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INVESTIGATION TO DEVELOP A HIGH STRENGTH STRESS-CORROSION RESISTANT NAVAL AIRCRAFT ALUMINUM ALLOY

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INVESTIGATION TO DEVELOP A HIGH STRENGTH STRESS-CORROSION RESISTANCE NAVAL AIRCRAFT ALUMINUM ALLOY

Final Report

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FOREWORD

This report presents the results of work sponsored by the U.S. Naval Air Systems Command under Contract N00019-70-C-0118. Mr. R. Schmidt administered the program. This report covers the period December 16, 1969 through September 16, 1970.

SYNOPSIS

This report presents the results of an evaluation of three tempers of commercially fabricated alloy MA15 plate in 1" to 6" thickness. Compared at equal strengths, MA15 developed higher resistance to stress-corrosion cracking, greater resistance to exfoliation corrosion, higher toughness, and better fatigue performance than established commercial aluminum alloys. Compared at equal resistance to stress-corrosion cracking, MA15 developed substantially higher strength than established commercial aluminum alloys. Field testing of this material is recommended.

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INTRODUCTION

This contract is an extension of Contracts N00019-68-C-0146[1] and N00019-69-C-0292[2]. Work performed under the second contract indicated that alloys such as NAVAIR 4 (6% Zn, 2.5% Mg, 2.5% Cu, and 0.1% Zr) and NAVAIR 6 (6.5% Zn, 2.1% Mg, 2.5% Cu, and 0.1% Zr) would develop high strength in thick sections along with good resistance to stress-corrosion cracking. The purpose of the present investigation was to confirm the indicated strength and stress-corrosion characteristics on commercially fabricated plate material and to determine fracture toughness, fatigue, resistance to exfoliation corrosion, and anodic coating characteristics. These properties were compared with those of standard alloys.

MATERIAL AND PROCESSING

Material used in this investigation was 1", 2", 4" and 6" thick plate commercially fabricated from three 12" x 48" x ∿146" (7900-8200 lb) DC ingots according to the practices presented in Figures 1, 2 and 3. This alloy was assigned Alcoa Research Laboratories No. MA15. Remelt chemical analyses of samples taken from the plate are presented in Table 1.

One lot each of commercially fabricated 0.775" thick 7075-T651 plate, 2" thick 7075-T651 plate, 2" thick 7075-T7351 plate, and four lots of 5" thick 7079-T651 plate were tested for comparison purposes.

One lot of 2" thick 2024-T351 plate was also used as a control in the anodic coating experiments.

Chemical analyses of the commercial alloys are also presented in Table 1.

Macrostructures of the MA15 plate are presented in Figure 4. Structures of the one, two, and four inch thick plate are typical of the structures of 7XXX alloy plate and exhibit no unusual features. The six-inch thick plate, however, exhibits evidence of a twin columnar grain structure adjacent to and extending inward from the rolled surfaces.

The microstructures of the MA15 plate are presented in Figures 5 through 8. The grain structures of the one, two, and four-inch thick plate are similar to the structures of corresponding products of 7XXX alloy plate containing Cr, but because of the lower iron and silicon contents of MA15, the volume fracture of undissolved constituents in the MA15 is noticeably less. The grain structures at the interior of the six-inch thick plate are also comparable to those of thick 7XXX alloy plate. The twin columnar grain structure is visible near the rolled surfaces.

The significance of the twin columnar grain structure is not apparent at this time. This structure is observed infrequently in 7075 ingots and is observed more frequently in 2219 ingots and plate rolled from these ingots.

The degrees of recrystallization at various locations in the interior of the MA15 plate and adjacent to the rolled surfaces were determined by standard x-ray diffraction techniques. Relative ratings are presented in Table 2. The low degree of recrystallization prevalent in most locations of the experimental alloy plate is typical of commercial 7XXX alloy plate.

Phases detected in these locations using a Guinier x-ray camera are also presented in Table 2. Significantly, almost no

Al_2CuMg (S phase) was detected. The small amounts of Fe and Si impurities present in this material were in the form of Al_7Cu_2Fe and Mg_2Si, respectively.

TEST PROCEDURE

Tensile

Duplicate tension specimens were taken in the longitudinal, long-transverse, and short-transverse directions of the MA15, 7075, and 7079 plate and were tested. Standard .505" diameter specimens were used unless the thickness of the pieces prevented their use; then the largest possible standard specimens were used. Short-transverse specimens were taken midway between rolled surfaces. Longitudinal and long-transverse specimens were taken from the midplanes of the 0.775 inch, one-inch, and two-inch thick plate and equidistant between midplanes and rolled surfaces of the four-inch, five-inch, and six-inch thick plate. These locations correspond with those normally employed in quality control procedures for plate of the respective thicknesses. Longitudinal and long-transverse tensile properties using 1/8 inch diameter specimens taken adjacent to the rolling surfaces of the two, four, and six-inch thick MA15 plate were also determined.

Fracture Toughness

Critical stress intensity factors, K_{Ic}, of MA15-T7X1 and MA15-T7X2 in the L-W*, W-L*, and T-L* directions were determined

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* First letter refers to direction of stress; second letter refers to direction of crack propagation.
L = length (longitudinal); W = width (long-transverse);
T = thickness (short-transverse).

using duplicate size 1" or 3/4" compact fracture toughness specimens described in Figure 9. Similar specimens were used to determine the fracture toughness of 7075 and 7079 plate for comparison purposes. Specimen locations corresponded to those of the tension specimens.

Notch Toughness

Notch tensile strengths were determined in the longitudinal, long-transverse, and where possible, the short-transverse directions of most items of the MA15, 7075, and 7079 plate using the specimen described in Figure 10. Specimen locations corresponded to those of the tension specimens. The stress concentration factor of this specimen is 16 or greater. The ratio of notch tensile strength to yield strength was used as the criterion of notch toughness.

Fatigue

Smooth longitudinal fatigue specimens of two-inch thick MA15 plate in the T7X1 and T7X2 tempers were supplied to the U.S. Naval Research Laboratories for axial fatigue tests at a stress ratio of 0.25. The specimen is described in Figure 11. The U.S. Naval Research Laboratories are also determining the fatigue characteristics of 7075 and 7079 plate using the same specimen and stress ratio.

Exfoliation Corrosion

Resistance to exfoliation corrosion was determined using 4" x 9" samples from the one-inch thick MA15 plate. One half of each sample was machined to the midplane, and 0.10" was machined from the rolled surface of the other half. The specimens were exposed for two weeks in a salt spray test as described in Reference 3.

Anodic Coating Characteristics

Anodic coating characteristics of two-inch thick MA15-T7X1 plate were compared with those of two-inch thick 7075-T651 plate and two-inch thick 2024-T351 plate.

All coatings were applied to machined panels according to military specification MIL-A-8625C as amended March 13, 1969. Prior to anodizing the panels were solvent wiped and cleaned by immersion for 3 minutes at 150 F in a 50 g/l solution of Alkalume 13, a cleaner which is mildly alkaline, non-silicated, and highly fortified with surfactants.

Three types of coating were evaluated:

Type I Modified CrO_3 - 5% (52.0 g/l CrO_3) - 20 volts - 95 F - 30 minutes

Type II H_2SO_4 - Alumilite 204 - 15% H_2SO_4 - 12 asf - 70 F - 30 minutes

Type III H_2SO_4 Hard Coating - Alumilite 226 - 275 g/l H_2SO_4 - 36 asf - 40 F - 40 minutes

The Type I and Type II anodic coatings were sealed for 15 minutes in boiling 50 g/l sodium dichromate at pH = 5.8 and were not desmudged before testing. The Type III hard coatings were not sealed.

Stress-Corrosion Cracking

Resistance to stress-corrosion cracking in the longitudinal and long-transverse directions of MA15 plate in the T6X1 and T7X1 tempers as well as the resistance in the short-transverse direction of plate in all tempers was determined. One lot each of 0.775" thick and 2" thick 7075-T651 plate and four lots of 5" thick

7079-T651 plate were tested along with the MA15 plate for control and comparison.

Longitudinal and long-transverse tests were made with 1/8" diameter specimens stressed in constant strain fixtures as previously described.[1][2] Specimens were removed from the mid-plane of all of the plate, and additional specimens were removed adjacent to the surfaces of the 2", 4", and 6" plate.

Short-transverse tests of the one-inch thick MA15 plate and the 0.775 inch thick 7075-T651 plate were made with C-ring specimens as described in Reference 4.

Short-transverse tests of all of the thicker plates were made with the same specimens and stressing frames used to determine the resistances in the other directions. In addition to the 1/8 inch diameter specimens, 1/4 inch diameter specimens and stressing frames, as described in Figure 12, were used for the four-inch and six-inch thick MA15 plate. The larger specimens were tested in an effort to differentiate between stress-corrosion failures and mechanical failures resulting from a reduction in the cross section by corrosion.

Replicate specimens were stressed as indicated in Table 3. Sets of triplicate stressed specimens along with unstressed specimens were exposed in three environments: 3.5% NaCl solution by alternate immersion, inland industrial atmosphere at New Kensington, Pa., and the seacoast atmosphere at Point Judith, R.I. The alternate immersion test was conducted according to Federal Test Method 823 with the exception that the temperature and humidity of the laboratory atmosphere were not controlled.

Metallographic examinations were made of representative fractured specimens to determine whether stress-corrosion cracking was the origin of the fracture. Criteria used in the interpretations of these examinations are given in the appendix.

RESULTS

Tensile Properties

Tensile properties of the MA15 plate in the three tempers are presented in Table 4. Strength and ductility (per cent elongation and reduction in area) in each temper generally decreased with increasing thickness. Strength decreased and ductility generally increased in the order T6X1, T7X1, and T7X2.

Tensile properties adjacent to the rolling surfaces of the two, four, and six-inch thick MA15 plate were determined because we evaluated the stress-corrosion performance at these locations. The properties are presented in Table 5. Based on the similarity of the tensile properties of the two, four, and six-inch thick plate, the presence of the twin columnar grains had no discernible effect on the tensile properties. In the case of the two-inch and four-inch thick plates the strengths of the sub-surface specimens were comparable to the strengths of specimens taken from the interior, but the strengths of the sub-surface specimens from the six-inch thick plate were higher than the strengths of specimens taken from the quarter planes of that material.

Tensile properties of the 7075-T651 and 7075-T7351 plate are presented in Table 6, and tensile properties of 7079-T651 plate are presented in Table 7. All passed guaranteed minimum properties.

Fracture Toughness

Critical plane-strain stress intensity factors, K_{Ic}, of MA15-T7X1 and MA15-T7X2 are presented in Tables 8 and 9. All of the values were valid according to the latest recommendations of ASTM Committee E24 on fracture testing of metals. Toughness decreased with increasing plate thickness and increasing strength and decreased with respect to orientation in the order longitudinal, long-transverse, short-transverse.

Plane-strain fracture toughness of the four lots of 7079-T651 plate are presented in Table 10, and average K_{Ic} values are presented in Table 11. Toughness of the four lots was comparable.

K_{Ic} values for the 7075 plate are presented in Table 12. Toughness of 7075-T7351 slightly exceeded that of 7075-T651.

Notch Toughness

Notch tensile strength/yield strength ratios of the MA15, 7079, and 7075 plate are presented in Tables 13, 14 and 15, respectively. Notch toughness agreed qualitatively with plane-strain fracture toughness.

Fatigue

Fatigue tests are not complete, but available data are plotted in Figure 13 and tabulated in Table 16. Lives of MA15-T7X1 and T7X2 exceeded lives of 7075-T651 and 7079-T651 plate.

Exfoliation Corrosion

Samples of the one-inch thick MA15 plate in the T7X1 and T7X2 tempers showed no susceptibility to exfoliation corrosion at either the midplane or near the rolling surface. Samples of this plate in the T6X1 temper showed no evidence of exfoliation 10% below the rolling surface but exhibited mild exfoliation at the midplane. Photographs of corroded MA15 test panels along with samples illustrating the range of conditions exhibited by 7075-T651, 7075-T7651, and 7075-T3651 plate in a thickness range encompassing one inch are presented in Figures 14 through 17.

Anodic Coating Characteristics

The Type I, CrO_3 anodic coatings had a uniform grainy surface appearance as anodized. After dichromate sealing the MA15 and 7075 panels had a gray-tan color while the 2024 panel had a tan color. The Type II, H_2SO_4 anodic coatings had a less noticeable grainy surface appearance as anodized, and all panels, after dichromate seal, were yellow-gold in color. The Type III, H_2SO_4 hard anodic coatings, developed a uniform light-to-medium yellow-bronze color on alloy MA15, a uniform light gray color on alloy 7075, and a uniform medium gray color on alloy 2024.

To determine the quality of the anodic coating formed, the anodized specimens were tested according to the methods described in Military Specification A-8625c plus Amendment I. The alloys passed the anodic coating weight test for the three types of coatings formed. Tables 17, 18, and 19 list the minimum weight required for each type of coating, plus the coating weight determined. (See Note 1 on Table 17 for method of stripping the anodic coatings.) In all instances, the anodic coatings formed were equal to or thicker than required by the specification. The anodic coating thicknesses as determined metallographically are also presented in these tables.

The photomicrographs of the cross sections are shown in Figures 18 (CrO_3), Figure 19 (H_2SO_4), and Figure 20 (H_2SO_4 - Hard Coat). The anodic coatings are all uniform and do not reveal any weak spots in the coating. The MA15 alloy, Type III Hard Coat, was very uniform, apparently because of the low number of constituents that interfere with anodizing. This observation suggests the possibility that thinner Hard Coatings than usually applied to commercial alloys may provide adequate protection for MA15.

To determine the corrosion resistance of the Type I and Type II coatings, the anodized and sealed panels were tested according to the specification. (See Note 2, Table 17 for method of corrosion testing employing 5% Salt Spray for 336 hours.) Both the Type I and Type II coatings on the three alloys passed the test without any pits or corrosion developing.

The Type III-Hard Coatings, unsealed, were the only specimens tested for abrasion resistance. (See note Table 19 for abrasion test method.) The hard coated alloys surpassed the specifications as listed. The MA15 and 7075 were equal in weight loss with the 2024 loss being greater, but still well below the specification maximum of 40 mg.

Stress-Corrosion Cracking

Alternate Immersion Test

Stress-corrosion performance of MA15 during 84 days exposure in the 3.5% NaCl alternate immersion test is presented in Tables 20 through 23 and results of similar tests on 7075-T651 and 7079-T651 plate are presented in Tables 24 and 25.

Alloys 7075-T651 and 7079-T651 performed as expected. Almost all short-transverse orientation specimens of both alloys failed, even at low stresses. Some highly stressed long-transverse specimens of both alloys failed, and some highly stressed longitudinal specimens of alloy 7079-T651 failed.

MA15-T6X1 performed comparable to 7075-T651 and 7079-T651. Stress-corrosion resistance of short-transverse orientation specimens increased with increasing plate thickness, while stress-corrosion resistance of longitudinal and long-transverse orientation specimens decreased with increasing plate thickness. Corrosion attack was predominantly along grain and grain fragment boundaries, and secondary stress-corrosion cracks were evident. Fractured specimens were classified as Type 1 as discussed in the Appendix. The type of attack and the nature of the secondary cracks in a short-transverse orientation specimen are illustrated in Figures 21 and 22.

MA15-T7X2 developed resistance to stress-corrosion cracking and to intergranular corrosion in the alternate immersion tests which appears to nearly equal that of 7075-T73. Some 1/8" diameter short-transverse orientation specimens fractured during the test; metallographic examination of these long time failures revealed no evidence of stress-corrosion cracking but did reveal transgranular cracks emanating from corrosion pits. Fractured specimens were classified as Type 2 as discussed in the Appendix. Pitting and secondary cracks are illustrated in Figure 23.

MA15-T7X1 performed intermediate to 7075-T651 and 7075-T7351. Corrosion attack was predominantly interfragmentary with directional pitting also present, as illustrated in Figure 24.

Resistance to stress-corrosion cracking in longitudinal and long-transverse directions of all MA15-T7X1 plate was excellent, but performance of short-transverse orientation specimens depended on plate thickness. Interpretation of the test results was more difficult than in the case of the MA15-T6X1 and MA15-T7X2, and examples of all three categories of resistance to stress-corrosion cracking discussed in the Appendix were found.

No cracking was visible in short-transverse orientation C-rings from the one-inch thick MA15-T7X1 plate, but metallographic examination revealed evidence of incipient stress-corrosion cracking in two specimens stressed at 75% of the long-transverse yield strength (55 ksi).

Short transverse specimens from two-inch thick MA15-T7X1 plate stressed at 30 ksi failed by stress-corrosion cracking in less than 40 days. The nature of the cracking was variable. Metallographic examination of some specimens revealed many sites of characteristic stress-corrosion cracking, while metallographic examination of other specimens revealed cracks which followed both transgranular and intergranular paths. Figures 25, 26, and 27 illustrate different types of cracks in triplicate specimens exposed at 40 ksi.

Performance of the four-inch thick MA15-T7X1 plate was better than that of the two-inch thick plate. Only one specimen stressed at 30 ksi and lower fractured, and metallographic examination of that specimen revealed transgranular cracking and no evidence of intergranular stress-corrosion cracking. Moreover, evidence of stress-corrosion cracking in specimens which fractured at higher stresses was sparse. Only the use of extraordinarily painstaking examination revealed evidence of stress-corrosion cracking. Evidence of stress-corrosion cracking in the four-inch thick MA15-T7X1 plate is illustrated in Figure 28. This secondary crack appears to proceed along both a transgranular and intergranular path.

The six-inch thick MA15-T7X1 plate performed best. No specimens fractured at any stress level in less than 39 days, and metallographic examination failed to reveal evidence of stress-corrosion cracking in any of the fractured specimens. The nature of the secondary cracks in the six-inch thick MA15-T7X1 plate is presented in Figure 29.

Percentage losses in tensile strength of specimens exposed in the alternate immersion test are presented in Tables 26 through 29. Attempts to rank the different tempers of MA15 and to rate MA15 relative to the standard alloys were unsuccessful because the scatter in the data appeared to be larger than differences between alloys and tempers. The most important observation is that percentage losses in strength of the high copper MA15 alloy were not noticeably higher than percentage losses in strength of the lower copper 7075 and 7079.

Percentage losses in strength of stressed 1/8" diameter short-transverse orientation MA15 specimens were generally higher than losses of comparable unstressed specimens, but losses in strength of stressed 1/4" diameter specimens were generally equal to losses of comparable unstressed specimens.

New Kensington Atmosphere (Preliminary)

Stress-corrosion performance of MA15-T6X1 plate in the industrial atmosphere of New Kensington, Pa., is presented in Table 30. Short-transverse specimens stressed at 40 ksi and higher have failed, and longitudinal and long-transverse specimens taken adjacent to the rolled surface of the 6" thick plate have also failed.

Stress-corrosion performance of two-inch thick MA15-T7X1 plate in the New Kensington atmosphere is presented in Table 31. Short-transverse orientation specimens stressed to 75% of their yield strength have failed. All other specimens are intact.

No specimens of MA15-T7X1 in the other thicknesses or MA15-T7X2 in any thickness have failed during exposure in the New Kensington atmosphere for 161 days.

Stress-corrosion performances of 7075-T651 and 7079-T651 plate in the New Kensington atmosphere are presented in Tables 32 and 33. Short-transverse orientation specimens of 7075-T651 failed at 40 ksi and higher and similar specimens of 7079-T651 failed at 10 ksi and higher.

Point Judith Atmosphere (Preliminary)

Stress-corrosion performances of MA15 plate during the test in the seacoast atmosphere of Point Judith, R.I. are presented in Tables 34-37. Results of similar tests on 7075-T651 plate are presented in Table 38.

Performances of MA15-T6X1 and 7075-T651 were comparable to their performances in the alternate immersion test. At least one short-transverse specimens from each plate failed at a stress-level of 25 ksi.

Stress-corrosion resistance of MA15-T7X1 in the Point Judith atmosphere for 100 days was not as high as the stress-corrosion resistance in the New Kensington atmosphere for 161 days. Short-transverse, 1/8" diameter specimens of the 2-6" thick plate failed at stresses as low as 30 ksi. The 1/4" diameter specimens were not exposed with the other specimens.

DISCUSSION

Tensile Properties

Long-transverse yield strengths of MA15 plate along with typical strengths of alloy 7079-T651, 7075-T651, and 7075-T7351 plate are plotted versus thickness in Figure 30.

Throughout the thickness range the strength of MA15-T6X1 exceeds the strength of any of the commercial alloys.

In the range of one to two inch thickness, the strength of MA15-T7X1 is comparable with that of 7075-T651 and exceeds strengths of the other alloys. In thicker sections MA15-T7X1 is superior to any of the commercial alloys.

The strength of MA15-T7X2 exceeds that of 7075-T7351 at any thickness, is only slightly lower than that of 7079-T651 at thicknesses less than five inches and is comparable with the strength of this alloy at six-inch thickness.

The short-transverse elongation values for the T7X1 and particularly the T7X2 temper material compare favorably with those considered typical for 7079-T651 plate of equivalent thickness.

Fracture Toughness

Because fracture toughness is a function of both strength and plate thickness, comparisons of fracture toughness of different alloys should be made at the same thickness and strength level. Ample data regarding plane-strain fracture toughness of commercial aluminum plate in the thickness range 0.5-1.75 in. are available.[5][6] Bands encompassing these data are presented in Figure 31 for the L-W orientation and in Figure 32 for the W-L orientation. Data on one-inch thick and two-inch thick plate generated during this investigation are also plotted on these figures. Toughness of MA15 equalled or exceeded that of the best commercial alloys in the longitudinal (L-W) direction, and equalled that of the commercial alloys in the long-transverse (W-L) direction.

Few data on the fracture toughness of thick aluminum alloy plate are available, so the toughness of the four-inch and six-inch thick MA15 plate is best compared with the toughness of the four lots of five-inch thick 7079-T651 plate tested in this investigation. Fracture toughness and strength of these materials are plotted in Figures 33, 34, and 35. Both the four-inch thick and six-inch thick MA15 plate developed higher fracture toughness than five-inch thick 7079-T651 in the longitudinal (L-W) direction, and the four-inch thick MA15 developed higher fracture toughness than 7079-T651 in the transverse (W-L) and (T-L) directions.

These results indicate that on an equal strength comparison of similar products the plane-strain fracture toughness of MA15 is at least as high as that of commercially available plate in the transverse directions and may be higher in the longitudinal direction.

Notch Toughness

Ratios of the notch tensile strength ($K_t \geq 16$) over the yield strength of one-inch thick MA15-T6X1, T7X1, and T7X2 plate, two-inch thick MA15-T6X1 and T7X1 plate, and 7075-T651 plate are compared in Figures 36 and 37 with similar data for 5/8 to 1.5 in. thick commercial Al-Zn-Mg-Cu alloy plate. Comparison of data indicates that in the longitudinal and long-transverse directions, MA15 developed a greater ability than the commercial alloys to plastically deform in the presence of a stress raiser.

