue-crack-growth testing. High-speed photography (1000 frames/sec) was used to detect fatigue crack pop-in and to measure slow crack growth for determining critical crack length. Also during fracture toughness testing, an accelerometer and a linearly varying differential transducer (LVDT) were used to aid in detecting fatigue crack pop-in. The accelerometer was taped to one corner of the specimen and the transducer was mounted across the crack to measure crack-opening displacement. Load-time trace, accelerometer noise trace, and transducer measurements were recorded simultaneously with high-response galvonometers in a time-based oscillograph. Testing for fracture toughness at -65° F did not use high-speed photography or transducers because of poor visability and the cold temperature of -65° F.

The crack growth of the baseline surface-flawed specimens was monitored with a 50-power microscope, and, when the surface crack had fully initiated in the periphery of the flaw, fatigue cycling was stopped and the panel was fracture-tested. A programmed gross-area stress rate of 1000 psi/sec was used. This test served as a baseline plane-strain critical-stress-intensity level, and the remaining four surface-flawed specimens were fatigue cycled to failure at selected, constant initial-stress-intensity levels. Crack growth measurements were taken with a 50-power microscope, and all fatigue cycling was conducted in dry air.

The finished, machined Charpy specimens were precracked by fatigue in a precracking machine to form a crack at the root of the machined notch. This machine applies simple beam-bending loads to the specimen through an eccentric at 1800 cpm and shuts off automatically as the deflection of the specimen increases with the initiation of a crack. Uniform cracks approximately 0.050 inch deep were grown by this method. Impact testing was then accomplished in an impact tester of 288 in.-lb capacity and at a hammer velocity of 11.4 fps. The energy required to fracture was measured in inch-pounds.

RESULTS AND DISCUSSION

The following paragraphs discuss the experimental results of the aging study and the fatigue-crack-propagation and fracture-toughness study.

Heat-Treatment Study

Transverse tensile properties were determined for each of four thicknesses (0.16, 0.25, 0.50, and 0.63 inch) for various aging times at 250 and 290° F. Table II lists the detailed transverse tensile properties for each of the specimens tested in the aging study. Aging times, temperature, ultimate strength, 0.2-percent offset yield strength, percent elongation in 1 inch, and percent reduction in area values are given.

Aging curves at 250 and 290° F are given in figures 6 and 7. It is apparent from each of these aging curves that each thickness of material differs slightly in its aging behavior at 250 and 290° F. The reason for this deviation may be due to the different quenching characteristics of the various panels or different processing techniques.

Based on the aging data presented above and a discussion with the contracting agency, the following heat treatments for the underaged, peak-age (T6), and overaged conditions were selected:

(1) Underaged— Use the as-received underaged condition of 4 hours at 250° F.

(2) Peak-age (T6) condition—Heat treat at 250° F for 48 hours (standard commercial practice).

(3) Overaged—Heat treat at 290° F for 56, 96, 120, and 90 hours for 0.16-, 0.25-, 0.50-, and 0.63-inch thicknesses, respectively.

Through-The-Thickness Fatigue-Crack-Growth Behavior

Through-the-thickness fatigue-crack-growth data for all center-cracked-panel tests conducted in this program are tabulated in table III. Presented in the table are specimen identification and laboratory raw data in the form of measured crack length and cycles and the crack lengths at which the maximum cyclic stress levels were changed. A coding system was used to identify the aged condition, thickness, and grain direction of each panel. In the panel number, U is underaged, P is peak age (T6), O is overaged, T is transverse grain, and L is longitudinal grain. In addition, the numbers 1, 2, 5, and 6 designate 0.16-, 0.25-, 0.50-, and 0.63-inch thicknesses, respectively. Plots of the fatigue-crack-growth data are presented in figures 8 through 11 in the form of fatigue crack length versus cycles and rate of fatigue crack growth versus maximum cyclic stress-intensity factor. To simplify the graphical presentation of the data, only crack length-cycles curves are presented and the straight-line plots of fatigue-crack-growth rate versus maximum-cyclic-stress-intensity factor are the results of the least-squares fit of a straight-line behavior through the calculated points from the raw data.

The following subsections are discussions of the results of the effects of heat treatment, thickness, test temperature, and panel width on fatigue-crack-growth behavior and a comparison of wet-air versus dry-air environments.

Effect of heat treatment.— The effect of heat treatment on fatigue-crack-growth behavior and rate of fatigue crack growth is shown in figures 8 through 11. Comparison of underaged, peak-age (T6), and overaged treatments of each thickness and for panel widths of 36, 12, and 8 inches are presented in figures 8 and 9. Figures 10 and 11 present data for further comparison of heat treatment.

In comparing the influence of the three aging treatments upon fatigue-crack-growth behavior and crack growth rates of the 7079 material tested in this program, no really consistent differences between overaging and underaging treatments were found. Generally, the peak-age (T6) condition tends to have somewhat faster crack growth or crack growth rates than either of the other two treatments. Looking at the crack-length-versus-cycles curves, it appears that figures 8 and 10 show some trend to favor underaging to obtain reduced crack-growth behavior. On the other hand, figures 8 and 10 show some data to indicate that overaging may require more cycles to develop a given crack length. With regard to the behavior of the crack growth rate, some of the curves for the overaged and underaged materials show diverging or converging K versus rate behavior over the test K-range. Other K-rate curves indicate overlapping likely due to scatter in the experimental data, whereas some curves show a reversal of rate severity over the range of data for the underaged and overaged conditions.

Effect of thickness. — The effect of panel thickness on the behavior of fatigue crack growth and rate of fatigue crack growth can be seen in figures 8 through 11. Curves of 0.16-, 0.25-, 0.50-, and 0.63-inch thicknesses of underaged, peak-age (T6), and overaged treatments and of panel widths of 36, 12, and 8 inches are presented.

Comparing the rate of fatigue crack growth for each thickness over the range of cyclic stress-intensity levels shows that the rates generally fall into two groups. The slowest fatigue-crack-growth rate is exhibited by the 0.16- and 0.25-inch-thick panels. The fastest rate is shown to occur in the 0.50- and 0.63-inch-thick panels.

In considering the modes of fracture, these results are what would be expected. The mode of failure for through-the-thickness cracks in thick gages is predominantly plane strain. A plane-strain condition around the tip of a crack is more damaging because of the high degree of triaxiality and, thus, should produce a faster fatigue-crack-growth rate in thicker gages.

Effect of panel width. — The effect of panel width on fatigue crack growth is shown in figures 8 and 9. Curves of 36-, 12-, and 8-inch-wide panels of each thickness and heat treatment are presented.

In comparing the rate of fatigue crack growth for the 36-, 12-, and 8-inch-wide panels, the 36-inch-wide panels generally showed the slowest rate of fatigue crack growth over the cyclic stress intensities tested. The 12- and 8-inch-wide-panel fatigue-crack-growth rates were essentially the same and faster than the 36-inch-wide-panel crack growth rates.

Effect of test temperature. — The effect of test temperature on fatigue-crack-growth behavior and rate is shown in figures 10 and 11. Curves of room temperature and data on -65° F tests of 12-inch-wide panels of each thickness and heat treatment are given.

These results show that the fatigue-crack-growth rate at -65° F is slower than that at room temperature for each thickness and heat-treatment condition.

Comparison of distilled-water and dry-air environments. — A comparison of fatigue-crack-growth behavior and rate in distilled-water and dry-air environments for underaged, peak-age (T6), and overaged treatments are shown in figures 10 and 11.

These comparative results for the transverse grain direction show the accelerating effect that distilled water has on fatigue-crack-growth rate over dry-air environment. The overaged material appears to have a lower crack growth rate than the underaged material. The peak-age (T6) material exhibits the fastest rate of all three conditions.

Through-the-Thickness Fracture Toughness

Plane-strain pop-in K_{Ic} and plane stress K_c results for 7079 underaged, peak-age (T6), and overaged conditions are given in table IV. In determining K_c for each test condition and at room temperature, slow-crack-growth measurements were taken with high-speed photography to establish the crack length at the onset of rapid crack growth (i.e. critical crack length). Data plots of gross area stress versus time before failure and of crack length versus time before failure as established from the oscillograph traces and motion picture results were developed. Typical examples of the slow-crack-growth measurements and the analysis are presented in figure 12.

There were two types of slow-crack-growth behavior. As the crack length increased with time, the velocity of crack growth was either constant or steadily increasing with time. The stress-time behavior was generally linear to failure. The critical crack length was established as the crack length at the onset of rapid crack growth and was determined by the nature of the slow-crack-growth curves. In the two examples given in figure 12, abrupt changes in crack velocity occurred at crack lengths of 3.30 and 5.25 inches and were, therefore, interpreted as the critical crack lengths. This procedure was used to establish the critical crack lengths from the slow-crack-growth curves.

Plane-strain pop-in K_{Ic}, plane stress K_c, and plastic-zone-corrected K_{Ic} and K_c values are given in table IV. Plane-strain, plane-stress, and plastic-zone-corrected fracture-toughness values are also given.

The effect of panel thickness on K_c and pop-in K_{Ic} is shown in figure 13. These data plots show that K_{Ic} and K_c decrease with an increase in panel thickness. An increase in panel thickness apparently changed the failure mode from predominately plane stress to predominately plane strain. In figure 13 it can be seen that the peak-age (T6) condition produced the lower levels of plane-strain and plane-stress critical stress intensities. The underaged condition produced the higher levels of K_{Ic} and K_c over the overaged condition.

In comparing the 12- by 36-inch-panel K_{Ic} and K_c test results, the transverse grain direction showed lower K_{Ic} and K_c values than the longitudinal-grain-direction values. A reduced temperature of -65° F produced lower K_{Ic} and K_c values when compared to K_{Ic} and K_c at room temperature.

The effect of panel width on measured K_c is shown in figure 14 for the underaged, peak-age (T6), and overaged conditions. The general trend of the data shows an increase in K_c with an increase in panel width. The largest increases are seen for the underaged and overaged conditions. A slight increase in K_c with an increase in panel width is seen in the peak condition. The largest K_c values measured in the program were 198.0 ksi $\sqrt{in.}$ and 170.4 ksi $\sqrt{in.}$ for 0.16-inch-thick underaged and overaged conditions.

Residual strength as measured by the ratio of gross-area-failure stress and ultimate strength shows the general trends as fracture toughness. These values are listed in table IV.

Figures 15, 16, and 17 are photographs of fracture surfaces of failed center-cracked panels. Some specimens, such as 6P-1T (figure 18), show beach marks produced by constant-amplitude loading. The light areas are regions of slow crack growth with surfaces having striations, whereas the dark areas are regions of fast crack growth exhibiting the rapid-tearing, dimple-like fracture surface found in the electron-microscope study of fatigue fracture surfaces. Specimen 6U-3L shows delamination or fissures that was demonstrated in some of the panels. However, the delamination was not consistent within a single plate of material (36 by 96 inches) or grain direction. Photomicrographs of the delamination as exhibited by specimen 2U-2L tested at -65° F is shown in figure 19. Figure 19 also shows a photomicrograph of the variation of microstructure for underaged 0.63-inch-thick material in contrast to a uniform microstructure for 0.25-inch-thick material. This variation in microstructure may be the cause of increased K_c for 0.63-in. thickness over 0.50-inch-thickness as shown in figure 13.

Surface-Flaw Crack-Growth Behavior and Fracture Toughness

Surface-flaw fatigue-crack-growth behaviors of underaged, peak-age (T6), and overaged 7079 0.63-inch-thick plate are shown in figure 20. The surface-flawed specimens were fatigue cycled at initial-stress-intensity levels K_{Ii} of 45, 50, 55, and 60 percent of K_{Ic}. Surface-flaw K_{Ic} values are given in table V. Figure 21 is a comparison plot of K_{Ii}/K_{Ic} versus number of load cycles to failure N_f.

These results show that overaged 7079 aluminum alloy produced the slowest surface-flaw crack growth rate and, thus, sustained the largest number of cycles. The peak-age (T6) condition sustained the lowest number of cycles and the underaged condition fell within peak and overaged conditions.

The K_{Ic} values for the three aged conditions showed essentially the same fracture toughness. Photographs showing the fracture surfaces of the failed surface-flaw specimens are shown in figure 22.

Verification Tensile Properties

The chemical analysis of each as-received panel thickness as determined by the manufacturer and Boeing is given in table VI.

Verification tensile properties as established by tensile testing of sheet and round tensile specimens are given in table VII for underaged, peak-age (T6), and overaged conditions. Additional verification tensile data for peak and overaged conditions are given in table VIII. The additional data are for tests of small tensile specimens. The specimens were heat treated with the 36-inch-wide panels. Tensile properties were determined for longitudinal and transverse grain directions at room temperature and for the longitudinal grain direction at -65° F.

Typical stress-strain curves to failure for 7079 underaged, peak-age (T6), and overaged conditions are shown in figures 23 through 26. These curves are the average of three verification tensile specimens tested to failure for each condition evaluated. Typical curves are presented for thicknesses of 0.16, 0.25, 0.50, and 0.63 inch of each of the three aged conditions for longitudinal and transverse grain directions at room temperature and for the longitudinal grain direction at -65° F.

Table IX shows a comparison of the verification transverse-tensile-yield strength and the estimated range of yield strength from the aging curves. The ranges are transverse yield strengths that are 12.5 ± 2.5 percent below peak transverse yield strengths as established from the aging curves generated for each thickness of material. These results show a good comparison of verified tensile properties and estimated values desired, except the 0.16-inch-thick underaged and the 0.16-inch-thick overaged materials, which were high and a little out of the range of desired values. However, the 0.16-inch-thick underaged and overaged materials were of essentially the same transverse yield strengths.

Precracked Charpy Toughness

The precracked Charpy impact toughness W_Q/A_O for each thickness and transverse and longitudinal grain directions for underaged, peak-age (T6), and overaged treatments are given in table X.

The trend of these results shows that the underaged aging treatment produced the highest toughness and the peak-age (T6) treatment produced the lowest toughness. Overaged toughness fell between the underaged and peak-age (T6) toughness levels. Transverse Charpy impact-toughness values were lower than the longitudinal values.

CONCLUSIONS

Based on the fatigue-crack-propagation and fracture-toughness data generated in this investigation, the following conclusions are made:

(1) The heat treatments selected for the underaged, peak-age (T6), and overaged conditions of 7079 aluminum alloy were selected as: (a) underaged—used the as-received underaged condition of 4 hours at 250° F; (b) peak-age (T6)—heat treated according to standard commercial practice of 250° F for 48 hours; and (c) overaged—heat treated at 290° F for 56, 96, 120, and 90 hours for thicknesses of 0.16, 0.25, 0.50, and 0.63 inch, respectively.

(2) Comparison of the through-the-thickness fatigue-crack-growth rate of underaged, peak-age (T6), and overaged 7079 aluminum alloys showed that there is no really consistent differences between underaging and overaging conditions. However, the peak-age (T6) condition generally exhibited the fastest fatigue-crack-growth rates than the other two treatments.

(3) Comparison of the through-the-thickness fatigue-crack-growth rate of center-cracked panels with thicknesses of 0.16, 0.25, 0.50, and 0.63 inch in the three aging conditions evaluated showed a thickness effect on fatigue-crack-growth rate; the slowest fatigue-crack-growth rate was exhibited by the 0.16- and 0.25-inch-thick panels and the fastest rate of fatigue crack growth occurred in the 0.50- and 0.63-inch-thick panels.

(4) A panel-width effect on the through-the-thickness fatigue-crack-growth rate was found in testing center-cracked panel widths of 8, 12, and 36 inches of the three aged conditions. The 8- and 12-inch-wide panel fatigue-crack-growth rates were essentially the same and faster than the 36-inch-wide-panel crack growth rates.

(5) The fatigue-crack-growth rate at -65° F was slower than that at room temperature for each thickness and aging condition.

(6) A comparison of rate of fatigue crack growth in distilled-water and dry-air environments for underaged, peak-age (T6), and overaged materials showed an acceleration in fatigue-crack-growth rate in distilled water over the dry-air rate for the transverse grain direction. The overaged material exhibited the slowest fatigue-crack-growth rate in distilled water.

(7) Through-the-thickness fracture-toughness test results showed that underaged 7079 aluminum alloy produced the highest levels of K_{Ic} and K_c over peak-age (T6) and overaged conditions. Also, peak-age (T6) produced the lowest levels of K_{Ic} and K_c.

(8) An increase in panel thickness showed a decrease in K_{Ic} and K_c levels for each of the three aging conditions, and an increase in center-cracked-panel width produced an increase in K_c. A reduced temperature of -65° F produced lower K_{Ic} and K_c values when compared to room temperature.

(9) Surface-flaw fatigue-crack-growth behavior measured as K_{Ii}/K_{Ic} versus loading-cycle-to-failure showed overaged 7079 aluminum alloy to have the slowest rate of growth and peak-age (T6) 7079 aluminium alloy to have the fastest rate of growth. Surface-flaw K_{Ic} test results showed all three treatments to have essentially the same K_{Ic} values.

(10) The verification-tensile-test results showed that heat treatment was verified, except for the 0.16-inch-thick underaged and the 0.16-inch-thick overaged 7079 aluminum alloys, which were on the high side of the desired tensile-strength range.

(11) The precracked Charpy impact-toughness tests showed that underaged 7079 aluminum alloy produced the highest toughness and peak-age (T6) 7079 aluminum alloy produced the lowest toughness. Longitudinal Charpy impact toughness was higher than transverse toughness.

Commercial Airplane Division
The Boeing Company
Renton, Washington, September 15, 1967

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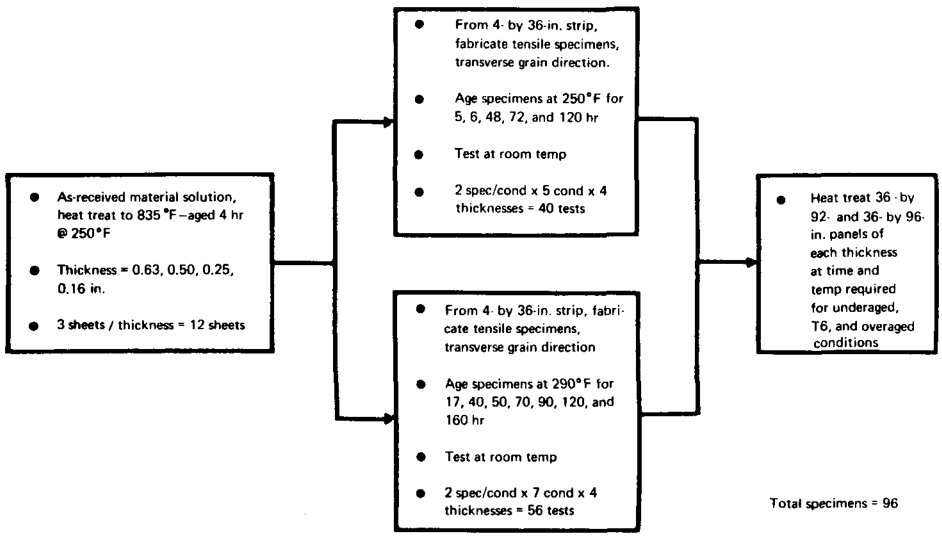
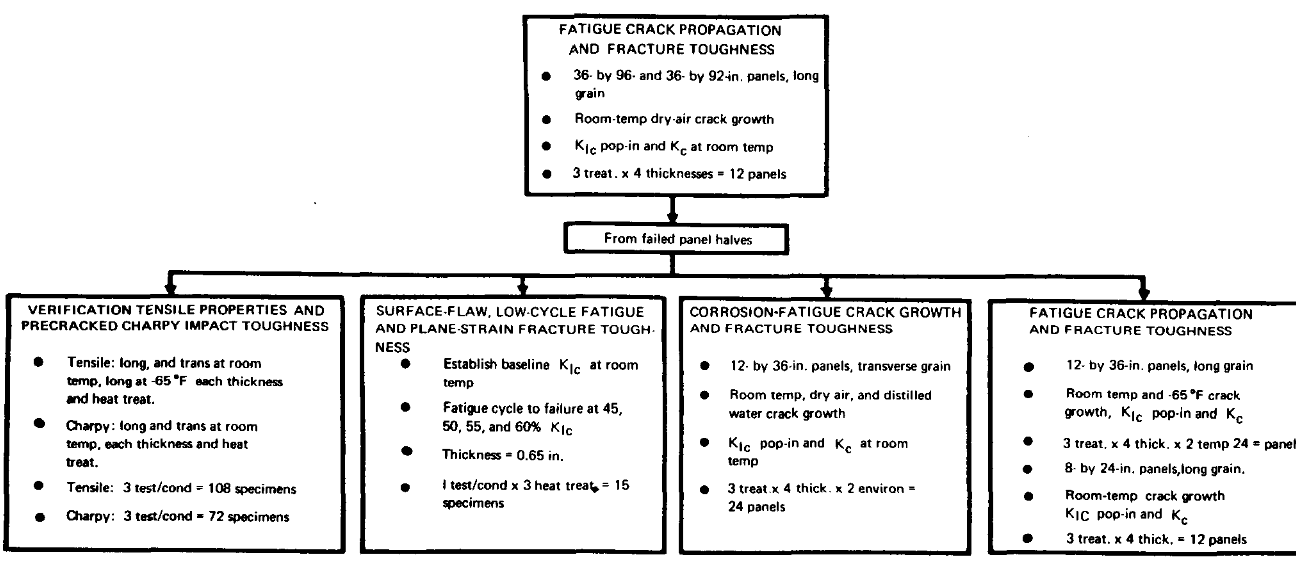
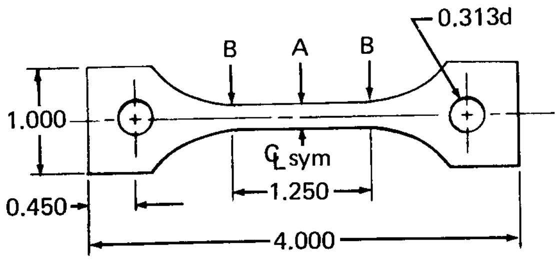


(a) AGING AND HEAT-TREATMENT STUDY



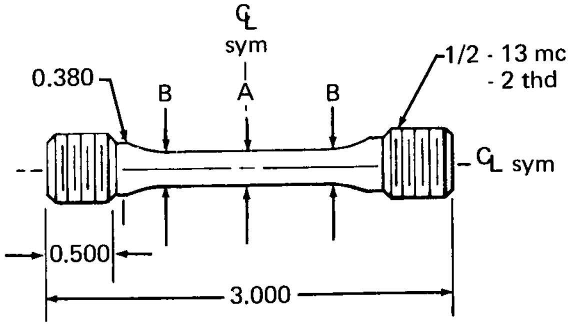
(b) FATIGUE-CRACK-PROPAGATION AND FRACTURE-TOUGHNESS STUDY

FIGURE 1.–FLOW CHARTS OF EXPERIMENTAL PROGRAM AND SPECIMENS



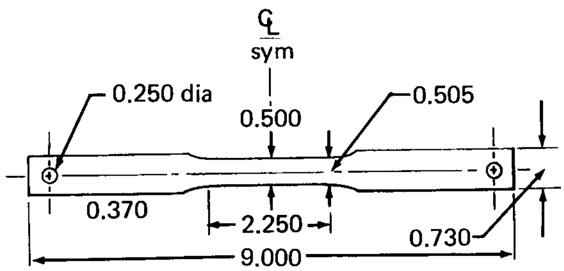
A = 0.248 TO 0.252
B = A + 0.003 TO 0.005