Notch tensile data in the short-transverse direction are sparse. Available notch tensile/yield strength ratios are plotted versus yield strength in Figure 38. These data indicate that the superior ability of MA15 to deform plastically in the presence of a stress raiser extends to the short-transverse direction.

Stress-Corrosion Cracking

Resistance to stress-corrosion cracking of commercial high strength aluminum alloys in some tempers may be highly dependent on grain structure and on the direction of stressing relative to the grain structure.[7] Alloy MA15 also showed this dependence in the T6X1 and T7X1 tempers. The relatively high resistance to stress-corrosion cracking of longitudinal and long-transverse orientation specimens of MA15-T6X1 decreased with increasing plate thicknesses while performance of short-transverse orientation specimens slightly increased with increasing plate thickness. This behavior is attributed to the progressive increase in grain directionality with increasing amount of reduction. Stress-corrosion performance of longitudinal and long-transverse orientation specimens of alloy MA15-T7X1 was excellent, but stress-corrosion performance of short-transverse orientation specimens depended strongly on section thickness. The following table epitomizes results of tests of the short-transverse stress-corrosion specimens of MA15-T7X1:

Plate Thick.	A.I. 84 Days		Pt. Judith 100 Days*		New Ken. 161 Days*	
	OK	SCC	OK	SCC	OK	SCC
1"	40 ksi	55 ksi	55 ksi	---	55 ksi	---
2"	25 ksi	30 ksi	25 ksi	30 ksi	40 ksi	51 ksi
4"	30 ksi	40 ksi	40 ksi	50 ksi	50 ksi	---
6"	48 ksi	---	30 ksi	40 ksi	48 ksi	---

OK = No stress-corrosion cracking detected in specimens exposed at this stress or lower.

SCC = Stress-corrosion cracking detected in specimens exposed at this stress.

--- = SCC not detected in specimens exposed at any stress level.

* = Preliminary results; expected to change with longer exposures.

Stress-corrosion performance generally decreased with decreasing thickness from 6" to 2", then appeared to increase at 1". Decrease in performance with decreasing thickness is attributed to an increase in grain directionality, while apparent higher performance of 1" thick plate is attributed to the use of C-rings rather than 1/8" diameter tensile bars.

These observations indicate that the resistance to stress-corrosion cracking of medium thickness MA15-T7X1 plate could be increased by using thinner ingot, thus reducing the grain directionality. Results of the fracture toughness tests indicate, however, that decreasing the amount of work decreases fracture toughness, so this approach is not recommended.

These observations further indicate that MA15-T7X1 could have a low resistance to stress-corrosion cracking across the parting plane in those types of die forgings in which a high degree of grain directionality is unavoidable. Longer second step precipitation heat treatment times were shown to provide higher resistance than presently afforded by the T7X1 temper. Additional work is needed, however, to determine the minimum second step precipitation heat treatment needed to impart a high resistance to stress-corrosion cracking in a material having a high degree of grain directionality.

The lower performance of the six-inch thick MA15-T7X1 plate in the Point Judith atmosphere relative to the performance in the alternate immersion test emphasizes the need for atmospheric exposures in stress-corrosion evaluations.

The 1/4" diameter and 1/8" diameter short-transverse orientation stress-corrosion specimens behaved differently. The larger specimens were included in the investigation in an effort to provide meaningful data in the event that excessive localized corrosion caused the 1/8" diameter specimens to fracture from mechanical overload. If susceptible to stress-corrosion cracking, however, they were expected to fracture during the 84 day test (such has been the previous experience with low-resistance alloys such as 7079-T6). The 1/4" diameter specimens of MA15-T6X1 did fail by stress-corrosion cracking, and mean failure times were only slightly longer than mean failure times of 1/8" diameter specimens. Only one 1/4" diameter specimen of MA15-T7X1 fractured**, although 1/8" diameter specimens fractured and most were diagnosed as stress-corrosion failures. These observations suggest that the particular 1/4" diameter specimen design combined with the particular stressing frame were not appropriate for testing intermediate resistance materials having a grain structure that is not highly directional.

CONCLUSIONS

Conclusions regarding the performance of MA15 are best expressed by the following tables comparing properties of MA15 in T6X1, T7X1, and T7X2 tempers with typical properties of commercial aluminum alloys. These conclusions are based on one lot of commercially fabricated plate and are subject to revision with additional experience and with results of longer atmospheric exposures of SCC test specimens.

** Specimen failed by corrosion outside the gage length under the protective coating.

T7X2 Temper

Property	Performance
Strength at 1"-2"	>7075-T7351
Strength at 6"	=7079-T651
K_{Ic}*	>Comm. Al Alloys
Exfoliation Resistance at 1"	=7075-T7351
Axial Fatigue at 2"	>7079-T651, 7075-T651
Short-Transverse SCC†	~7075-T7351

T7X1 Temper

Property	Performance
Strength at 1"-2"	>7075-T651
Strength at 6"	>7079-T651
K_{Ic}*	>Comm. Al Alloys
NTS/YS*	>Comm. Al Alloys
Exfoliation Resistance at 1"	=7075-T7651
Axial Fatigue at 2"	>7079-T651, 7075-T651
Short-Transverse SCC†	7075-T651<res.<7075-T7351
Anodic Coating Characteristics	=7075-T651

T6X1 Temper

Property	Performance
Strength at 1"-2"	>7075-T651
Strength at 6"	>>7079-T651
NTS/YS*	>Comm. Al Alloys
Exfoliation Resistance at 1"	7075-T651<res.<7075-T7651
Short-Transverse SCC†	=7075-T651, 7079-T651

* At equal strength and thickness.

† Based on 3.5% NaCl alternate immersion test and preliminary results of atmospheric exposures.

RECOMMENDATIONS

1. Produce and evaluate additional MA15 and generate service experience.

2. Increase second step precipitation heat treatment time for MA15-T7X1 to improve stress-corrosion performance.

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(6) J. G. Kaufman, R. L. Moore, P. E. Schilling, "Fracture Toughness of Structural Aluminum Alloys," presented at 1969 ASM Materials Engineering Congress, Fracture Mechanics in Engineering Design, Philadelphia, Pennsylvania, October 14, 1969.

(7) D. O. Sprowls and R. H. Brown, "What Every Engineer Should Know About Stress-Corrosion of Aluminum," Metal Progress, Vol. 81, No. 4, pp 79-85, 1962 and Vol. 81, No. 5, pp 77-83, 1962.

(8) B. W. Lifka and D. O. Sprowls, "Stress-Corrosion Testing of 7079-T6 Aluminum Alloy in Various Environments," STP 425, Symposium on Stress-Corrosion Testing published by ASTM (1967).

Table 1

CHEMICAL ANALYSES

Alloy	Specimen No.	Plate Thickness	Zn	Mg	Cu	Zr	Fe	Si	Ti	Cr	Mn
MA15	379068	1"	6.29	2.41	2.28	.14	.06	.04	.03	.00	.00
MA15	379069	2"	6.23	2.40	2.24	.13	.07	.04	.03	.01	.00
MA15	379070	4"	6.35	2.44	2.31	.13	.07	.04	.03	.01	.00
MA15	379071	6"	6.23	2.41	2.26	.13	.07	.04	.03	.01	.00
7075	315070	0.775"	Not Determined								
7075	379574 379575	2"	5.82	2.18	1.54	.00	.30	.09	.03	.20	.01
7079	373280	5"	4.60	3.28	.80	.00	.22	.12	.04	.16	.19
7079	373281	5"	4.60	3.45	.78	.00	.21	.10	.03	.16	.17
7079	373282	5"	4.56	3.50	.82	.00	.21	.13	.04	.17	.20
7079	373283	5"	4.63	3.37	.79	.00	.23	.12	.04	.16	.20
2024	344799	2"	.15	1.69	4.49	.00	.27	.14	.04	.01	.59

Table 2

RESULTS OF X-RAY DIFFRACTION EXAMINATIONS OF MA15-T7X1 PLATE

S. No.	Plate Thickness	Site Examined	Degree of Recrystallization	Phases Detected Al_7Cu_2Fe	M	Mg_2Si	Al_2CuMg
379068	1"	Midplane	Partial	X	X	X	
379069	2"	5/16" below surface	Almost complete	X	X	X	
	2"	Midplane	Partial	X	X	X	
379070	4"	5/16" below surface	Started	X	X	X	
	4"	Quarter-plane	Just started	X	X	X	
	4"	Midplane	Just barely started	X	X	X	
379071	6"	5/16" below surface	Just barely started	X	X	X	
	6"	Quarter-plane	Just barely started	X	X	X	*
	6"	Midplane	Just started	X	X	X	

X = Detected

* = Probable trace detected

M = $Mg(Zn\text{-}Cu\text{-}Al)_2$

Table 3

STRESS-CORROSION TEST SCHEDULE
NEW KENSINGTON, POINT JUDITH, AND 3.5% NaCl ALTERNATE IMMERSION

Material	Specimen Direction	Specimen Location†	Specimen Type	Unst.	10 ksi	25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
				Number of Specimens Exposed in Each Environment at Indicated Stress Levels						
1" thick MA15 and	L & LT	M	1/8" dia.	2	0	0	0	0	3	0
.775" thick 7075-T651	ST	M	"C" rings	0	0	3	3	3	3	0
2" thick MA15 and	L	M	1/8" dia.	2	0	0	0	0	3	0
2" thick 7075-T651	L*	S	1/8" dia.	2	0	0	0	0	3	0
	LT	M	1/8" dia.	2	0	0	0	0	3	3*
	LT*	S	1/8" dia.	2	0	0	0	0	3	3
	ST	M	1/8" dia.	1-2**	0	3	3	3	3	0
4" and 6" thick MA15	L	M	1/8" dia.	2	0	0	0	0	3	0
	L*	S	1/8" dia.	2	0	0	0	0	3	0
	LT	M	1/8" dia.	2	0	0	0	0	3	3*
	LT*	S	1/8" dia.	2	0	0	0	0	3	3
	ST	M	1/8" dia.	1-2**	0	3	3	3	3	0
	ST*	M	1/4" dia.	2	0	3	3	3	3	0
5" thick 7079-T651††	L	M	1/8" dia.	0	0	0	0	0	3	3
	LT	M	1/8" dia.	0	0	0	0	0	3	3
	ST	M	1/8" dia.	2	3	3	0	0	3	0

† M = Midway between rolled surfaces, S = adjacent to rolled surface.
* MA15 in T6X1 and T7X1 tempers only to be tested.
All three tempers of MA15 to be tested identically if not otherwise indicated.
** Two specimens in A.I, one specimen in New Kensington and Point Judith.
†† 7079-T651 not exposed in Point Judith.

Table 4

TENSILE PROPERTIES OF MA15 PLATE

Plate Thickness	Test Direction	T6X1 T.S. psi	T6X1 Y.S. psi	T6X1 % El. in 4D	T6X1 R of A %	T7X1 T.S. psi	T7X1 Y.S. psi	T7X1 % El. in 4D	T7X1 R of A %	T7X2 T.S. psi	T7X2 Y.S. psi	T7X2 % El. in 4D	T7X2 R of A %
1"	L	89.4	84.1	11.8	28	83.0	75.0	14.5	38	78.5	69.0	15.0	42
	L-T	87.3	81.2	12.0	27	81.6	73.6	13.0	32	77.3	67.8	14.0	35
2"	L	87.7	82.4	12.0	23	81.0	74.3	13.0	28	76.2	67.0	14.0	24
	L-T	85.4	79.3	10.5	18	81.7	73.7	10.3	22	76.7	66.4	12.0	26
	S-T	85.0	73.3	7.2	N.D.	80.3	67.6	9.0	N.D.	75.2	61.5	9.0	N.D.
4"	L	81.7	78.8	12.0	24	77.6	71.8	12.0	30	73.5	65.4	14.0	34
	L-T	85.2	78.0	6.2	8	80.3	71.3	8.0	10	75.5	64.4	9.0	14
	S-T	82.7	72.9	5.0	4	77.7	67.0	4.9	7	73.1	61.4	7.1	8
6"	L	80.7	76.9	8.2	12	76.4	69.6	9.0	16	72.3	63.4	11.0	23
	L-T	82.1	74.3	3.0	4	78.0	67.7	5.0	5	73.6	61.2	8.0	12
	S-T	78.7	70.3	2.5	2	74.1	64.2	3.5	6	70.9	58.6	5.5	8

NOTES:

N.D. = not determined.

T6X1 temper = SHT, Quenched, Stretched, PHT 4 hrs. 250 F Plant, + PHT 4 hrs. 335 F Lab.
T7X1 temper = SHT, Quenched, Stretched, PHT 4 hrs. 250 F + 9 hrs. 325-335 F Plant.
T7X2 temper = T7X1 temper plus 15 additional hours at 325 F in Lab.

Longitudinal and long-transverse direction properties are average of duplicate .505" dia. specimens taken from midplanes of 1" and 2" thick plate and from quarter-planes of 4" and 6" thick plate.

Short-transverse direction properties are average of duplicate .125" dia. specimens from 2" thick plate, .357" dia. specimens from 4" thick plate, and .505" dia. specimens from 6" thick plate.

Table 5

TENSILE PROPERTIES OF MA15 PLATE ADJACENT TO ROLLED SURFACES

Plate Thickness	Test Direction	T6X1 T.S. ksi	T6X1 Y.S. ksi	T6X1 % El. in 4D	T7X1 T.S. ksi	T7X1 Y.S. ksi	T7X1 % El. in 4D
2"	L	84.7	80.3	15	81.0	75.0	17
	L-T	86.2	79.5	14	82.7	73.8	12
4"	L	84.0	80.2	15	81.4	73.5	16
	L-T	85.0	78.3	13	81.1	71.7	10
6"	L	86.2	81.4	13	81.4	73.6	16
	L-T	85.7	78.0	14	80.6	70.2	16

NOTES: T6X1 temper = SHT, Quenched, Stretched, PHT 4 hrs. 250 F Plant, + PHT 4 hrs. 335 F Lab.
T7X1 temper = SHT, Quenched, Stretched, PHT 4 hrs. 250 F + 9 hrs. 325-335 F Plant.

Properties are average of duplicate 0.125" dia. specimens taken adjacent to the rolled surfaces.

Table 6

TENSILE PROPERTIES OF 7075 PLATE

S. No.	Plate Thickness	Temper	Test Direction	T.S. ksi	Y.S. ksi	% El. in 4D	R of A %
315070	0.775"	T651	L	89.2	81.6	12.5	17
			L-T	89.3	80.8	10.9	18
379574	2"	T651	L	84.5	76.8	10.0	11
			L-T	82.3	74.1	8.5	9
			S-T	74.2	64.7	2.0	N.D.
379575	2"	T7351	L	68.0	57.3	11.3	24
			L-T	67.0	56.5	10.5	16
			S-T	64.7	54.3	4.0	N.D.

NOTES:

Properties of 0.775" thick plate are average of duplicate 0.160" dia. specimens taken from midplane.

Longitudinal and long-transverse properties of two-inch thick plate are average of duplicate one-half inch dia. specimens taken from midplane.

Short-transverse tensile properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

Table 7

TENSILE PROPERTIES OF FOUR LOTS OF FIVE-INCH THICK 7079-T651 PLATE

S. No.	Test Direction	T.S. ksi	Y.S. ksi	% El. in 2"	R of A %
373280	L	73.4	66.4	12.5	20
	L-T	75.0	66.0	11.0	18
	S-T	70.0	60.6	4.7	7
373281	L	72.9	65.8	12.0	18
	L-T	74.9	65.2	10.2	15
	S-T	69.4	61.6	2.9	6
373282	L	72.6	65.7	12.0	21
	L-T	74.5	64.6	11.0	16
	S-T	68.9	60.5	3.2	7
373283	L	73.4	66.9	12.0	20
	L-T	75.2	65.5	10.8	16
	S-T	70.4	61.8	3.6	8
Average	L	72.8	66.2	12.1	20
	L-T	74.9	65.3	10.8	16
	S-T	69.7	61.1	3.6	7

NOTES:

Longitudinal and long-transverse properties are average of duplicate 1/2" dia. specimens taken from quarter planes.

Short-transverse properties are average of duplicate 1/2" dia. specimens taken midway between rolled surfaces.

Table 8

PLANE STRAIN FRACTURE TOUGHNESS OF MA15-T7X1 PLATE

Plate Thickness	Specimen Orientation†	Specimen Number	Specimen Thickness	Crack Length	$2.5\left[\frac{K_{Ic}}{Y.S.}\right]^2$		K_{Ic} ksi$\sqrt{in.}$	Y.S. ksi
1"	L-W	L1	1.00	1.05	0.51		33.9	
		L2	1.00	1.07	0.50		33.6	
						Avg.	33.8	75.0
	W-L	T1	1.00	1.06	0.37		28.4	
		T2	1.00	1.03	0.36		27.8	
						Avg.	28.1	73.6
2"	L-W	L3	1.00	0.98	0.50		33.1	
		L4	1.00	0.99	0.44		31.0	
						Avg.	32.0	74.3
	W-L	T3	1.00	1.01	0.31		25.8	
		T4	1.00	1.01	0.30		25.3	
						Avg.	25.6	73.7
	T-L	N45	0.75	0.73	0.40		27.0	
		N46	0.75	0.71	0.42		24.3	
						Avg.	25.6	67.6
4"	L-W	L3	1.00	0.94	0.48		31.5	
		L4	1.00	0.95	0.47		31.2	
						Avg.	31.4	71.9
	W-L	T3	1.00	0.99	0.28		23.8	
		T4	1.00	1.00	0.27		23.4	
						Avg.	23.6	71.3
	T-L	N45	1.00	0.97	0.29		21.9	
		N46	1.00	0.97	0.30		22.6	
						Avg.	22.2	64.7
6"	L-W	L3	1.00	0.94	0.35		26.0	
		L4	1.00	0.92	0.37		27.0	
						Avg.	26.5	69.6
	W-L	T3	1.00	0.99	0.30		23.6	
		T4	1.00	1.02	0.29		23.0	
						Avg.	23.3	67.7
	T-L	N45	1.00	0.96	0.29		21.1	
		N46	1.00	0.94	0.29		21.3	
						Avg.	21.2	62.1

NOTES: †For fracture toughness specimens; L = length, W = width, T = thickness. First letter is direction of stressing; second letter is direction of crack propagation.

Table 9

PLANE STRAIN FRACTURE TOUGHNESS OF MA15-T7X2 PLATE

Plate Thickness	Specimen Orientation†	Specimen Number	Specimen Thickness	Crack Length	$2.5\left(\frac{K_{Ic}}{Y.S}\right)^2$		K_{Ic} ksi$\sqrt{in.}$	Y.S. ksi
1"	L-W	L1	1.00	1.04	0.83		39.6	
		L2	1.00	1.05	0.85		40.3	
						Avg.	40.0	69.0
	W-L	T1	1.00	1.03	0.80		38.4	
		T2	1.00	1.01	0.71		36.0	
						Avg.	37.2	67.8
2"	L-W	L1	1.00	0.99	0.95		41.3	
		L2	1.00	0.98	0.89		40.0	
						Avg.	40.6	67.0
	W-L	T1	1.00	1.01	0.63		33.2	
		T2	1.00	0.98	0.61		32.8	
						Avg.	33.0	66.4
	T-L	N45	0.75	0.72	0.64		31.1	
		N46	0.75	0.73	0.57		29.2	
						Avg.	30.2	61.5
4"	L-W	L3	1.00	0.95	0.73		34.8	
		L4	1.00	0.97	0.85		37.5	
						Avg.	36.2	65.4
	W-L	T3	1.00	0.99	0.44		27.5	
		T4	1.00	0.97	0.51		29.6	
						Avg.	28.6	64.4
	T-L	N45	1.00	0.97	0.52		27.0	
		N46	1.00	0.96	0.50		26.6	
						Avg.	26.8	59.3
6"	L-W	L3	1.00	0.94	0.63		31.8	
		L4	1.00	0.96	0.71		33.8	
						Avg.	32.8	63.4
	W-L	T3	1.00	0.97	0.40		24.4	
		T4	1.00	0.97	0.39		24.3	
						Avg.	24.4	61.2
	T-L	N45	1.00	0.94	0.46		24.3	
		N46	1.00	0.95	0.53		26.1	
						Avg.	25.2	56.9

NOTES: †For fracture toughness specimens; L = length, W = width, T = thickness. First letter is direction of stressing; second letter is direction of crack propagation.

Table 10

PLANE STRAIN FRACTURE TOUGHNESS OF FIVE-INCH THICK 7079-T651 PLATE

S. No.	Specimen Orientation†	Specimen Number	Specimen Thickness	Crack Length	$2.5\left(\frac{K_{Ic}}{Y.S.}\right)^2$		K_{Ic} ksi√in.	Y.S. ksi
373280	L-W	L3	1.00	1.02	0.38		25.9	
		L4	1.00	1.01	0.37		25.5	
						Avg.	25.7	66.4
	W-L	T3	1.00	1.02	0.36		25.0	
		T4	1.00	1.06	0.39		26.2	
						Avg.	25.6	66.0
	T-L	N3	1.00	1.00	0.37		23.4	
		N4	1.00	0.99	0.33		21.9	
						Avg.	22.6	60.6
373281	L-W	L3	1.00	1.01	0.39		25.8	
		L4	1.00	1.02	0.41		26.7	
						Avg.	26.2	65.8
	W-L	T3	1.00	1.04	0.36		24.8	
		T4	1.00	1.05	0.42		26.6	
						Avg.	25.7	65.2
	T-L	N3	1.00	1.02	0.31		21.6	
		N4	1.00	1.02	0.30		21.5	
						Avg.	21.6	61.6
373282	L-W	L3	1.00	0.99	0.37		25.4	
		L4	1.00	1.01	0.36		24.8	
						Avg.	25.1	65.7
	W-L	T3	1.00	1.06	0.39		25.4	
		T4	1.00	1.00	0.36		24.4	
						Avg.	24.9	64.6
	T-L	N3	1.00	1.02	0.32		21.7	
		N4	1.00	1.02	0.31		21.3	
						Avg.	21.5	60.5
373283	L-W	L3	1.00	1.04	0.36		25.3	
		L4	1.00	1.01	0.36		25.5	
						Avg.	25.4	66.9
	W-L	T3	1.00	1.02	0.36		24.7	
		T4	1.00	1.05	0.37		25.0	
						Avg.	24.8	65.5
	T-L	N3	1.00	1.03	0.30		21.6	
		N4	1.00	1.02	0.31		21.8	
						Avg.	21.7	61.8

NOTES: †For fracture toughness specimens; L = length, W = width, T = thickness.
First letter is direction of stressing; second letter is direction of crack propagation.

Table 11

AVERAGE PLANE STRAIN FRACTURE TOUGHNESS
VALUES OF FOUR LOTS OF FIVE-INCH THICK 7079-T651 PLATE

Specimen Orientation	K_{Ic} ksi$\sqrt{\text{in.}}$	Y.S. ksi
L-W	25.6	66.2
W-L	25.3	65.3
T-L	21.9	61.1

Table 12

PLANE STRAIN FRACTURE TOUGHNESS OF TWO-INCH THICK 7075 PLATE

Temper	Specimen Orientation†	Specimen Number	Specimen Thickness	Crack Length	$2.5\left(\frac{K_{Ic}}{Y.S.}\right)^2$		K_{Ic} ksi$\sqrt{in.}$	Y.S. ksi
T651	L-W	L1	1.00	1.00	0.36		29.1	
		L2	1.00	1.01	0.36		29.0	
						Avg.	29.0	76.8
	W-L	T1	1.00	0.96	0.25		23.3	
		T2	1.00	0.98	0.26		24.0	
						Avg.	23.6	74.1
	T-L	N1	0.75	0.73	0.21		18.7	
		N2	0.75	0.73	0.22		19.1	
						Avg.	18.9	64.7
T7351	L-W	L1	1.00	0.97	0.66		29.4	
		L2	1.00	0.98	0.61		28.4	
						Avg.	28.9	57.3
	W-L	T1	1.00	0.98	0.46		24.3	
		T2	1.00	0.96	0.43		23.4	
						Avg.	23.8	56.5
	T-L	N1	0.75	0.73	0.33		19.6	
		N2	0.75	0.72	0.33		19.4	
						Avg.	19.5	54.0

NOTES: †For fracture toughness specimens; L = length, W = width, T = thickness. First letter is direction of stressing; second letter is direction of crack propagation.

Table 13

NOTCH TOUGHNESS OF MA15 PLATE

S. No.	Temper	Thickness	Test Direction	Y.S. ksi	NTS* Y.S.
379536	T6X1	1"	L	84	1.37
			L-T	81	1.27
379068-1	T7X1	1"	L	75	1.43
			L-T	74	1.41
379068-2	T7X2	1"	L	69	1.48
			L-T	68	1.49
379537	T6X1	2"	L	82	1.35
			L-T	79	1.28
			S-T	73	1.04
379069-1	T7X1	2"	L	74	1.43
			L-T	74	1.35
			S-T	68	1.28
379538	T6X1	4"	L	79	1.21
			L-T	78	0.93
			S-T	73	0.87
379070-1	T7X1	4"	L	72	1.33
			L-T	71	1.20
			S-T	67	1.00
379539	T6X1	6"	L	77	1.11
			L-T	74	0.93
			S-T	70	0.78
379071-1	T7X1	6"	L	70	1.23
			L-T	68	1.05
			S-T	64	1.04

NOTES:

* Ratio of notch tensile strength to yield strength. Properties are average of duplicate specimens.

Notch specimen illustrated in Figure 10.

Stress concentration factor ≥16.

Table 14

NOTCH TOUGHNESS OF FOUR LOTS OF FIVE-INCH THICK 7079-T651 PLATE

S. No.	Test Direction	Y.S.	NTS* / Y.S.
373280	L	66	1.25
	LT	66	1.29
	ST	61	1.09
373281	L	66	1.28
	LT	65	1.23
	ST	62	1.03
373282	L	66	1.33
	LT	65	1.28
	ST	61	1.09
373283	L	67	1.28
	LT	66	1.27
	ST	62	1.06
Average	L	66	1.28
	LT	65	1.27
	ST	61	1.07

NOTES:

* Ratio of notch tensile strength to yield strength. Properties are average of duplicate specimens.

Notch specimen illustrated in Figure 10.

Stress concentration factor >16.

Table 15

NOTCH TOUGHNESS OF 7075 PLATE

S. No.	Temper	Thickness	Test Direction	Y.S. ksi	NTS* / Y.S.
315070	T651	0.775"	L	82	1.23
			L-T	81	1.16
379574	T651	2"	L	77	1.29
			L-T	74	1.10
			S-T	65	0.81
379575	T7351	2"	L	57	1.47
			L-T	57	1.38
			S-T	54	1.07

NOTES:

* Ratio of notch tensile strength to yield strength. Properties average of duplicate specimens.

Notch specimen illustrated in Figure 10.

Stress concentration factor ≥ 16.

Table 16

FATIGUE OF MA15, 7075, AND 7079 PLATE

Cycles to Fail

Stress psi	7075-T651	7079-T651	MA15-T7X1	MA15-T7X2
70	17,000	12,000	28,000	14,000
60	--	--	78,000	40,000
50	58,000	70,000	186,000	99,000
45	--	--	180,000†	--
40	470,000	140,000	--	1,240,000*
35	1,300,000	--	--	--
30	1,000,000*	--	--	--
25	--	4,500,000†	--	--

NOTES:

$\frac{\text{Min. Stress}}{\text{Max. Stress}} = 0.25$

* Did not fail

† Test still running

Table 17

ANODIZING CHARACTERISTICS OF TYPE I, Cr_2O_3 ACID COATING

S. No.	Alloy & Temper	Coating Weight[1] Mg/Sq. Ft.	Coating Thickness Mils	Corrosion Resistance[2] 336 Hr. Salt Spray
Mil. Spec. A-8625C		200 Minimum	Min. 0.05 mils Max. 0.30 mils	<5 spots or pits, <1/32 inch diameter in 30 sq. in.
379069-1	MA15-T7X1	317	0.05	No pits.
379574	7075-T6	455	0.065	No pits.
344799	2024-T351	418	0.06	No pits.

NOTES: [1]Coating Weight - Test panels were immersed in phosphoric-chromic stripping solution at 180 F until anodic coating removed.

[2]Corrosion Resistance - 336 hours 5% salt spray with significant surface inclined 6 degrees from vertical.

TABLE 18

ANODIZING CHARACTERISTICS OF TYPE II, H_2SO_4 ACID COATINGS

S. No.	Alloy & Temper	Coating Weight mg/ft^2	Coating Thickness Mils	Corrosion Resistance 336 hr salt spray
Mil.Spec.A8625C		600 Minimum	Min. 0.10 mils Max. 1.00 mils	<5 spots or pits, <1/32 inch diameter in 30 sq. in.
379069-1	MA15-T7X1	2,700	0.44	No pits.
379574	7075-T651	2,724	0.44	No pits.
344799	2024-T351	1,932	0.39	No pits.

TABLE 19

ANODIZING CHARACTERISTICS OF TYPE III HARD COAT ANODIZING

S. No.	Alloy & Temper	Coating Weight mg/ft^2	Coating Thickness Mils	Abrasion Resistance* Weight Loss
Mil.Spec.A-8625C		4320 at 1.0 mil thick 8640 at 2.0 mil thick	Min. 0.50 mils Max. 4.50 mils	<40 milligrams
379069-1	MA15-T7X1	15,320	2.36	11.1 mg
379574	7075-T651	14,550	2.52	10.5 mg
344799	2024-T351	11,971	2.14	19.9 mg

NOTE:

* Taber Abrasion Test 10,000 cycles, 1,000 g load, 70 rpm using CS-17 sheels.

TABLE 20

STRESS-CORROSION PERFORMANCE OF ONE-INCH THICK MA15 PLATE IN THE ALTERNATE IMMERSION TEST

Specimen No.	Temper	Test Direction	Specimen Type	Days to Fracture After Exposure at Indicated Stress Level				
				25 ksi	30 ksi	40 ksi	75% Y.S.†	50% Y.S.
379536-5	T6X1	L	1/8" bars	--	--	--	OK,OK,OK	--
	T6X1	L-T	1/8" bars	--	--	--	84,OK,OK	--
	T6X1	S-T	"C" rings	8,8,8	3,4,4	3,3,3	2,2,2	--
379068-1	T7X1	L	1/8" bars	--	--	--	OK,OK,OK	--
	T7X1	L-T	1/8" bars	--	--	--	OK,OK,OK	OK,OK,OK
	T7X1	S-T	"C" rings	OK,OK,OK	OK,OK,OK	OK*,OK*,OK*	i,i,OK*	--
379068-2	T7X2	L	1/8" bars	--	--	--	OK,OK,OK	--
	T7X2	L-T	1/8" bars	--	--	--	OK,OK,OK	OK,OK,OK
	T7X2	S-T	"C" rings	OK,OK,OK	OK,OK,OK	OK*,OK*,OK*	OK*,OK*,OK*	--

NOTES:

Triplicate specimens exposed. Test terminated after 84 days.

Specimens removed midway between rolled surfaces.

† Short-transverse specimens stressed to 75% of the long-transverse yield strength.

--means no specimens exposed at that stress level.

i Specimens were intact at end of test, but metallographic examination revealed evidence of intergranular stress-corrosion cracking.

* Specimens were intact at end of test, and metallographic examination revealed no evidence of intergranular stress-corrosion cracking.

OK = Specimen intact at end of test.

TABLE 21

STRESS-CORROSION PERFORMANCE OF TWO-INCH THICK
MA15 PLATE IN THE ALTERNATE IMMERSION TEST

Specimen No.	Temper	Test Direction	Specimen Type	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level: 25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
379537-6	T6X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,17[i],84	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	OK,33[i],58[n]	OK,OK,OK
		S-T	1/8" bars	Mid.	5,4,14	3,3,3	2,3,4	2,3,3	--
379069-1	T7X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	84[t],OK,OK	OK,39[i],79	6[i],20[i],26[i]	10[i],14[i],20[t]	--
379069-2	T7X2	S-T	1/8" bars	Mid.	OK,OK,OK	OK,79,OK	OK,OK,OK	43[t],52[t],84	--

NOTES:

Triplicate specimens exposed. Test terminated after 84 days.

--means no specimens exposed at that stress level.

[n] No secondary cracks found.

[i] Metallographic examination revealed evidence of typical intergranular stress-corrosion cracking.

[t] Metallographic examination revealed transgranular cracking and no evidence of stress-corrosion cracking.

OK = Specimen intact at end of test.

TABLE 22

STRESS-CORROSION PERFORMANCE OF FOUR-INCH THICK MA15 PLATE IN THE ALTERNATE IMMERSION TEST

Specimen No.	Temper	Test Direction	Specimen Type	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level				
					25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
379538-6	T6X1	L	1/8" bars	Mid.	--	--	--	42,54[i],OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	8,11,20	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	6,29,OK	6,14,OK
		S-T	1/8" bars	Mid.	5,7,18	6,7,10	5,3,3	3,3,4	--
		S-T	1/4" bars	Mid.	19,35,OK	9,10,20	6,7,7	5,4,5	--
379070-1	T7X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	84[i],OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	OK,OK,OK	OK,75[t],OK	36[t],51[i],84	19[i],29[t],42[t]	--
		S-T	1/4" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--
379070-2	T7X2	S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	60[t],OK,OK	84,84,OK	--

NOTES:

Triplicate specimens exposed. Test terminated after 84 days.

--means no specimens exposed at that stress level.

[i] Metallographic examination revealed evidence of typical intergranular stress-corrosion cracking.

[t] Metallographic examination revealed transgranular cracking and no evidence of stress-corrosion cracking.

OK = Specimen intact at end of test.

TABLE 23

STRESS-CORROSION PERFORMANCE OF SIX-INCH THICK MA15 PLATE IN THE ALTERNATE IMMERSION TEST

Specimen No.	Temper	Test Direction	Specimen Type	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level 25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
379539-6	T6X1	L	1/8" bars	Mid.	--	--	--	30,34,84	--
		L	1/8" bars	Surf.	--	--	--	29,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	7,12,OK	--
		L-T	1/8" bars	Surf.	--	--	--	6,12,84	OK,OK,OK
		S-T	1/8" bars	Mid.	OK,OK,OK	8,OK,OK	6,6,6	3,4,5	6,84,84
		S-T	1/4" bars	Mid.	OK,OK OK	OK,OK,OK	10,12,14	2,2,6	--
379071-1	T7X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	42[t],OK,OK	--
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	63,84[s],OK	39[t],56[t,s],68	OK,OK,OK
		S-T	1/4" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	84[s],OK,OK	--
379071-2	T7X2	S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	75[t],OK,OK	--

NOTES:

Triplicate specimens exposed. Test terminated after 84 days.

--means no specimens exposed at that stress level.

t Metallographic examination revealed transgranular cracking and no evidence of stress-corrosion cracking.

s Failed at shoulder.

OK = Specimens intact at end of test.

TABLE 24

STRESS-CORROSION PERFORMANCE OF 7075-T651
PLATE IN ALTERNATE IMMERSION TEST

Specimen No.	Plate Thick.	Test Direction	Specimen Type	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level				
					25 ksi	30 ksi	40 ksi	75% Y.S.*	50% Y.S.
315070	0.775"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	29[i],OK,OK	--
		S-T	"C" rings	Mid.	3,3,3	2,2,3	2,2,2	2,2,2	--
379574	2"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	6,13,8	5,7,8	5,3,6	3,3,3	--

NOTES:

Triplicate specimens exposed. Test terminated after 84 days.

--means no specimens exposed at that stress level.

* Short-transverse specimens of 0.775" thick plate stressed to 75% of the long-transverse yield strength.

i Metallographic examination revealed evidence of typical intergranular stress-corrosion cracking.

OK = Specimen intact at end of test.

TABLE 25

STRESS-CORROSION PERFORMANCE OF FOUR LOTS OF FIVE-INCH THICK 7079-T651 PLATE IN THE 3.5% NaCl ALTERNATE IMMERSION TEST

Specimen No.	Test Direction	Specimen Type	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level: 10 ksi	25 ksi	75% Y.S.	50% Y.S.
373280	L	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	L-T	1/8" bars	Mid.	--	--	84,OK,OK	OK,OK,OK
	S-T	1/8" bars	Mid.	31,OK,OK	5,5,6	2,2,3	--
373281	L	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	L-T	1/8" bars	Mid.	--	--	8,84,OK	OK,OK,OK
	S-T	1/8" bars	Mid.	9,31,35	5,5,5	2,3,5	--
373282	L	1/8" bars	Mid.	--	--	14,OK,OK	OK,OK,OK
	L-T	1/8" bars	Mid.	--	--	14,16,OK	OK,OK,OK
	S-T	1/8" bars	Mid.	9,10,OK	5,5,5	3,3,5	--
373283	L	1/8" bars	Mid.	--	--	84,84,OK	OK,OK,OK
	L-T	1/8" bars	Mid.	--	--	9,84,OK	OK,OK,OK
	S-T	1/8" bars	Mid.	3,5,OK	5,5,7	3,5,OK	--

NOTES:

Triplicate specimens exposed. Test terminated after 84 days.

--means no specimens exposed at that stress level.

OK = Specimen intact at end of test.

Table 26

LOSS IN TENSILE STRENGTH OF SPECIMENS OF MA15-T6X1 PLATE EXPOSED IN 3.5% NaCl ALTERNATE IMMERSION TEST

					% Loss in Tensile Strength						
					Stressed as Indicated, Removed after 84 Days					Unstressed, Removed as Indicated	
S. No.	Plate Thick.	Specimen Diameter	Specimen Location	Specimen Orientation	25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.	33 Days	84 Days
379536-6	1"	1/8"	M	L	--	--	--	8	--	5	7
	1"	1/8"	M	LT	--	--	--	16	--	5	9
379537-6	2"	1/8"	M	L	--	--	--	11	--	11	5
	2"	1/8"	M	LT	--	--	--	43	20	10	8
	2"	1/8"	M	ST	F	F	F	F	--	27	24
	2"	1/8"	S	L	--	--	--	6	--	6	7
	2"	1/8"	S	LT	--	--	--	13	18	9	13
379538-6	4"	1/8"	M	L	--	--	--	26	--	14	14
	4"	1/8"	M	LT	--	--	--	F	25	15	15
	4"	1/8"	M	ST	F	F	F	F	--	20	33
	4"	1/4"	M	ST	F	F	F	F	--	11	9
	4"	1/8"	S	L	--	--	--	8	--	6	9
	4"	1/8"	S	LT	--	--	--	13	13	7	11
379539-6	6"	1/8"	M	L	--	--	--	F	--	12	20
	6"	1/8"	M	LT	--	--	--	24	28	12	28
	6"	1/8"	M	ST	38	32	F	F	--	21	36
	6"	1/4"	M	ST	14	23	F	F	--	10	8
	6"	1/8"	S	L	--	--	--	17	--	7	8
	6"	1/8"	S	LT	--	--	--	F	F	14	11

NOTES:

M = Midway between rolled surfaces
S = Adjacent to rolled surfaces

F = All specimens failed during exposure

-- = No specimens exposed

Table 27

LOSS IN TENSILE STRENGTH OF SPECIMENS OF MA15-T7X1 PLATE EXPOSED IN 3.5% NaCl ALTERNATE IMMERSION TEST

					% Loss in Tensile Strength						
					Stressed as Indicated					Unstressed	
					Removed after 84 Days					Removed as Indicated	
S. No.	Plate Thick.	Specimen Diameter	Specimen Location	Specimen Orientation	25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.	33 Days	84 Days
379068-1	1"	1/8"	M	L	--	--	--	5	--	3	4
	1"	1/8"	M	LT	--	--	--	11	--	9	4
379069-1	2"	1/8"	M	L	--	--	--	8	--	6	7
	2"	1/8"	M	LT	--	--	--	11	14	9	11
	2"	1/8"	M	ST	69	54	F	F	--	22	25
	2"	1/8"	S	L	--	--	--	6	--	4	3
	2"	1/8"	S	LT	--	--	--	15	14	8	9
379070-1	4"	1/8"	M	L	--	--	--	13	--	6	8
	4"	1/8"	M	LT	--	--	--	10	13	11	20
	4"	1/8"	M	ST	34	32	F	F	--	12	13
	4"	1/4"	M	ST	14	15	15	20	--	10	14
	4"	1/8"	S	L	--	--	--	15	--	0	8
	4"	1/8"	S	LT	--	--	--	45	13	6	12
379071-1	6"	1/8"	M	L	--	--	--	10	--	7	8
	6"	1/8"	M	LT	--	--	--	21	15	10	20
	6"	1/8"	M	ST	23	27	23	F		13	12
	6"	1/4"	M	ST	12	12	14	14		8	9
	6"	1/8"	S	L	--	--	--	15	--	5	5
	6"	1/8"	S	LT	--	--	--	22	14	12	11

NOTES:

F = All specimens exposed failed during exposure

M = Midway between rolled surfaces
S = Adjacent to rolled surface

-- = No specimens exposed

Table 28

LOSS IN TENSILE STRENGTH OF SPECIMENS OF MA15-T7X2 PLATE EXPOSED IN 3.5% NaCl ALTERNATE IMMERSION TEST

		% Loss in Tensile Strength					
		Stressed as Indicated				Unstressed	
	Plate	Removed after 84 Days				Removed as Indicated	
S. No.	Thickness	25 ksi	30 ksi	40 ksi	75% Y.S.	33 Days	84 Days
379069-2	2"	39	42	60	F	9	32
379070-2	4"	20	55	65	53	--	13
379071-2	6"	21	28	45	32	13	23

NOTES:

Short-transverse orientation, 1/8" diameter specimens from midway between rolled surfaces.

-- = Not exposed

F = Failed during exposure

Table 29

LOSS IN TENSILE STRENGTH OF 7075 AND 7079 PLATE

S. No.	Alloy & Temper	Thickness	Location	% Loss in Tensile Strength									
				Stressed				Unstressed					
				75% Y.S.		50% Y.S.		33 Days' Exposure			84 Days' Exposure		
				L	LT	L	LT	L	LT	ST	L	LT	ST
315070	7075-T651	.775"	M	11	25	--	--	8	10	--	20	20	--
379574	7075-T651	2"	M	14	20	--	12	7	6	5	8	7	12
			S	9	10	--	7	3	4	--	5	7	--
373280	7079-T651	5"	M	15	22	9	13	4	4	4	9	5	17
373281				15	33	10	11	4	3	9	2	3	11
373282				17	84	9	23	1	5	9	6	7	13
373283				16	14	9	14	4	3	7	6	3	34
Average	7079-T651	5"	M	16	38	9	15	3	4	7	6	5	19

NOTES:

M = Taken midway between rolled surfaces
S = Taken adjacent to rolled surfaces
-- = None exposed
Stressed specimens removed after 84 days

Table 30

STRESS-CORROSION PERFORMANCE OF MA15-T6X1 PLATE
IN THE NEW KENSINGTON ATMOSPHERE

S. No.	Thick.	Test Direction	Specimen Type	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level 25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
379536-6	1"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		LT	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		ST	"C" rings	Mid.	OK,OK,OK	OK,OK,OK	114,OK,OK	77,77,77	--
379537-6	2"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		LT	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		LT	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		ST	1/8" bars	Mid.	OK,OK,OK	133,133,133	30,56,77	21,25,56	--
379538-6	4"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		LT	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		LT	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		ST	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	77,OK,OK	63,67,72	--
		ST	1/4" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	74,77,81	--
379539-6	6"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		LT	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		LT	1/8" bars	Surf.	--	--	--	36,161,OK	105,105,OK
		ST	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	149,OK,OK	--
		ST	1/4" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--

NOTES: Triplicate specimens exposed May 11, 1970
-- means no specimens exposed at that stress level.
OK specimen intact at 161 days.

TABLE 31

STRESS-CORROSION PERFORMANCE OF TWO-INCH THICK MA15-T7X1 PLATE IN THE NEW KENSINGTON ATMOSPHERE

Specimen No.	Test Direction	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level				
			25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
379069-1	L	Mid.	--	--	--	OK,OK,OK	--
	L	Surf.	--	--	--	OK,OK,OK	--
	L-T	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
	L-T	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
	S-T	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	149,154,159	--

NOTES:

Triplicate 1/8" diameter specimens exposed.

--means no specimens exposed at that stress level.

OK = Specimen intact at 161 days.

TABLE 32

STRESS-CORROSION PERFORMANCE OF 7075-T651 PLATE IN THE NEW KENSINGTON ATMOSPHERE

Specimen No.	Plate Thick.	Test Direction	Specimen Type	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level: 25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
135070	0.775"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		S-T	"C" rings	Mid.	OK,OK,OK	OK,OK,OK	44,60,65	39,39,39	--
379574	2"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars		133,OK,OK	133,OK,OK	72,79,91	63,63,105	--

NOTES:

Triplicate specimens exposed May 11, 1970.

* Short-transverse specimens of 0.775" thick plate stressed to 75% of the long transverse yield strength.

--means no specimens exposed at that stress level.

OK = Specimen intact at 161 days.