(a) AGING SHEET TENSILE SPECIMEN

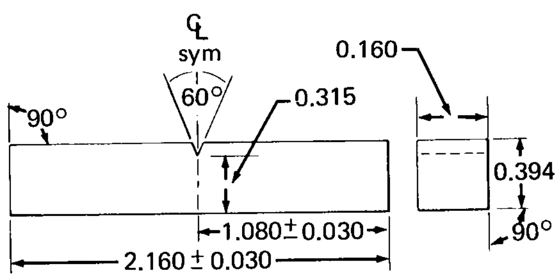


A = 0.247 TO 0.250
B = A + 0.003 TO 0.005

(b) ROUND TENSILE SPECIMEN



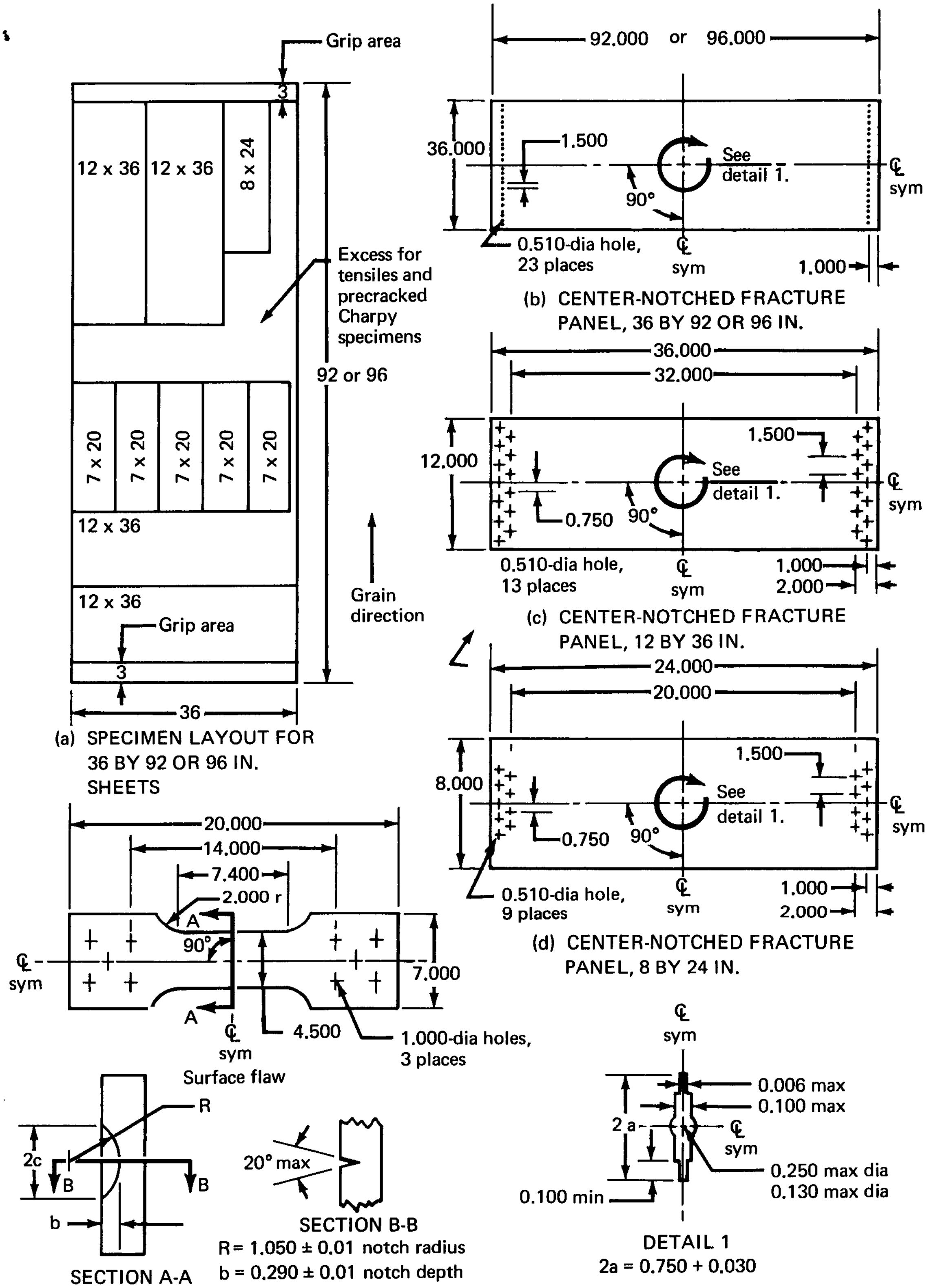
(c) LARGE SHEET TENSILE SPECIMEN



(d) CHARPY IMPACT SPECIMEN

Note: All dimensions in inches

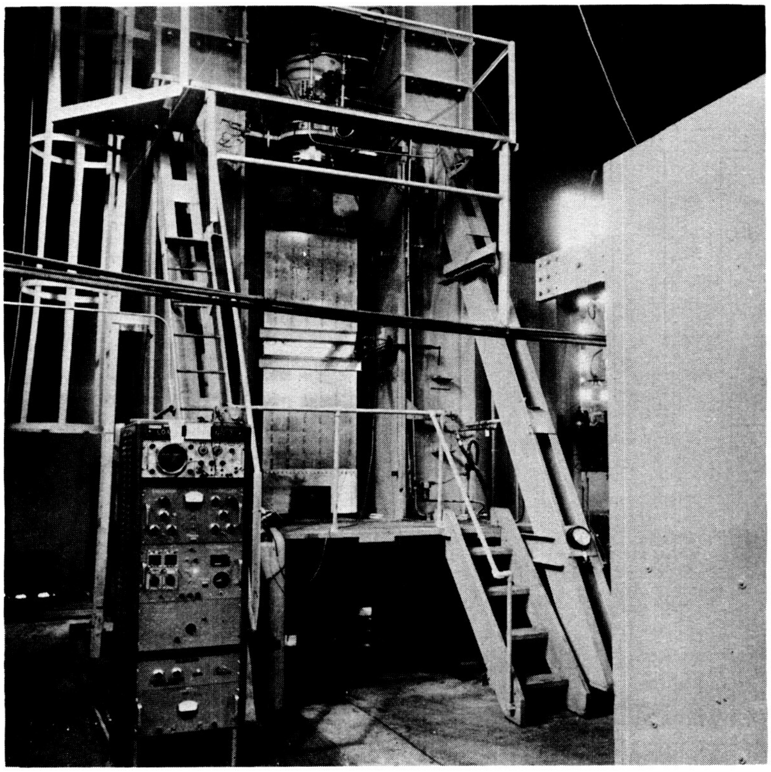
FIGURE 2.–CONFIGURATIONS OF TENSILE AND CHARPY IMPACT SPECIMENS



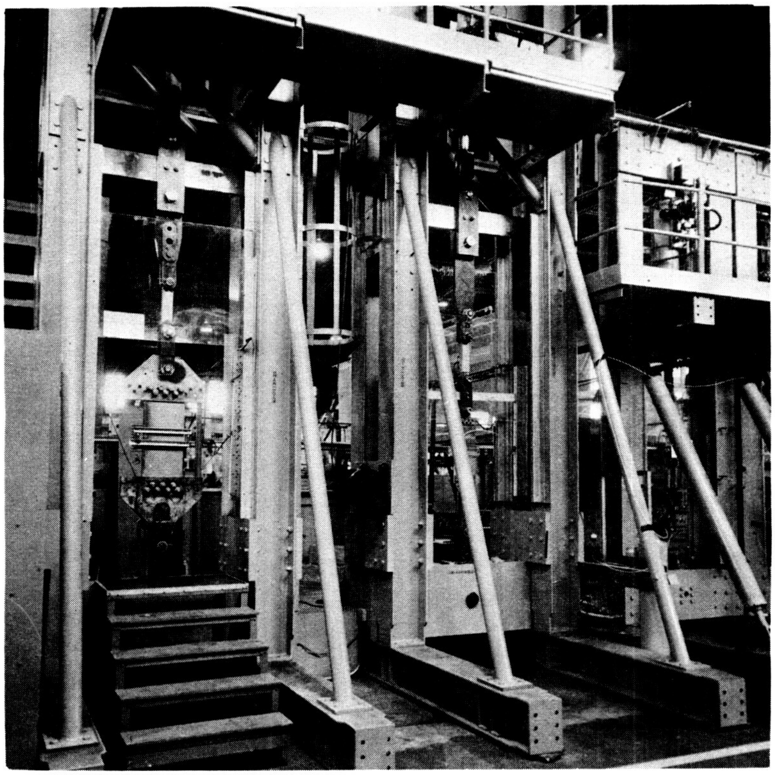
(e) SURFACE-NOTCHED FRACTURE PANEL

NOTE: All dimension in inches

FIGURE 3.—SPECIMEN LAYOUT, AND CENTER-NOTCHED AND SURFACE-FLAWED SPECIMEN CONFIGURATIONS

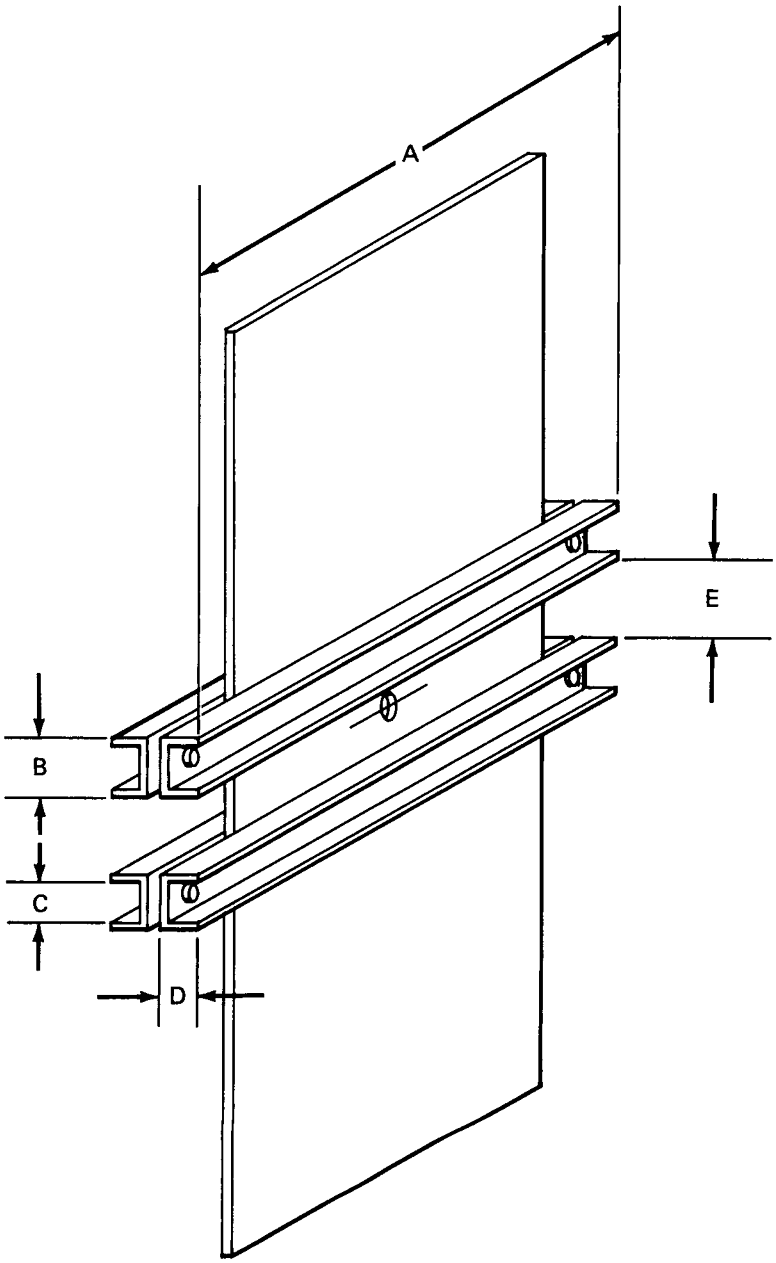


(a) 1000-KIP MACHINE



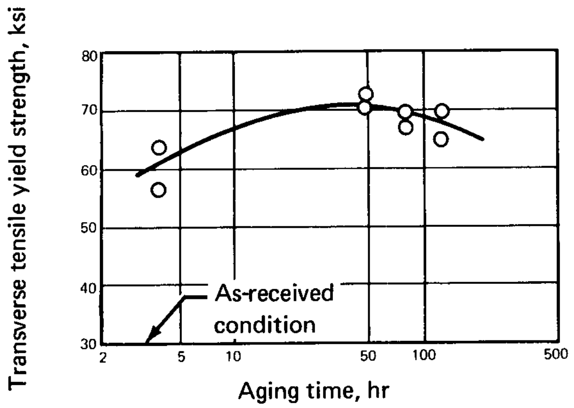
(b) 180-, 250- AND 300-KIP MACHINES

FIGURE 4.—HYDRAULIC LOAD MACHINES

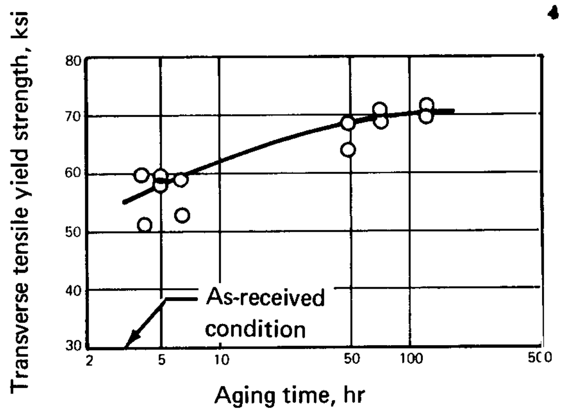


Panel width, in.	A	B	C	D	E
8	10.0	1.5	1.12	1.120	2
12	17.0	1.5	1.12	1.120	2
36	39.5	4.0	3.50	1.647	2

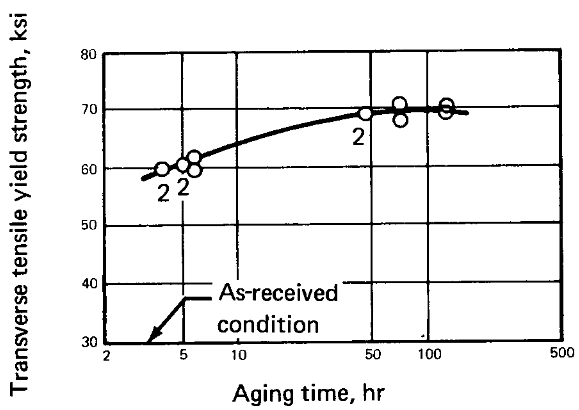
FIGURE 5.—SCHEMATIC DIAGRAM OF ALUMINUM-CHANNEL BUCKLING RESTRAINTS, TYPICAL INSTALLATION



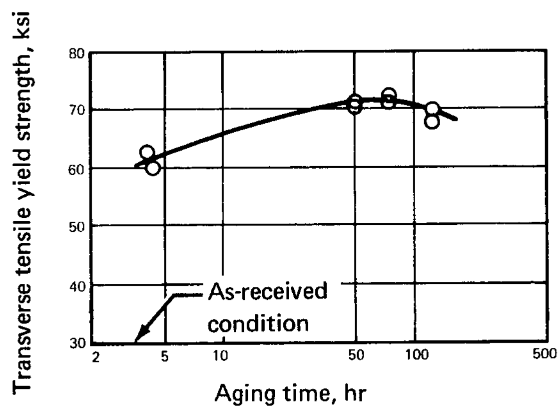
(a) t = 0.16 IN.



(b) t = 0.25 IN.



(c) t = 0.50 IN.



(d) t = 0.63 IN.

FIGURE 6.–AGING CURVES FOR 7079 ALUMINUM ALLOY FOR AGING TEMPERATURE OF 250° F

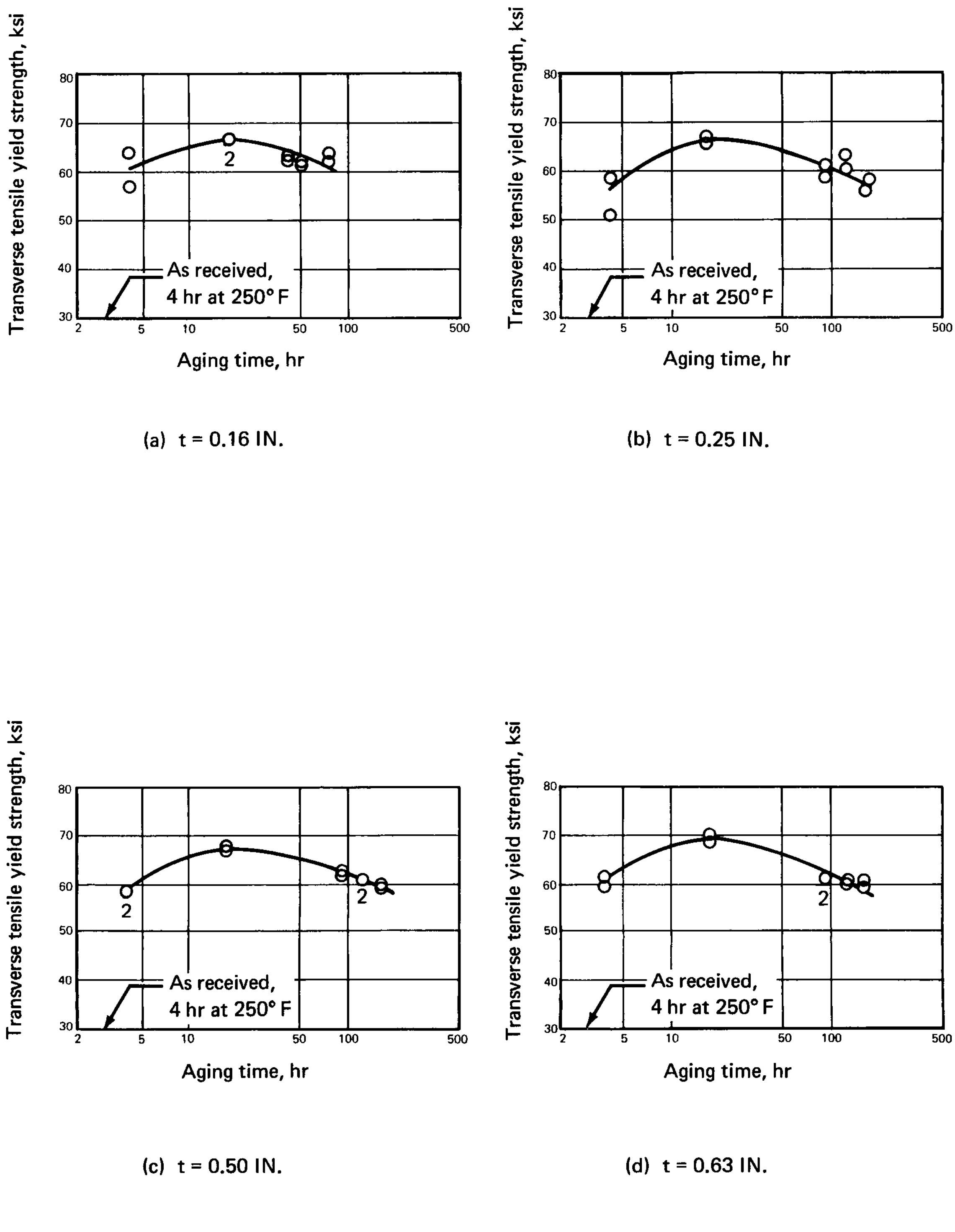


FIGURE 7.–AGING CURVES FOR 7079 ALUMINUM ALLOY FOR AGING TEMPERATURE OF 290° F.

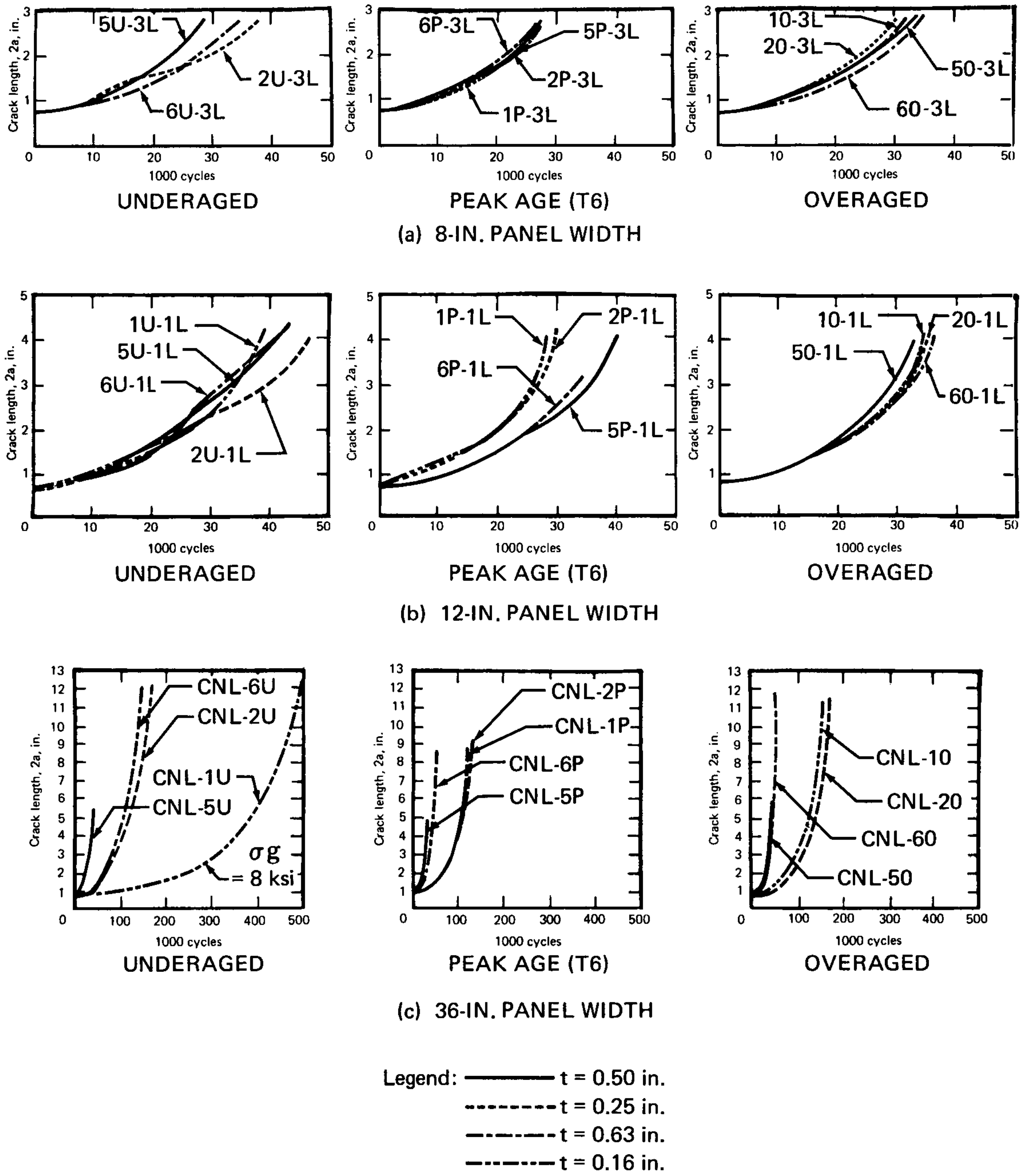
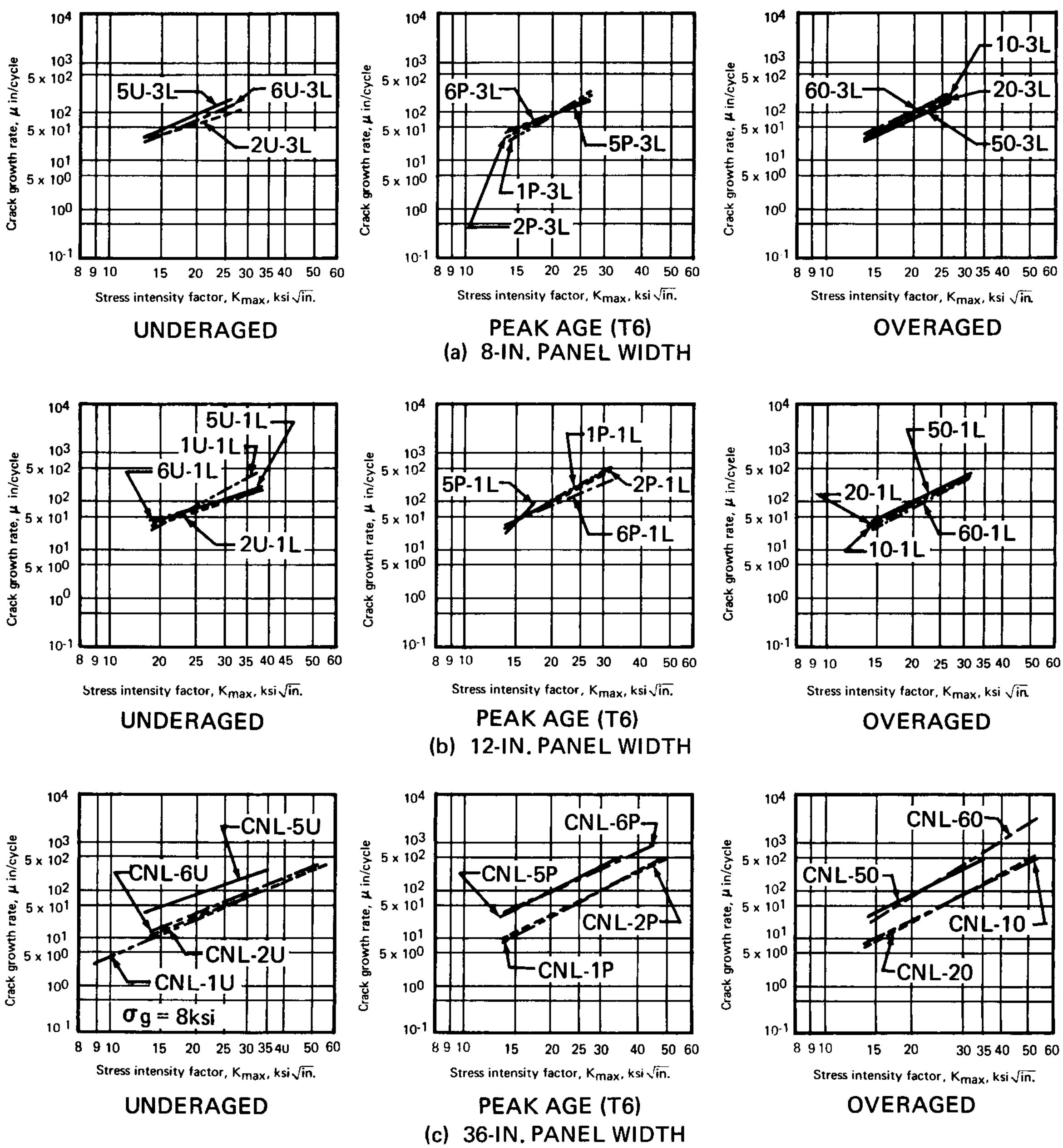


FIGURE 8.—FATIGUE-CRACK-PROPAGATION CURVES, LONGITUDINAL GRAIN, ROOM-TEMPERATURE, DRY AIR, σ_g = 12 KSI (EXCEPT AS NOTED), R = 0.05, f = 35 TO 120 CPM



Legend —— t = 0.50 IN.
---- t = 0.25 IN.
—-— t = 0.63 IN.
—--— t = 0.16 IN.