Table 33

STRESS-CORROSION PERFORMANCE OF FOUR LOTS OF
FIVE-INCH THICK 7079-T651 PLATE IN THE NEW KENSINGTON ATMOSPHERE

Specimen No.	Test Direction	Specimen Type	Specimen Location	Days to Fracture After Exposure at Indicated Stress Level: 10 ksi	25 ksi	75% Y.S.	50% Y.S.
373280	L	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	L-T	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	S-T	1/8" bars	Mid.	OK,OK,OK	67,77,91	23,23,36	--
373281	L	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	L-T	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	S-T	1/8" bars	Mid.	OK,OK,OK	OK,56,72	17,17,17	--
373282	L	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	L-T	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	S-T	1/8" bars	Mid.	OK,OK,OK	63,91,91	17,32,36	--
373283	L	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	L-T	1/8" bars	Mid.	--	--	OK,OK,OK	OK,OK,OK
	S-T	1/8" bars	Mid.	67,OK,OK	52,72,OK	20,23,23	--

NOTES:

Triplicate specimens exposed May 11, 1970.

-- means no specimens exposed at that stress level.

OK - Specimen intact at 161 days.

Table 34

STRESS-CORROSION PERFORMANCE OF ONE-INCH THICK MA15 PLATE IN THE POINT JUDITH ATMOSPHERE

Specimen No.	Temper	Test Direction	Specimen Type	Days to Fracture+ After Exposure at Indicated Stress Level				
				25 ksi	30 ksi	40 ksi	75% Y.S.++	50% Y.S.
379536-6	T6X1	L	1/8" bars	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	--	--	--	OK,OK,OK	--
		S-T	C-ring	66,66,OK	66,66,66	66,66,66	66,66,66	--
379068-1	T7X1	L	1/8" bars	--	--	--	--	--
		L-T	1/8" bars	--	--	--	--	--
		S-T	C-ring	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--
379068-2	T7X2	S-T	C-ring	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--

NOTES:

Triplicate specimen exposed.

-- means no specimens exposed at that stress level.

Specimens removed midway between rolled surfaces.

++Short transverse specimen stressed to 75% of long-transverse yield strength.

+Specimens examined at 66 and 100 days.

OK - Specimens intact at 100 days.

TABLE 35

STRESS-CORROSION PERFORMANCE OF TWO-INCH THICK MA15 PLATE IN THE POINT JUDITH ATMOSPHERE

Specimen No.	Temper	Test Direction	Specimen Type	Specimen Location	Days to Fracture† After Exposure at Indicated Stress Level: 25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
379537-6	T6X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	66,OK,OK	OK,CX,OK
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	66,66,66	66,66,66	66,66,66	66,66,66	--
379069-1	T7X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	66,66,66	66,66,66	--
379069-2	T7X2	S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--

NOTES:

Triplicate specimens exposed.

--means no specimens exposed at that stress level.

† Specimens examined at 66 and 100 days

OK = Specimens intact at 100 days.

TABLE 36

STRESS-CORROSION PERFORMANCE OF FOUR-INCH THICK MA15 PLATE IN THE POINT JUDITH ATMOSPHERE

Specimen No.	Temper	Test Direction	Specimen Type	Specimen Location	Days to Fracture† After Exposure at Indicated Stress Level				
					25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
379538-6	T6X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	66,66,66	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	66,66,66	OK,OK,OK
		S-T	1/8" bars	Mid.	66,66,66	66,66,66	66,66,66	66,66,66	--
		S-T	1/4" bars*	Mid.	OK,OK,OK	36,OK,OK	36,36,36	36,36,36	--
379070-1	T7X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	66,100,OK	--
		S-T	1/4" bars*	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--
379072-2	T7X2	S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--

NOTES:

Triplicate specimens exposed.

--means no specimens exposed at that stress level.

OK = 1/8" diameter specimens intact at 100 days; 1/4" diameter specimens intact at 36 days.

* = 1/4" diameter specimens exposed 64 days after 1/8" diameter specimens exposed.

† 1/8" diameter specimens examined at 66 days and 100 days.

† 1/4" diameter specimens examined at 36 days.

TABLE 37

STRESS-CORROSION PERFORMANCE OF SIX-INCH THICK MA15 PLATE IN THE POINT JUDITH ATMOSPHERE

Specimen No.	Temper	Test Direction	Specimen Type	Specimen Location	Days to Fracture† After Exposure at Indicated Stress Level				
					25 ksi	30 ksi	40 ksi	75% Y.S.	50% Y.S.
379539-6	T6X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	66,66,66	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	66,66,66	66,66,OK
		S-T	1/8" bars	Mid.	66,OK,OK	66,66,66	66,66,66	66,66,66	--
		S-T	1/4" bars*	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	36,36,36	--
379071-1	T7X1	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	66,66,OK	66,OK,OK	--
		S-T	1/4" bars*	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--
379071-2	T7X2	S-T	1/8" bars	Mid.	OK,OK,OK	OK,OK,OK	OK,OK,OK	OK,OK,OK	--

NOTES:

Triplicate specimens exposed.

--means no specimens exposed at that stress level.

OK = 1/8" diameter specimens intact at 100 days; 1/4" diameter specimens intact at 36 days.

* = 1/4 diameter specimens exposed 64 days after 1/8" diameter specimens exposed.

† 1/8" diameter specimens examined at 66 days and 100 days.

† 1/4" diameter specimens examined at 36 days.

TABLE 38

STRESS-CORROSION PERFORMANCE OF 7075-T651
PLATE IN THE POINT JUDITH ATMOSPHERE

Specimen No.	Plate Thick.	Test Direction	Specimen Type	Specimen Location	Days to Fracture† After Exposure at Indicated Stress Level				
					25 ksi	30 ksi	40 ksi	75% Y.S.††	50% Y.S.
315070	0.775"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		S-T	C-rings	Mid.	66,66,66	66,66,66	66,66,66	66,66,66	--
379574	2"	L	1/8" bars	Mid.	--	--	--	OK,OK,OK	--
		L	1/8" bars	Surf.	--	--	--	OK,OK,OK	--
		L-T	1/8" bars	Mid.	--	--	--	OK,OK,OK	OK,OK,OK
		L-T	1/8" bars	Surf.	--	--	--	OK,OK,OK	OK,OK,OK
		S-T	1/8" bars	Mid.	66,66,66	66,66,66	66,66,66	66,66,66	--

NOTES:

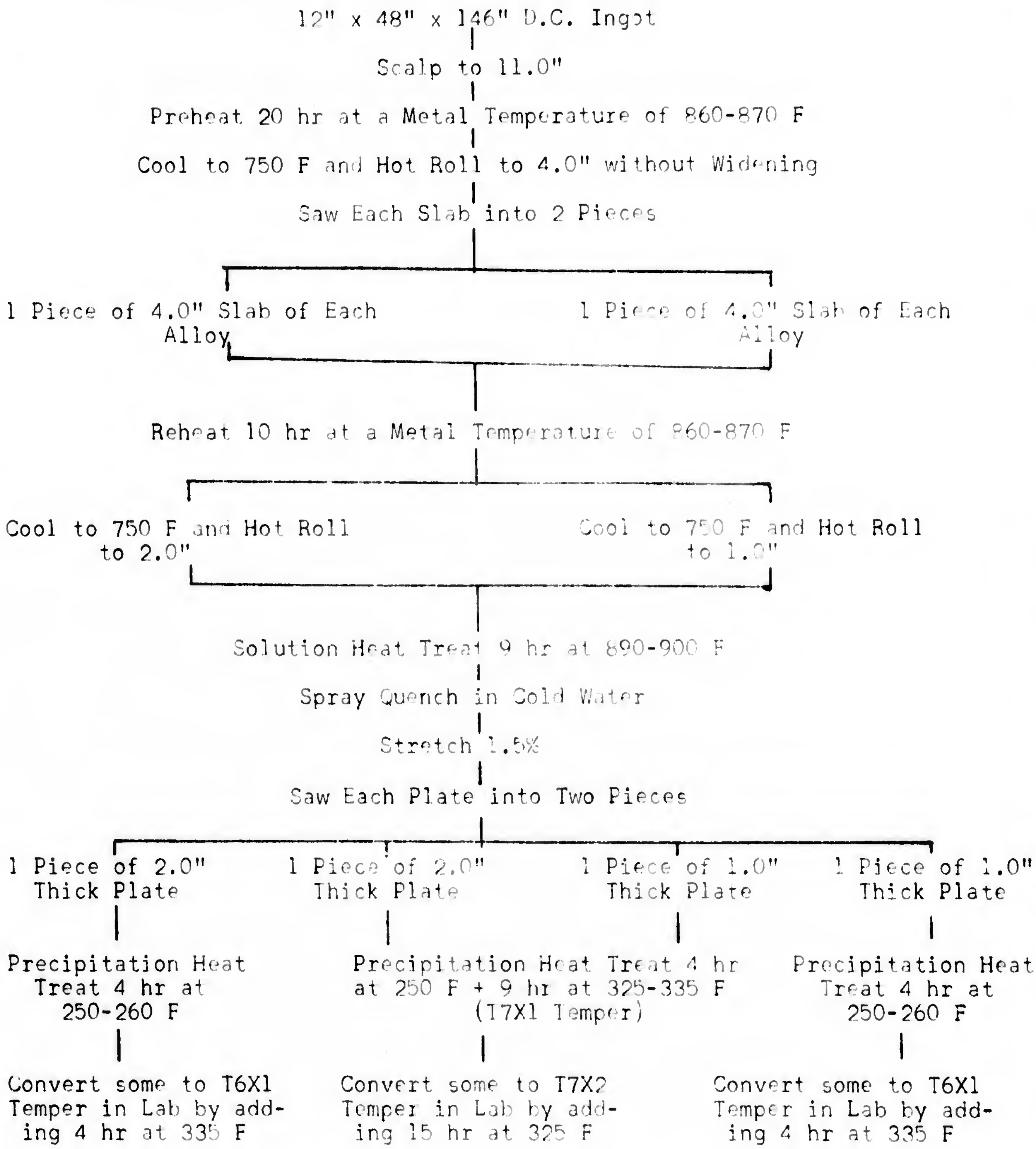
Triplicate specimens exposed.

†† Short transverse specimens of 0.775" thick plate stressed at 75% of long-transverse yield strength.

OK = Specimens intact at 100 days.

--means no specimens exposed at that stress level.

† Specimens examined after 66 and 100 days.



FABRICATION AND HEAT TREATMENT OF 1.0" AND 2.0" THICK MA15 PLATE

Figure 1

12" x 48" x 146" D.C. Ingot

Scalp to 11.0"

Preheat 20 hr at a Metal Temperature of 860-870 F

Cool to 750 F and Hot Roll to 8.0" without Widening

Reheat 10 hr at a Metal Temperature of 860-870 F

Cool to 750 F and Hot Roll to 4.0"

Solution Heat Treat 9 hr at 890-900 F

Spray Quench in Cold Water

Stretch 1.5%

Saw Each Plate into Two Pieces

1 Piece of 4.0" Thick Plate

Precipitation Heat Treat 4 hr at 250-260 F

Convert some to T6X1 Temper in Lab by adding 4 hr at 335 F

1 Piece of 4.0" Thick Plate

Precipitation Heat Treat 4 hr at 250 F + 9 hr at 325-335 F (T7X1 Temper)

Convert some to T7X2 Temper in Lab by adding 15 hr at 325 F

FABRICATION AND HEAT TREATMENT OF 4.0" THICK MA15 PLATE

Figure 2

12" x 48" x 146" D.C. Ingot

Scalp to 11.0"

Preheat 20 hr at a Metal Temperature of 860-870 F

Cool to 750 F and Hot Roll to 8.0" without Widening

Reheat 10 hr at a Metal Temperature of 860-870 F

Cool to 750 F and Hot Roll to 6.0"

Solution Heat Treat 9 hr at 890-900 F

Spray Quench in Cold Water

Stretch 1.5%

Saw Each Plate into Two Pieces

1 Piece of 6.0" Thick Plate

Precipitation Heat Treat 4 hr at 250-260 F

Convert some to T6X1 Temper in Lab by adding 4 hr at 335 F

1 Piece of 6.0" Thick Plate

Precipitation Heat Treat 4 hr at 250-260 F + 9 hr at 325-335 F (T7X1 Temper)

Convert some to T7X2 Temper in Lab by adding 15 hr at 325 F

FABRICATION AND HEAT TREATMENT OF 6.0" THICK MA15 PLATE

Figure 3

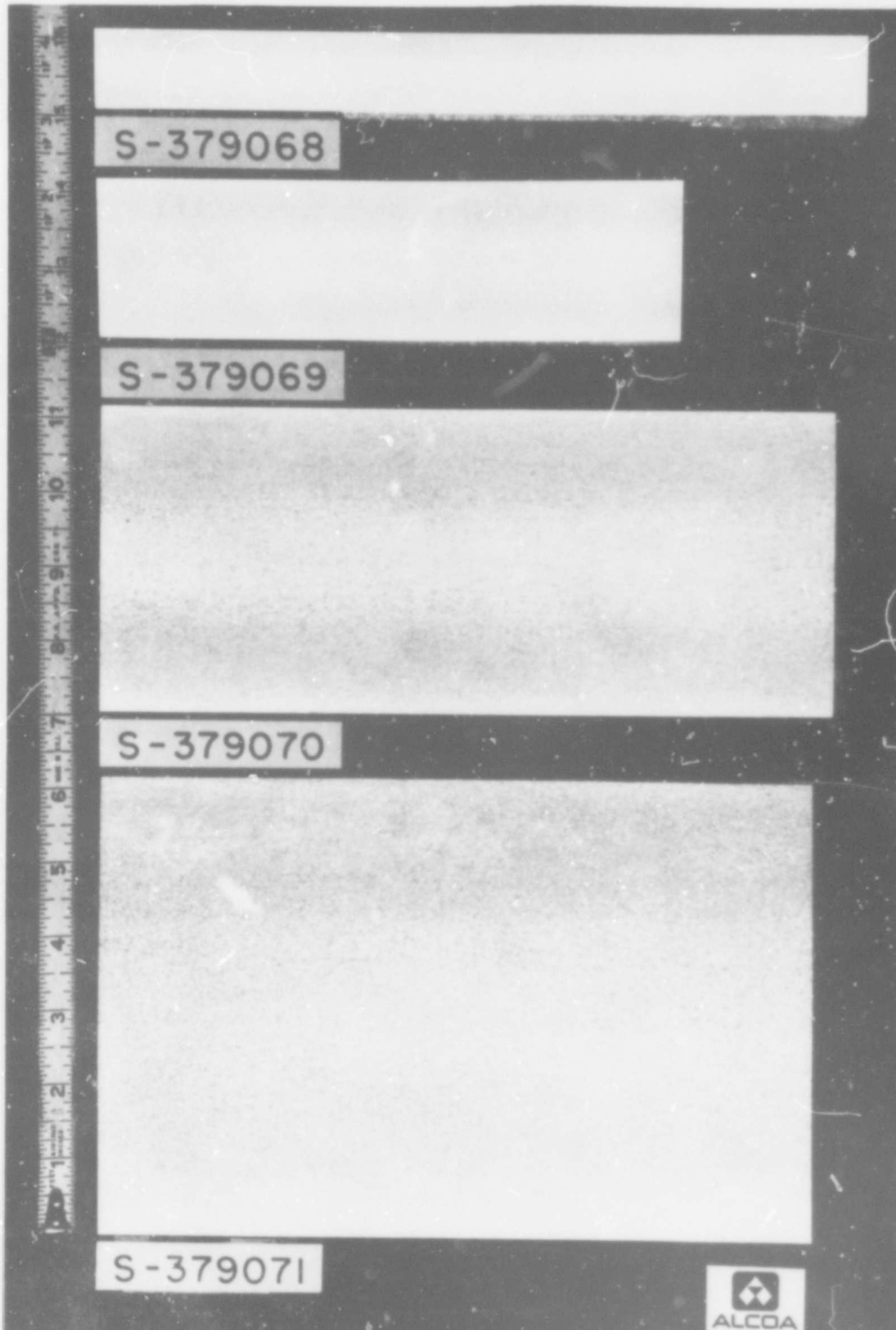
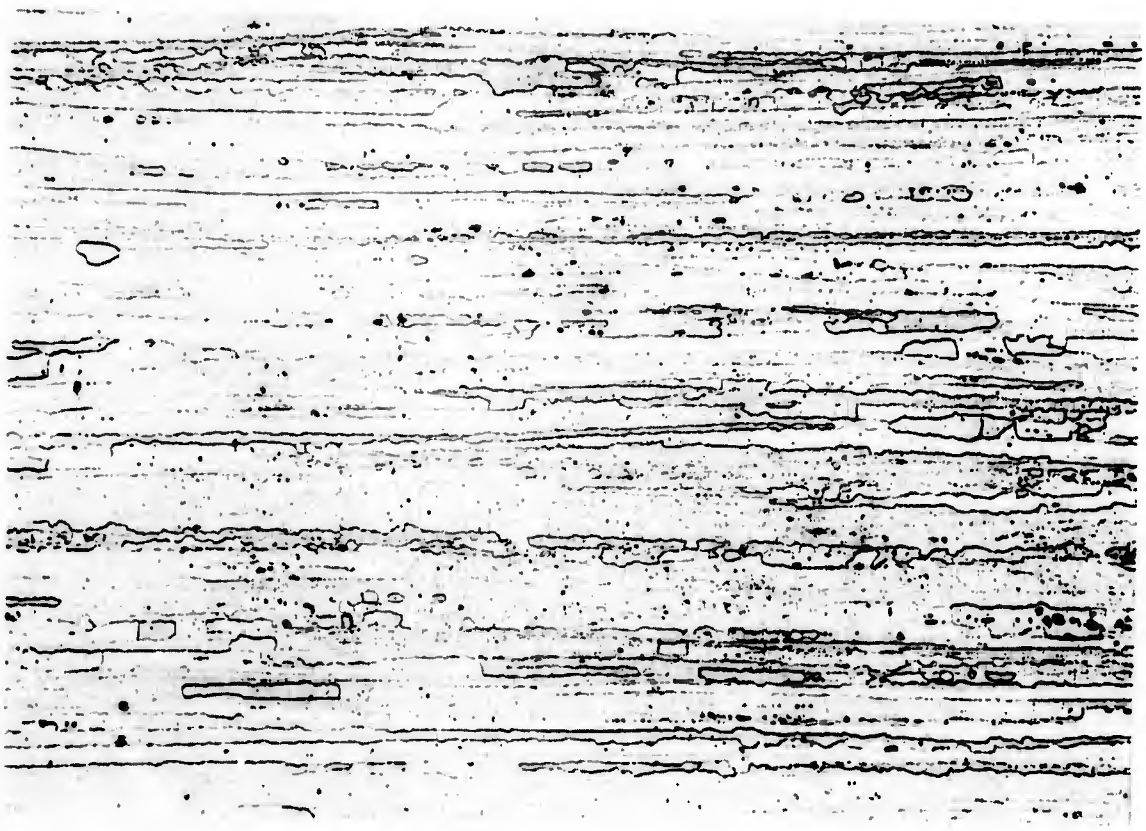


FIG. 4 MACROSTRUCTURES OF MA15 PLATE.

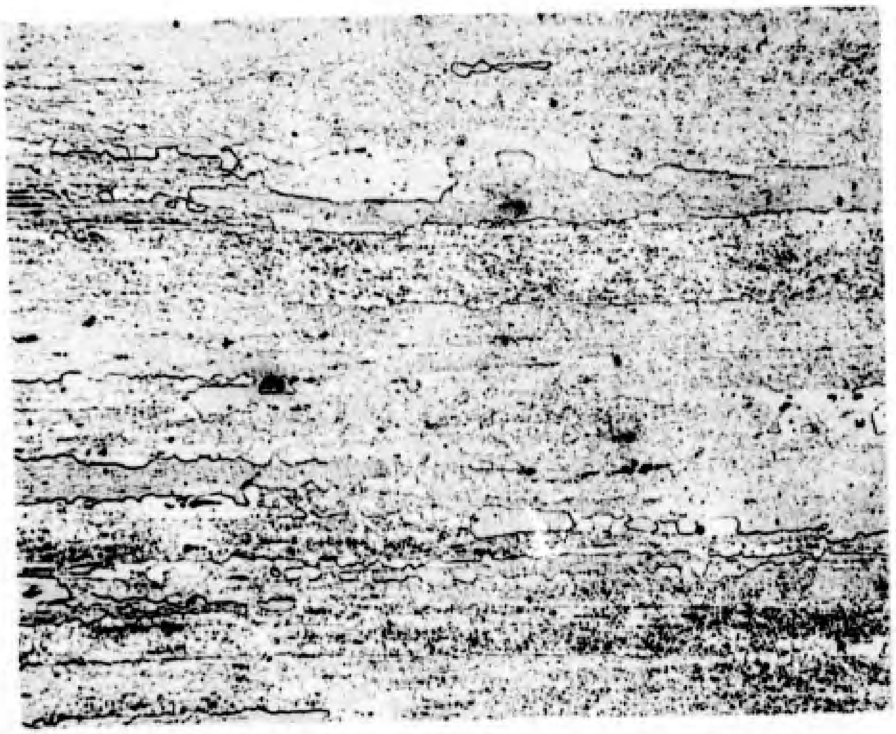


NEG. NO. 178071A 100X KELLER'S ETCH

MIDPLANE

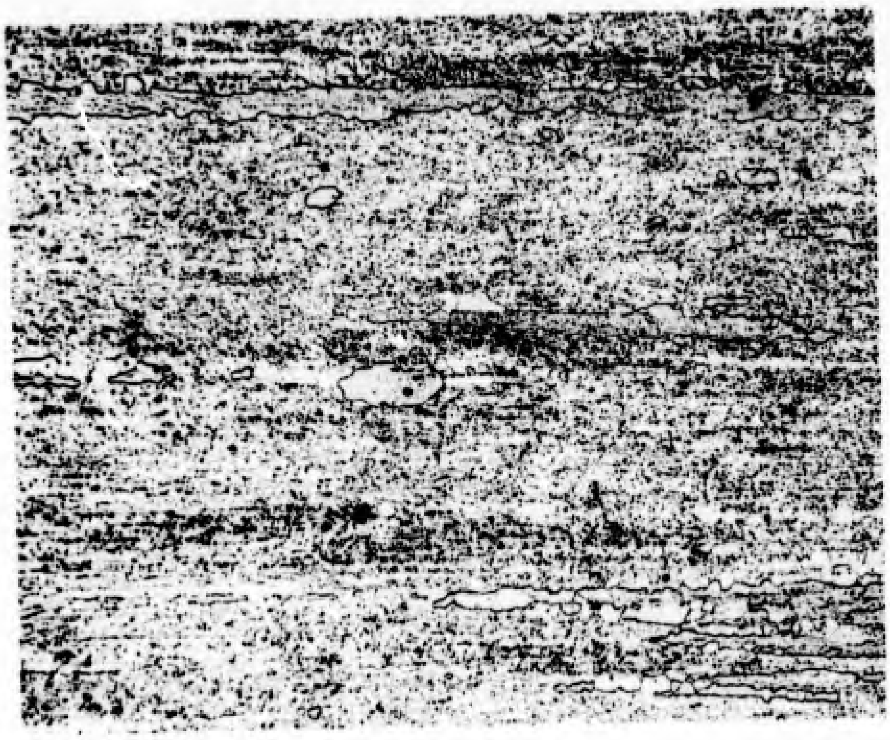
FIG. 5 GRAIN STRUCTURE OF ONE-INCH THICK PLATE

S. NO. 379068



NEG. NO. 178072A 100X KELLER'S ETCH

5/16" FROM SURFACE

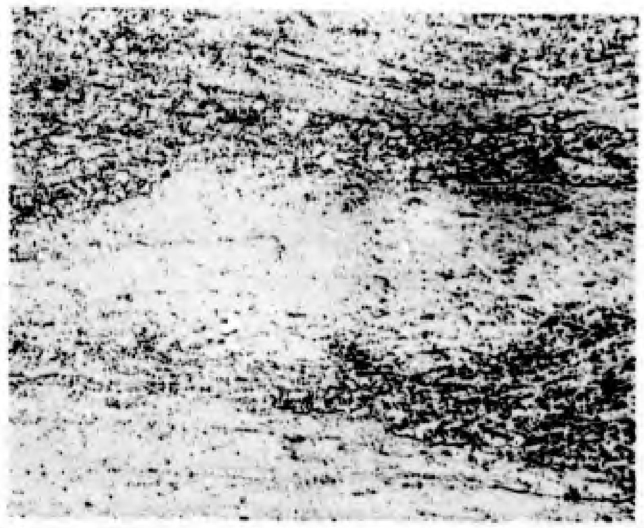


NEG. NO. 178073A 100X KELLER'S ETCH

MIDPLANE

FIG. 6 GRAIN STRUCTURE OF TWO-INCH THICK PLATE

S. NO. 379069

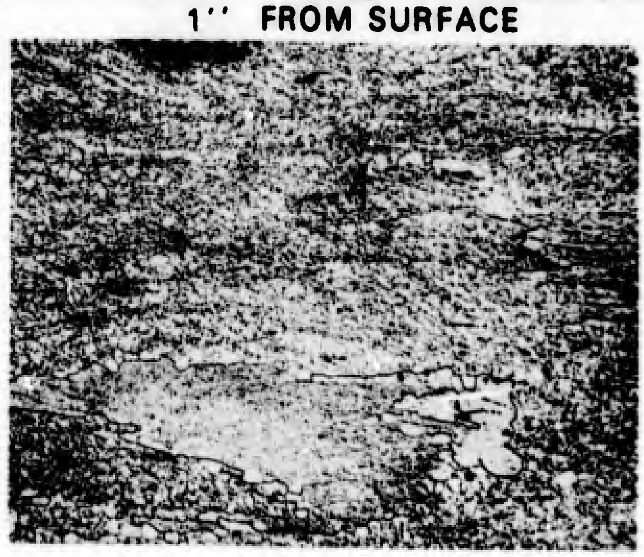


NEG. NO. 178074A 100X KELLER'S ETCH

5/16" FROM SURFACE

NEG. NO. 178075A 100X KELLER'S ETCH

1'' FROM SURFACE

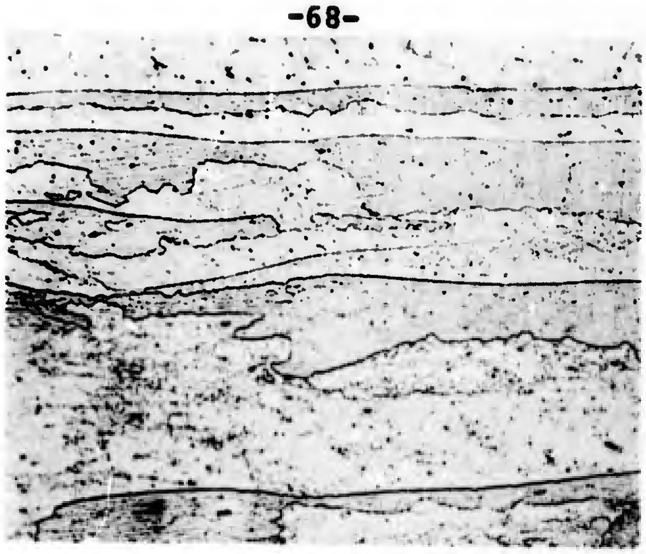


NEG. NO. 178076A 100X KELLER'S ETCH

MIDPLANE

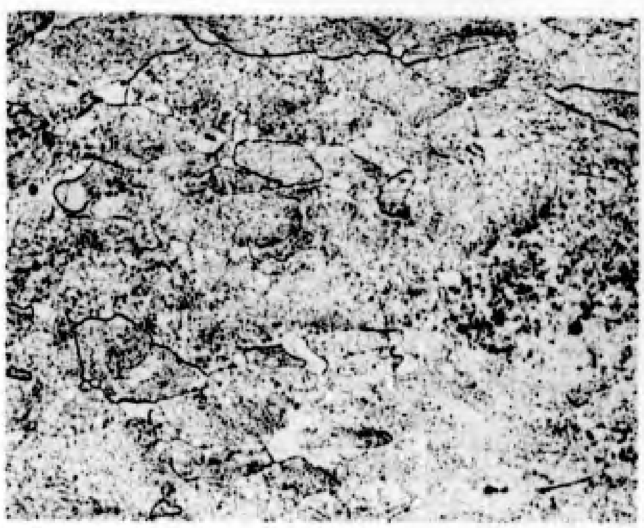
FIG. 7 GRAIN STRUCTURE OF FOUR-INCH THICK PLATE

S. NO. 379069



NEG. NO. 178077A   100X   KELLER'S ETCH
5/16" FROM SURFACE

NEG. NO. 178078A   100X   KELLER'S ETCH
1½" FROM SURFACE

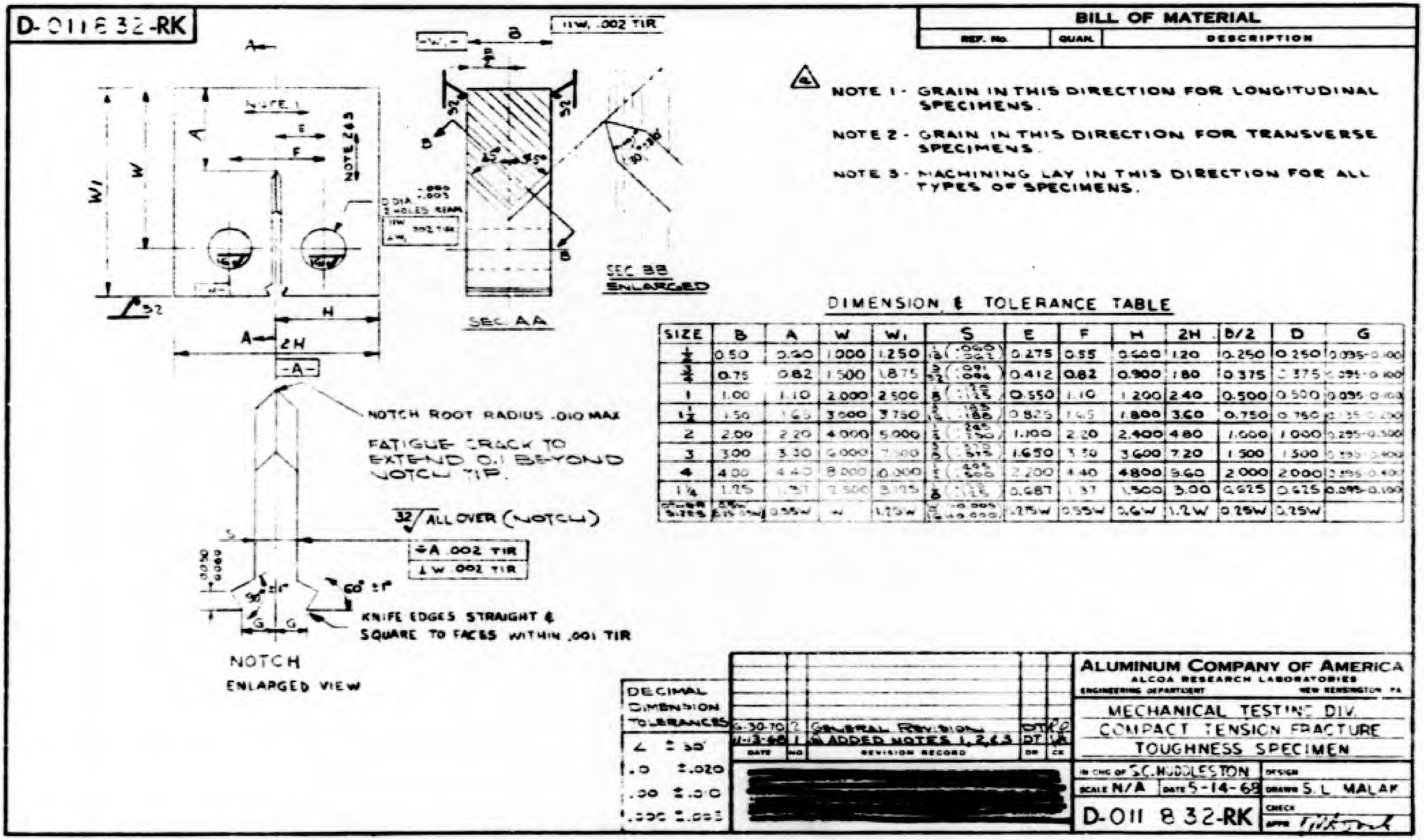


NEG. NO. 178079A   100X   KELLER'S ETCH

MIDPLANE

FIG. 8 GRAIN STRUCTURE OF SIX-INCH THICK PLATE

S. NO. 379070



DIMENSION & TOLERANCE TABLE

SIZE	B	A	W	W1	S	E	F	H	2H	B/2	D	G
1/2	0.50	0.55	1.000	1.250	1/16 (.060/.062)	0.275	0.55	0.600	1.20	0.250	0.250	0.095-0.100
3/4	0.75	0.82	1.500	1.875	3/32 (.091/.094)	0.412	0.82	0.900	1.80	0.375	0.375	0.095-0.100
1	1.00	1.10	2.000	2.500	1/8 (.120/.125)	0.550	1.10	1.200	2.40	0.500	0.500	0.095-0.100
1 1/2	1.50	1.65	3.000	3.750	3/16 (.185/.188)	0.825	1.65	1.800	3.60	0.750	0.750	0.135-0.200
2	2.00	2.20	4.000	5.000	1/4 (.245/.250)	1.100	2.20	2.400	4.80	1.000	1.000	0.295-0.300
3	3.00	3.30	6.000	7.500	3/8 (.370/.375)	1.650	3.30	3.600	7.20	1.500	1.500	0.395-0.400
4	4.00	4.40	8.000	10.000	1/2 (.495/.500)	2.200	4.40	4.800	9.60	2.000	2.000	0.395-0.400
1 1/4	1.25	1.37	2.500	3.125	1/8 (.120/.125)	0.687	1.37	1.500	3.00	0.625	0.625	0.095-0.100
OTHER SIZES	[illegible]	0.55W	W	1.25W	W/16 (+0.005/-0.000)	.275W	0.55W	0.6W	1.2W	0.25W	0.25W	