FIGURE 9.—RATE OF FATIGUE CRACK GROWTH VERSUS STRESS INTENSITY, LONGITUDINAL GRAIN, ROOM TEMPERATURE, DRY AIR, σ_g = 12 KSI (EXCEPT AS NOTED), R = 0.05, f = 35 TO 120 CPM

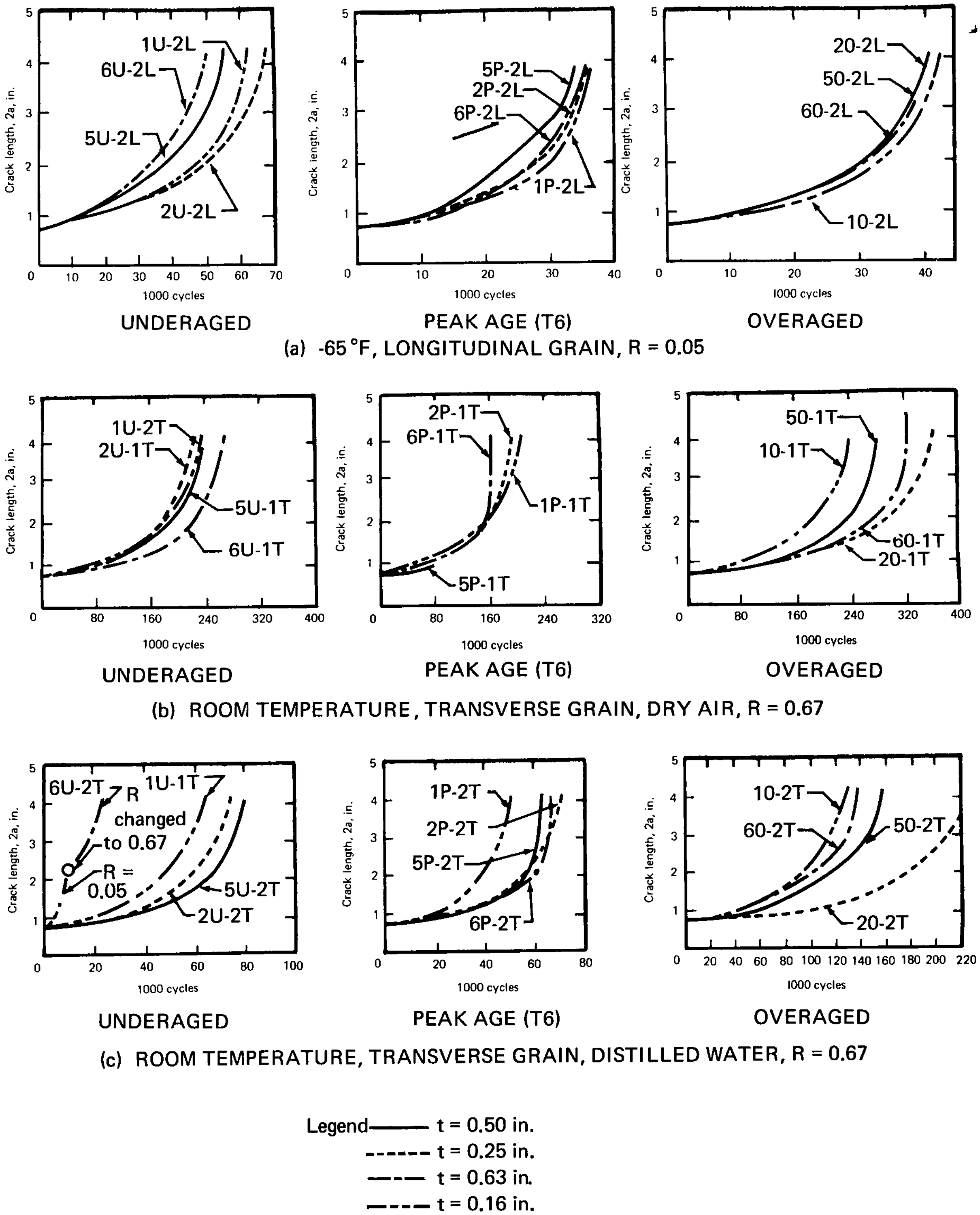


FIGURE 10.—FATIGUE-CRACK-PROPAGATION CURVES, 12-IN. PANEL WIDTH, σ_g = 12 KSI, f = 120 CPM

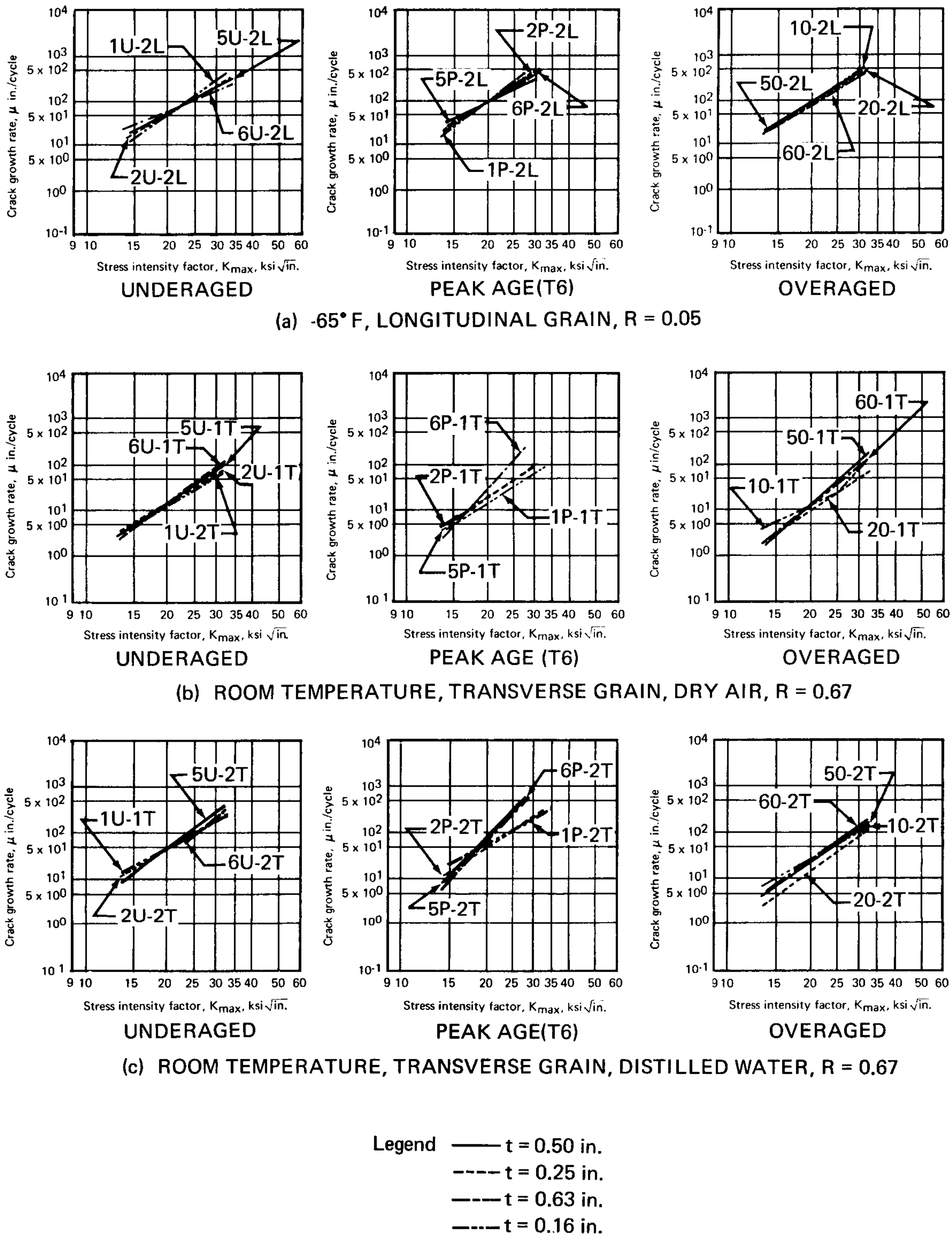
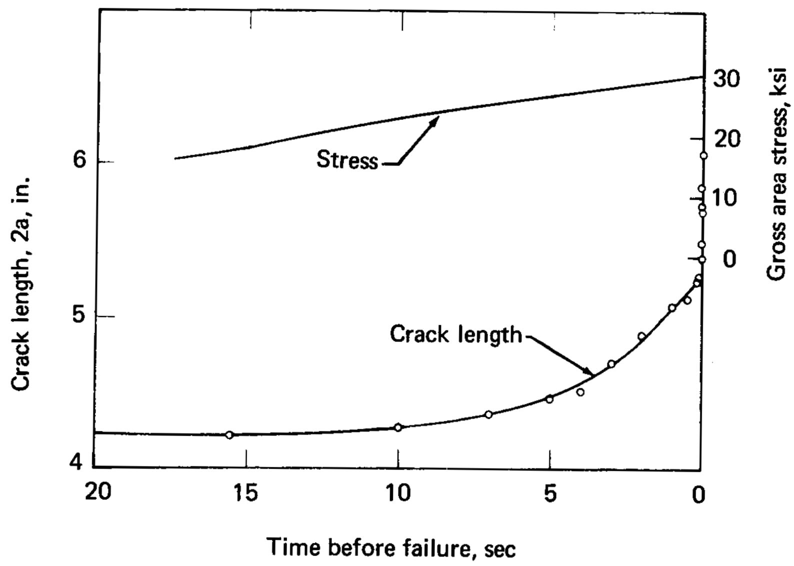
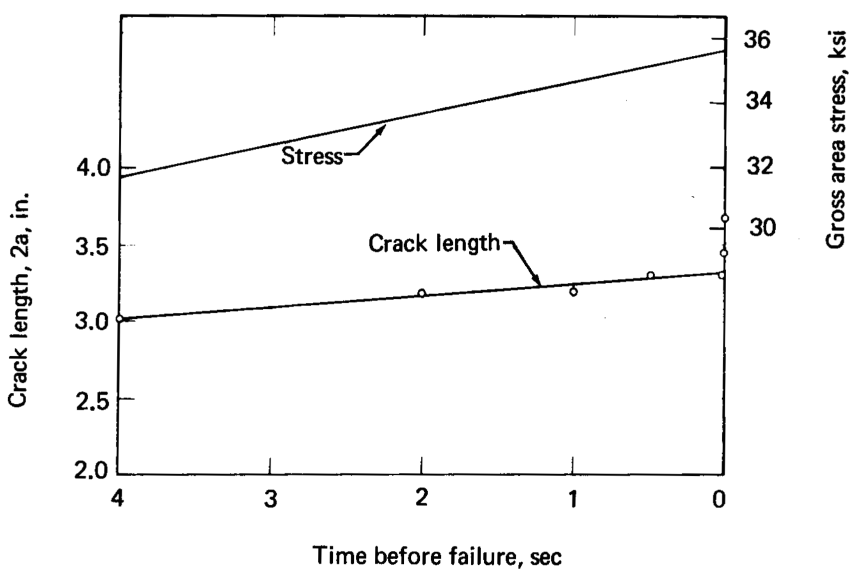


FIGURE 11.—RATE OF FATIGUE CRACK GROWTH VERSUS STRESS INTENSITY, 12-IN. PANEL WIDTH, σ_g = 12 KSI, f = 120 CPM



(a) SPECIMEN 1U-1T, $2a_{cr}$ = 5.25 IN.



(b) SPECIMEN 10-3L, $2a_{cr}$ = 3.30 IN.

FIGURE 12.—TYPICAL SLOW-CRACK-GROWTH MEASUREMENTS

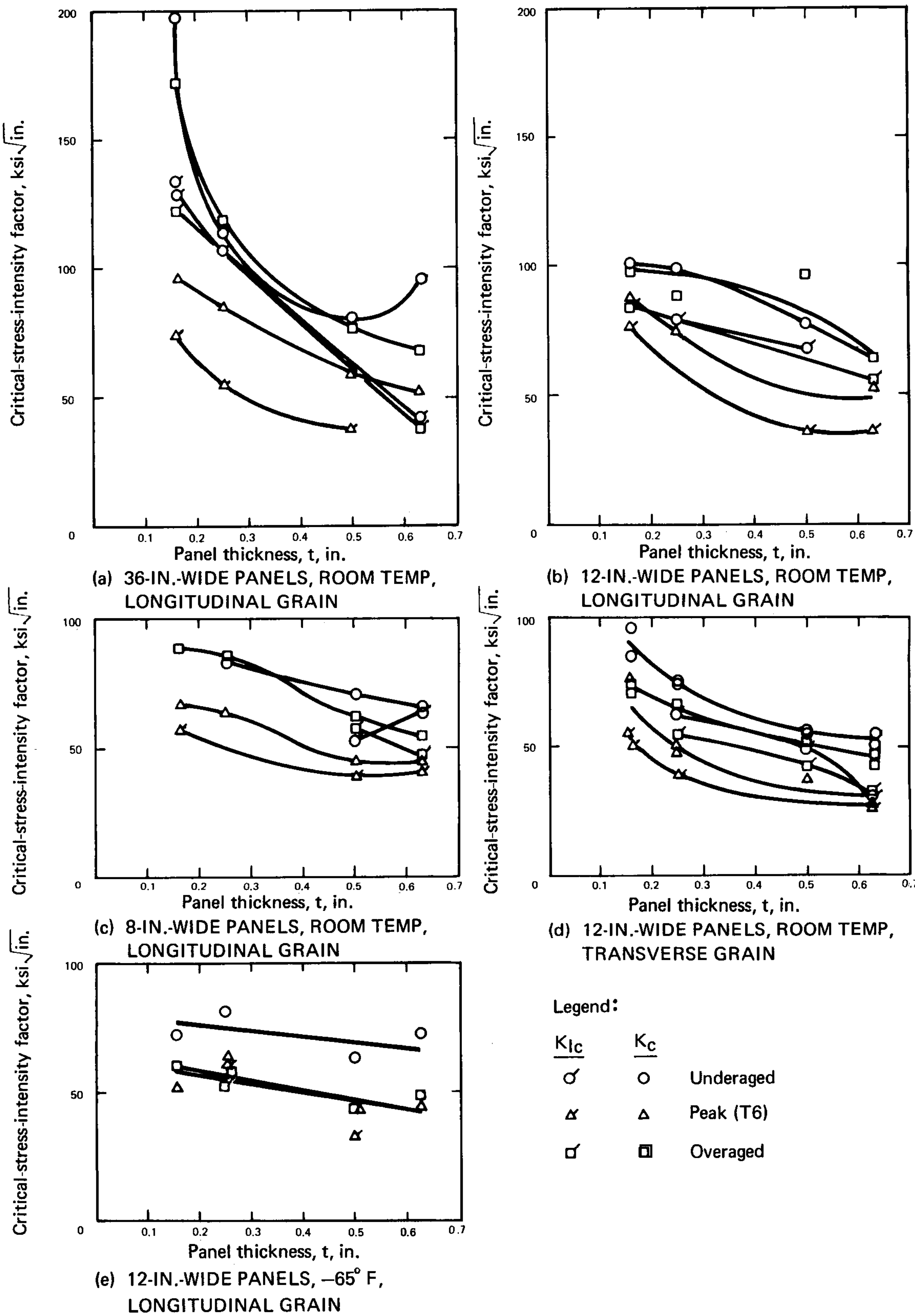


FIGURE 13.—EFFECT OF THICKNESS ON POP-IN K_{Ic} AND K_c

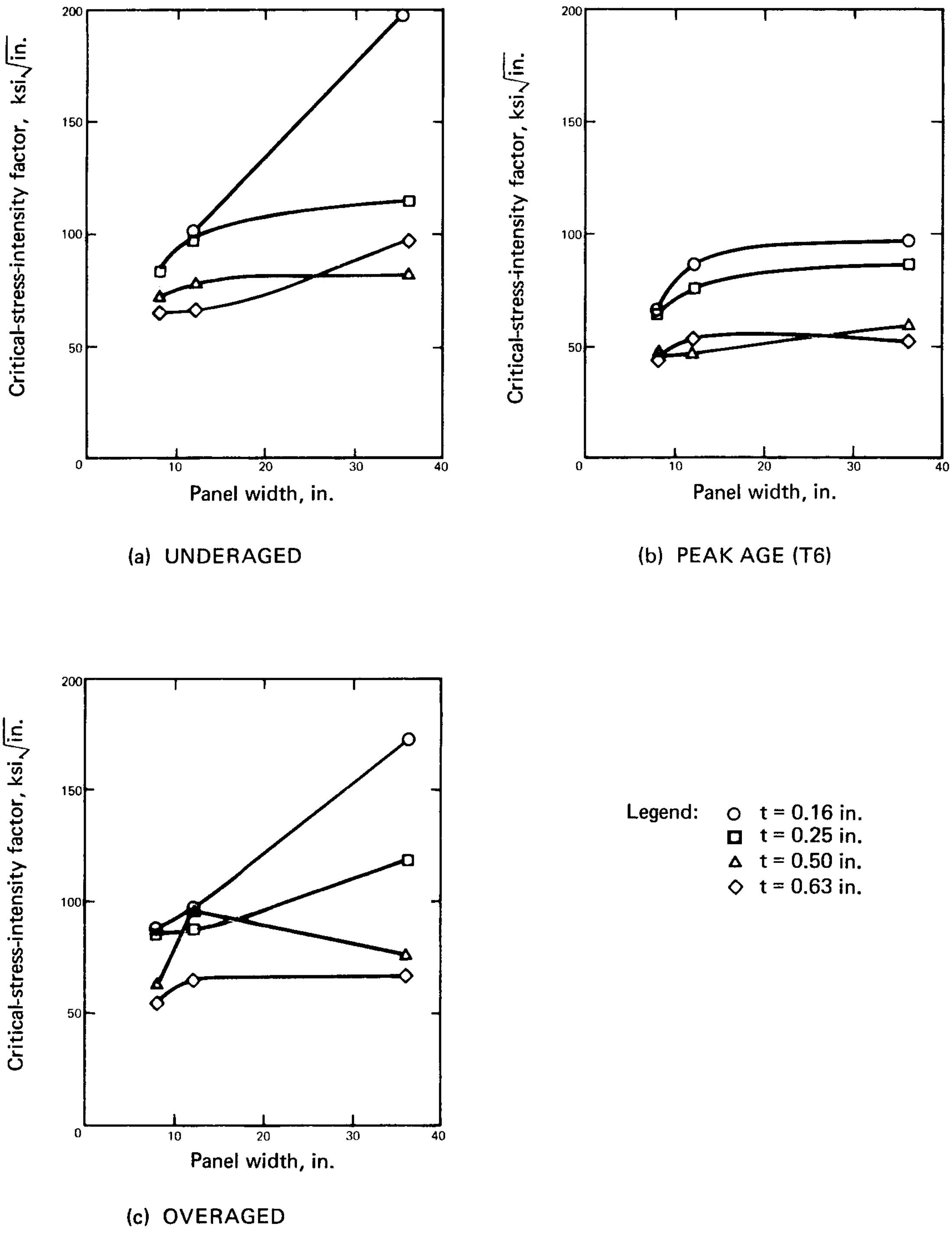
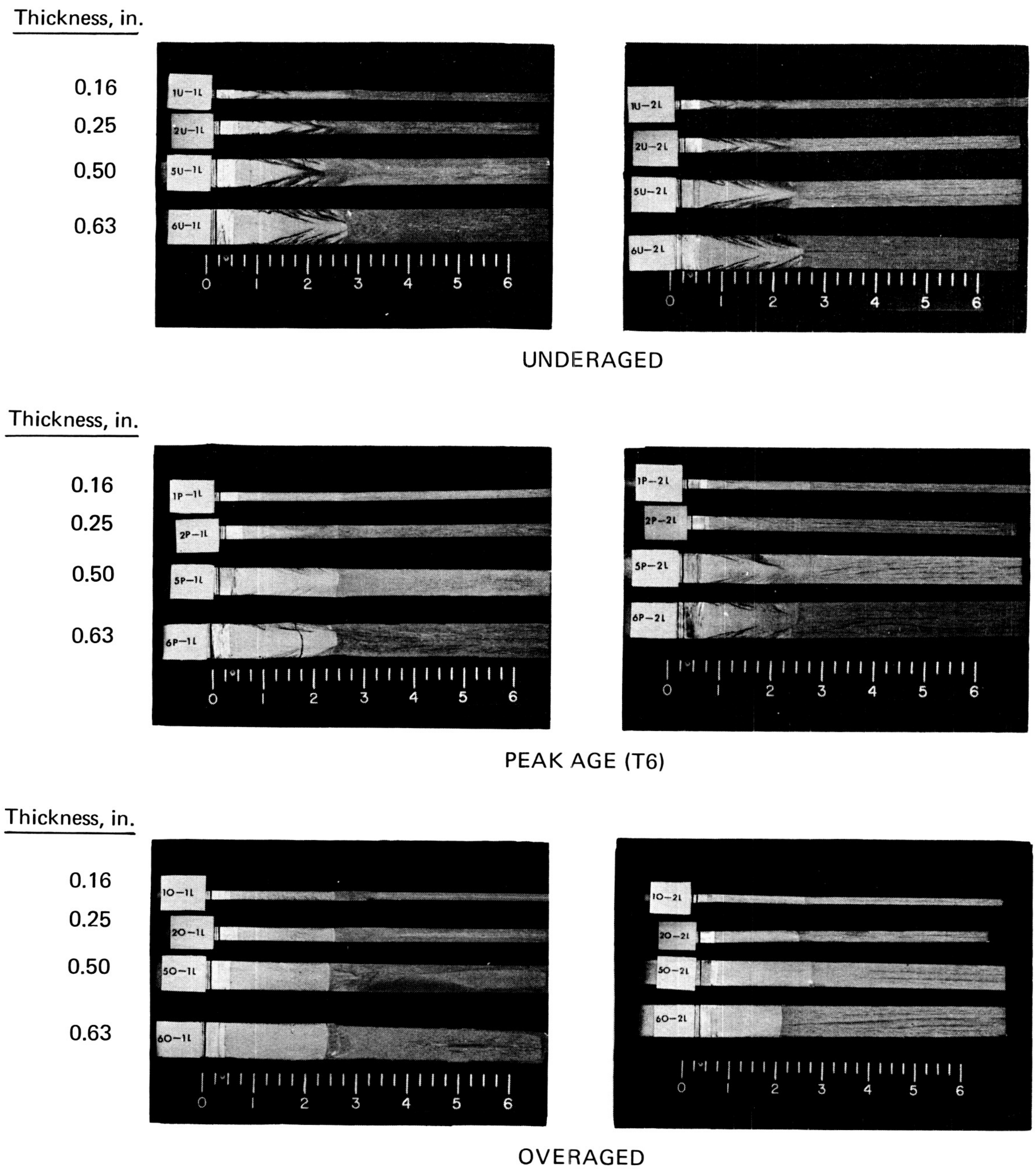


FIGURE 14.—EFFECT OF CENTER-CRACKED-PANEL WIDTH ON K_c

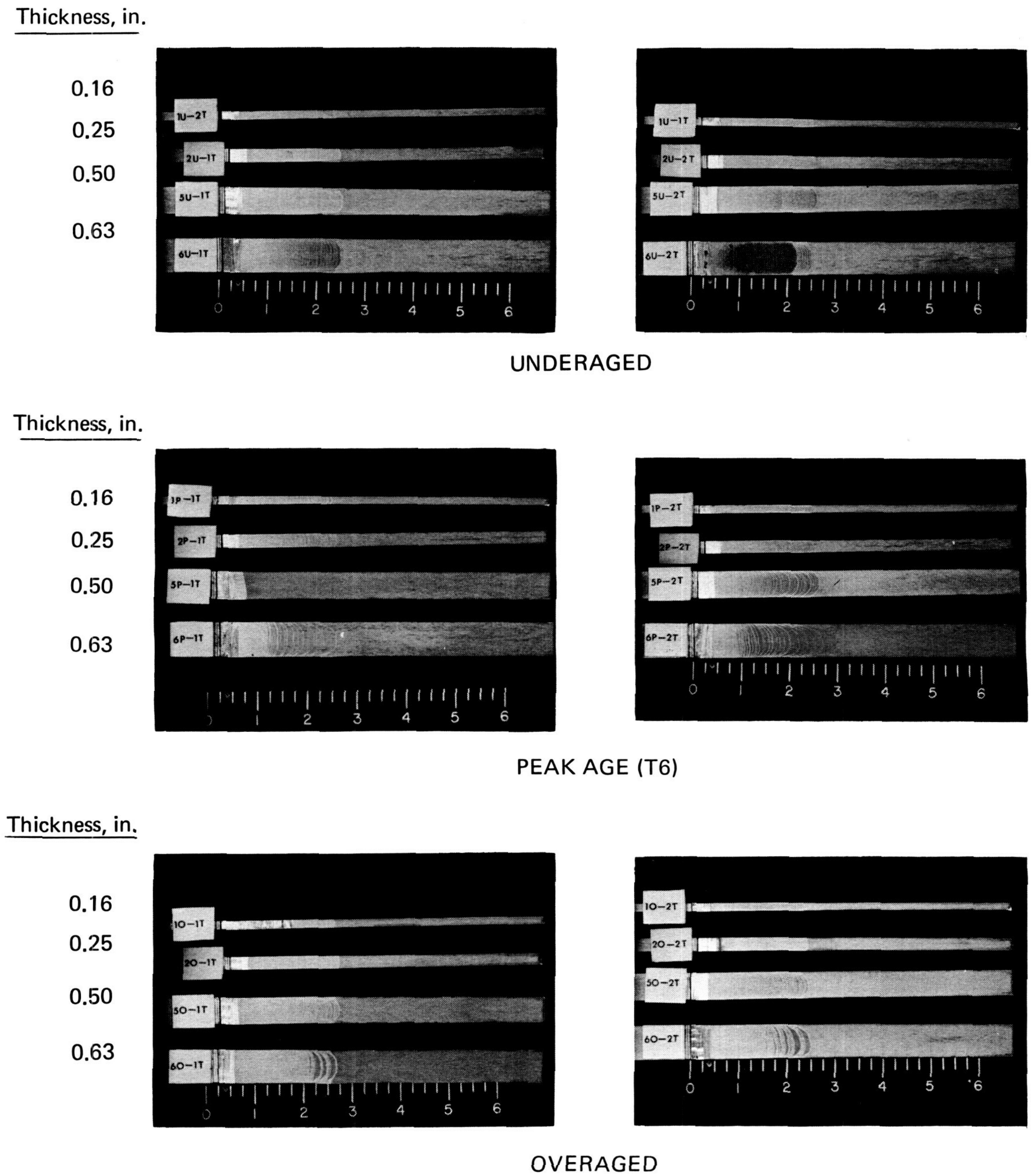


(a) LONGITUDINAL GRAIN, ROOM TEMPERATURE, DRY AIR

(b) LONGITUDINAL GRAIN, –65°F, LIQUID NITROGEN

Notes: 1. Length in inches
2. One-half of surface shown

FIGURE 15.–FRACTURE SURFACES OF FAILED 12-INCH-WIDE CENTER-CRACKED PANELS TESTED AT –65°F AND ROOM TEMPERATURE



(a) TRANSVERSE GRAIN, ROOM TEMPERATURE, DISTILLED WATER

(b) TRANSVERSE GRAIN, ROOM TEMPERATURE, DRY AIR

Notes: 1. Length in inches.
2. One-half of surface shown

FIGURE 16.—FRACTURE SURFACES OF FAILED 12-INCH-WIDE CENTER-CRACKED PANELS TESTED IN DRY AIR AND DISTILLED WATER

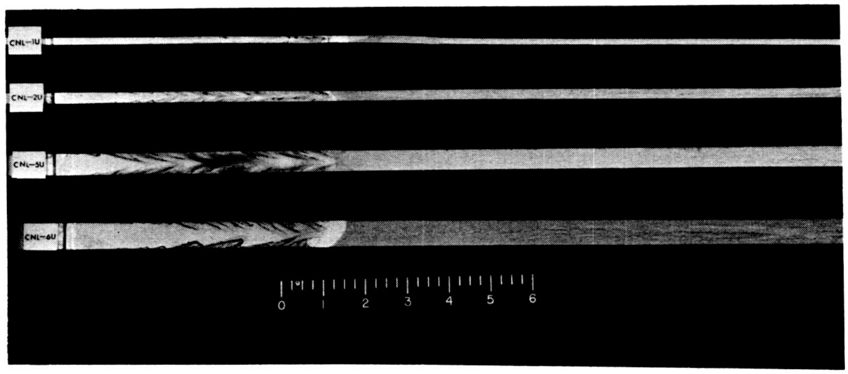
Thickness, in.

0.16

0.25

0.50

0.63



UNDERAGED

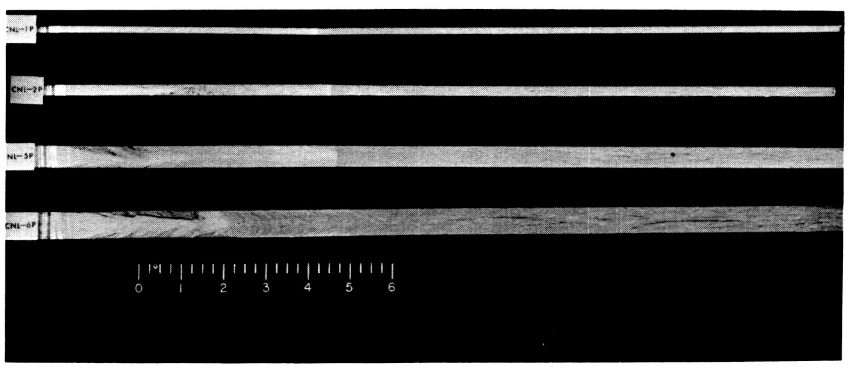
Thickness, in.

0.16

0.25

0.50

0.63



PEAK AGE (T6)

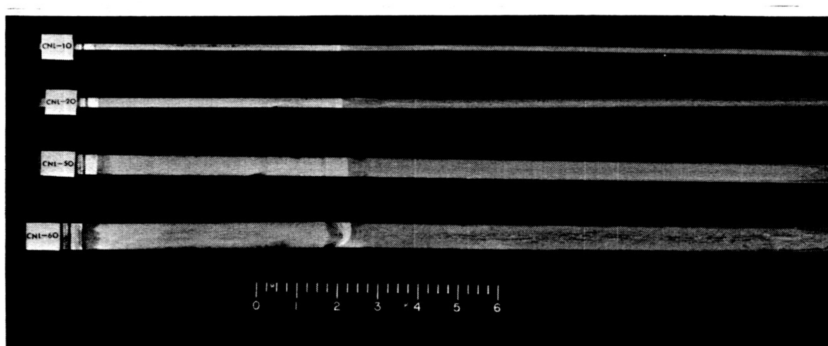
Thickness, in.

0.16

0.25

0.50

0.63

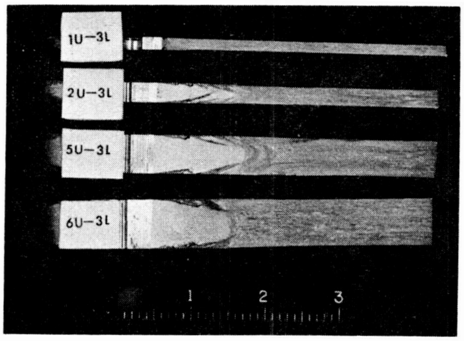


OVERAGED

FIGURE 17.—FRACTURE SURFACES OF FAILED 36-INCH-WIDE CENTER-CRACKED PANELS TESTED, LONGITUDINAL GRAIN, ROOM TEMPERATURE, DRY AIR

Thickness, in.

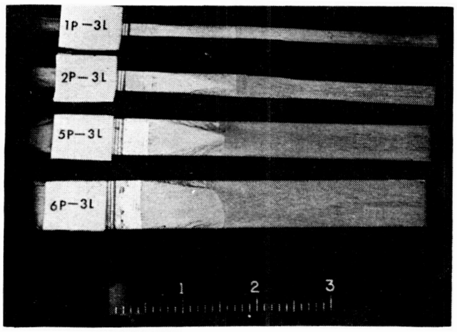
0.16
0.25
0.50
0.63



UNDERAGED

Thickness, in.

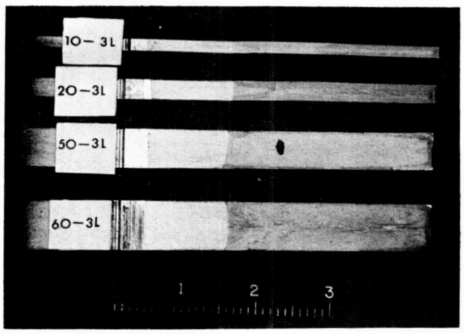
0.16
0.25
0.50
0.63



PEAK AGE (T6)

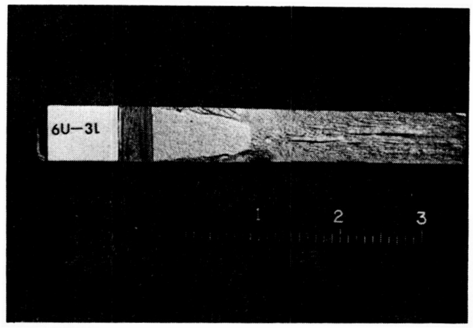
Thickness, in.

0.16
0.25
0.50
0.63

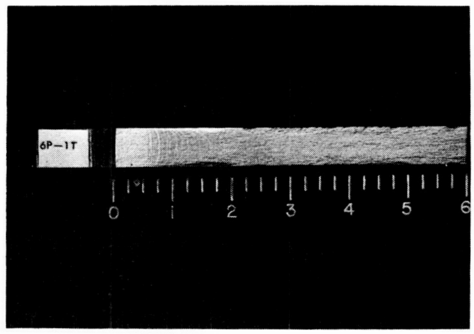


OVERAGED

(a) LONGITUDINAL GRAIN, ROOM TEMPERATURE, DRY AIR



(b) DELAMINATION APPEARANCE

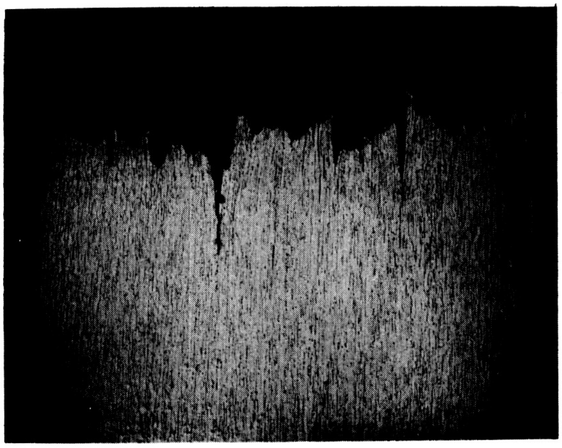


Peak age (T6), 0.63 in. thick, transverse grain

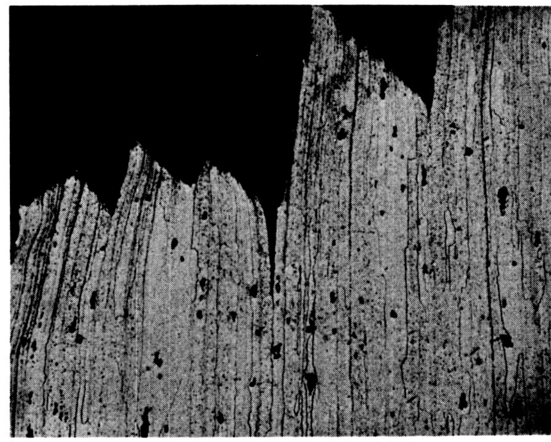
(c) BEACH MARKS, CONSTANT-AMPLITUDE LOADING (12 IN. WIDE)

Notes: 1. Length in inches
2. One-half of surface shown

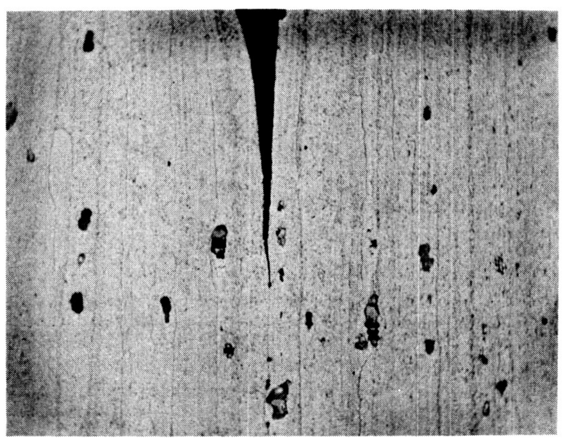
FIGURE 18.—FRACTURE SURFACES OF FAILED 8-IN.-WIDE CENTER-CRACKED PANELS AND ONE 12-IN.-WIDE PANEL TESTED



MAGNIFICATION: 16.5X

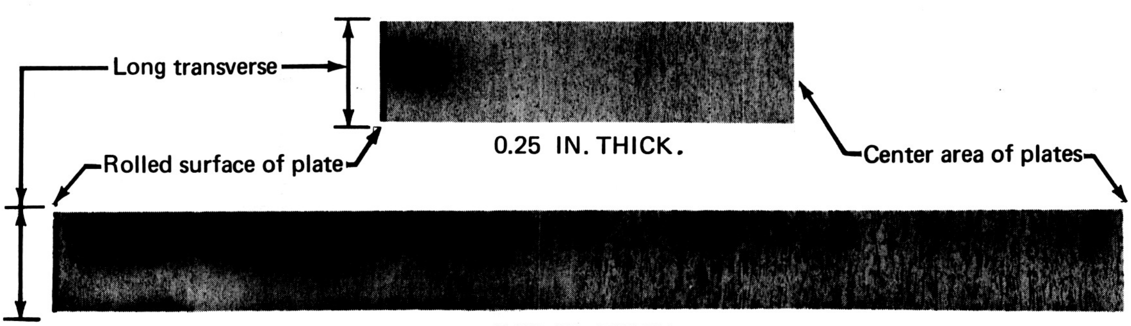


MAGNIFICATION: 200X



MAGNIFICATION: 500X

(a) DELAMINATION



(b) VARIATION OF MICROSTRUCTURE

FIGURE 19.—DELAMINATION AND VARIATION OF MICROSTRUCTURE

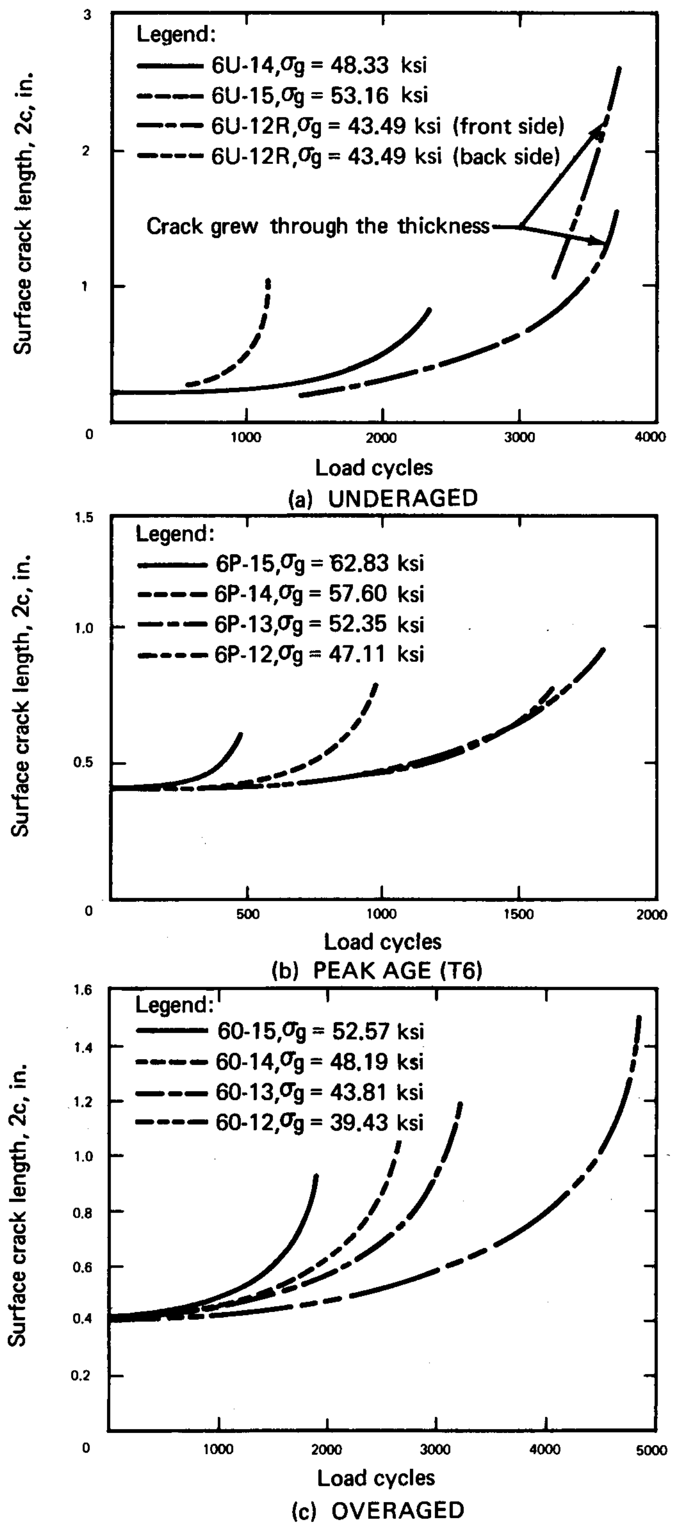


FIGURE 20.–SURFACE-FLAW FATIGUE-CRACK-GROWTH CURVES FOR 0.63-IN.-THICK 7079 ALUMINUM ALLOY, LONGITUDINAL LOADING DIRECTION, DRY AIR, f = 60 TO 120 CPM

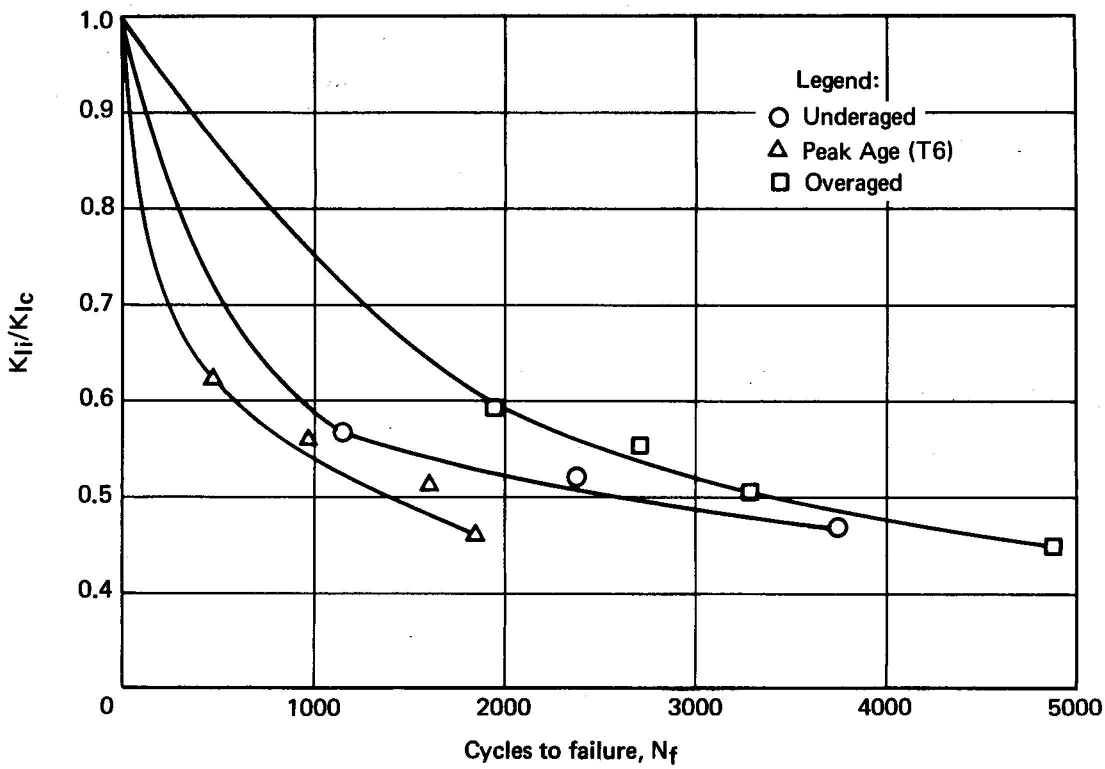
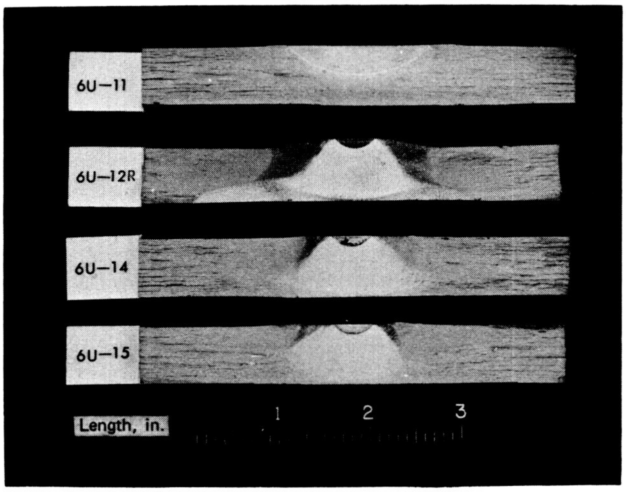
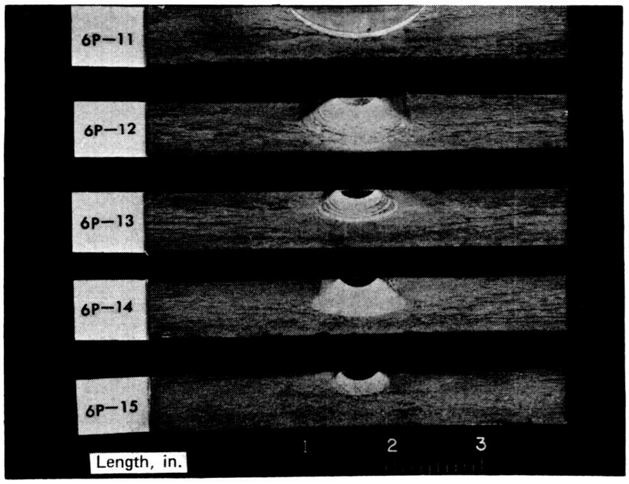


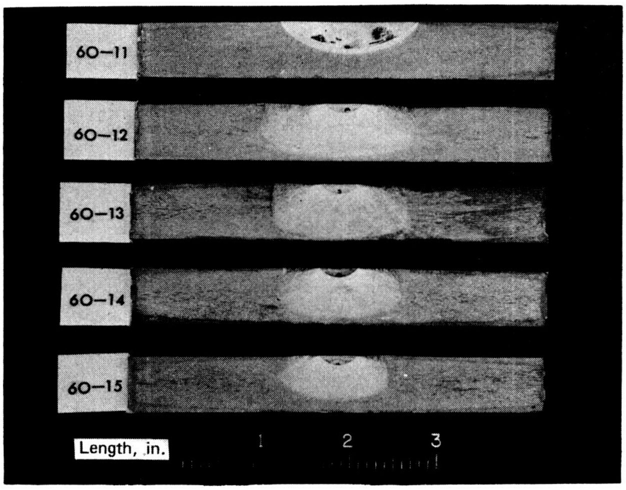
FIGURE 21.—COMPARISON OF K_{Ii}/K_{Ic} VERSUS FATIGUE CYCLES TO FAILURE FOR 0.63-IN.-THICK 7079 UNDERAGED, PEAK-AGE (T6), AND OVERAGED MATERIALS



(a) UNDERAGED



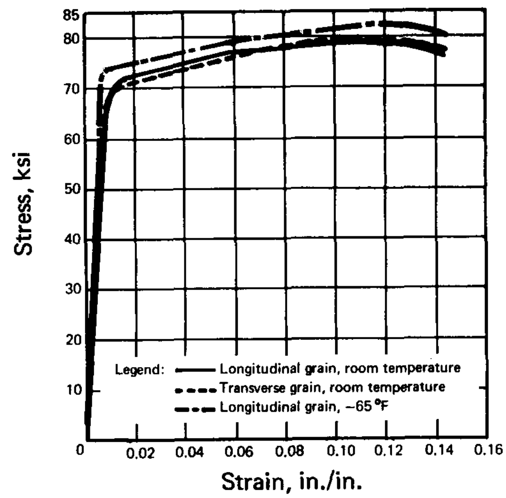
(b) PEAK AGE (T6)



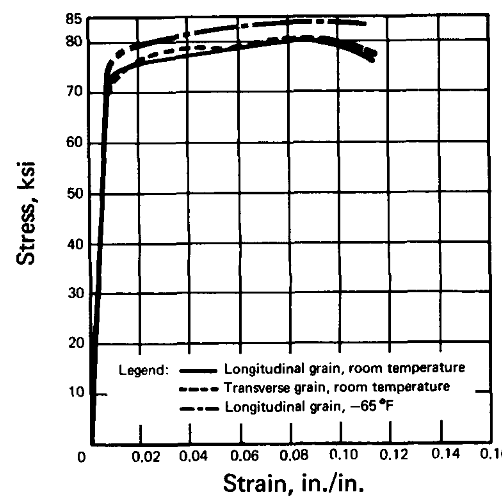
Note: Length in inches

(c) OVERAGED

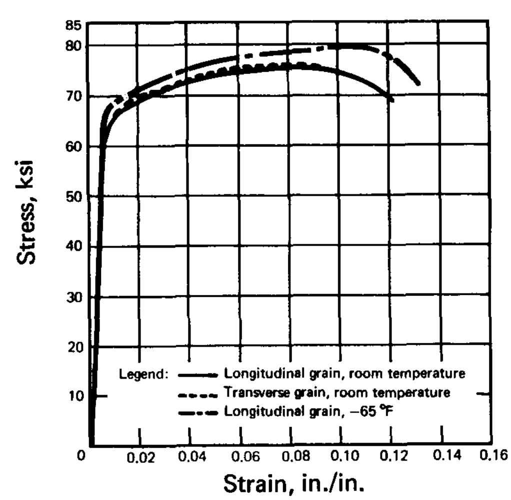
FIGURE 22.—FRACTURE SURFACES OF SURFACE-FLAWED PANELS



(a) UNDERAGED

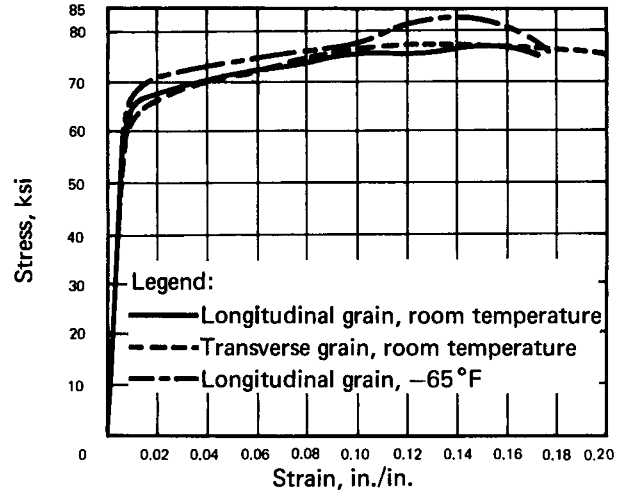


(b) PEAK AGE (T6)

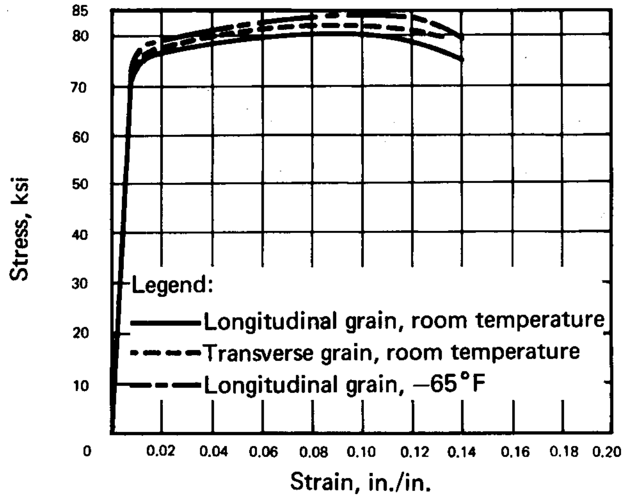


(c) OVERAGED

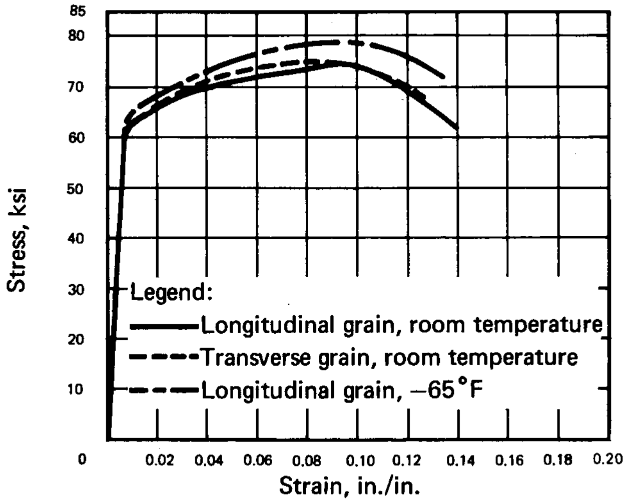
FIGURE 23. –STRESS-STRAIN CURVES FOR 0.16-IN.-THICK 7079 ALUMINUM ALLOY



(a) UNDERAGED

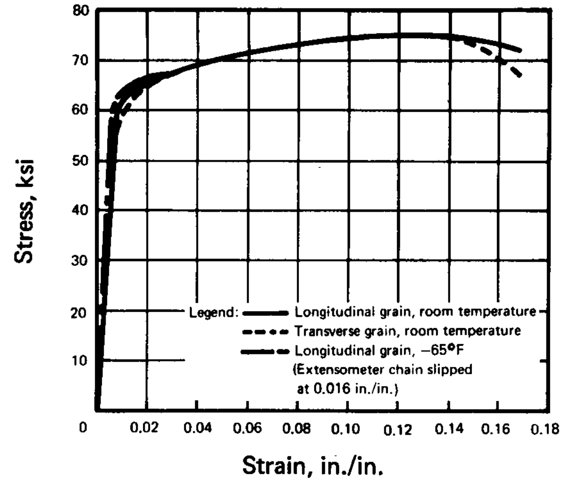


(b) PEAK AGE (T6)

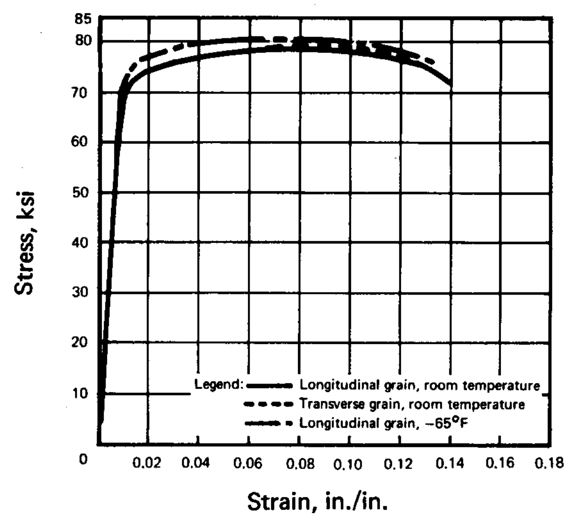


(c) OVERAGED

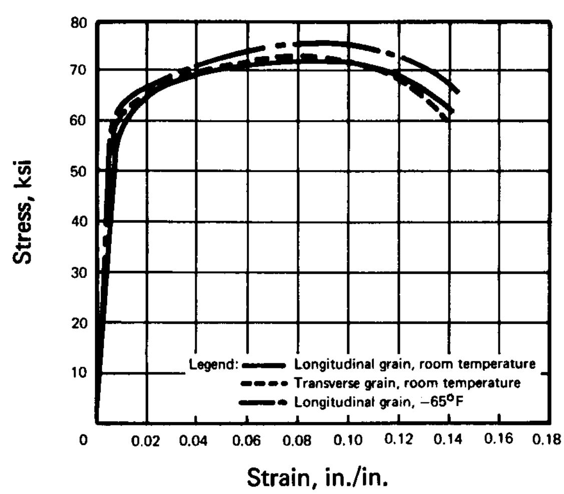
FIGURE 24. –STRESS-STRAIN CURVES FOR 0.25-IN.-THICK 7079 ALUMINUM ALLOY



(a) UNDERAGED



(b) PEAK AGE (T6)