FIG. 9 FRACTURE TOUGHNESS SPECIMEN

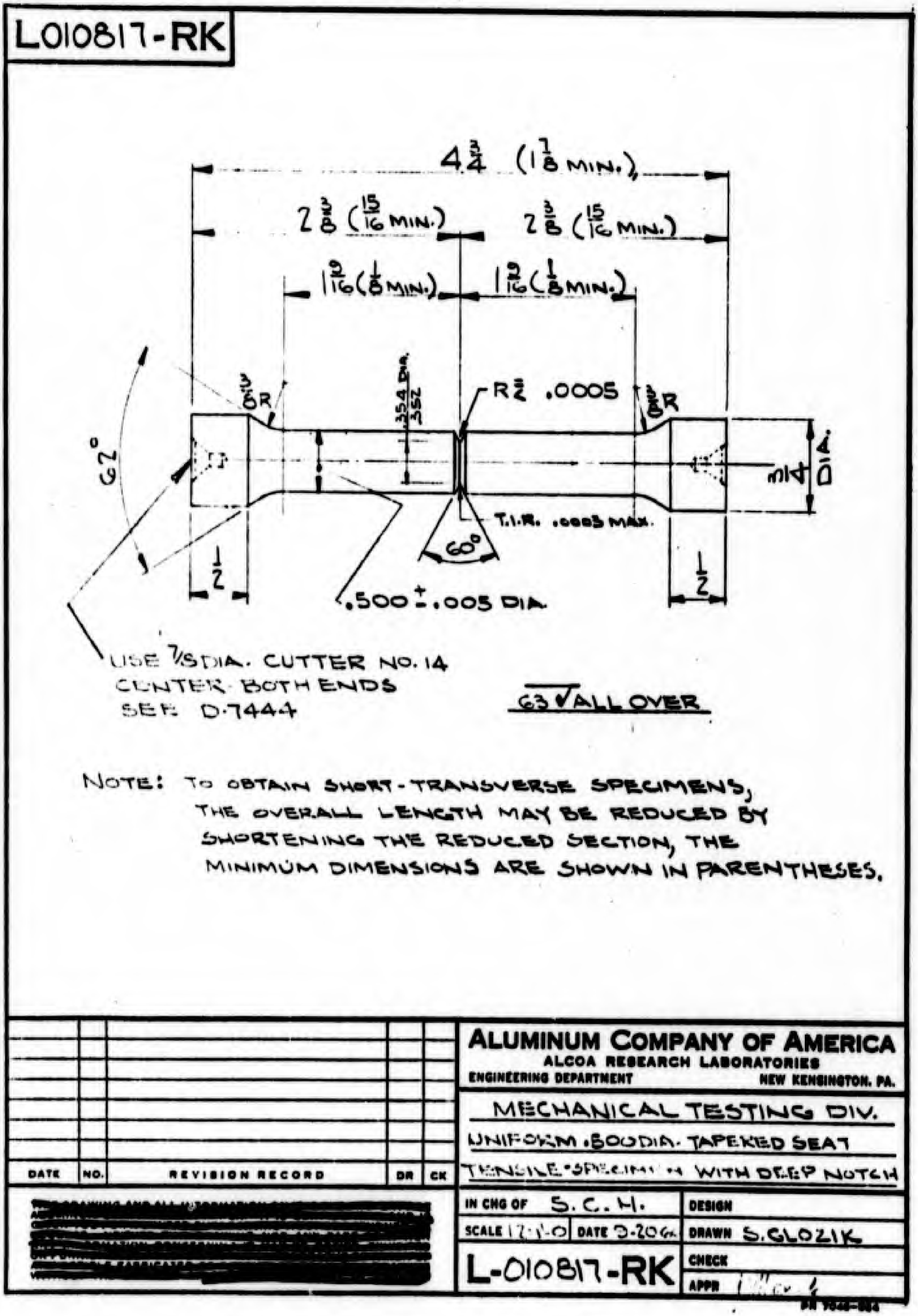


FIG. 10 NOTCH TENSILE SPECIMEN

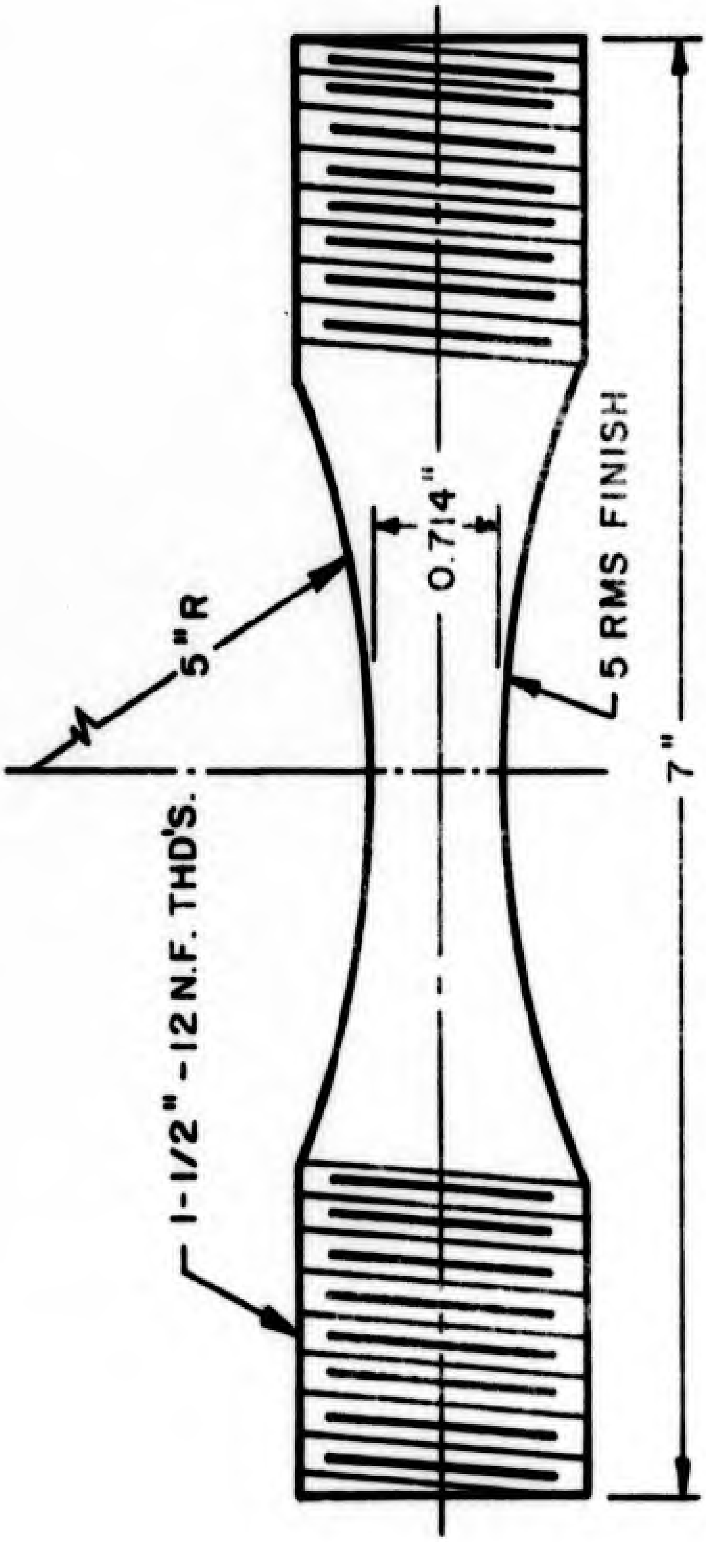


FIG. 11 FATIGUE SPECIMEN

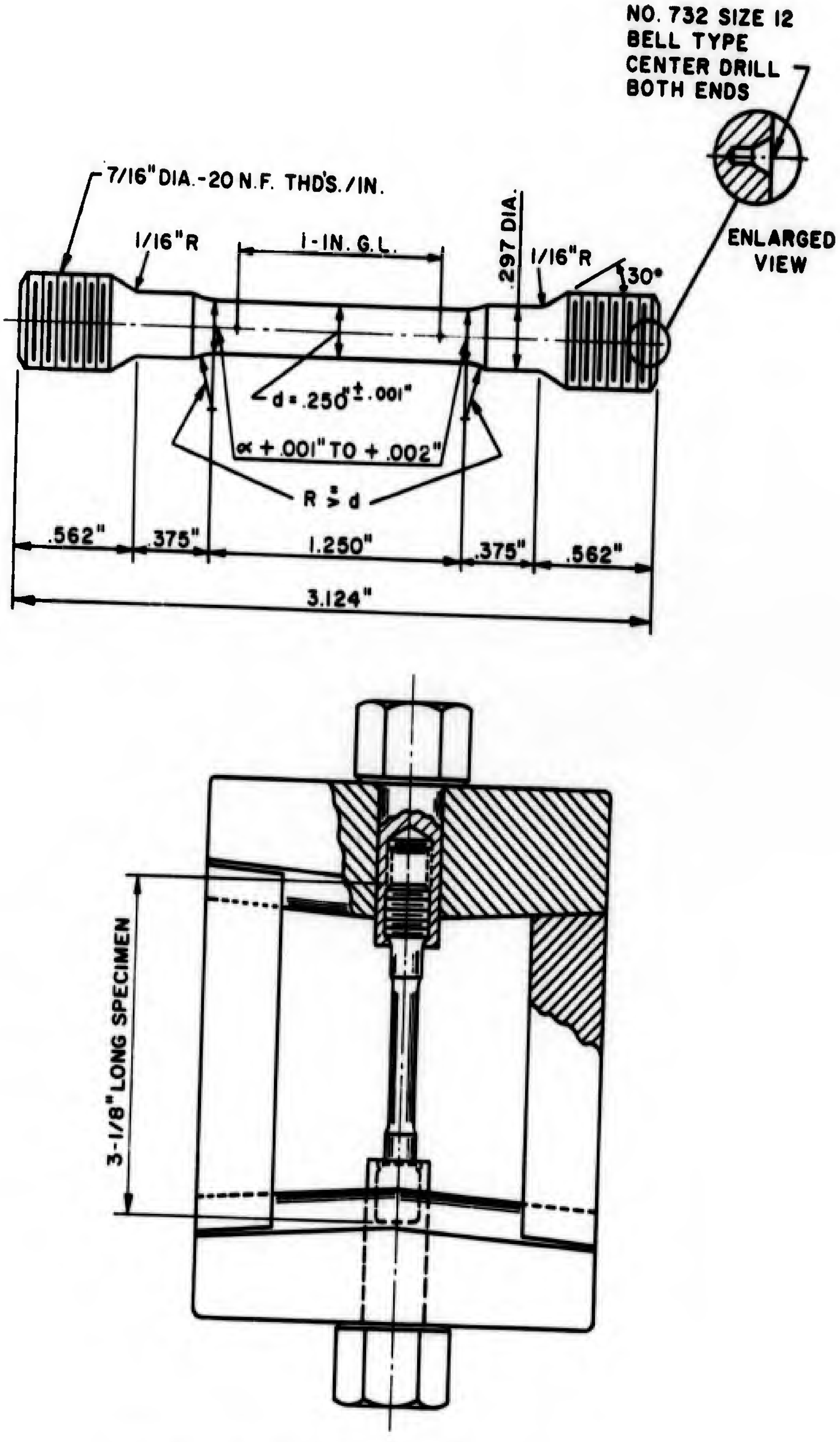


FIG. 12 1/4-IN. DIA. SPECIMEN AND STRESSING FRAME

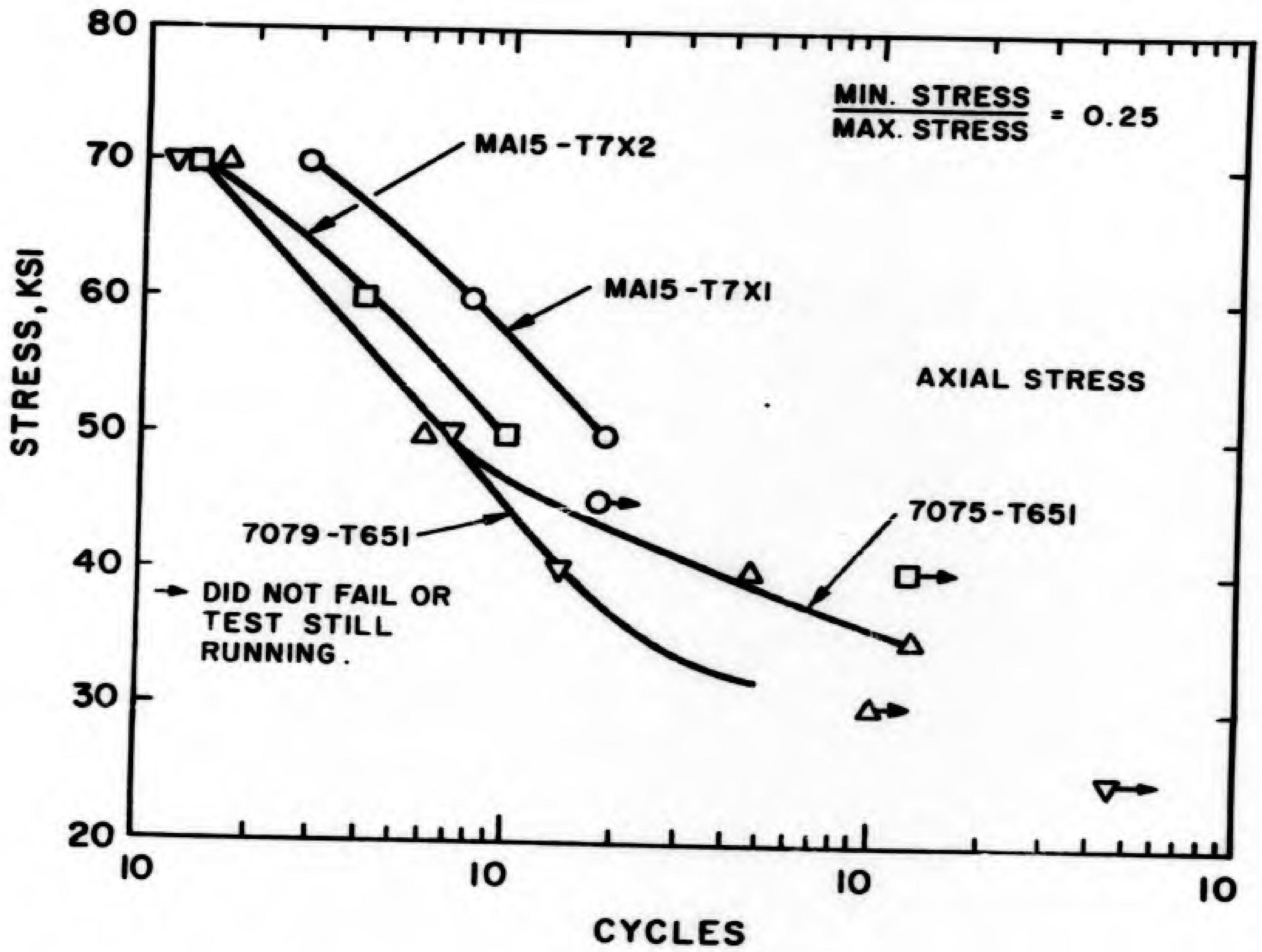


FIG. 13 FATIGUE CHARACTERISTICS OF MAI5, 7075-T65I, AND 7079-T65I PLATE.

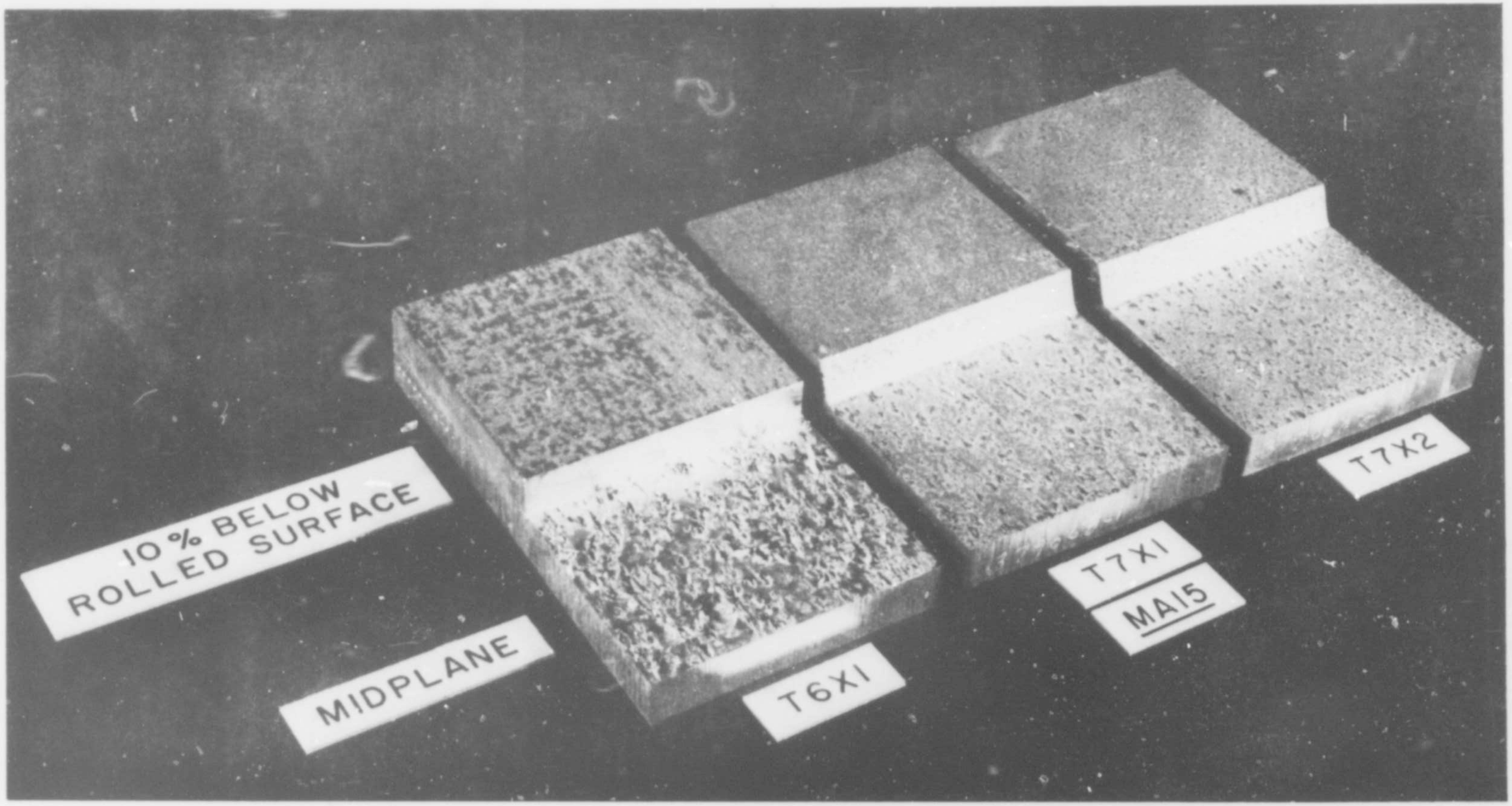


FIG. 14 APPEARANCES OF ONE–INCH THICK MA15 PLATE AFTER EXPOSURE IN ACCELERATED EXFOLIATION TEST

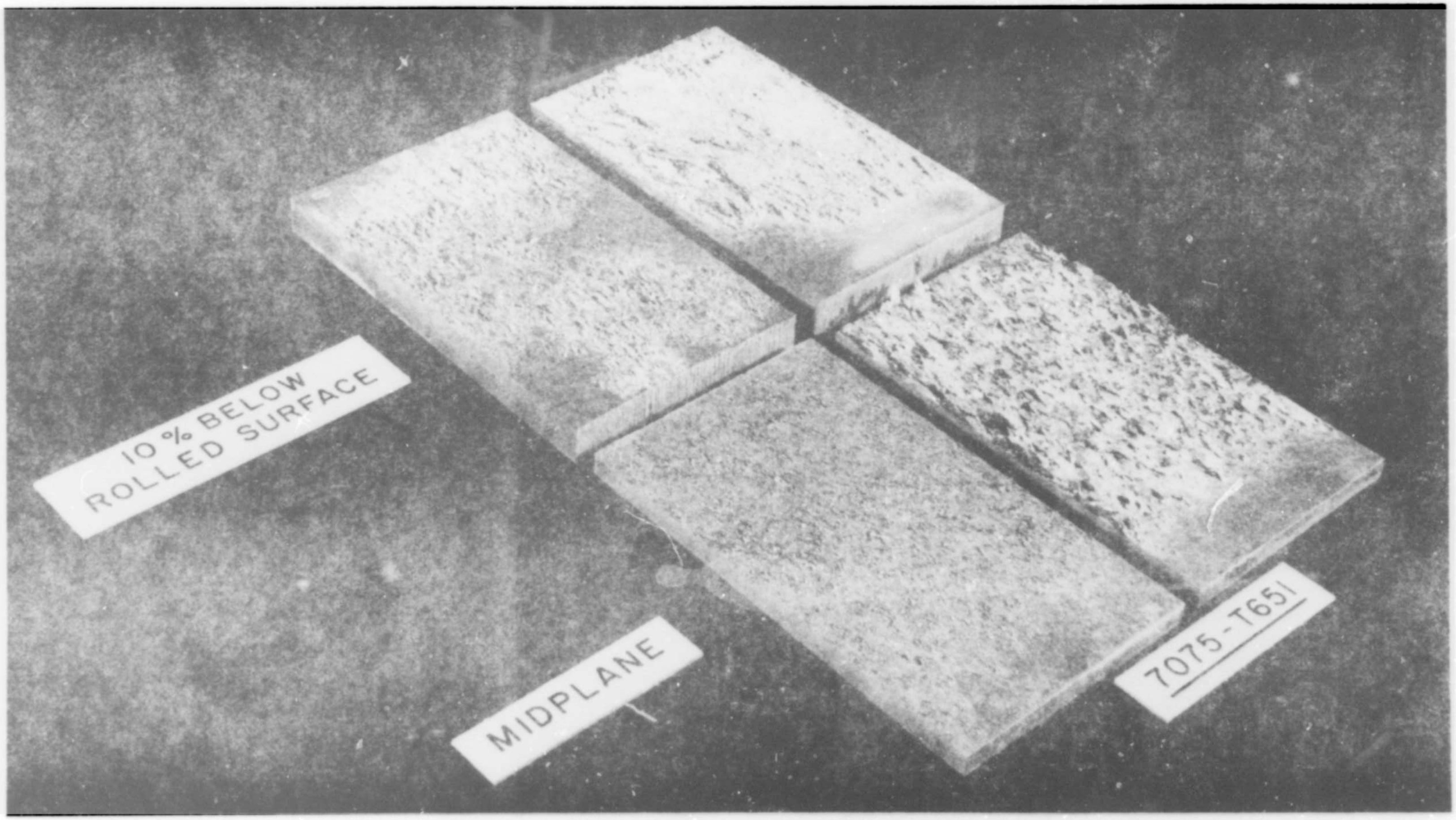


FIG. 15 RANGE OF APPEARANCES OF THIN 7075–T651 PLATE AFTER EXPOSURE IN ACCELERATED EXFOLIATION TEST

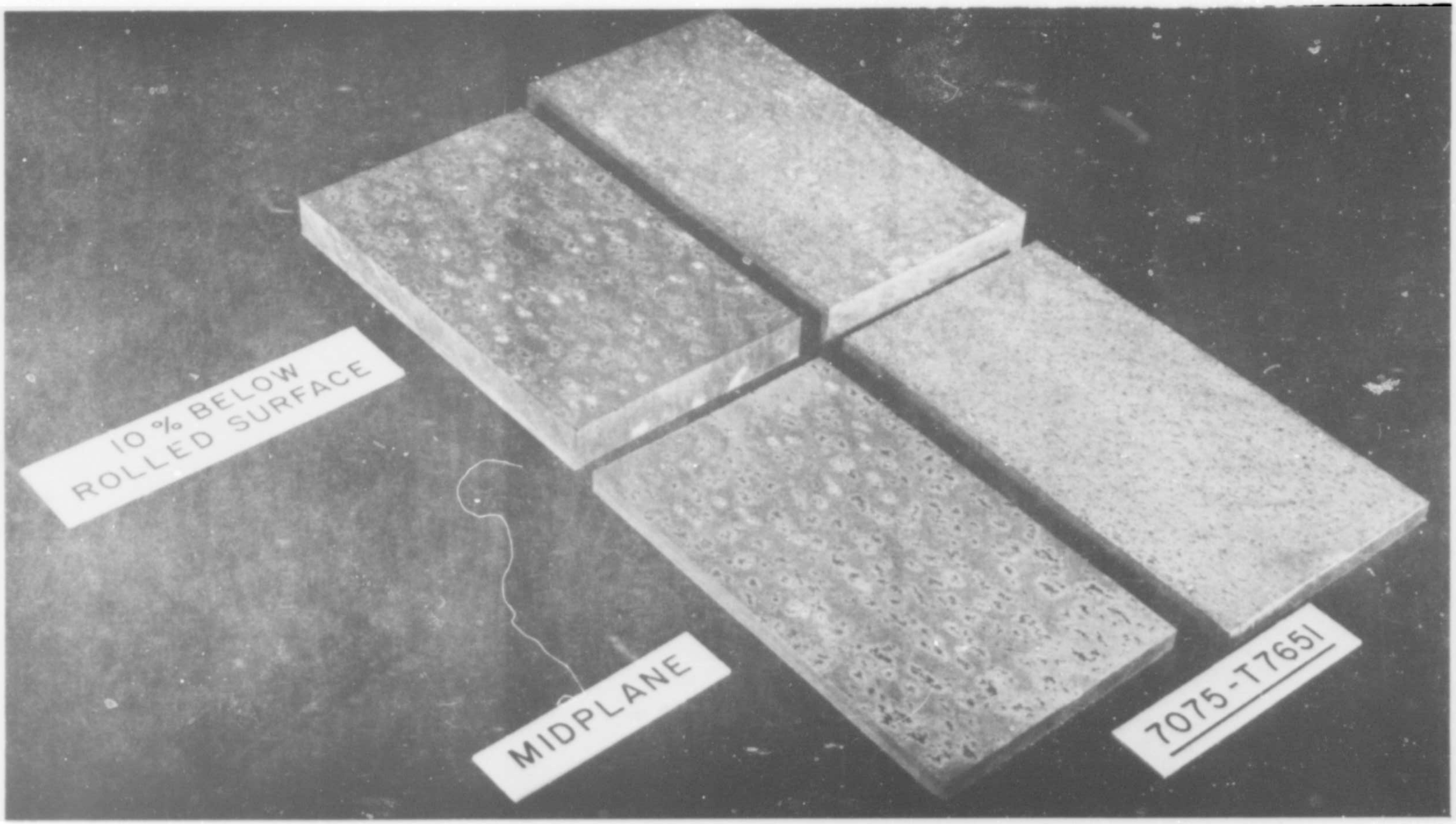


FIG. 16 RANGE OF APPEARANCES OF THIN 7075—T7651 PLATE AFTER EXPOSURE IN ACCELERATED EXFOLIATION TEST

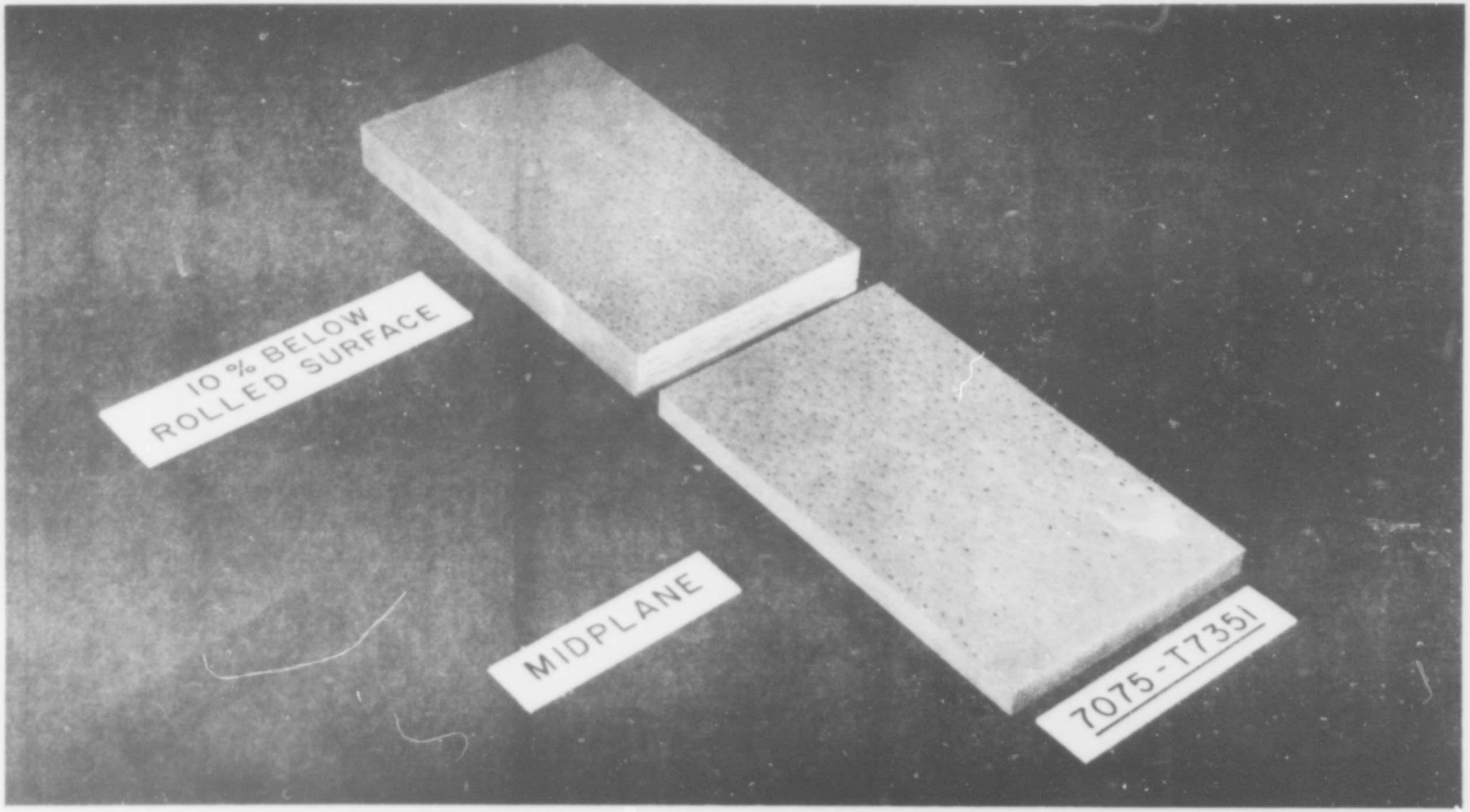
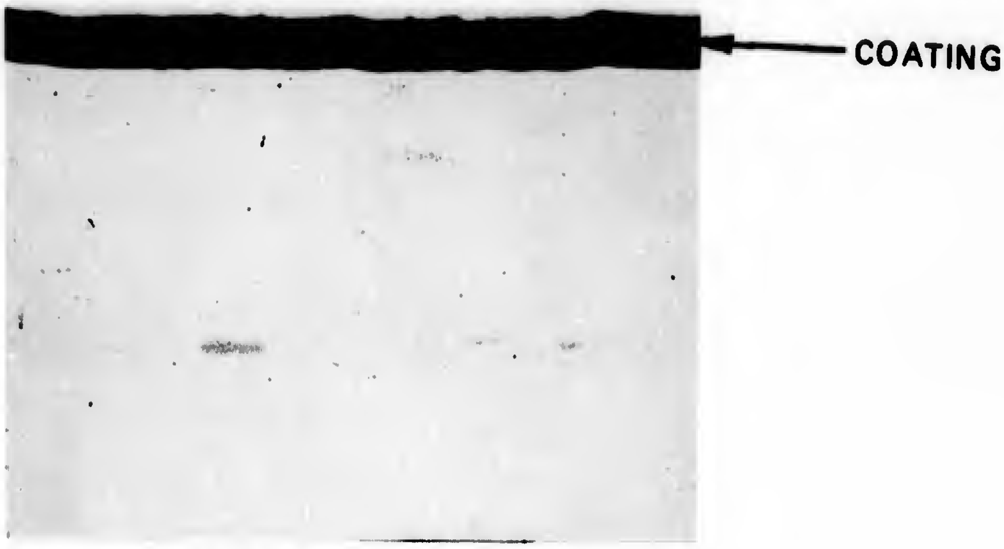
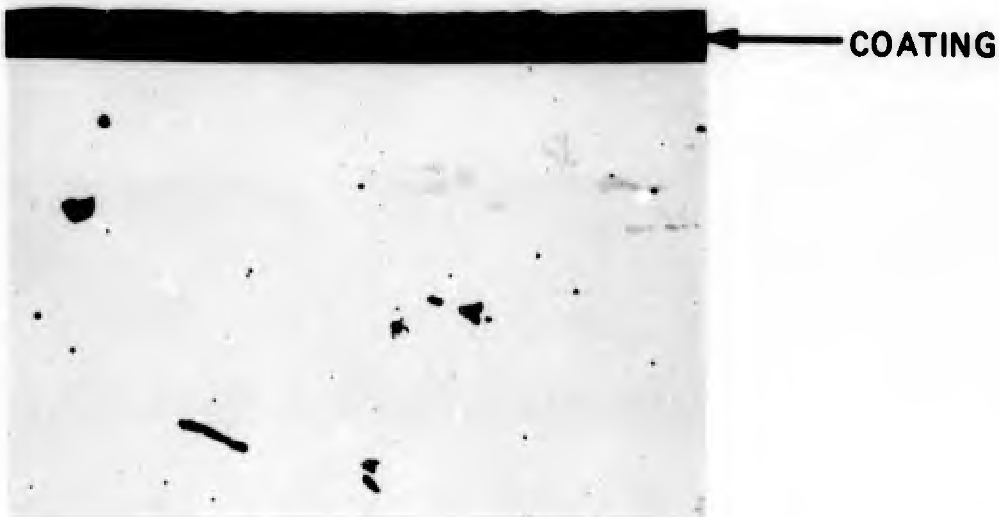