(c) OVERAGED

FIGURE 25. –STRESS-STRAIN CURVES FOR 0.50-IN.-THICK 7079 ALUMINUM ALLOY

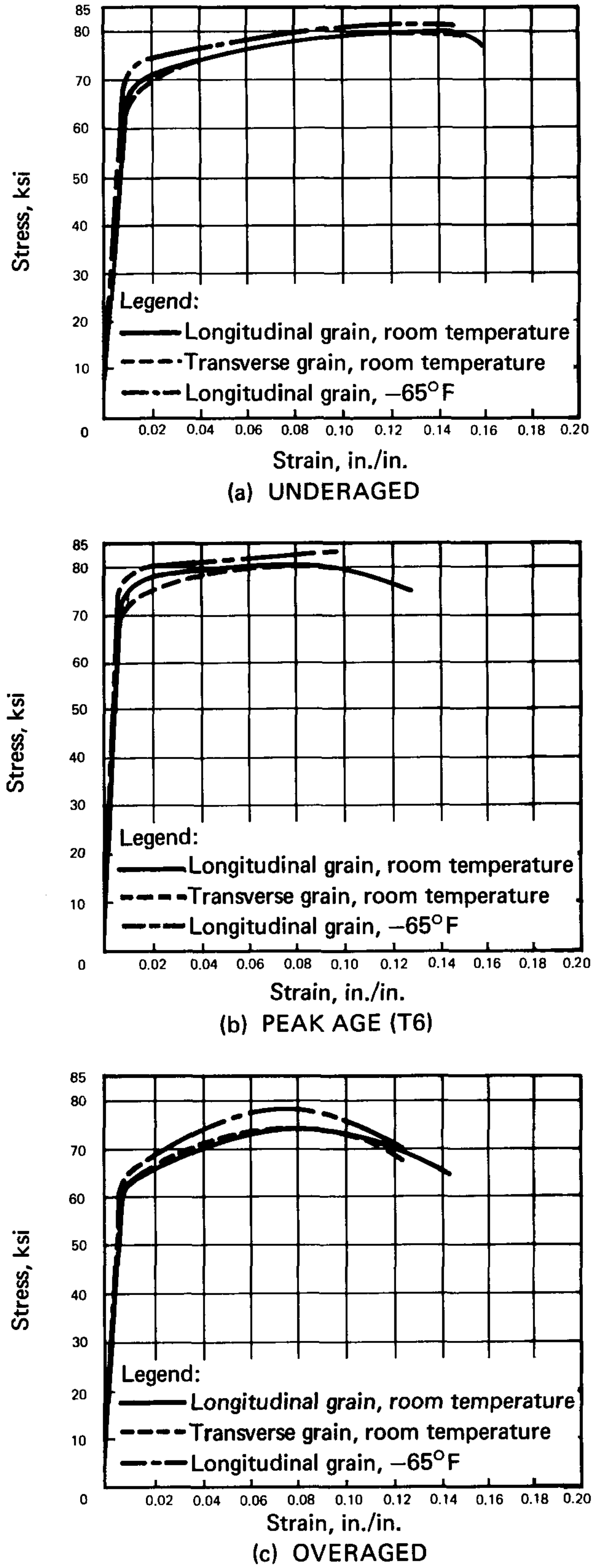


FIGURE 26.–STRESS-STRAIN CURVES FOR 0.63-IN.-THICK 7079 ALUMINUM ALLOY

TABLE I.—MECHANICAL PROPERTIES AND AGING CONDITIONS FOR 7079 MATERIALS AS REPORTED BY MANUFACTURER

Thickness, in.	Aging temp, °F	Aging time, hr	UTS, ksi	YS, ksi	Elong (2 in.), %
0.160	245 to 255	4	77.3	63.1	16.0
0.250	↕	4	75.7	60.2	16.0
0.500	↕	4	74.3	59.4	16.5
0.630	245 to 255	4	76.6	63.3	13.0

TABLE II. – TRANSVERSE TENSILE PROPERTIES AND AGING DATA FOR 7079 ALUMINUM ALLOY AT ROOM TEMPERATURE

Speci- men	Thickness, in.	Aging Temp, °F	Aging time, hr (a)	UTS, ksi	YS, ksi	Elong (1 in.), %	RA, %
1-19	0.160	------	0	79.1	63.7	15	26
1-21	.160	------	0	71.7	57.3	[b]8	27
1-11	.160	250	44	80.0	70.1	(c)	19
1-14	.160	250	44	81.5	71.1	12	25
1-2	.160	250	68	79.4	69.5	12	25
1-8	.160	250	68	78.8	68.1	11	24
1-1	.160	250	116	79.2	69.6	11	17
1-7	.160	250	116	74.4	65.3	(c)	23
2-19	.250	------	0	50.9	69.1	16	23
2-21	.250	------	0	58.6	76.6	17	23
2-12	.250	250	1	57.4	75.2	(c)	23
2-15	.250	250	1	77.0	58.6	18	23
2-6	.250	250	2	75.7	58.1	16	22
2-9	.250	250	2	67.4	53.1	(c)	18
2-11	.250	250	44	72.4	63.4	8	31
2-14	.250	250	44	80.0	67.9	13	24
2-2	.250	250	68	79.9	69.3	13	23
2-8	.250	250	68	79.1	68.5	12	26
2-1	.250	250	116	79.1	68.9	11	20
2-7	.250	250	116	80.6	70.3	12	20
5-18	.500	------	0	75.1	58.9	17	30
5-20	.500	------	0	75.0	58.8	17	26
5-1	.500	250	1	76.2	60.0	17	30
5-8	.500	250	1	75.2	59.8	16	31
5-5	.500	250	2	76.0	61.7	16	32
5-11	.500	250	2	75.6	60.7	16	31
5-7	.500	250	44	79.3	68.9	13	38
5-12	.500	250	44	79.3	69.0	14	29
5-6	.500	250	68	79.0	69.7	13	31
5-14	.500	250	68	77.7	68.0	9	30

TABLE II. – TRANSVERSE TENSILE PROPERTIES AND AGING DATA FOR 7079 ALUMINUM ALLOY AT ROOM TEMPERATURE - Continued

Specimen	Thickness, in.	Aging temp, °F	Aging time, hr (a)	UTS, ksi	YS, ksi	Elong (1 in.), %	RA, %
5-2	0.500	250	116	78.6	69.2	13	29
5-15	.500	250	116	79.0	69.5	16	32
6-18	.630	------	0	77.5	62.3	15	26
6-20	.630	------	0	77.2	60.8	15	25
6-7	.630	250	44	81.1	71.1	12	25
6-12	.630	250	44	81.2	70.8	12	26
6-6	.630	250	68	80.8	71.2	13	27
6-14	.630	250	68	81.2	71.9	13	27
6-2	.630	250	116	80.4	70.1	13	27
6-15	.630	250	116	80.0	68.8	13	28
1-3	.160	290	13	78.4	66.5	12	20
1-16	.160	290	13	77.5	66.6	13	23
1-12	.160	290	36	75.8	64.0	12	21
1-15	.160	290	36	75.5	63.4	12	20
1-20	.160	290	46	74.7	62.5	12	22
1-23	.160	290	46	75.0	62.8	11	18
1-18	.160	290	66	75.5	62.9	11	21
1-22	.160	290	66	74.5	61.9	13	27
2-3	.250	290	13	78.8	67.0	11	22
2-16	.250	290	13	78.4	66.2	12	24
2-4	.250	290	86	75.6	61.7	12	18
2-24	.250	290	86	74.3	59.8	12	23
2-20	.250	290	116	74.2	59.8	12	20
2-23	.250	290	116	74.0	63.4	12	22
2-18	.250	290	156	72.6	57.2	12	19
2-22	.250	290	156	73.3	58.1	11	18
5-4	.500	290	13	76.5	67.0	12	29
5-13	.500	290	13	77.8	67.7	12	30
5-9	.500	290	86	73.9	62.1	12	30
5-23	.500	290	86	73.7	61.5	13	31

TABLE II.–TRANSVERSE TENSILE PROPERTIES AND AGING DATA FOR 7079 ALUMINUM ALLOY AT ROOM TEMPERATURE - Concluded

Speci-men	Thickness, in.	Aging temp, °F	Aging time, hr (a)	UTS, ksi	YS, ksi	Elong (1 in.), %	RA, %
5-19	0.500	290	116	73.5	61.0	12	31
5-22	.500	290	116	73.3	61.0	13	33
5-17	.500	290	156	72.1	59.2	12	33
5-21	.500	290	156	72.6	59.5	12	32
6-4	.630	290	13	79.4	69.0	11	26
6-13	.630	290	13	80.6	70.2	12	27
6-9	.630	290	86	74.8	61.7	11	26
6-23	.630	290	86	75.6	61.8	13	31
6-19	.630	290	116	74.2	60.5	11	28
6-22	.630	290	116	75.0	61.4	11	26
6-17	.630	290	156	73.5	59.7	11	28
6-21	.630	290	156	74.0	60.1	11	24

[a] Aging treatment performed by Boeing; the material had been aged 4 hr at 250° F when received by Boeing.

[b] Speciment 1-21 broke 0.09 in. from gage mark.

[c] Specimen broke outside of gage length; no elongation data available.

TABLE III.—FATIGUE-CRACK LENGTH-CYCLE DATA

(a) Crack length versus cycles for underaged 7079 aluminum, specimen number CNL-1U

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT
.05	.1600	60.0	92.8	8.000	36.00	79.200	70.700	L	Y

SMAX REDUCED TO 6.0 KSI FOR 2A=12.2 IN
PANEL OVERLOADED WHEN 2A=12.49 IN
SMAX CHANGED TO 8.0 KSI WHEN 2A=12.525 IN
SMAX REDUCED TO 4.63 KSI WHEN 2A=12.770 IN

SMAX REDUCED TO 4.63 KSI FOR 2A=12.485 IN
SMAX CHANGED TO6.0 KSI WHEN 2A=12.525 IN
SMAX REDUCED TO 6.0 KSI AT 627 KILOCYCLES

ENVIRONMENT
DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.780	227.500	1.745	367.500	4.330	489.000	11.520
10.000	.780	230.500	1.780	369.500	4.400	489.630	11.570
25.000	.780	236.500	1.840	375.100	4.520	490.000	11.605
32.500	.780	240.000	1.875	378.000	4.680	490.500	11.655
36.000	.790	250.000	1.975	383.250	4.800	491.000	11.730
42.500	.800	260.000	2.095	388.000	5.050	491.500	11.780
46.250	.820	265.800	2.185	395.200	5.300	492.000	11.825
54.500	.840	271.000	2.240	401.000	5.600	492.500	11.885
65.000	.860	275.000	2.270	405.000	5.790	493.000	11.950
70.500	.865	279.080	2.350	410.000	6.020	493.500	12.005
76.500	.890	282.000	2.395	415.500	6.280	494.000	12.065
80.750	.900	285.000	2.475	420.500	6.545	494.500	12.125
85.500	.910	290.000	2.530	425.000	6.790	495.000	12.160
91.250	.925	295.500	2.630	430.300	7.000	495.250	12.200
96.500	.935	300.250	2.705	435.000	7.215	498.000	12.205
106.500	.980	310.000	2.885	439.000	7.485	498.500	12.210
113.375	.995	320.000	3.095	445.300	7.960	503.000	12.260
118.250	1.030	325.000	3.180	450.000	8.300	507.500	12.485
128.000	1.055	330.000	3.295	455.200	8.635	508.000	12.490
139.750	1.110	334.250	3.400	460.000	9.040	564.500	12.525
150.000	1.149	337.250	3.485	465.000	9.410	618.042	12.525
160.000	1.190	342.500	3.625	468.750	9.710	622.000	12.550
170.000	1.270	346.000	3.705	473.500	10.125	623.000	12.570
180.000	1.360	349.500	3.820	478.250	10.545	624.000	12.585
190.000	1.430	352.000	3.890	481.500	10.820	629.000	12.700
200.500	1.510	355.500	3.985	485.000	11.095	632.000	12.770
210.000	1.585	358.500	4.060	487.500	11.445	638.500	12.885
220.000	1.680	362.790	4.190	488.000	11.470	639.500	12.950
225.250	1.725	365.000	4.250	488.500	11.500	640.500	12.970

(b) Crack length versus cycles for underaged 7079 aluminum, specimen number 1U-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1575	120.0	36.0	12.000	12.04	79.200	70.700	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI FOR 2A=4.094 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.756	15.000	1.376	29.500	2.295	37.250	3.958
3.500	.845	17.750	1.520	32.000	2.615	37.500	4.094
5.000	.913	20.000	1.648	34.000	2.930	37.750	4.138
7.250	1.009	22.250	1.787	36.000	3.445	37.900	4.179
10.250	1.150	24.500	1.906	36.750	3.724	37.950	4.204
12.500	1.254	27.000	2.081				

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(c) Crack length versus cycles for underaged 7079 aluminum, specimen number 1U-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1590	120.0	36.0	12.000	12.01	81.800	74.000	L	Y	-65 DEG

SMAX REDUCED TO 11.0 KSI FOR 2A=4.082 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.785	35.000	1.416	54.500	2.524	60.000	3.545
5.650	.840	40.000	1.602	56.000	2.691	60.500	3.696
10.000	.926	43.250	1.727	57.500	2.924	61.250	3.958
15.000	1.056	46.000	1.855	58.500	3.163	61.500	4.082
20.000	1.150	49.000	2.009	59.000	3.279	62.250	4.189
25.000	1.192	52.000	2.253	59.500	3.398	62.350	4.223
30.000	1.299						

(d) Crack length versus cycles for underaged 7079 aluminum, specimen number 1U-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.1590	120.0	36.0	12.000	12.02	79.700	64.300	T	Y	DIST WATER

SMAX REDUCED TO 11.0 KSI FOR 2A=4.104 IN   ONE SIDE OF PANEL DRY FOR THE RANGE 2A= 1.339 TO 3.365

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.770	30.000	1.339	52.000	2.466	61.500	3.613
5.000	.796	36.250	1.562	54.500	2.694	62.750	3.843
10.250	.869	41.000	1.768	56.500	2.922	63.550	4.031
15.000	.951	45.000	1.978	58.200	3.120	63.900	4.104
20.250	1.071	49.000	2.230	60.000	3.365	64.500	4.202
25.000	1.198						

(e) Crack length versus cycles for underaged 7079 aluminum, specimen number 1U-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.1590	120.0	36.0	12.000	12.00	79.700	64.300	T	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.1 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.751	125.000	1.289	197.000	2.537	224.000	3.446
11.000	.770	142.000	1.540	202.000	2.677	226.500	3.598
30.000	.822	150.000	1.696	207.000	2.835	229.500	3.762
50.000	.904	158.000	1.800	211.000	2.952	231.500	3.880
70.000	.988	165.000	1.896	215.000	3.087	233.500	4.022
90.000	1.104	175.000	2.082	219.000	3.245	234.650	4.100
100.000	1.162	183.000	2.206	222.000	3.365	237.000	4.200
115.000	1.240	191.500	2.384				

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(f) Crack length versus cycles for underaged 7079 aluminum, specimen number CNL-2U

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2550	65.0	96.0	12.000	36.25	77.500	63.900	L	Y	DRY RT AIR

SMAX REDUCED TO 10.0 KSI WHEN 2A=12.0 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.4 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=12.2 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.785	100.000	3.620	145.000	7.400	164.800	11.325
9.000	.810	103.100	3.800	147.000	7.585	165.200	11.460
17.000	.895	106.000	3.980	149.000	7.850	165.600	11.630
25.000	.995	109.200	4.205	150.500	8.050	166.000	11.830
33.000	1.105	111.700	4.385	152.000	8.310	166.350	12.000
40.000	1.250	114.300	4.590	153.000	8.490	167.000	12.040
46.300	1.390	116.000	4.710	154.000	8.650	167.500	12.090
52.000	1.520	118.100	4.870	155.000	8.805	168.000	12.160
58.000	1.690	120.000	5.010	156.000	9.020	168.250	12.200
63.300	1.855	122.200	5.180	157.000	9.200	169.000	12.205
67.300	2.005	124.000	5.320	158.000	9.410	171.750	12.310
70.000	2.105	126.000	5.490	158.700	9.560	173.000	12.370
73.000	2.250	128.000	5.710	159.700	9.795	173.700	12.400
76.000	2.365	129.500	5.850	160.500	9.970	175.500	12.405
79.000	2.500	131.000	5.960	161.200	10.175	177.500	12.430
82.000	2.635	133.000	6.170	161.800	10.345	179.000	12.475
85.000	2.775	135.000	6.350	162.400	10.520	181.000	12.525
88.000	2.920	137.000	6.560	163.100	10.725	182.000	12.565
91.000	3.095	139.000	6.760	163.600	10.925	182.500	12.580
94.000	3.255	141.000	6.935	164.300	11.125	182.800	12.590
97.000	3.410	143.000	7.180				

(g) Crack length versus cycles for underaged 7079 aluminum, specimen number 2U-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2540	120.0	36.0	12.000	12.00	77.500	63.900	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.106 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.757	20.000	1.467	32.600	2.488	43.200	3.545
4.000	.791	23.700	1.794	35.100	2.679	44.500	3.730
8.000	.932	26.000	2.041	37.500	2.878	45.500	3.929
12.000	1.111	27.300	2.154	39.500	3.088	46.400	4.106
15.000	1.216	29.200	2.273	41.400	3.317	47.400	4.201
17.000	1.311						

TABLE III.—FATIGUE CRACK LENGTH—CYCLE DATA - Continued

(h) Crack length versus cycles for underaged 7079 aluminum, specimen number 2U-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2560	120.0	36.0	12.000	12.00	78.800	67.200	L	Y	-65 DEG

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.737	35.000	1.373	54.000	2.204	63.700	3.314
3.500	.765	39.200	1.522	56.000	2.336	65.700	3.625
10.000	.903	43.000	1.629	58.000	2.504	67.100	3.892
15.000	1.001	47.000	1.733	60.750	2.856	68.000	4.086
20.000	1.095	49.500	1.911	61.900	2.986	68.200	4.220
27.300	1.215	52.000	2.095				

(i) Crack length versus cycles for underaged 7079 aluminum, specimen number 2U-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2560	120.0	24.0	12.000	8.03	77.500	63.900	L	Y	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.761	12.000	1.174	23.000	1.670	33.150	2.297
2.250	.779	14.000	1.294	25.000	1.778	35.200	2.530
3.250	.799	17.000	1.443	27.000	1.902	36.100	2.621
5.000	.865	18.000	1.496	29.000	2.021	37.000	2.708
7.000	.924	20.000	1.545	31.000	2.134	37.850	2.805
10.500	1.096						

(j) Crack length versus cycles for underaged 7079 aluminum, specimen number 2U-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.2590	120.0	36.0	12.000	12.00	78.100	60.400	T	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.149 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.759	81.000	1.011	160.000	1.860	215.000	3.571
10.000	.759	91.000	1.067	170.000	2.042	218.000	3.770
20.000	.775	100.000	1.138	180.800	2.303	220.200	3.910
30.700	.806	110.000	1.238	188.500	2.507	222.300	4.041
40.000	.837	120.000	1.370	195.500	2.750	223.600	4.149
50.000	.876	130.000	1.531	201.000	2.965	224.000	4.149
60.000	.914	140.000	1.633	206.000	3.158	225.000	4.190
70.000	.954	150.000	1.748	211.000	3.372	225.200	4.200

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(k) Crack length versus cycles for underaged 7079 aluminum, specimen number 2U-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.2590	120.0	36.0	12.000	12.00	78.100	60.400	T	Y	DIST WATER

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.103 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.740	48.000	1.531	64.500	2.572	72.000	3.611
10.000	.753	51.100	1.664	66.000	2.741	73.150	3.865
20.000	.862	54.300	1.828	67.500	2.905	74.000	4.082
30.000	1.033	57.000	1.977	69.100	3.122	74.100	4.103
38.000	1.211	60.000	2.175	70.000	3.255	74.600	4.192
44.000	1.388	62.500	2.385	71.000	3.432	74.650	4.202

(l) Crack length versus cycles for underaged 7079 aluminum, specimen number CNL-5U

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5010	35.0	94.0	12.000	36.25	75.000	61.800	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=5.575 IN
SMAX REDUCED TO 9.0 KSI WHEN 2A=9.585 IN
SMAX REDUCED TO 7.0 KSI WHEN 2A=12.090 IN
SMAX REDUCED TO 10.0 KSI WHEN 2A=8.69 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=10.285 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.450 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.780	35.000	3.680	48.000	6.850	58.200	10.285
4.200	.810	35.500	3.775	48.500	6.965	58.800	10.385
6.032	.880	36.000	3.900	59.000	7.130	59.200	10.505
7.000	.910	36.600	4.010	49.500	7.245	59.500	10.590
7.796	.945	37.000	4.070	50.000	7.365	59.900	10.695
10.000	1.040	37.500	4.185	50.500	7.480	60.300	10.810
12.016	1.210	38.000	4.310	51.000	7.650	60.700	10.905
15.000	1.330	38.500	4.390	51.500	7.830	61.100	10.965
17.500	1.570	39.000	4.470	52.000	8.040	61.500	11.040
20.000	1.775	39.500	4.540	52.400	8.220	62.000	11.190
22.000	1.970	40.000	4.625	52.800	8.390	62.400	11.285
24.000	2.180	40.500	4.720	53.200	8.605	62.800	11.380
25.500	2.335	41.000	4.855	53.600	8.690	63.200	11.460
26.500	2.490	41.500	5.000	54.000	8.795	63.600	11.585
27.750	2.510	42.000	5.155	54.400	8.930	64.000	11.660
28.500	2.670	42.500	5.345	54.800	9.095	64.500	11.830
29.500	2.820	42.930	5.575	55.200	9.280	64.800	11.980
30.300	2.935	43.400	5.720	55.500	9.390	65.000	12.090
31.050	3.060	44.000	5.875	55.800	9.540	65.600	12.125
31.500	3.140	44.500	5.995	56.100	9.585	66.100	12.180
32.200	3.270	45.000	6.130	56.400	9.685	67.000	12.300
32.600	3.380	45.500	6.235	56.700	9.740	67.500	12.370
33.200	3.410	46.000	6.305	57.000	9.780	67.900	12.450
33.600	3.470	46.500	6.435	57.300	9.860	68.700	12.510
34.000	3.515	47.000	6.555	57.600	9.950	69.200	12.570
34.500	3.590	47.500	6.690	57.900	10.085	69.400	12.600

TABLE III.–FATIGUE-CRACK LENGTH–CYCLE DATA–Continued

(m) Crack length versus cycles for underaged 7079 aluminum, specimen number 5U-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5020	120.0	36.0	12.000	12.00	75.000	61.800	L	N	DRY RT AIR

SMAX REDUCED TO 11.0 KST WHEN 2A=4.162 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.793	17.000	1.538	31.000	2.732	37.500	3.475
3.000	.809	20.100	1.742	32.100	2.845	39.000	3.668
7.200	.944	23.000	1.949	33.500	3.004	40.000	3.858
10.000	1.088	25.500	2.135	35.000	3.161	40.800	4.162
13.200	1.263	27.600	2.322	36.500	3.384	41.000	4.204
15.100	1.420	29.500	2.548				

(n) Crack length versus cycles for underaged 7079 aluminum, specimen number 5U-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5045	120.0	36.0	12.000	12.01	75.300	63.000	L	N	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.096 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.773	29.100	1.506	45.000	2.569	52.000	3.442
5.200	.797	32.500	1.707	47.400	2.788	53.000	3.646
13.000	.996	36.000	1.886	49.000	2.970	54.000	3.980
18.000	1.138	39.600	2.156	50.000	3.078	54.500	4.096
23.200	1.300	43.050	2.407	51.100	3.237	55.300	4.201
26.200	1.417						

(o) Crack length versus cycles for underaged 7079 aluminum, specimen number 5U-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5040	120.0	24.0	12.000	8.00	75.000	61.800	L	N	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.731	13.000	1.248	21.000	1.830	26.000	2.440
1.500	.741	15.000	1.366	23.200	2.041	27.500	2.681
5.000	.836	17.000	1.520	25.100	2.338	28.100	2.798
10.000	1.054	19.300	1.694				

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA- Continued

(p) Crack length versus cycles for underaged 7079 aluminum, specimen number 5U-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.5040	120.0	36.0	12.000	12.01	74.900	58.700	T	N	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.109

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.741	90.000	1.044	180.400	1.965	229.100	3.596
10.000	.741	100.000	1.098	190.700	2.149	231.300	3.794
20.000	.752	110.500	1.171	200.000	2.348	233.000	3.975
30.000	.787	120.000	1.237	207.000	2.534	234.000	4.068
41.000	.836	130.000	1.311	212.600	2.718	234.300	4.109
50.000	.868	140.000	1.403	216.100	2.847	235.000	4.126
60.500	.907	150.350	1.526	220.000	3.018	235.500	4.155
70.000	.949	160.000	1.646	224.000	3.224	235.703	4.197
80.000	.985	170.000	1.799	227.000	3.423		

(q) Crack length versus cycles for underaged 7079 aluminum, specimen number 5U-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	0.5036	120.0	36.0	12.000	12.01	74.900	58.700	T	N	DIST WATER

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.092 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.781	58.000	1.652	73.500	2.845	78.000	3.810
13.000	.797	62.000	1.835	74.500	3.005	78.500	3.977
23.000	.859	65.000	2.008	75.500	3.184	78.800	4.092
34.100	1.000	68.000	2.252	76.500	3.301	79.000	4.129
44.000	1.201	70.000	2.411	77.500	3.657	79.410	4.230
52.200	1.416	72.000	2.644				

(r) Crack length versus cycles for underaged 7079 aluminum, specimen number CNL-6U

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6280	40.0	96.0	12.000	36.00	80.000	67.400	L	Y	DRY RT AIR

SMAX REDUCED TO 10.0 KSI WHEN 2A=12.035
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.430 IN

SMAX REDUCED TO 8.0 KSI WHEN 2A=12.29 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.810	85.180	2.690	130.000	7.470	150.000	12.035
20.250	.875	90.000	3.010	133.671	7.965	152.500	12.290
31.500	1.045	95.000	3.400	135.000	8.149	155.500	12.330
35.000	1.103	100.000	3.835	137.000	8.410	156.500	12.355
40.000	1.160	105.000	4.398	140.500	9.374	156.900	12.430
45.000	1.272	110.830	4.771	142.000	9.763	164.250	12.430
50.000	1.370	113.500	5.325	143.500	10.135	165.063	12.435
55.500	1.485	116.000	5.585	145.000	10.465	165.500	12.440
60.000	1.625	119.000	5.855	146.000	10.725	166.711	12.440
65.000	1.785	122.000	6.145	147.000	10.910	168.030	12.450
70.000	1.900	125.150	6.625	148.000	11.180	170.000	12.470
75.000	2.169	127.250	7.010	149.000	11.465	173.000	12.955
80.500	2.435	128.000	7.185				

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(s) Crack length versus cycles for underaged 7079 aluminum, specimen number 6U-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6340	120.0	36.0	12.000	12.02	80.000	67.400	L	N	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.093 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.759	21.500	1.729	30.500	2.694	39.000	3.752
7.300	.884	23.000	1.864	32.200	2.871	39.800	3.845
10.000	.976	24.500	2.043	33.600	3.028	40.800	3.952
12.000	1.041	25.500	2.169	35.000	3.197	41.600	4.093
15.000	1.212	26.600	2.301	36.700	3.423	42.400	4.128
17.500	1.388	27.500	2.409	38.000	3.619	43.250	4.211
19.500	1.507	29.000	2.526				

(t) Crack length versus cycles for underaged 7079 aluminum, specimen number 6U-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6340	80.0	36.0	12.000	11.97	81.600	71.400	L	N	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.131 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.731	28.000	1.609	40.000	2.444	48.500	3.758
4.000	.759	30.000	1.745	44.000	2.974	49.000	3.825
7.000	.827	31.500	1.851	45.600	3.269	49.500	3.978
13.500	.998	33.000	1.997	46.000	3.363	49.750	4.022
17.000	1.115	34.250	2.073	46.600	3.416	50.000	4.067
20.500	1.251	35.500	2.158	47.150	3.491	50.250	4.131
23.000	1.349	36.750	2.215	47.800	3.600	51.150	4.258
25.500	1.487	38.250	2.318				

(u) Crack length versus cycles for underaged 7079 aluminum, specimen number 6U-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6330	120.0	24.0	12.000	8.03	80.000	67.400	L	N	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.755	13.000	1.064	22.500	1.610	30.500	2.293
2.700	.782	16.000	1.177	24.500	1.752	32.900	2.580
5.000	.815	19.000	1.308	26.500	1.911	33.750	2.670
10.000	.958	20.500	1.472	28.500	2.068	34.700	2.779

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(v) Crack length versus cycles for underaged 7079 aluminum, specimen number 6U-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.6320	120.0	36.0	12.000	11.98	80.300	63.600	T	N	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.112 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.763	90.000	.936	176.200	1.506	246.000	2.776
10.000	.763	100.000	.972	186.700	1.609	250.000	2.947
20.000	.763	110.000	1.008	196.000	1.718	253.000	3.122
30.000	.770	120.000	1.078	205.200	1.839	255.700	3.298
35.000	.787	129.000	1.135	212.000	1.942	259.000	3.523
40.000	.795	138.000	1.198	219.000	2.059	260.700	3.677
50.000	.818	146.000	1.269	227.600	2.233	263.100	3.959
60.000	.843	156.000	1.339	235.400	2.414	264.000	4.112
70.300	.876	165.500	1.411	241.200	2.583	265.500	4.217
80.000	.906						

(w) Crack length versus cycles for underaged 7079 aluminum, specimen number 6U-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6320	80.0	36.0	12.000	12.00	80.300	63.600	T	N	DIST WATER

FIRST PART OF TEST

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.767	5.000	1.190	6.500	1.488	8.000	2.006
2.750	.932	5.500	1.292	7.000	1.630	8.250	2.121
4.000	1.094	6.000	1.386	7.500	1.805	8.500	2.267

(x) Crack length versus cycles for underaged 7079 aluminum, specimen number 6U-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.6320	120.0	36.0	12.000	12.00	81.900	64.000	T	N	DIST WATER

SECOND PART OF TEST

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.155 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
8.750	2.277	14.700	2.711	20.350	3.513	22.300	4.042
9.500	2.323	16.100	2.864	20.900	3.651	22.400	4.081
10.500	2.392	17.400	3.021	21.300	3.693	22.450	4.096
11.600	2.463	18.300	3.150	21.800	3.883	22.800	4.155
12.600	2.540	19.000	3.255	22.300	3.952	22.900	4.176
13.650	2.623	19.600	3.360	22.100	3.976	23.000	4.196

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA—Continued

(y) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number CNL-1P

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1570	45.0	96.0	12.000	35.97	79.600	73.900	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 WHEN 2A=8.925 IN
SMAX REDUCED TO 9.0 KSI WHEN 2A=11.800 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.430 IN
SMAX REDUCED TO 10.0 KSI WHEN 2A=10.015 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=12.285 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.760	93.500	3.500	118.200	6.810	126.400	9.815
6.500	.815	96.000	3.700	119.200	7.085	126.800	10.015
10.000	.850	98.000	3.870	119.800	7.245	127.200	10.135
20.000	.965	100.000	4.005	120.500	7.460	127.700	10.310
30.000	1.100	102.500	4.300	121.000	7.625	128.200	10.495
35.000	1.195	104.000	4.460	121.500	7.800	128.700	10.690
40.000	1.290	105.600	4.645	122.000	7.975	129.100	10.850
47.700	1.465	107.000	4.825	122.700	8.255	129.600	11.060
53.000	1.615	108.500	5.010	123.200	8.455	130.000	11.235
57.000	1.740	110.000	5.235	123.500	8.585	130.400	11.415
62.000	1.900	111.000	5.395	123.800	8.730	130.800	11.590
66.250	2.050	112.000	5.555	124.000	8.825	131.200	11.800
70.000	2.200	113.000	5.715	124.200	8.925	131.800	11.975
71.800	2.280	114.000	5.885	124.500	9.020	132.400	12.200
75.050	2.420	115.000	6.085	124.900	9.160	132.600	12.285
79.100	2.615	116.100	6.310	125.300	9.335	133.400	12.430
83.500	2.855	117.000	6.510	125.700	9.495	134.700	12.535
87.500	3.080	117.600	6.665	126.000	9.630	135.300	12.600
91.600	3.355						

(z) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 1P-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1580	120.0	36.0	12.000	11.97	79.600	73.900	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=3.998 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.761	15.700	1.528	24.600	2.597	28.390	3.885
1.800	.792	18.000	1.725	25.900	2.894	28.700	3.998
6.100	.961	19.700	1.892	26.500	3.067	28.850	4.053
9.000	1.103	21.000	2.035	27.000	3.238	29.000	4.125
11.300	1.233	22.500	2.245	27.500	3.435	29.100	4.175
13.100	1.343	23.700	2.433	27.900	3.613	29.150	4.208

TABLE III.–FATIGUE-CRACK LENGTH–CYCLE DATA–Continued

(aa) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 1P-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1590	120.0	36.0	12.000	12.00	83.800	77.500	L	Y	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=3.583 IN

SMAX REDUCED TO 10.0 KSI WHEN 2A=3.989 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.729	13.000	1.046	29.500	1.996	35.500	3.583
2.000	.742	16.000	1.153	31.500	2.277	36.000	3.828
5.500	.807	19.500	1.292	33.000	2.595	36.300	3.989
8.000	.880	23.500	1.496	34.000	2.866	36.700	4.128
10.500	.960	26.500	1.696	34.500	3.054	37.000	4.266

(ab) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 1P-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1585	120.0	24.0	12.000	8.00	79.600	73.900	L	Y	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.750	14.100	1.316	24.000	2.065	27.000	2.572
2.000	.779	16.000	1.424	25.000	2.206	27.500	2.698
6.000	.921	18.700	1.589	25.500	2.296	27.750	2.763
9.500	1.079	21.100	1.752	26.000	2.383	27.900	2.804
12.000	1.208	23.000	1.943	26.500	2.471		

(ac) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 1P-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.1590	120.0	36.0	12.000	12.00	80.100	70.500	T	Y	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.800	82.000	1.233	151.000	1.992	197.000	3.346
10.000	.800	92.400	1.318	161.000	2.178	200.000	3.542
14.200	.813	103.900	1.420	170.000	2.374	202.000	3.688
23.500	.862	113.000	1.503	178.000	2.620	204.300	3.870
36.000	.930	123.000	1.607	185.500	2.829	205.700	3.995
49.000	1.013	129.000	1.678	190.000	3.000	207.000	4.112
61.000	1.084	140.000	1.833	194.000	3.173	208.100	4.202
71.000	1.155						

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(ad) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 1P-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.1590	120.0	36.0	12.810	12.00	80.100	70.500	T	Y	DIST WATER

SMAX REDUCEC TO 11.0 KSI WHEN 2A=4.136 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.744	36.000	1.727	44.500	2.604	49.000	3.461
10.000	.812	38.000	1.888	45.500	2.761	49.750	3.665
20.000	.995	40.000	2.071	46.500	2.920	50.500	3.885
26.200	1.206	42.000	2.281	47.500	3.119	51.150	4.136
30.000	1.366	43.500	2.470	48.250	3.290	51.600	4.201
34.000	1.590						

(ae) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number CNL-2P

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2520	65.0	96.0	12.000	36.75	80.400	74.000	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=9.270 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=12.210 IN
SMAX REDUCED TO 10.0 KSI WHEN 2A=10.635 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.410 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.770	90.600	3.270	124.000	7.290	133.500	10.785
8.000	.800	93.200	3.480	125.450	7.700	134.000	10.950
16.000	.860	95.100	3.615	126.460	8.010	134.600	11.160
24.200	.965	97.600	3.835	127.000	8.230	135.100	11.360
32.000	1.065	99.000	3.955	127.500	8.385	135.500	11.505
40.000	1.185	101.000	4.115	128.000	8.580	135.900	11.675
45.600	1.310	103.400	4.310	128.500	8.775	136.300	11.845
53.200	1.460	105.700	4.500	129.000	9.005	136.700	12.015
58.200	1.625	108.000	4.695	129.500	9.270	137.100	12.210
63.500	1.860	110.000	4.920	130.000	9.410	137.700	12.230
67.200	2.035	112.800	5.275	130.500	9.570	138.200	12.330
71.200	2.180	115.900	5.715	131.000	9.755	138.650	12.410
75.400	2.370	118.000	6.070	131.500	9.965	139.500	12.425
79.000	2.570	120.200	6.450	132.000	10.165	140.200	12.475
82.000	2.735	121.000	6.600	132.400	10.345	141.000	12.515
85.000	2.910	122.200	6.855	132.950	10.635	142.300	12.605
88.000	3.100	123.000	7.030				

(af) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 2P-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2535	120.0	36.0	12.000	12.00	80.400	74.000	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.061 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.762	15.000	1.509	24.000	2.458	28.800	3.580
1.400	.797	17.300	1.704	25.000	2.596	29.300	3.817
5.000	.931	19.100	1.860	26.000	2.752	29.700	4.061
8.000	1.066	21.200	2.100	27.000	2.962	30.100	4.209
12.600	1.326	22.500	2.270	28.180	3.331		

TABLE III.–FATIGUE-CRACK LENGTH–CYCLE DATA - Continued

(ag) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 2P-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2550	120.0	36.0	12.000	12.00	84.300	77.200	L	Y	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=3.924 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.746	23.100	1.570	32.200	2.728	35.100	3.635
2.800	.763	25.400	1.773	33.000	2.937	35.400	3.768
7.100	.855	27.400	1.988	33.500	3.065	35.700	3.924
12.300	1.016	29.000	2.160	34.000	3.232	36.000	3.978
16.300	1.174	30.000	2.314	34.400	3.369	36.400	4.125
20.100	1.391	31.200	2.508	34.800	3.538	36.600	4.200

(ah) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 2P-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2540	120.0	24.0	12.000	8.05	80.400	74.000	L	Y	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.763	14.000	1.282	23.000	2.093	26.500	2.711
3.000	.793	16.000	1.414	24.000	2.247	26.700	2.783
5.000	.831	18.000	1.607	25.000	2.407	26.800	2.790
8.000	.943	20.000	1.747	25.500	2.506	26.900	2.813
11.000	1.088	22.000	1.910	26.000	2.610		

(ai) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 2P-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.2550	120.0	36.0	12.000	12.00	81.900	72.300	T	Y	DIST WATER

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.109 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.743	49.000	1.600	62.000	2.448	69.800	3.690
10.700	.772	52.000	1.748	64.000	2.664	70.400	3.853
20.000	.872	54.000	1.856	65.500	2.848	71.000	4.054
30.000	1.049	56.100	1.992	67.000	3.086	71.150	4.109
38.000	1.226	58.000	2.106	68.000	3.267	71.600	4.189
45.000	1.443	60.000	2.272	69.000	3.495	71.675	4.204

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(aj) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 2P-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.2556	120.0	36.0	12.000	12.00	81.900	72.300	T	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.102IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.740	81.000	1.122	158.000	2.176	187.000	3.689
10.000	.740	92.000	1.213	164.000	2.373	188.000	3.806
20.000	.755	100.000	1.268	170.000	2.620	189.900	4.042
30.000	.796	110.000	1.368	175.000	2.842	190.300	4.102
40.000	.842	120.200	1.483	180.000	3.086	191.000	4.129
50.000	.895	130.500	1.613	184.000	3.355	191.400	4.187
60.000	.954	140.600	1.783	186.000	3.595	191.600	4.199
72.000	1.045	150.000	1.972				

(ak) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number CNL-5P

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.4990	53.0	96.0	12.000	36.21	78.500	71.500	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.890 IN
SMAX REDUCED TO 9.0 KSI WHEN 2A=6.510 IN
SMAX REDUCED TO 7.0 KSI WHEN 2A= 9.540 IN
SMAX REDUCED TO 10.0 KSI WHEN 2A=5.225 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=7.665 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=11.230 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.760	32.500	3.875	41.500	7.395	50.500	10.125
3.000	.815	33.000	4.030	41.800	7.505	51.010	10.270
5.500	.890	33.500	4.180	42.100	7.665	51.523	10.430
9.000	1.025	34.000	4.325	42.500	7.770	52.189	10.700
12.000	1.190	34.500	4.565	43.000	7.880	52.600	10.810
14.000	1.310	35.000	4.890	43.500	8.040	53.040	11.025
16.000	1.450	35.300	4.980	44.000	8.195	53.140	11.060
18.000	1.590	35.700	5.225	44.600	8.410	53.500	11.230
20.000	1.785	36.050	5.335	45.000	8.545	53.800	11.270
21.500	1.930	36.500	5.495	45.600	8.760	54.000	11.315
22.500	2.030	37.000	5.685	46.000	8.920	54.400	11.430
24.000	2.200	37.400	5.835	46.500	9.150	54.800	11.540
25.000	2.355	37.800	5.990	46.800	9.285	55.300	11.725
26.000	2.495	38.200	6.130	47.000	9.380	55.700	11.875
27.000	2.630	38.600	6.290	47.300	9.540	56.100	12.040
28.000	2.775	39.000	6.510	47.600	9.585	56.400	12.170
29.200	3.050	39.500	6.650	48.000	9.690	56.700	12.285
30.000	3.215	40.000	6.805	48.500	9.785	57.040	12.440
30.750	3.390	41.400	6.950	49.000	9.870	57.260	12.520
31.500	3.585	40.800	7.100	49.500	9.965	57.400	12.610
32.000	3.715	41.200	7.265	50.000	10.060		

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(al) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 5P-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5000	120.0	36.0	12.000	12.00	78.500	71.500	L	N	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=1.354 IN
SMAX REDUCED TO 10.0 KSI WHEN 2A= 4.110 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.795	16.000	1.250	28.000	2.197	37.900	3.531
4.000	.813	17.000	1.354	29.800	2.343	38.500	3.659
5.000	.831	19.000	1.399	31.500	2.502	39.000	3.763
6.000	.853	21.000	1.516	32.000	2.671	39.500	3.920
8.000	.911	23.000	1.725	34.000	2.827	40.000	4.110
10.000	.980	24.500	1.945	35.000	2.950	40.200	4.144
12.000	1.062	25.500	2.020	36.000	3.109	40.500	4.230
14.000	1.149	26.900	2.113	37.000	3.302		

(am) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 5P-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5030	120.0	36.0	12.000	12.01	81.200	74.900	L	N	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.029 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.763	19.000	1.586	27.000	2.558	33.000	3.660
3.700	.806	21.000	1.760	28.000	2.645	33.400	3.827
7.000	.917	23.000	2.037	29.000	2.729	33.800	4.029
10.500	1.068	24.000	2.198	30.000	2.847	34.200	4.156
14.000	1.229	25.000	2.352	32.000	3.222	34.350	4.203
17.200	1.442	26.000	2.469				

(an) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 5P-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5020	120.0	24.0	12.000	8.01	78.500	71.500	L	N	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.751	13.000	1.263	23.000	2.034	26.600	2.515
3.200	.799	15.200	1.399	24.250	2.179	27.500	2.656
6.700	.935	18.000	1.599	25.500	2.376	28.200	2.765
9.000	1.053	19.700	1.752	26.000	2.457	28.400	2.806
11.000	1.161	21.500	1.889				

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(ao) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 5P-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.5030	120.0	36.0	12.000	12.00	79.400	69.300	T	N	DRY RT AIR

PANEL FAILED AT 85.320 KILOCYCLES

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.779	30.000	.804	50.000	.839	70.000	.937
10.500	.779	40.000	.814	60.000	.897	80.000	.999
20.000	.779						

(ap) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 5P-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.5030	120.0	36.0	12.000	12.00	79.400	69.300	T	N	DIST WATER

SMAX REDUCED TO 11.0 KSI WHEN 2A=3.174 IN
SMAX REDUCED TO 9.0 KSI WHEN 2A=4.101 IN
SMAX REDUCED TO 10.0 KSI WHEN 2A=3.677 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.761	54.000	1.826	61.300	3.174	63.200	3.822
10.000	.768	56.000	1.966	61.600	3.270	63.500	3.926
20.800	.861	58.000	2.109	61.900	3.400	63.800	4.101
31.000	.996	60.000	2.662	62.200	3.511	63.950	4.153
40.600	1.218	60.500	2.845	62.500	3.677	64.050	4.174
48.200	1.499	60.900	2.953	62.800	3.679	64.120	4.192
51.000	1.642						

(aq) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number CNL-6P

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6290	40.0	96.0	12.000	36.25	80.100	72.300	L	Y	DRY RT AIR

CYCLED TO FAILURE

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.770	26.000	2.230	39.000	4.780	42.500	6.400
5.600	.830	28.000	2.520	39.500	5.000	43.000	6.640
9.600	.975	30.000	2.820	40.100	5.300	43.500	7.040
11.200	1.070	32.000	3.145	40.500	5.450	44.000	7.360
14.000	1.220	34.000	3.530	41.000	5.670	44.600	7.735
17.000	1.460	35.500	3.825	41.500	5.895	45.000	7.970
20.000	1.640	37.250	4.275	42.000	6.170	45.575	8.660
23.000	1.900	38.000	4.425				

TABLE III.–FATIGUE-CRACK LENGTH–CYCLE DATA–Continued

(ar) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 6P-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6320	77.0	36.0	12.000	12.00	80.100	72.300	L	Y	DRY RT AIR

POSSIBLE PEAK OVERLOAD AT 33901 CYCLES

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.096 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.790	21.000	1.550	31.200	2.692	37.800	3.819
5.000	.820	22.500	1.688	32.100	2.842	38.100	3.952
10.000	.931	24.000	1.793	33.000	2.971	38.350	4.013
12.000	1.005	26.100	2.024	33.900	3.179	38.700	4.096
15.000	1.133	27.200	2.150	34.700	3.226	39.000	4.107
17.150	1.269	28.300	2.299	35.600	3.280	39.400	4.158
18.750	1.379	29.400	2.442	37.000	3.585	39.700	4.223
20.000	1.481	30.300	2.555				

(as) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 6P-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6320	80.0	36.0	12.000	12.02	83.700	75.500	L	N	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.078 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.773	24.700	1.785	31.500	2.736	35.500	3.911
5.000	.802	26.000	1.917	32.000	2.872	35.700	4.014
10.000	.942	27.000	2.028	32.500	3.070	35.810	4.078
14.000	1.063	28.000	2.118	33.000	3.161	35.860	4.090
18.200	1.274	29.000	2.259	33.870	3.418	35.950	4.111
20.150	1.392	30.000	2.429	34.500	3.542	36.100	4.170
22.000	1.517	31.100	2.646	34.750	3.612	36.180	4.201
23.670	1.682						

(at) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 6P-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6300	120.0	24.0	12.000	8.00	80.100	72.300	L	N	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.783	13.500	1.282	20.300	1.893	25.500	2.492
5.500	.883	15.700	1.445	21.500	1.995	26.300	2.615
9.000	1.021	17.800	1.634	22.800	2.141	27.250	2.816
11.000	1.136	19.000	1.747	24.300	2.325		

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(au) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 6P-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.6330	80.0	36.0	12.000	12.00	79.800	69.900	T	N	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=3.583 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.794	66.200	1.026	115.000	1.405	153.100	2.094
10.000	.794	76.000	1.082	123.000	1.495	158.900	2.957
22.000	.814	86.300	1.152	129.000	1.562	159.972	3.583
35.500	.878	96.600	1.226	134.000	1.628	161.000	3.872
46.000	.932	106.300	1.310	140.000	1.718	161.279	4.250
56.400	.973	110.800	1.350	147.000	1.864		

(av) Crack length versus cycles for peak-age (T6) 7079 aluminum, specimen number 6P-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.6360	80.0	36.0	12.000	11.98	79.800	69.900	T	N	DIST WATER

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.780	26.000	.985	53.000	1.598	62.750	2.210
8.000	.795	32.000	1.077	56.000	1.709	64.000	2.463
11.000	.832	38.500	1.212	59.000	1.856	65.000	2.747
16.000	.871	43.500	1.322	61.000	2.015	66.595	4.034
21.000	.917	48.500	1.451				

(aw) Crack length versus cycles for overaged 7079 aluminum, specimen number CNL-10

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1580	66.0	96.0	12.000	36.06	75.300	65.300	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=11.485 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=12.215 IN
SMAX REDUCED TO 10.0 KSI WHEN 2A=12.105 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.400 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.775	104.400	3.225	144.540	7.350	157.700	11.630
8.500	.825	107.250	3.400	145.810	7.615	158.050	11.775
17.000	.910	110.000	3.575	146.850	7.865	158.500	11.960
20.000	.930	113.000	3.780	147.500	8.020	158.800	12.105
25.000	.985	115.200	3.950	148.500	8.280	159.100	12.170
30.000	1.050	117.000	4.100	149.730	8.595	159.250	12.215
35.500	1.115	119.000	4.260	150.500	8.815	160.000	12.220
40.500	1.180	121.600	4.485	151.000	8.975	160.300	12.245
48.300	1.300	123.650	4.660	151.540	9.145	160.900	12.290
54.000	1.415	125.000	4.790	152.000	9.290	161.200	12.325
60.000	1.535	126.500	4.925	152.500	9.450	161.600	12.365
65.500	1.680	128.000	5.070	153.000	9.620	161.900	12.400
70.000	1.795	129.500	5.215	153.500	9.815	162.900	12.400
75.500	1.960	131.000	5.360	154.070	10.045	163.700	12.405
80.000	2.130	132.900	5.590	154.500	10.220	164.500	12.440
85.000	2.305	134.000	5.725	155.400	10.580	165.200	12.465
89.600	2.485	136.250	6.005	156.075	10.900	166.000	12.510
94.200	2.695	138.000	6.260	156.500	11.120	166.900	12.555
97.100	2.845	140.200	6.575	157.000	11.400	167.500	12.595
100.000	2.980	142.300	6.930	157.300	11.485	167.550	12.600

TABLE III.–FATIGUE-CRACK LENGTH–CYCLE DATA - Continued

(ax) Crack length versus cycles for overaged 7079 aluminum, specimen number 10-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1580	120.0	36.0	12.000	11.98	75.300	65.300	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.106

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.748	20.500	1.654	30.000	2.765	34.000	3.807
2.200	.767	22.700	1.846	31.000	2.968	34.500	4.006
7.500	.929	24.600	2.040	31.750	3.138	34.750	4.106
11.000	1.074	26.000	2.202	32.500	3.332	35.100	4.191
15.100	1.290	27.500	2.381	33.000	3.481	35.150	4.205
18.400	1.502	29.000	2.599	33.500	3.636		

(ay) Crack length versus cycles for overaged 7079 aluminum, specimen number 10-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1593	120.0	36.0	12.000	11.99	79.000	67.200	L	Y	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.111 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.724	28.200	1.565	38.300	2.682	41.540	3.648
2.200	.732	31.200	1.783	39.000	2.832	42.000	3.878
7.000	.818	33.000	1.943	39.500	2.982	42.400	4.111
12.200	.937	35.000	2.169	40.000	3.107	42.550	4.131
17.000	1.082	36.100	2.315	40.500	3.263	42.700	4.189
22.000	1.251	37.000	2.442	41.000	3.425	42.726	4.200
25.100	1.404						

(az) Crack length versus cycles for overaged 7079 aluminum, specimen number 10-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.1590	120.0	24.0	12.000	8.00	75.300	65.300	L	Y	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.747	13.000	1.151	23.000	1.758	30.500	2.559
2.500	.763	16.000	1.309	25.500	1.947	31.400	2.716
6.000	.857	19.400	1.513	27.500	2.153	31.800	2.805
10.000	1.014	21.100	1.622	29.200	2.356		

TABLE III.—FATIGUE-CRACK LENGTH–CYCLE DATA - Continued

(ba) Crack length versus cycles for overaged 7079 aluminum, specimen number 10-1T, first part

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.1580	120.0	36.0	12.000	11.98	75.500	64.400	T	Y	DRY RT AIR

FIRST PART OF TEST SPEC OVERLOADED AT 208,760 CYCLES

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.769	56.000	.953	116.000	1.328	177.000	1.990
10.000	.769	66.000	1.004	126.000	1.402	184.000	2.099
17.000	.786	76.000	1.062	136.200	1.501	193.000	2.270
23.000	.808	86.000	1.114	146.000	1.606	200.000	2.412
35.000	.855	96.000	1.177	157.700	1.735	207.000	2.587
45.000	.898	106.000	1.250	167.200	1.851		

(bb) Crack length versus cycles for overaged 7079 aluminum, specimen number 10-1T, second part

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.1580	120.0	36.0	12.000	11.98	75.500	64.400	T	Y	DRY RT AIR