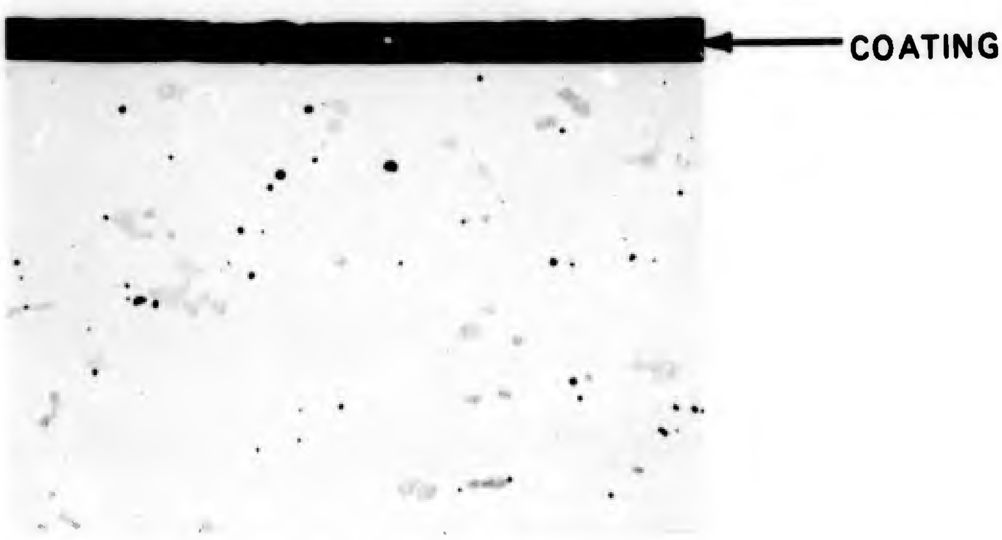
FIG. 17 APPEARANCE OF THIN 7075—T7351 PLATE AFTER EXPOSURE IN ACCELERATED EXFOLIATION TEST



MA15-T7X1 500X

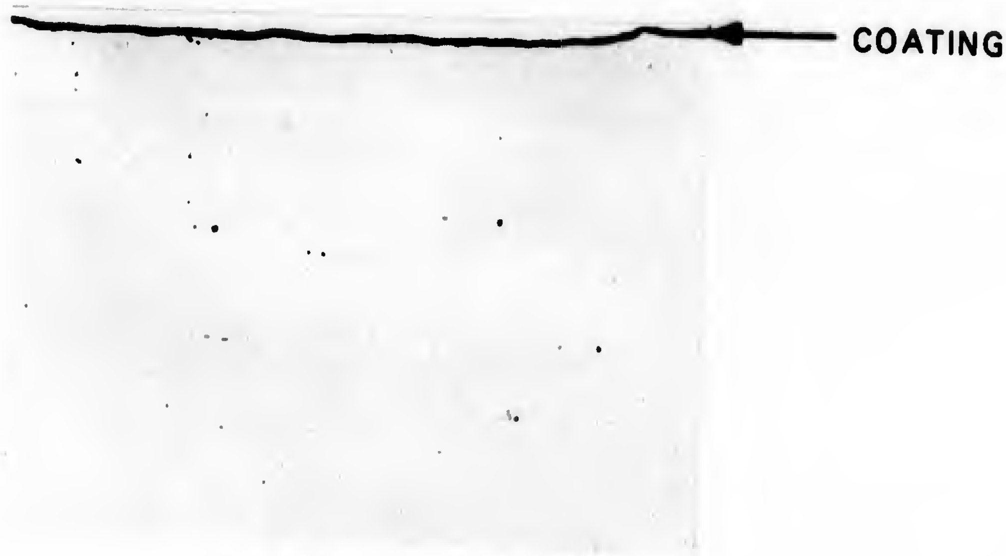


7075-T651 500X



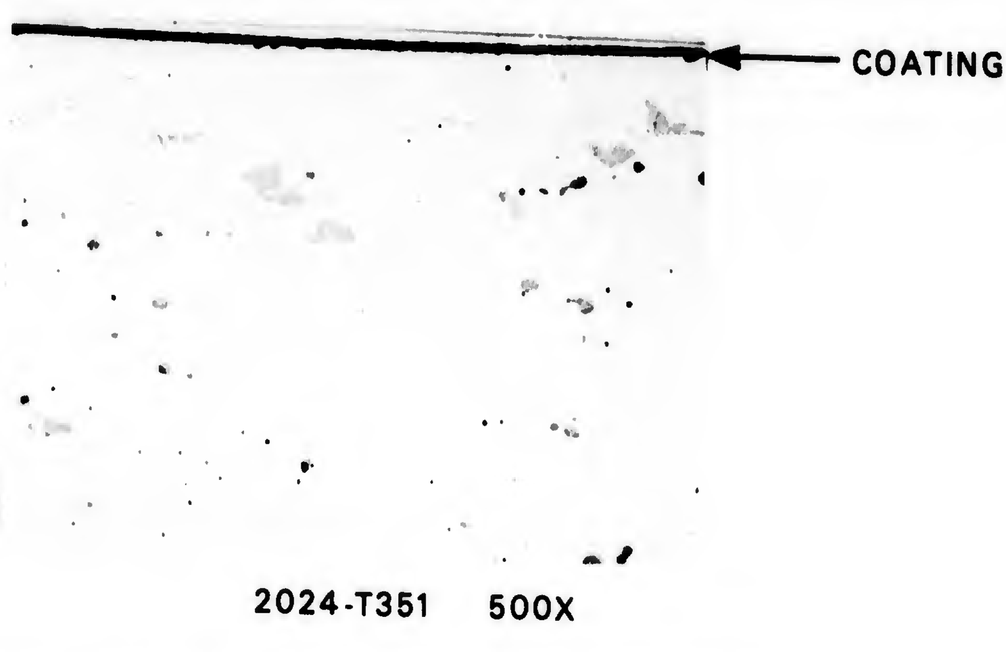
2024-T351 500X

FIG. 18 SULPHURIC ACID ANODIC COATINGS



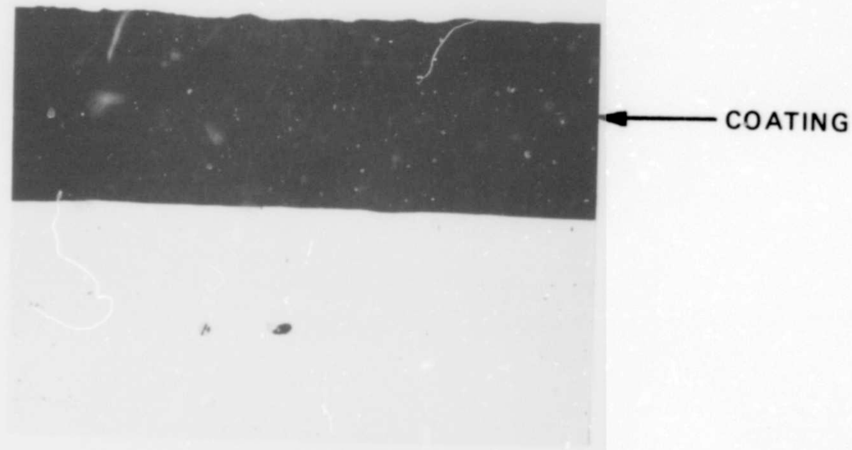
MA15-T7X1 500X

7075-T651 500X

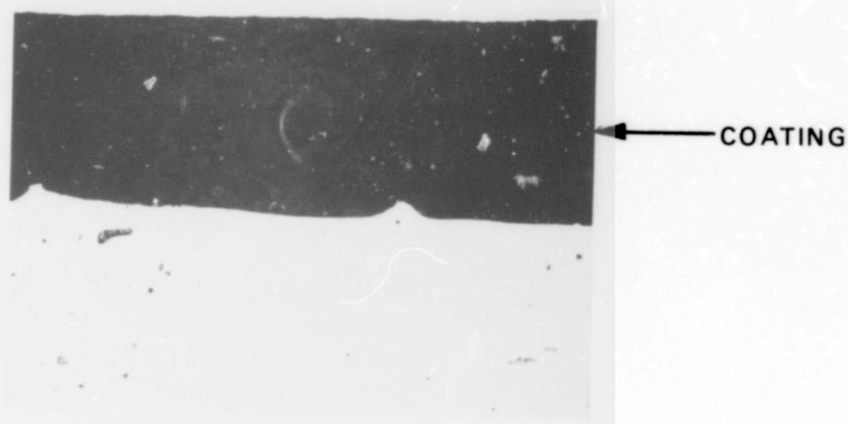


2024-T351 500X

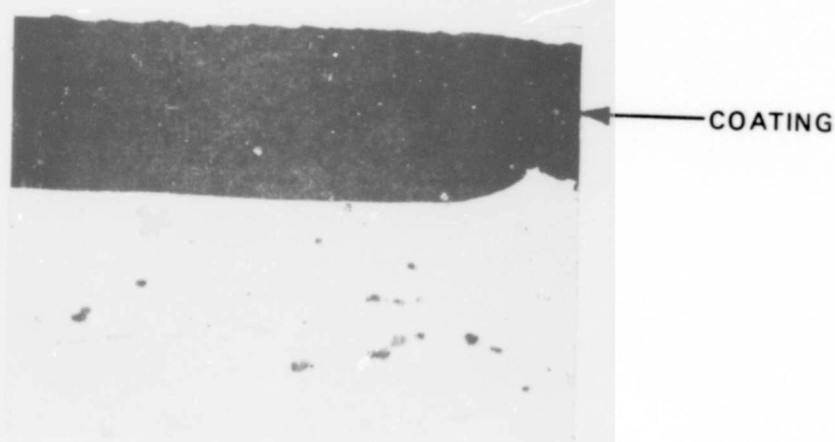
FIG. 19 CHROMIC ACID ANODIC COATINGS



MA15-T7X1 500X



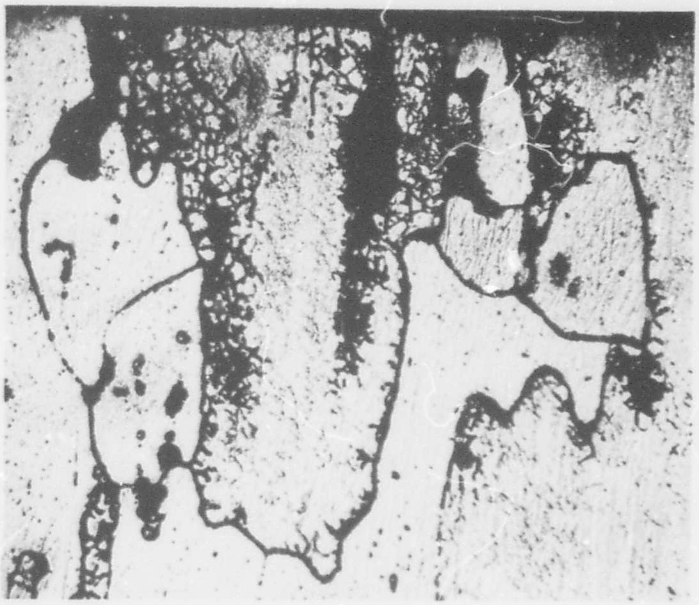
7075-T651 500X



2024-T351 500X

FIG. 20 HARD COAT ANODIC COATINGS

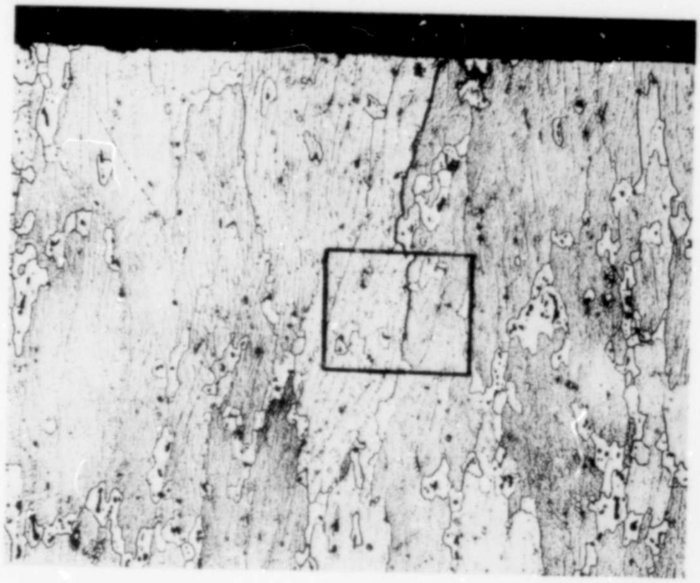
NEG. NO. 180733 100X KELLER'S ETCH



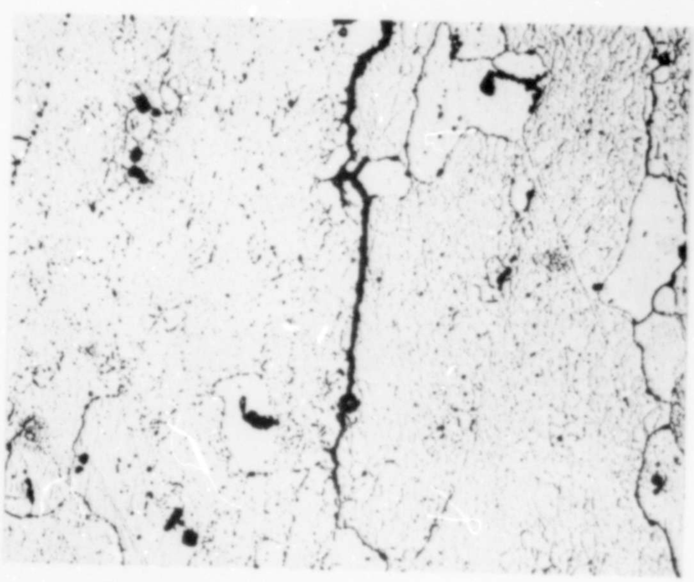
NEG. NO. 180734 500X KELLER'S ETCH

TWO-INCH THICK MA15-T6X1

FIG. 21 ILLUSTRATES CORROSION ALONG GRAIN AND GRAIN FRAGMENT BOUNDARIES IN S. NO. 379537-6-N40



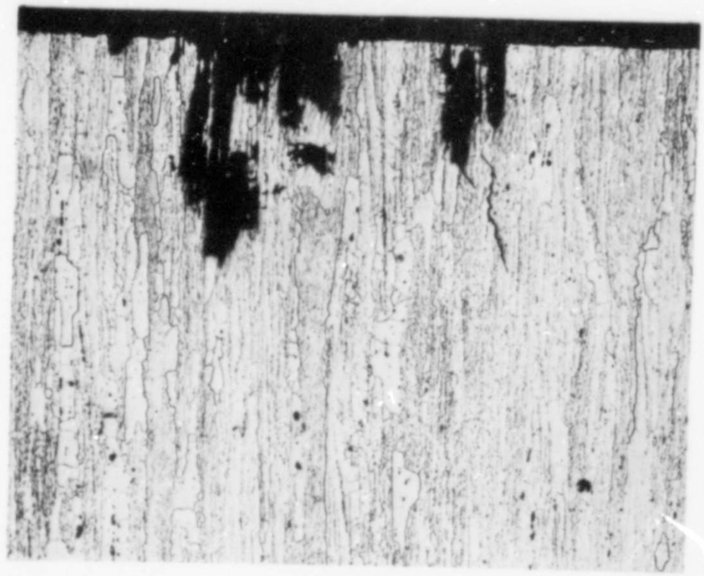
NEG. NO. 180737 100X KELLER'S ETCH



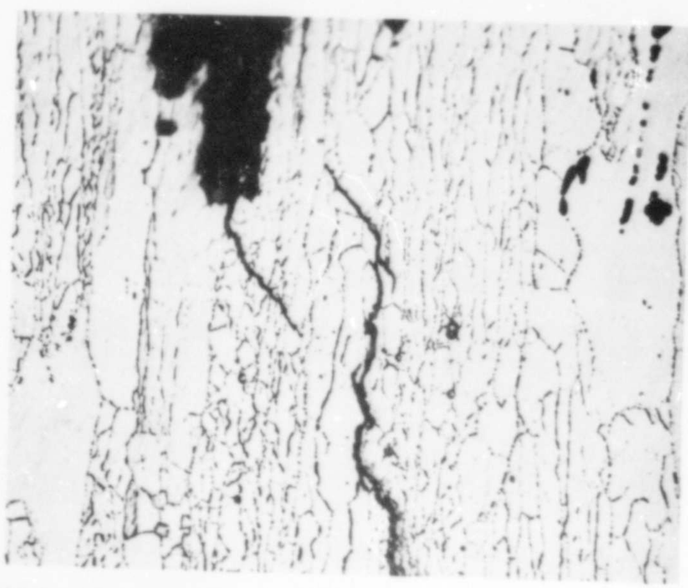
NEG. NO. 180738 500X KELLER'S ETCH

TWO-INCH THICK MA15-T6X1 PLATE

FIG. 22 ILLUSTRATES STRESS-CORROSION CRACK IN S. NO. 379537-6-N40



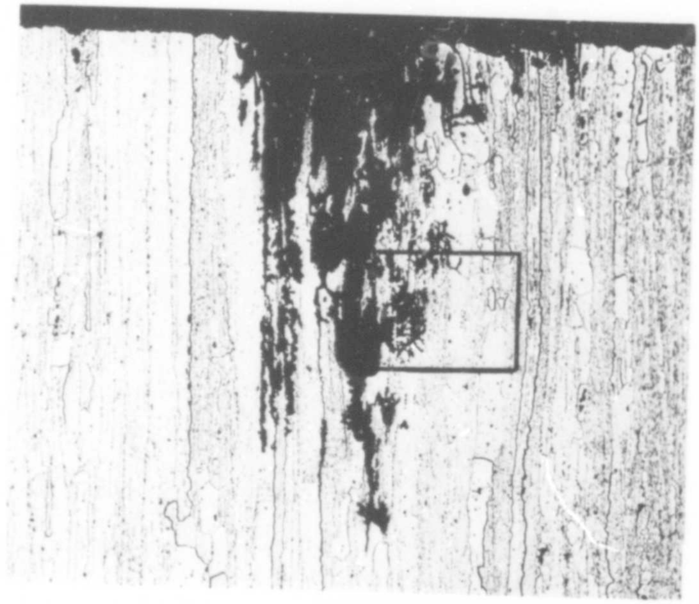
NEG. NO. 180735 100X KELLER'S ETCH



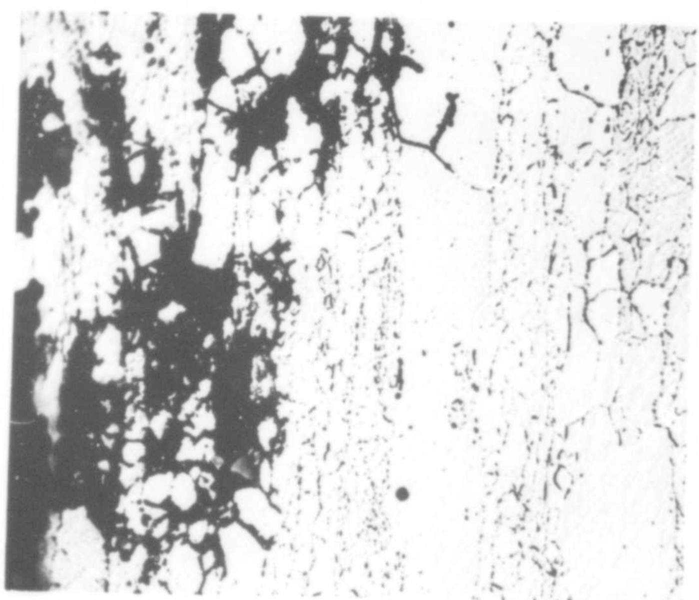
NEG. NO. 180736 500X KELLER'S ETCH

TWO-INCH THICK MA15-T7X2 PLATE

FIG. 23 ILLUSTRATES PITTING ATTACK AND TRANSGRANULAR CRACKING IN S. NO. 379069-2-N44



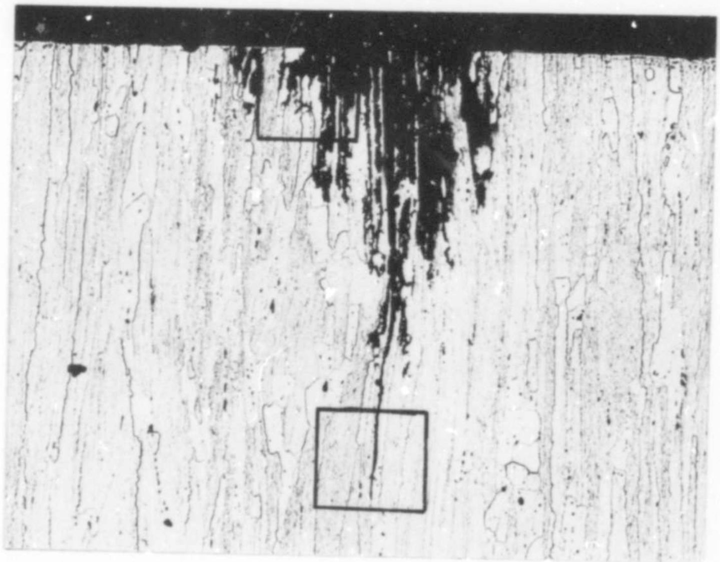
NEG. NO. 180731 100X KELLER'S ETCH



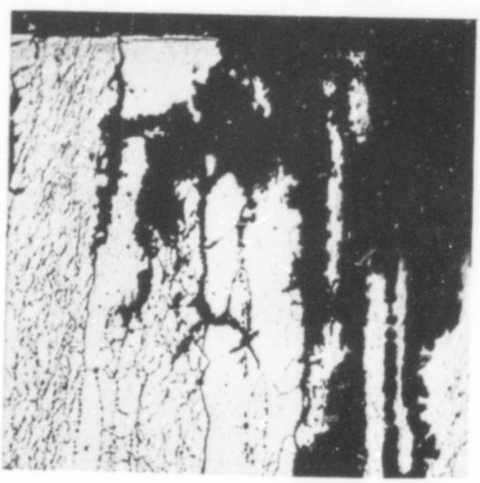
NEG. NO. 180732 500X KELLER'S ETCH

TWO-INCH THICK MA15-T7X1 PLATE

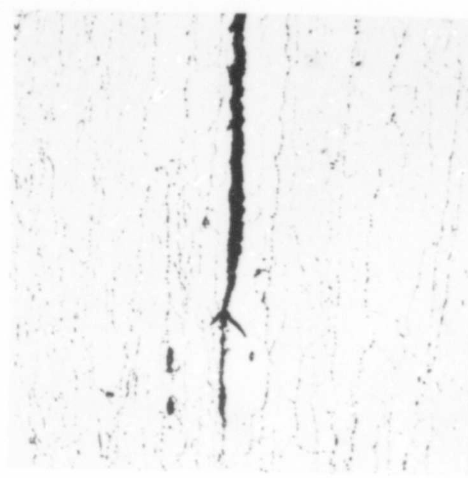
FIG. 24 ILLUSTRATES CORROSION ATTACK ALONG GRAIN AND GRAIN FRAGMENT BOUNDARIES IN S. NO. 379069-1-N38