SECOND PART OF TEST CRACK EXTENDED TO 2.738 IN BY SAWCUT SMAX REDUCED TO 11.0 KSI WHEN 2A=4.115

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
208.760	2.738	224.000	3.185	232.100	3.665	237.700	4.115
211.000	2.750	227.000	3.351	234.500	3.833	239.000	4.118
216.500	2.866	230.200	3.525	236.050	3.958	239.200	4.200
221.000	3.038						

(bc) Crack length versus cycles for overaged 7079 aluminum, specimen number 10-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.1598	120.0	36.0	12.000	12.00	75.500	64.400	T	Y	DIST WATER

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.105 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.754	75.100	1.514	111.500	2.767	128.000	4.001
12.000	.770	82.000	1.669	114.200	2.918	128.700	4.068
24.500	.841	89.000	1.852	117.250	3.106	128.850	4.105
34.000	.923	95.000	2.043	121.100	3.364	129.500	4.139
45.000	1.042	100.000	2.210	124.000	3.593	130.000	4.182
55.800	1.179	104.700	2.407	125.600	3.741	130.200	4.202
65.100	1.326	108.500	2.600	127.000	3.871		

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(bd) Crack length versus cycles for overaged 7079 aluminum, specimen number CNL-20

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2520	62.0	96.0	12.000	36.02	73.300	61.600	L	Y	DRY RT AIR

SMAX REDUCED TO 10.0 KSI WHEN 2A=11.610 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.400 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=12.225 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.790	106.300	2.720	153.250	7.220	164.400	10.430
10.000	.805	109.200	2.860	154.000	7.370	164.800	10.610
15.000	.835	112.000	3.010	154.750	7.535	165.200	10.790
20.000	.875	114.500	3.165	155.500	7.700	165.600	10.980
27.000	.930	117.000	3.320	156.200	7.860	166.000	11.180
32.000	.985	119.600	3.485	157.000	8.075	166.400	11.380
37.000	1.030	122.400	3.685	157.500	8.185	166.800	11.610
45.000	1.120	125.200	3.895	158.100	8.345	167.300	11.675
55.400	1.260	127.500	4.080	158.600	8.470	168.200	11.895
63.000	1.385	130.000	4.285	159.100	8.630	168.600	12.010
69.000	1.510	132.200	4.485	159.600	8.760	169.300	12.225
73.400	1.605	134.200	4.670	160.100	8.920	170.000	12.275
77.500	1.700	136.100	4.860	160.600	9.075	170.500	12.325
83.000	1.845	139.200	5.190	161.100	9.235	171.000	12.390
87.400	1.965	141.500	5.440	161.600	9.395	171.050	12.400
90.300	2.075	143.700	5.715	162.000	9.535	172.000	12.475
93.400	2.185	145.700	5.990	162.500	9.695	172.800	12.470
97.000	2.330	148.000	6.330	163.100	9.910	174.400	12.575
100.000	2.445	149.900	6.615	163.600	10.100	174.500	12.595
103.200	2.580	151.900	6.965	164.000	10.260		

(be) Crack length versus cycles for overaged 7079 aluminum, specimen number 20-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2535	120.0	36.0	12.000	12.00	73.300	61.600	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.117 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.755	19.100	1.572	28.500	2.572	34.000	3.632
2.200	.771	21.000	1.724	29.800	2.763	34.700	3.837
6.200	.880	23.000	1.919	31.000	2.955	35.300	4.036
10.000	1.030	24.600	2.080	32.000	3.149	35.500	4.117
14.000	1.239	26.000	2.247	32.800	3.331	35.800	4.177
17.000	1.426	27.500	2.442	33.500	3.499	35.850	4.204

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(bf) Crack length versus cycles for overaged 7079 aluminum, specimen number 20-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2550	120.0	36.0	12.000	12.00	78.400	64.200	L	Y	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.102 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.753	28.000	1.763	37.500	2.973	40.000	3.776
2.000	.763	30.900	2.019	38.100	3.132	40.300	3.883
10.000	.917	33.300	2.279	38.600	3.274	40.600	4.006
15.000	1.089	35.000	2.511	39.000	3.399	40.800	4.102
19.000	1.258	36.000	2.680	39.400	3.541	41.000	4.124
22.000	1.411	36.800	2.821	39.700	3.660	41.400	4.243
25.000	1.571						

(bg) Crack length versus cycles for overaged 7079 aluminum, specimen number 20-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.2550	120.0	24.0	12.000	8.01	73.300	61.600	L	Y	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.746	13.000	1.200	22.000	1.805	28.000	2.424
2.000	.773	15.500	1.341	24.000	1.979	29.000	2.573
6.000	.890	18.000	1.500	25.500	2.127	29.600	2.678
10.100	1.064	20.000	1.644	27.000	2.303	30.300	2.809

(bh) Crack length versus cycles for overaged 7079 aluminum, specimen number 20-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.2550	120.0	36.0	12.000	12.00	74.600	61.400	T	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.112 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.781	130.000	1.092	248.500	1.734	342.000	3.231
10.000	.781	140.400	1.131	260.000	1.854	348.000	3.475
21.000	.785	152.000	1.176	270.000	1.876	351.000	3.637
31.000	.796	169.000	1.241	281.000	1.995	353.000	3.751
46.000	.825	179.000	1.291	290.000	2.116	355.000	3.880
64.000	.866	190.000	1.340	300.000	2.265	357.000	4.038
77.000	.913	200.000	1.391	310.000	2.432	357.800	4.112
87.500	.948	210.000	1.448	320.000	2.637	358.200	4.115
98.700	.975	220.200	1.519	328.000	2.867	358.800	4.153
109.500	1.018	230.400	1.586	335.200	3.016	359.500	4.196
120.000	1.054	240.000	1.662				

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA—Continued

(bi) Crack length versus cycles for overaged 7079 aluminum, specimen number 20-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.2550	120.0	36.0	12.000	12.00	74.600	61.400	T	Y	DIST WATER

SMAX REDUCED TO 11.0 KSI WHEN 2A=0.102 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.762	100.000	.981	194.400	2.409	223.000	3.863
10.000	.762	110.000	1.056	200.000	2.597	224.500	4.016
20.000	.776	120.500	1.151	204.200	2.748	225.000	4.059
30.000	.783	130.000	1.245	208.100	2.912	225.500	4.102
40.000	.799	140.000	1.368	212.000	3.109	225.700	4.107
50.000	.833	150.000	1.494	215.000	3.285	226.000	4.130
60.500	.870	160.180	1.682	217.000	3.408	226.500	4.166
70.000	.896	170.400	1.838	219.000	3.546	226.900	4.190
80.000	.920	180.000	2.040	221.000	3.690	227.000	4.200
90.000	.940	188.000	2.234				

(bj) Crack length versus cycles for overaged 7079 aluminum, specimen number CNL-50

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.4980	45.0	96.0	12.000	36.12	72.100	60.000	L	Y	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=5.890 IN
SMAX REDUCED TO 9.0 KSI WHEN 2A=7.425 IN
SMAX REDUCED TO 7.0 KSI WHEN 2A=10.390 IN
SMAX REDUCED TO 10.0 KSI WHEN 2A=6.335 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=8.785 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.410 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.775	40.000	3.830	49.100	7.425	58.200	10.790
8.500	.885	40.800	4.080	50.000	7.725	58.700	10.910
13.000	.970	41.500	4.300	50.500	7.950	59.250	11.050
16.000	1.080	42.000	4.465	51.000	8.075	59.800	11.220
19.000	1.280	42.800	4.730	51.500	8.285	60.200	11.345
22.000	1.470	43.600	5.040	52.000	8.515	60.600	11.480
23.000	1.555	44.400	5.440	52.300	8.635	61.000	11.610
25.500	1.745	44.700	5.590	52.600	8.785	61.400	11.750
27.500	1.925	45.300	5.845	53.200	8.925	61.800	11.910
30.000	2.190	45.600	5.975	53.700	9.130	62.100	12.020
32.000	2.425	45.900	6.115	54.250	9.320	62.400	12.130
33.000	2.555	46.200	6.285	54.750	9.530	62.700	12.240
34.000	2.690	46.500	6.335	55.300	9.800	63.000	12.380
35.100	2.830	47.000	6.510	55.600	9.930	63.100	12.410
36.000	2.950	47.500	6.720	55.900	10.035	63.400	12.480
37.000	3.110	47.800	6.835	56.300	10.215	63.800	12.580
38.000	3.285	48.300	7.055	56.600	10.390	63.900	12.610
38.900	3.535	48.800	7.275	57.500	10.575		

TABLE III.–FATIGUE-CRACK LENGTH–CYCLE DATA–Continued

(bk) Crack length versus cycles for overaged 7079 aluminum, specimen number 50-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5010	120.0	36.0	12.000	12.01	72.100	60.000	L	N	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.108 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.744	18.000	1.523	27.000	2.566	31.700	3.586
1.700	.763	20.000	1.697	28.000	2.747	32.400	3.816
6.000	.875	21.500	1.850	28.800	2.908	32.900	4.000
10.000	1.021	23.000	2.010	29.500	3.053	33.150	4.108
13.000	1.175	24.500	2.197	30.200	3.202	33.500	4.194
15.500	1.337	26.100	2.427	31.100	3.434	33.525	4.201

(bl) Crack length versus cycles for overaged 7079 aluminum, specimen number 50-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5030	120.0	36.0	12.000	12.01	75.700	62.200	L	N	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=0.017

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.782	21.000	1.351	34.000	2.337	39.500	3.568
2.600	.801	25.000	1.574	35.500	2.579	40.000	3.800
7.000	.876	28.000	1.767	36.500	2.732	40.400	4.017
12.500	1.024	30.500	1.983	37.500	2.940	41.179	4.257
17.000	1.191	32.500	2.171	38.500	3.126		

(bm) Crack length versus cycles for overaged 7079 aluminum, specimen number 50-3L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.5015	120.0	24.0	12.000	7.99	72.100	60.000	L	N	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.764	13.000	1.154	21.000	1.595	29.600	2.343
1.500	.772	14.600	1.224	23.000	1.723	31.000	2.500
5.500	.859	16.700	1.326	25.000	1.899	32.500	2.714
10.000	1.021	19.000	1.454	27.600	2.148	33.000	2.796

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(bn) Crack length versus cycles for overaged 7079 aluminum, specimen number 50-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.5020	120.0	36.0	12.000	12.01	72.800	60.100	T	N	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=6.165 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.764	100.300	.981	200.000	1.626	266.250	3.143
11.200	.772	110.700	1.026	210.000	1.744	268.000	3.267
20.400	.778	120.200	1.067	220.000	1.873	270.000	3.416
30.500	.780	130.000	1.129	231.900	2.060	271.000	3.510
40.000	.795	140.600	1.170	240.000	2.218	272.500	3.712
50.000	.818	150.000	1.226	250.000	2.461	273.600	3.862
60.000	.832	160.000	1.290	258.000	2.726	275.000	4.086
70.000	.877	170.000	1.368	262.000	2.892	275.350	4.165
80.000	.910	180.000	1.441	264.000	3.009	275.800	4.200
90.000	.943	190.000	1.549				

(bo) Crack length versus cycles for overaged 7079 aluminum, specimen number 50-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.5030	120.0	36.0	12.000	12.00	72.800	60.100	T	N	DIST WATER

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.117 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.746	70.000	1.169	130.000	2.300	151.100	3.420
10.100	.752	80.000	1.293	134.000	2.446	153.100	3.619
20.000	.812	90.000	1.429	138.000	2.603	154.900	3.856
30.000	.835	100.300	1.602	142.000	2.778	156.500	4.080
40.400	.897	110.000	1.789	145.000	2.936	156.650	4.117
50.000	.977	118.000	1.968	147.500	3.108	157.000	4.210
61.100	1.082	126.000	2.191				

(bp) Crack length versus cycles for overaged 7079 aluminum, specimen number CNL-60

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6300	40.0	96.0	12.000	36.31	73.900	61.700	L	Y	DRY RT AIR

SMAX REDUCED TO 10.0 KSI WHEN 2A=12.020 IN
SMAX REDUCED TO 6.35 KSI WHEN 2A=12.410 IN
SMAX REDUCED TO 8.0 KSI WHEN 2A=12.250 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.790	44.000	4.430	49.800	8.525	51.150	12.020
10.000	.855	45.000	4.825	50.000	8.845	51.340	12.180
17.000	1.070	46.000	5.275	50.200	9.225	51.400	12.250
19.500	1.210	47.000	5.790	50.400	9.630	52.500	12.300
25.000	1.570	47.500	6.110	50.600	10.110	53.000	12.410
30.000	1.975	48.000	6.530	50.700	10.385	54.500	12.420
35.200	2.510	48.700	7.120	50.800	10.670	58.400	12.445
39.500	3.255	49.000	7.425	50.900	10.930	59.700	12.570
41.500	3.730	49.250	7.720	51.000	11.235	60.000	12.590
43.000	4.115	49.600	8.190	51.100	11.605	60.100	12.610

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Continued

(bq) Crack length versus cycles for overaged 7079 aluminum, specimen number 60-1L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6270	120.0	36.0	12.000	11.99	73.900	61.700	L	N	DRY RT AIR

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.113 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.799	20.000	1.595	30.000	2.682	34.000	3.552
2.500	.817	22.000	1.748	31.000	2.861	34.700	3.735
7.000	.904	24.000	1.947	31.800	3.037	35.300	3.954
12.000	1.100	26.400	2.175	32.500	3.209	35.700	4.113
15.000	1.258	28.500	2.456	33.200	3.351	36.150	4.202
17.500	1.405						

(br) Crack length versus cycles for overaged 7079 aluminum, specimen number 60-2L

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6340	120.0	36.0	12.000	12.02	77.600	63.800	L	N	-65 DEG

SMAX REDUCED TO 11.0 KSI WHEN 2A=3.134 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.785	23.000	1.446	34.500	2.416	38.650	3.134
3.000	.794	26.000	1.625	36.000	2.594	38.800	3.150
10.000	.929	29.000	1.855	37.500	2.790	38.975	3.198
16.000	1.121	32.500	2.185	38.500	3.083	39.000	3.193
20.000	1.290						

(bs) Crack length versus cycles for overaged 7079 aluminum, specimen number 60-3L

R	T-IN	CPM,	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.05	.6289	120.0	24.0	12.000	8.01	73.900	61.700	L	N	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.724	13.200	1.094	24.100	1.708	33.500	2.616
2.000	.736	16.000	1.229	27.200	1.957	34.000	2.736
6.000	.827	18.800	1.373	29.300	2.155	34.400	2.834
10.000	.961	21.500	1.537	33.000	2.516		

TABLE III.—FATIGUE-CRACK LENGTH—CYCLE DATA - Concluded

(bt) Crack length versus cycles for overaged 7079 aluminum, specimen number 60-1T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.6280	120.0	36.0	120.000	12.01	74.100	60.800	T	N	DRY RT AIR

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.763	94.000	.922	196.500	1.374	292.500	2.476
10.000	.763	105.000	.961	211.500	1.488	302.000	2.731
20.000	.763	116.000	.992	220.000	1.541	307.500	2.924
27.000	.774	126.400	1.020	230.000	1.625	312.600	3.165
38.000	.790	137.800	1.065	240.000	1.705	318.100	3.618
49.000	.807	148.200	1.105	250.000	1.800	321.000	4.068
62.400	.830	159.000	1.146	260.000	1.911	321.250	4.117
72.000	.850	177.000	1.246	270.000	2.044	322.000	4.182
83.000	.879	184.500	1.284	280.500	2.232	322.150	4.205

(bu) Crack length versus cycles for overaged 7079 aluminum, specimen number 60-2T

R	T-IN	CPM	L-IN	SIG(MAX GROSS)	W-IN	F(U)-KSI	F(Y)-KSI	GRAIN	RESTRAINT	ENVIRONMENT
.67	.6330	120.0	36.0	12.000	12.01	74.100	60.800	T	N	DIST WATER

SMAX REDUCED TO 11.0 KSI WHEN 2A=4.107 IN

N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES	N KILOCYCLES	2A INCHES
0.	.774	70.000	1.351	120.000	2.499	135.200	3.784
8.600	.774	80.000	1.510	124.100	2.705	136.000	3.924
18.500	.801	90.000	1.710	127.100	2.873	136.500	4.029
29.000	.866	98.000	1.890	130.000	3.098	136.800	4.107
40.000	.964	104.000	2.041	132.000	3.293	137.000	4.126
50.000	1.077	109.000	2.160	133.000	3.422	137.300	4.197
60.000	1.197	114.500	2.301	134.000	3.563		

TABLE IV.–FRACTURE-TOUGHNESS DATA FOR CENTER-CRACKED 7079 ALUMINUM ALLOY

(a) Underaged heat treatment

Specimen (a)	t, in.	Temp, °F	W, in.	$\dot{\sigma}_g$ ksi/sec	2a, in.	$2a_{cr}$, in.	σ_g at pop-in, ksi	$\frac{\sigma_{net}}{YS}$ pop-in	σ_g ULT, ksi	$\frac{\sigma_{net}}{YS}$ ULT	$\frac{\sigma_g}{UTS}$	S, %	K_{Ic}, ksi$\sqrt{in.}$	K_c, ksi$\sqrt{in.}$	G_{Ic}, in.-lb/in.^{2}	G_c, in.-lb/in.^{2}	$\bar{w}$, in.	$\frac{\bar{w}}{t}$, in./in.	$\bar{K}_{Ic}$, ksi$\sqrt{in.}$	$\bar{K}_c$, ksi$\sqrt{in.}$	$\bar{G}_{Ic}$, in.-lb/in.^{2}	$\bar{G}_c$, in.-lb/in.^{2}
CNL-1U	0.160	68	36.00	0.98	12.970	15.10	28.0 26.8	0.620, .592	37.4	0.912	0.473	75	133.6, 127.9	198.0	1620, 1490	3920	1.250	7.800	136.5, 130.3	229.0	1660, 1513	5250
1U-1L	.158	70	12.04	.72	4.204	4.95	(b)	- - -	33.1	.796	.418	75	- - -	100.6	- - -	1012	0.321	2.030	- - -	110.8	- - -	1229
1U-2L	.159	-65	12.01	1.25	4.223	(c)	(b)	- - -	26.3	.550	.322	0	- - -	71.8	- - -	517	.150	.840	- - -	75.0	- - -	563
1U-3L	(d)	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
1U-1T	.159	74	12.02	.58	4.202	5.25	(b)	- - -	26.8	.743	.336	60	- - -	84.3	- - -	710	.274	1.720	- - -	90.5	- - -	819
1U-2T	.159	68	12.00	.73	4.200	5.25	(b)	- - -	29.8	.823	.374	70	- - -	93.4	- - -	873	.336	2.110	- - -	102.0	- - -	1042
CNL-2U	.255	72	36.25	.79	12.595	13.35	22.7	.544	23.4	.580	.302	30	106.5	113.9	1011	1298	.506	1.980	108.0	119.4	1040	1426
2U-1L	.254	73	12.00	1.09	4.201	5.30	29.1	.701	30.9	.868	.399	10	78.9	97.9	555	958	.373	1.470	80.8	108.0	582	1167
2U-2L	.256	-65	12.00	1.09	4.220	(c)	(b)	- - -	29.8	.684	.378	0	- - -	81.0	- - -	656	.231	.900	- - -	86.5	- - -	749
2U-3L	.256	75	8.03	.86	2.805	3.15	(b)	- - -	34.8	.899	.450	30	- - -	83.2	- - -	693	.270	1.050	- - -	92.8	- - -	861
2U-1T	.259	71	12.00	1.02	4.200	4.90	23.1	.588	24.9	.698	.319	20	62.6	74.7	350	558	.243	.940	63.7	79.8	361	636
2U-2T	.259	71	12.00	1.00	4.202	5.00	(b)	- - -	24.8	.703	.318	30	- - -	75.4	- - -	568	.247	.950	- - -	80.4	- - -	647
CNL-5U	.501	68	36.25	.74	12.600	15.00	(b)	- - -	15.3	.422	.204	30	- - -	80.4	- - -	646	.269	.540	- - -	82.3	- - -	678
5U-1L	.502	70	12.00	.94	4.204	(e)	24.9	.620	28.5	.709	.380	5	67.6	77.3	407	597	.245	.500	68.8	82.9	422	688
5U-2L	.505	-65	12.01	1.03	4.201	(c)	(b)	- - -	22.8	.559	.309	0	- - -	62.0	- - -	385	.154	.310	- - -	64.9	- - -	421
5U-3L	.504	64	8.00	.64	2.798	3.55	23.7	.590	27.1	.788	.361	2	52.5	70.2	245	492	.205	.410	53.3	76.1	253	579
5U-1T	.504	87	12.01	.92	4.197	4.50	18.5	.484	19.6	.532	.261	2	50.1	55.3	224	306	.141	.280	50.7	57.5	229	331
5U-2T	.504	82	12.01	1.02	4.230	4.80	18.2	.479	19.0	.540	.254	2	49.6	56.2	219	316	.146	.290	50.1	58.5	224	342
CNL-6U	.628	68	36.00	.63	12.960	16.10	8.5	.197	17.4	.467	.217	1	40.6	96.0	147	921	.323	.514	40.7	98.7	148	975
6U-1L	.634	74	12.02	.86	4.211	(e)	(b)	- - -	24.1	.550	.301	1	- - -	65.5	- - -	430	.150	.237	- - -	68.4	- - -	468
6U-2L	.634	-65	12.02	.80	4.258	(c)	(b)	- - -	26.4	.571	.323	0	- - -	72.0	- - -	520	.162	.255	- - -	75.4	- - -	569
6U-3L	.633	70	8.03	1.00	2.779	(e)	29.0	.658	29.3	.665	.366	0	64.0	64.5	364.0	416	.145	.229	65.2	68.7	379	472
6U-1T	.632	73	11.98	.94	4.217	5.15	10.7	.258	17.6	.483	.215	2	29.1	54.4	75.4	296	.115	.182	29.2	56.1	76	315
6U-2T	.632	72	12.00	.99	4.192	4.55	(b)	- - -	17.5	.441	.214	0	- - -	50.0	- - -	250	.097	.153	- - -	51.2	- - -	262

TABLE IV.–FRACTURE-TOUGHNESS DATA FOR CENTER-CRACKED 7079 ALUMINUM ALLOY – Continued

(b) Peak (T6) heat treatment

Specimen (a)	t, in.	Temp, °F	W, in.	$\dot{\sigma}_g$ ksi/sec	2a, in.	$2a_{cr}$, in.	σ_g at pop-in, ksi	$\frac{\sigma_{net}}{YS}$ pop-in	σ_g ULT, ksi	$\frac{\sigma_{net}}{YS}$ ULT	$\frac{\sigma_g}{UTS}$	S, %	K_{Ic}, ksi $\sqrt{in.}$	K_c, ksi $\sqrt{in.}$	G_{Ic}, in.-lb/in.^{2}	G_c, in.-lb/in.^{2}	$\bar{w}$, in.	$\frac{\bar{w}}{t}$, in./in.	$\bar{K}_{Ic}$, ksi $\sqrt{in.}$	$\bar{K}_c$, ksi $\sqrt{in.}$	$\bar{G}_{Ic}$, in.-lb/in.^{2}	$\bar{G}_c$, in.-lb/in.^{2}
CNL-1P	0.157	72	35.97	0.97	12.600	(e)	15.7	0.327	20.6	0.429	0.259	50	73.7	96.6	485.	936.0	0.273	1.740	74.1	99.4	490	988
1P-1L	.158	71	11.97	1.01	4.208	4.88	28.4	.593	28.9	.661	.363	90	77.1	86.4	530.	746.0	.218	1.380	78.4	91.6	548	840
1P-2L	.159	-65	12.00	.91	4.266	(c)	(b)	- - -	19.0	.380	.227	3	- - -	52.0	- - -	270.0	.072	.450	- - -	53.1	- - -	282
1P-3L	.159	68	8.00	.89	2.800	3.05	25.9	.539	28.2	.614	.354	60	57.4	65.6	293.	431.0	.125	.790	58.2	69.1	301	478
1P-1T	.159	69	12.00	1.08	4.202	4.60	18.6	.406	19.7	.454	.246	50	50.5	56.7	227.	320.0	.103	.650	50.9	58.3	230	340
1P-2T	.159	68	12.00	.96	4.201	6.00	20.2	.440	21.9	.622	.273	50	54.8	76.0	267.	577.0	.185	1.160	55.3	79.8	272	636
CNL-2P	.252	76	36.75	.82	12.605	15.30	11.4	.234	16.2	.375	.201	30	53.4	86.1	254.	739.0	.215	.850	53.6	87.6	256	767
2P-1L	.254	70	12.00	1.08	4.210	5.40	(b)	- - -	23.3	.571	.290	15	- - -	74.4	- - -	552.0	.161	.630	- - -	77.6	- - -	602
2P-2L	.255	-65	12.00	1.01	4.200	(c)	22.1	.440	22.8	.454	.271	0	59.9	61.7	320.	381.0	.102	.400	60.5	63.6	326	404
2P-3L	.254	72	8.05	.94	2.813	3.30	(b)	- - -	26.2	.600	.326	20	- - -	64.4	- - -	414.0	.120	.470	- - -	67.5	- - -	456
2P-1T	.256	71	12.00	1.00	4.199	(e)	14.2	.302	17.7	.375	.216	10	38.7	47.9	132.	229.0	.070	.270	38.7	48.8	133	238
2P-2T	.255	75	12.00	1.03	4.210	4.50	(b)	- - -	17.9	.397	.219	10	- - -	50.8	- - -	258.0	.078	.310	- - -	51.9	- - -	269
CNL-5P	.499	69	36.21	1.09	12.610	14.20	7.9	.169	11.7	.269	.149	1	37.1	59.1	123.	350.0	.109	.220	37.2	59.7	123	357
5P-1L	.500	71	12.00	1.01	4.230	4.90	13.4	.289	15.7	.371	.200	2	36.5	47.0	119.	221.0	.069	.140	36.6	47.8	120	229
5P-2L	.503	-65	12.01	1.04	4.203	(c)	12.0	.246	15.9	.326	.196	0	32.6	43.2	94.	186.0	.053	.100	32.6	43.7	95	191
5P-3L	.502	71	8.01	.84	2.806	2.93	17.4	.375	19.9	.439	.254	2	38.6	45.2	133.	205.0	.064	.130	38.8	45.3	134	217
5P-1T	.503	81	12.00	- - -	- - -	(f)	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
5P-2T	.503	89	12.00	1.00	4.192	4.80	(b)	- - -	12.8	.307	.161	1	- - -	37.7	- - -	142.0	.047	.090	- - -	38.2	- - -	146
CNL-6P	.629	66	36.25	- - -	11.000	(f)	- - -	- - -	12.0	.238	.150	0	- - -	52.0	- - -	271.0	.082	.130	- - -	52.4	- - -	274
6P-1L	.632	74	12.00	1.00	4.223	4.223	13.2	.282	19.5	.416	.243	5	36.0	53.3	115.	281.0	.086	.140	36.1	54.4	116	295
6P-2L	.632	-65	12.02	1.28	4.200	(c)	- - -	- - -	16.5	.336	.197	0	- - -	44.6	- - -	199.0	.056	.088	- - -	45.4	- - -	206
6P-3L	.630	70	8.00	.98	2.816	(e)	18.30	.391	20.1	.430	.251	2	40.6	44.7	147.	200.0	.061	.097	41.0	45.9	149	211
6P-1T	.633	72	12.00	.82	4.250	(e)	9.95	.220	10.8	.240	.135	1	27.3	29.7	65.8	87.7	.029	.045	27.2	29.9	66	89
6P-2T	.636	74	11.98	1.01	4.030	4.20	- - -	- - -	12.0	.263	.150	0	- - -	32.5	- - -	105.6	.034	.054	- - -	32.8	- - -	107

TABLE IV. – FRACTURE-TOUGHNESS DATA FOR CENTER-CRACKED 7079 ALUMINUM ALLOY – Concluded

(c) Overaged heat treatment

Specimen (a)	t, in.	Temp, °F	W, in.	$\dot{\sigma}_g$, ksi/sec	2a, in.	$2a_{cr}$, in.	σ_g at pop-in, ksi	$\frac{\sigma_{net}}{YS}$ pop-in	σ_g ULT, ksi	$\frac{\sigma_{net}}{YS}$ ULT	$\frac{\sigma_g}{UTS}$	S, %	K_{Ic}, ksi$\sqrt{in.}$	K_c, ksi$\sqrt{in.}$	G_{Ic}, in.-lb/in.^{2}	G_c, in.-lb/in.^{2}	$\bar{w}$, in.	$\frac{\bar{w}}{t}$, in./in.	$\bar{K}_{Ic}$, ksi$\sqrt{in.}$	$\bar{K}_c$, ksi$\sqrt{in.}$	$\bar{G}_{Ic}$, in.-lb/in.^{2}	$\bar{G}_c$, in.-lb/in.^{2}
CNL-1O	0.158	64	36.06	1.35	12.600	13.50	26.00	0.612	34.8	0.851	0.463	90	122.0	170.4	1328	2903.0	1.084	6.860	124.3	188.1	1377	3540
1O-1L	.158	74	11.98	.91	4.205	5.10	31.50	.743	31.7	.845	.421	95	85.5	98.0	651	951.0	.355	2.250	87.8	107.2	687	1148
1O-2L	.159	-65	11.99	1.01	4.200	(c)	(b)	- - -	22.0	.506	.279	20	- - -	60.0	- - -	360.0	.126	.790	- - -	62.1	- - -	386
1O-3L	.159	68	8.00	1.06	2.805	3.30	(b)	- - -	35.9	.937	.477	80	- - -	88.7	- - -	782.0	.292	1.830	- - -	99.4	- - -	99
1O-1T	.158	74	11.98	1.01	4.200	4.60	25.40	.607	25.7	.648	.341	80	68.9	73.9	423	546.0	.209	1.320	70.1	78.3	438	612
1O-2T	.160	72	12.00	1.05	4.202	4.56	(b)	- - -	25.1	.628	.333	60	- - -	71.7	- - -	514.0	.196	1.230	- - -	75.6	- - -	571
CNL-2O	.252	66	36.02	.87	12.595	14.20	(b)	- - -	23.5	.629	.321	70	- - -	119.7	- - -	1415.0	.594	2.350	- - -	125.5	- - -	1576
2O-1L	.254	73	12.00	.93	4.204	(e)	(b)	- - -	32.7	.815	.447	80	- - -	88.5	- - -	783.5	.327	1.290	- - -	97.1	- - -	944
2O-2L	.255	-65	12.00	1.05	4.243	(c)	19.50	.470	21.1	.507	.269	10	53.2	57.4	252	331.0	.127	.500	53.8	59.7	258	356
2O-3L	.255	77	8.01	.85	2.809	3.45	(b)	- - -	34.3	.977	.467	75	- - -	86.9	- - -	755.0	.317	1.240	- - -	98.5	- - -	970
2O-1T	.255	71	12.00	1.01	4.196	4.50	(b)	- - -	21.8	.567	.293	40	- - -	61.6	- - -	380.0	.160	.630	- - -	64.4	- - -	415
2O-2T	.255	72	12.00	1.07	4.200	5.10	20.30	.509	21.6	.610	.289	40	55.1	66.3	270	439.0	.185	.730	55.7	69.7	277	485
CNL-5O	.498	71	36.13	.95	12.610	13.30	(b)	- - -	15.6	.411	.217	20	- - -	75.8	- - -	575.0	.254	.510	- - -	77.5	- - -	602
5O-1L	.501	72	12.01	1.07	4.700	4.90	(b)	- - -	[g]32.2	.905	.447	30	- - -	96.5	- - -	930.0	.410	.820	- - -	107.4	- - -	1153
5O-2L	.503	-65	12.01	.98	4.257	(c)	(b)	- - -	15.8	.392	.209	2	- - -	43.1	- - -	185.0	.076	.150	- - -	44.0	- - -	194
5O-3L	.502	70	7.99	.99	2.796	2.96	25.80	.661	27.1	.717	.376	10	57.1	62.0	290	385.0	.170	.340	58.3	66.7	303	444
5O-1T	.502	80	12.01	1.03	4.200	4.50	(b)	- - -	17.7	.472	.243	2	- - -	50.3	- - -	253.0	.111	.220	- - -	51.8	- - -	268
5O-2T	.503	81	12.00	1.04	4.210	4.90	15.70	.402	17.3	.488	.238	2	42.6	51.8	162	268.0	.119	.240	43.0	53.6	165	288
CNL-6O	.630	70	36.31	1.24	12.610	(e)	8.08	.201	14.3	.355	.194	15	37.9	67.2	128	452.0	.189	.300	38.0	68.5	129	469
6O-1L	.627	71	11.99	1.06	4.202	4.80	20.60	.514	22.2	.599	.300	10	55.9	65.6	278	429.0	.179	.280	56.6	68.7	285	473
6O-2L	.634	-65	12.02	.93	3.193	(c)	(b)	- - -	20.8	.443	.268	0	- - -	47.8	- - -	229.0	.090	.140	- - -	49.4	- - -	244
6O-3L	.629	68	8.01	.89	2.834	3.05	20.70	.519	23.4	.610	.317	5	46.1	54.8	189.0	295.0	.124	.197	46.8	57.3	195	328
6O-1T	.628	76	12.01	.95	4.205	4.30	11.80	.299	15.7	.402	.212	2	32.0	43.1	91.4	186.0	.080	.128	32.2	44.1	92	195
6O-2T	.633	77	12.01	.91	4.197	5.00	(b)	- - -	16.0	.451	.216	2	- - -	48.7	- - -	237.0	.102	.160	- - -	49.9	- - -	249

[a] Letters T and L indicate grain direction.

[b] No pop-in indicated by accelerometer.

[c] Slow crack growth measurements not taken at -65°F.

[d] Panel failed because of malfunction in test equipment.

[e] Critical crack length missed on film record.

[f] Panel failed during fatigue cycling.

[g] Previously loaded to 30.2 ksi and unloaded.

TABLE V. – FRACTURE-TOUGHNESS DATA FOR SURFACE-FLAWED 7079 ALUMINUM ALLOY [a]

Specimen	Temp, °F	Relative humidity, %	$\dot{\sigma}_g$, ksi/sec	σ_g, ksi	σ_g/UTS	σ_g/YS	b, in.	$\frac{b}{2c}$	K_{Ic}, ksi$\sqrt{in.}$	G_{Ic}, in.-lb/in.^{2}	K_{Ic}, ksi$\sqrt{in.}$	G_{Ic}, in.-lb/in.^{2}
6U-11 longitudinal grain, underaged	72	32	0.78	52.3	0.654	0.777	0.32	0.216	39.3	138	49.2	215
6P-11 longitudinal grain, peak (T6)	72	29	.93	55.4	.691	.766	.35	.236	42.7	162	53.3	253
6O-11 longitudinal grain, overaged	78	47	.90	46.2	.625	.748	.35	.236	37.0	122	44.6	178

[a]W = 4.5 in.,
t = 0.63 in.

TABLE VI.–CHEMICAL ANALYSES OF 7079 ALUMINUM ALLOY BY MANUFACTURER AND BOEING

Thickness, in.	Mn, wt %	Si, wt %	Cr, wt %	Cu, wt %	Zn, wt %	Ti, wt %	Fe, wt %	Mg, wt %	Ni, wt %	Al, wt %
Manufacturer's analysis										
0.16	0.21	0.10	0.16	0.62	4.66	0.05	0.14	3.48	0.03	Balance
.25	.18	.07	.18	.69	4.52	.04	.16	3.50	.02	
.50	.21	.10	.16	.62	4.66	.05	.14	3.48	.03	
.63	.18	.07	.18	.69	4.52	.04	.16	3.50	.02	Balance
Boeing's analysis										
.16	.20	.08	.18	.55	4.70	<.01	.15	3.36	(a)	Balance
.25	.17	.07	.19	.60	4.72		.14	3.60	(a)	
.50	.20	.07	.18	.55	4.71		.14	3.32	(a)	
.63	.16	.06	.22	.56	4.62	<.01	.12	3.51	(a)	Balance

[a] No nickel content recorded.

TABLE VII.–VERIFICATION TENSILE PROPERTIES FOR 7079 ALUMINUM ALLOY

(a) Underaged heat treatment

Specimen (a)	Test temp, °F	UTS, ksi	YS, ksi	Elongation (2 in.), %	RA, %
0.16-in. thickness					
1U-3T	69	79.8	64.9	14.0	23.0
1U-4T	70	79.8	64.7	14.0	25.0
1U-5T	73	79.5	63.4	14.0	22.0
Average		79.7	64.3	14.0	23.3
1U-4L	73	79.0	70.4	14.0	25.0
1U-5L	74	79.2	71.1	13.0	22.0
1U-6L	74	79.4	70.6	13.0	24.0
Average		79.2	70.7	13.3	23.7
1U-7L	-65	82.3	75.0	14.0	21.0
1U-8L	-65	81.7	73.7	14.0	25.0
1U-9L	-65	81.4	73.4	14.0	25.0
Average		81.8	74.0	14.0	23.7
0.25-in. thickness					
2U-3T	RT	78.1	60.5	16.0	25.0
2U-4T	RT	77.7	60.4	15.0	24.0
2U-5T	RT	78.5	60.4	17.0	24.0
Average		78.1	60.4	16.0	24.3
2U-4L	RT	77.4	64.2	17.0	27.0
2U-5L	RT	77.6	63.8	17.0	25.0
2U-6L	RT	77.6	63.8	17.0	27.0
Average		77.5	63.9	17.0	26.3
2U-7L	-65	79.0	67.2	17.0	24.0
2U-8L	-65	78.8	67.4	17.0	27.0
2U-9L	-65	78.6	66.9	18.0	24.0
Average		78.8	67.2	17.3	25.0

TABLE VII.–VERIFICATION TENSILE PROPERTIES FOR 7079 ALUMINUM ALLOY – Continued

(a) Underaged heat treatment – Concluded

Specimen (a)	Test temp, °F	UTS, ksi	YS, ksi	Elongation (1 in.), %	RA, %
0.50-in. thickness					
5U-3T	RT	74.6	58.2	18.0	32.0
5U-4T	RT	75.1	59.1	17.0	31.0
5U-5T	RT	75.1	58.8	17.0	29.0
Average		74.9	58.7	17.3	30.7
5U-4L	RT	75.0	61.4	17.0	34.0
5U-5L	RT	75.6	61.9	18.0	35.0
5U-6L	RT	74.4	62.0	17.0	36.0
Average		75.0	61.8	17.3	35.0
5U-7L	–65	75.7	63.7	17.0	32.0
5U-8L	–65	75.1	62.2	16.0	33.0
5U-9L	–65	75.2	63.0	16.0	34.0
Average		75.3	63.0	16.3	33.0
0.63-in. thickness					
6U-3T	RT	80.3	63.3	16.0	25.0
6U-4T	RT	80.3	63.9	16.0	24.0
6U-5T	RT	[b] 85.2	[b] 64.7	[b] 16.0	[b] 24.0
Average		80.3	63.6	16.0	24.5
6U-4L	RT	80.5	67.8	17.0	32.0
6U-5L	RT	80.0	67.6	16.0	31.0
6U-6L	RT	79.6	66.9	16.0	25.0
Average		80.0	67.4	16.3	29.3
6U-7L	–65	81.5	70.6	16.0	26.0
6U-8L	–65	82.0	71.2	16.0	26.0
6U-9L	–65	81.3	72.4	15.0	23.0
Average		81.6	71.4	15.7	25.0

TABLE VII.–VERIFICATION TENSILE PROPERTIES FOR 7079 ALUMINUM ALLOY – Continued

(b) Peak age (T6) heat treatment

Specimen (a)	Test temp, °F	UTS, ksi	YS, ksi	Elongation (2 in.), %	RA, %
0.16-in. thickness					
1P-3T	RT	77.6	68.4	11.0	24.0
1P-4T	RT	81.5	71.7	11.0	25.0
1P-5T	RT	81.2	71.4	11.0	25.0
Average		80.1	70.5	11.0	24.7
1P-4L	RT	79.7	73.7	11.0	25.0
1P-5L	RT	79.6	74.3	11.0	24.0
1P-6L	RT	79.5	73.6	11.0	25.0
Average		79.6	73.9	11.0	24.7
1P-7L	–65	84.5	78.2	12.0	22.0
1P-8L	–65	82.3	76.1	12.0	25.0
1P-9L	–65	84.5	78.2	13.0	25.0
Average		83.8	77.5	12.3	24.0
0.25-in. thickness					
2P-3T	RT	81.8	72.4	12.0	24.0
2P-4T	RT	82.0	72.7	12.0	23.0
2P-5T	RT	81.8	71.9	12.0	24.0
Average		81.9	72.3	12.0	23.7
2P-4L	RT	80.6	74.3	13.0	28.0
2P-5L	RT	80.5	74.1	13.0	28.0
2P-6L	RT	80.2	73.6	13.0	27.0
Average		80.4	74.0	13.0	27.7
2P-7L	–65	84.8	78.3	15.0	24.0
2P-8L	–65	83.8	75.7	13.0	23.0
2P-9L	–65	83.9	77.7	14.0	25.0
Average		84.3	77.2	14.0	24.0

TABLE VII.–VERIFICATION TENSILE PROPERTIES FOR 7079 ALUMINUM ALLOY – Continued

(b) Peak-age (T6) heat treatment – Concluded

Specimen (a)	Test temp, °F	UTS, ksi	YS, ksi	Elongation (1 in.), %	RA, %
0.50-in. thickness					
5P-3T	RT	79.6	69.0	13.0	31.0
5P-4T	RT	79.3	69.5	13.0	29.0
5P-5T	RT	79.4	69.4	14.0	29.0
Average		79.4	69.3	13.3	29.7
5P-4L	RT	78.8	72.1	14.0	36.0
5P-5L	RT	78.0	70.8	14.0	35.0
5P-6L	RT	78.8	71.6	14.0	37.0
Average		78.5	71.5	14.0	36.0
5P-7L	–65	80.8	75.0	12.0	36.0
5P-8L	–65	81.0	74.4	14.0	34.0
5P-9L	–65	81.9	75.4	15.0	33.0
Average		81.2	74.9	13.7	34.3
0.63-in. thickness					
6P-3T	RT	79.3	69.0	12.0	23.0
6P-4T	RT	80.4	70.6	12.0	25.0
6P-5T	RT	79.8	70.0	11.0	24.0
Average		79.8	69.9	11.7	24.0
6P-4L	RT	80.9	73.4	13.0	35.0
6P-5L	RT	79.7	72.0	12.0	32.0
6P-6L	RT	79.6	71.8	12.0	29.0
Average		80.1	72.3	12.3	32.0
6P-7L	–65	84.5	74.5	12.0	28.0
6P-8L	–65	83.9	(c)	(c)	(c)
6P-9L	–65	82.7	76.4	13.0	24.0
Average		83.7	75.5	12.5	27.5

TABLE VII.–VERIFICATION TENSILE PROPERTIES FOR 7079 ALUMINUM ALLOY – Continued

(c) Overaged heat treatment

Specimen (a)	Test temp, °F	UTS, ksi	YS, ksi	Elongation (2 in), %	RA, %
0.16-in. thickness					
10-3T	RT	75.5	63.8	10.0	18.0
10-4T	RT	75.5	64.1	10.0	19.0
10-5T	RT	75.5	65.2	10.0	19.0
Average		75.5	64.4	10.0	18.7
10-4L	RT	75.0	65.2	12.0	27.0
10-5L	RT	75.6	65.4	11.0	23.0
10-6L	RT	75.3	65.2	12.0	26.0
Average		75.3	65.3	11.7	25.3
10-7L	–65	78.9	66.8	12.0	27.0
10-8L	–65	79.0	67.5	11.0	24.0
10-9L	–65	79.1	67.3	12.0	26.0
Average		79.0	67.2	11.7	25.7
0.25-in. thickness					
20-3T	RT	74.7	61.2	12.0	26.0
20-4T	RT	74.5	61.6	11.0	21.0
20-5T	RT	74.7	61.4	10.0	15.0
Average		74.6	61.4	11.0	21.0
20-4L	RT	73.5	61.5	13.0	31.0
20-5L	RT	73.4	61.7	12.0	22.0
20-6L	RT	73.1	61.6	12.0	30.0
Average		73.3	61.6	12.3	27.7
20-7L	–65	78.7	64.5	13.0	29.0
20-8L	–65	78.5	63.5	14.0	26.0
20-9L	–65	78.1	64.6	14.0	29.0
Average		78.4	64.2	13.7	28.0

TABLE VII.–VERIFICATION TENSILE PROPERTIES FOR 7079 ALUMINUM ALLOY – *Concluded*

(c) Overaged heat treatment – Concluded

Specimen (a)	Test temp, °F	UTS, ksi	YS, ksi	Elongation (1 in.), %	RA, %
0.50-in. thickness					
50-3T	RT	73.0	60.3	13.0	33.0
50-4T	RT	72.8	60.1	13.0	34.0
50-5T	RT	72.6	59.9	13.0	31.0
Average		72.8	60.1	13.0	32.7
50-4L	RT	72.3	60.3	15.0	38.0
50-5L	RT	72.2	60.1	15.0	41.0
50-6L	RT	71.8	59.7	15.0	41.0
Average		72.1	60.0	15.0	40.0
50-7L	–65	76.3	62.9	15.0	37.0
50-8L	–65	76.2	62.6	15.0	38.0
50-9L	–65	74.6	61.2	15.0	38.0
Average		75.7	62.2	15.0	37.7
0.63-in. thickness					
60-3T	RT	74.0	60.8	13.0	32.0
60-4T	RT	73.9	60.7	13.0	29.0
60-5T	RT	74.3	61.0	13.0	30.0
Average		74.1	60.8	13.0	30.0
60-4L	RT	74.0	61.9	14.0	38.0
60-5L	RT	74.1	61.9	14.0	38.0
60-6L	RT	73.7	61.4	15.0	39.0
Average		73.9	61.7	14.3	38.3
60-7L	–65	77.3	63.5	14.0	36.0
60-8L	–65	77.7	63.5	15.0	33.0
60-9L	–65	77.7	64.3	15.0	37.0
Average		77.6	63.8	14.7	35.3

[a] Letters T and L indicate grain direction.

[b] Sudden load change before failure. [c] Clamps stepped prior to yield.

TABLE VIII.–ADDITIONAL VERIFICATION TENSILE PROPERTIES FOR PEAK AND OVERAGED 7079 ALUMINUM ALLOYS [a]

Specimen	Thickness, in.	Test temp, °F	UTS, ksi	YS, ksi	Elongation (2 in.) %	RA, %
Peak-age (T6) heat treatment						
1-9	0.160	72	79.8	70.0	13.0	25.0
1-24	0.160	72	79.4	69.1	12.0	22.0
Average			79.6	69.6	12.5	23.5
2-5	0.250	72	80.4	69.9	12.0	19.0
6-3	0.630	71	80.6	72.7	11.0	25.0
6-24	0.630	70	81.1	71.9	11.0	24.0
Average			80.8	72.3	11.0	24.5
Overaged heat treatment						
1-6	0.160	72	74.1	61.7	12.0	24.0
1-10	0.160	72	73.3	61.0	12.0	23.0
Average			73.7	61.4	12.0	23.5
2-13	0.250	72	73.2	59.8	12.0	21.0
2-17	0.250	72	71.5	57.6	12.0	22.0
Average			72.4	58.7	12.0	21.5
5-16	0.500	72	71.6	58.4	13.0	32.0
5-24	0.500	71	71.6	58.7	12.0	30.0
Average			71.6	58.6	12.5	31.0
6-5	0.630	69	73.6	60.5	12.0	28.0
6-16	0.630	69	73.6	60.3	11.0	26.0
Average			73.6	60.4	11.5	27.0

[a]Transverse grain direction

TABLE IX.—COMPARISON OF VERIFICATION YIELD STRENGTH AND ESTIMATED RANGE OF YIELD STRENGTH, FROM AGING CURVES FOR 7079 ALUMINUM ALLOY

Thickness, in.	Peak Aging Time, hr	Transverse YS (aging curve), ksi	Estimated range from aging curve, 12.5 ± 2.5%, ksi-ksi	Verification transverse YS, ksi
Underaged heat treatment[a]				
0.16	4 (as received)	70.8	60.2-63.7	64.3
0.25	↑	70.0	59.5-63.0	60.4
0.50	↓	69.2	58.8-62.3	58.7
0.63	4 (as received)	71.6	60.9-64.4	63.6
Peak-age (T6) heat treatment[b]				
0.16	48	70.8	——	70.5
0.25	48	70.0	——	72.3
0.50	48	69.2	——	69.3
0.63	48	71.6	——	69.9
Overaged heat treatment[c]				
0.16	56	70.8	60.2-63.7	64.4
0.25	96	70.0	59.5-63.0	61.4
0.50	120	69.2	58.8-62.3	60.1
0.63	90	71.6	60.9-64.4	60.8

[a]250 °F

[b]Commercial practice, 250°F

[c]290°F

TABLE X.—PRECRACKED CHARPY TOUGHNESS DATA FOR 7079 ALUMINUM ALLOY

(a) Underaged heat treatment

Specimen (a)	Thickness, in.	Uncracked area, A_o, in.^{2}	Fracture, W_o, in.-lb	Impact toughness, W_o/A_o, in.-lb/in.^{2}
0.16-in. gage[b]				
1UT1	0.157	0 041	8.00	196
1UT2	.157	.044	9.10	207
1UT3	.157	.044	9.02	205
1UL4	.157	.042	12.12	286
1UL5	.157	.044	12.70	289
1UL6	.147	.041	11.35	278
0.25-in. gage[c]				
2UT1	0.161	0.043	15.55	362
2UT2	.162	.042	13.80	329
2UT3	.161	.042	14.55	346
2UL4	.161	.040	21.00	525
2UL5	.161	.046	24.20	526
2UL6	.160	.043	23.00	535
0.50-in. gage[c]				
5UT1	0.161	0.043	9.10	212
5UT2	.162	.043	8.85	206
5UT3	.162	.042	8.60	204
5UL4	.162	.043	12.35	287
5UL5	.162	.046	13.70	298
5UL6	.162	.043	12.75	296
0.63-in. gage[c]				
6UT1	0.161	0.048	14.90	310
6UT2	.162	.049	14.40	294
6UT3	.162	.005	1.00	220
6UL4	.162	.049	27.80	567
6UL5	.162	.048	28.00	583
6UL6	.162	.049	27.30	557

TABLE X.–PRECRACKED CHARPY TOUGHNESS DATA FOR 7079 ALUMINUM ALLOY – Continued

(b) Peak-age (T6) heat treatment (73°F test temperature)

Specimen (a)	Thickness, in.	Uncracked area, A, in.^{2}	Fracture energy, W_o, in.-lb	Impact toughness, W_o/A_o, in.-lb/in.^{2}
0.16-in. gage				
1PT1	0.158	0.040	5.80	145
1PT2	.157	.042	6.15	146
1PT3	.147	.042	6.10	145
1PL4	.157	.042	8.10	193
1PL5	.157	.040	7.80	195
1PL6	.147	.042	8.55	204
0.25-in. gage				
2PT1	0.161	0.043	8.90	207
2PT2	.161	.047	9.75	207
2PT3	.161	.042	8.55	204
2PL4	.162	.046	16.85	366
2PL5	.161	.044	15.70	357
2PL6	.161	.046	15.95	347
0.50-in. gage				
5PT1	0.162	0.045	6.90	153
5PT2	.162	.043	6.40	149
5PT3	.161	.045	6.80	151
5PL4	.162	.045	11.00	244
5PL5	.162	.045	10.75	239
5PL6	.162	.045	10.70	238
0.63-in. gage				
6PT1	0.161	0.050	6.55	131
6PT2	.160	.050	6.40	128
6PT3	.160	.049	6.50	133
6PL4	.162	.047	14.20	302
6PL5	.160	.047	13.95	297
6PL6	.161	.047	13.00	276

TABLE X.—PRECRACKED CHARPY TOUGHNESS DATA FOR 7079 ALUMINUM ALLOY— Concluded

(c) Overaged heat treatment (73°F test temperature)

Specimen (a)	Thickness, in.	Uncracked area, A_o, in.^{2}	Fracture energy, W_o, in.-lb	Impact toughness, W_o/A_o, in.-lb/in.^{2}
0.16-in. gage				
10T1	0.159	0.043	9.25	215
10T2	.159	.041	9.00	220
10T3	.159	.041	8.80	215
10L4	.159	.039	10.70	274
10L5	.159	.045	12.25	272
10L6	.158	.046	11.60	252
0.25-in. gage				
20T1	0.161	0.043	9.30	216
20T2	.161	.042	9.00	214
20T3	.162	.043	9.90	230
20L4	.161	.043	13.40	312
20L5	.161	.043	14.55	338
20L6	.162	.043	13.40	312
0.50-in. gage				
50T1	0.161	0.043	9.50	221
50T2	.161	.043	9.50	221
50T3	.161	.042	9.00	214
50L4	.161	.040	11.80	295
50L5	.161	.044	14.30	325
50L6	.161	.044	14.30	325
0.63-in. gage				
60T1	0.162	0.044	8.40	191
60T2	.161	.042	8.00	190
60T3	.161	.044	8.20	186
60L4	.161	.044	14.25	324
60L5	.161	.044	14.50	330
60L6	.161	.046	14.05	305

[a]Letters T and L indicate grain direction.
[b]76°F test temperature
[c]73°F test temperature

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