NEG. NO. 179505 100X KELLER S ETCH



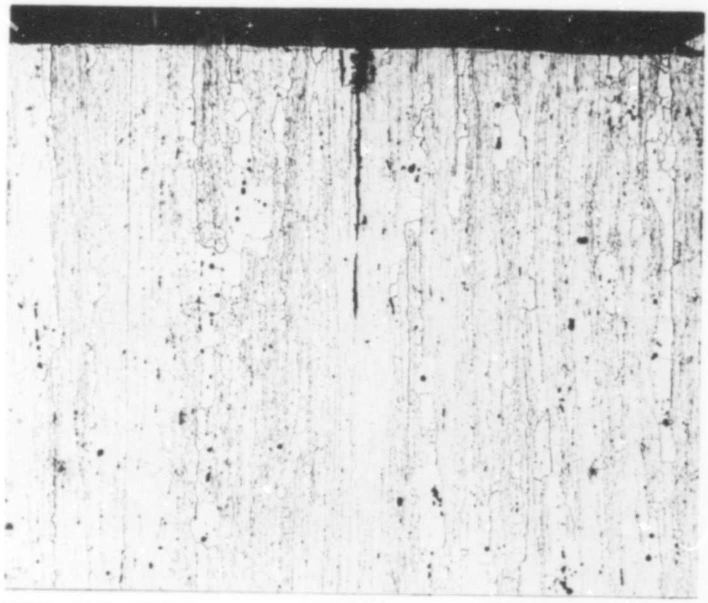
NEG. NO. 179506 50X KELLER S ETCH



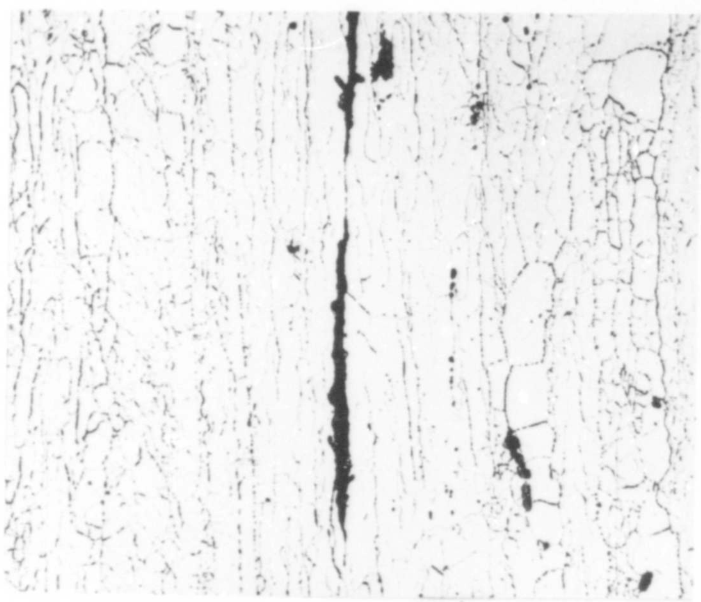
NEG. NO. 179507 500X KELLER S ETCH

SHORT – TRANSVERSE SPECIMEN OF TWO – INCH THICK PLATE STRESSED AT 40 KSI. FRACTURED AFTER 20 DAYS EXPOSURE 3.5% NaCl ALTERNATE IMMERSION

FIG. 25 ILLUSTRATES NATURE OF CORROSION ATTACK AND CRACKING IN S. NO. 379069 – 1 – N39



NEG. NO. 179508 100X KELLER S ETCH



NEG. NO. 179509 500X KELLER S ETCH

MA15—T7X1

SHORT — TRANSVERSE SPECIMEN OF T [illegible] — INCH THICK PLATE STRESSED AT 40 KSI.
FRACTURED AFTER 6 DAYS EXPOSURE IN 3.5 % NaCl ALTERNATE IMMERSION

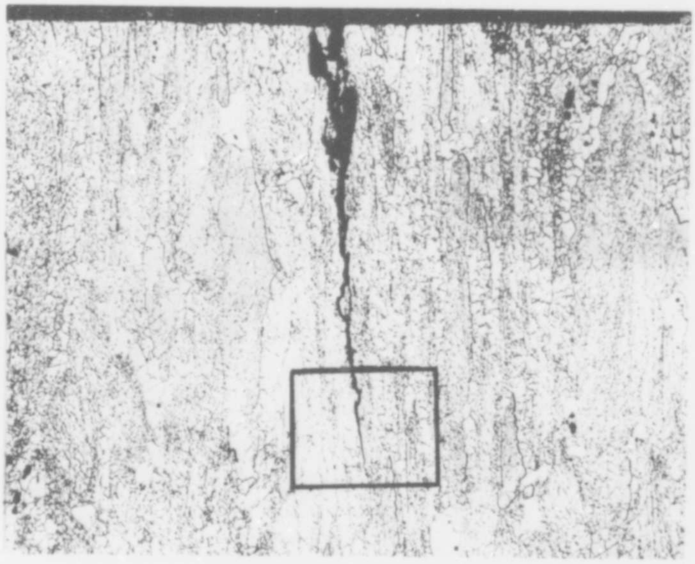
FIG. 26 ILLUSTRATES NATURE OF CORROSION ATTACK AND CRACKING IN S. NO. 379069 — I — N40

NEG. NO. 179510 100X KELLER S ETCH

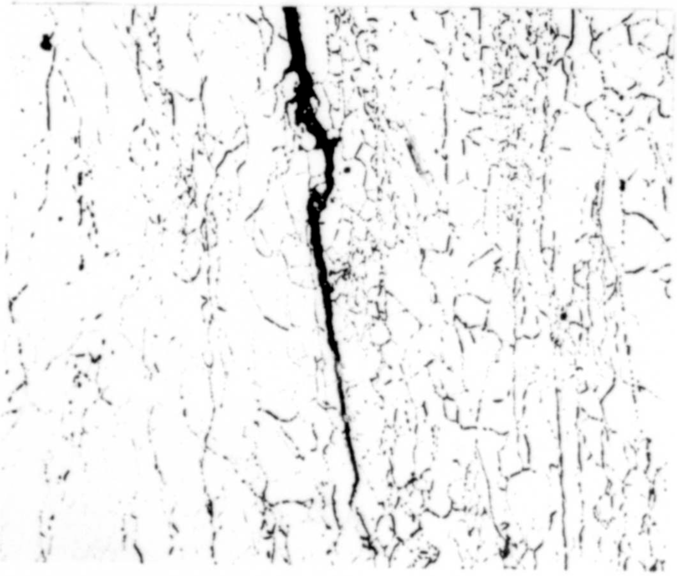
MA15—T7X1

SHORT — TRANSVERSE SPECIMEN OF TWO — INCH THICK PLATE STRESSED AT 40 KSI. FRACTURED AFTER 26 DAYS EXPOSURE IN 3.5 % NaCl ALTERNATE IMMERSION

FIG. 27 ILLUSTRATES NATURE OF CORROSION ATTACK AND CRACKING IN S. NO. 379069 — N41



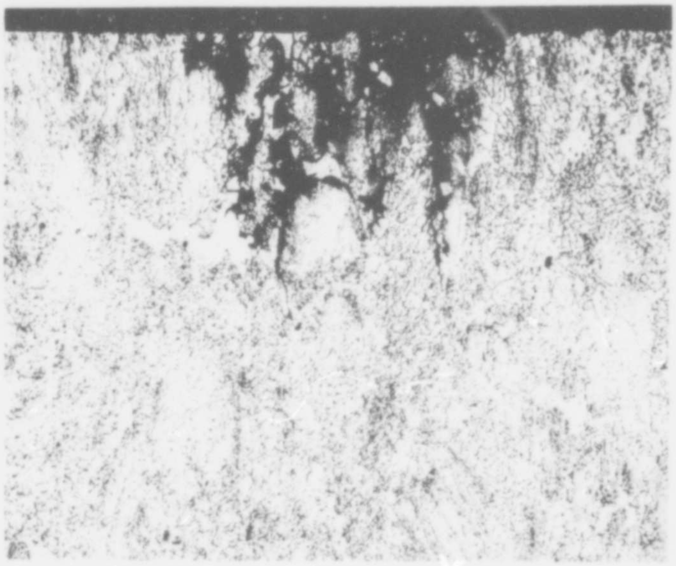
NEG. NO. 180741 100X KELLER'S ETCH



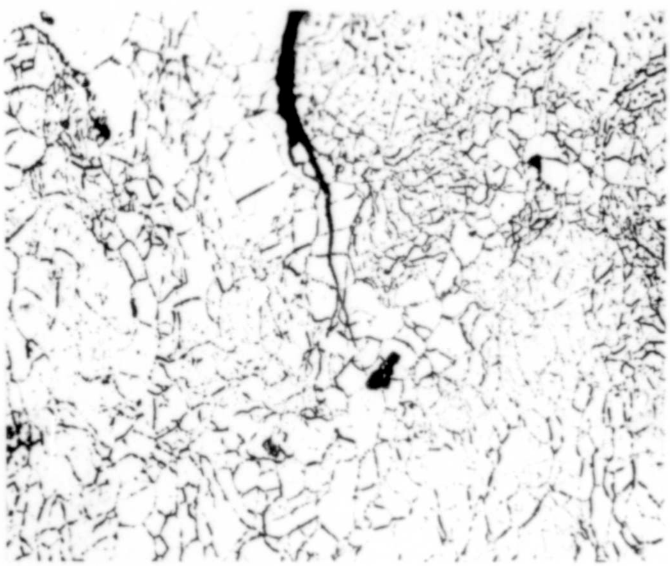
NEG. NO. 180742 500X KELLER'S ETCH

FOUR–INCH THICK MA15–T7X1 PLATE

FIG. 28 ILLUSTRATES CRACK WHICH APPEARS TO PROGRESS ALONG BOTH A TRANSGRANULAR AND AN INTERGRANULAR PATH IN S. NO. 379070–1–N39



NEG. NO. 180739 100X KELLER'S ETCH



NEG. NO. 180740 500X KELLER'S ETCH

SIX–INCH THICK MA15–T7X1 PLATE

FIG. 29 ILLUSTRATES TRANSGRANULAR CRACKING EMANATING FROM CORROSION ALONG GRAIN FRAGMENT BOUNDARIES

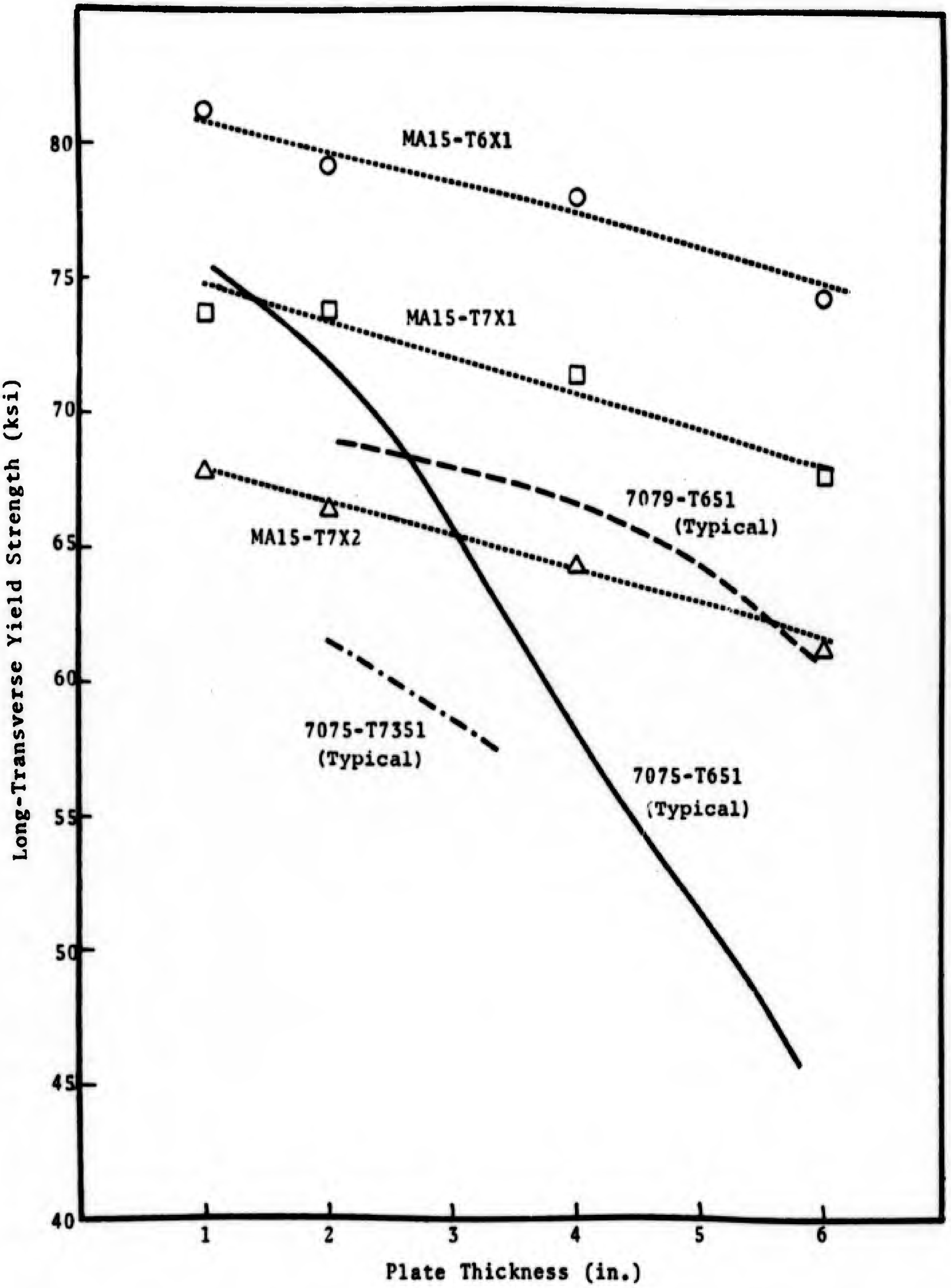


Figure 30 Comparison Between MA15 and Commerical Alloy Plate.

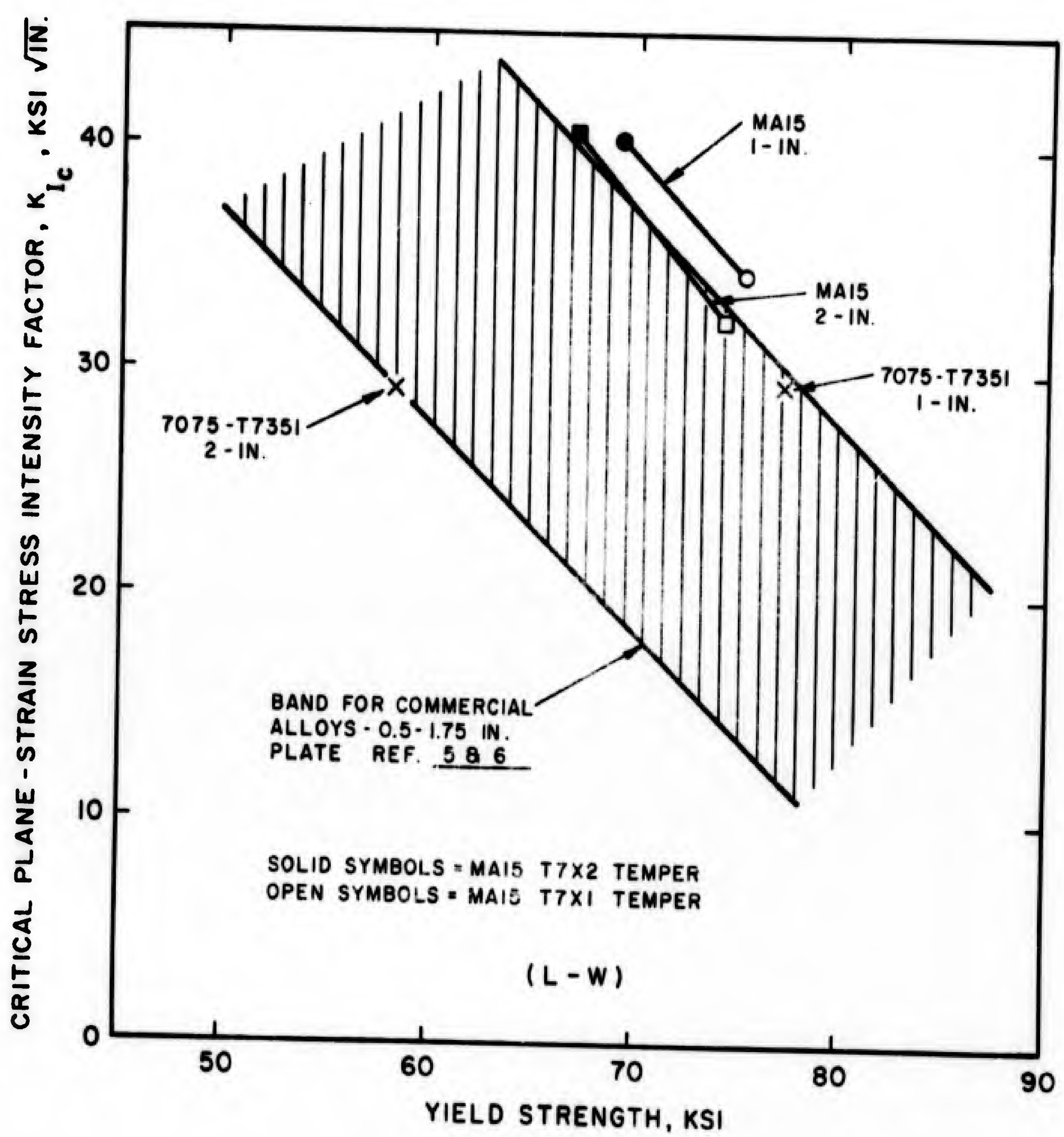


FIG. 31 LONGITUDINAL FRACTURE TOUGHNESS 0.5 - 2-IN. PLATE

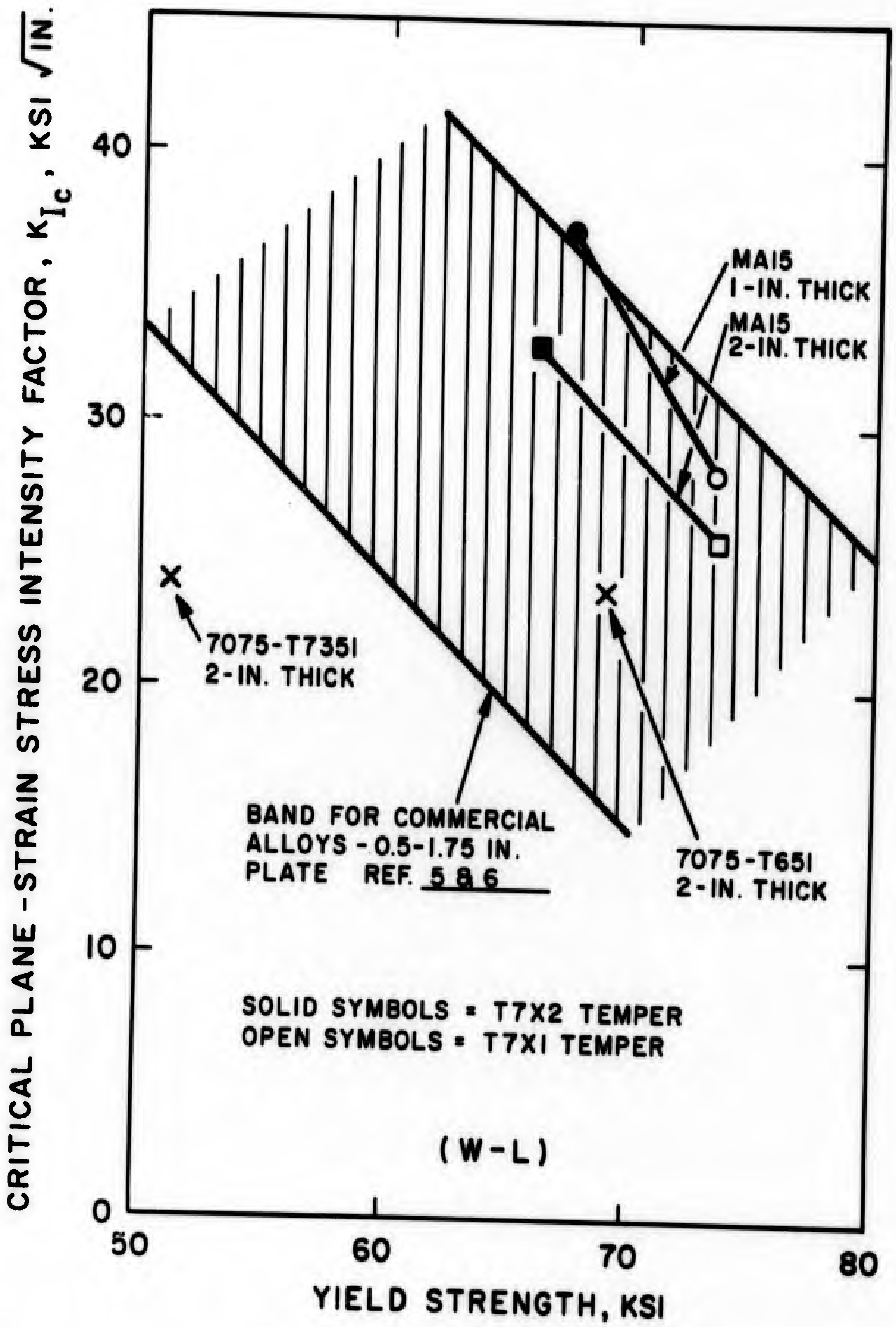


FIG. 32 LONG - TRANSVERSE FRACTURE TOUGHNESS
0.5 - 2-IN. PLATE

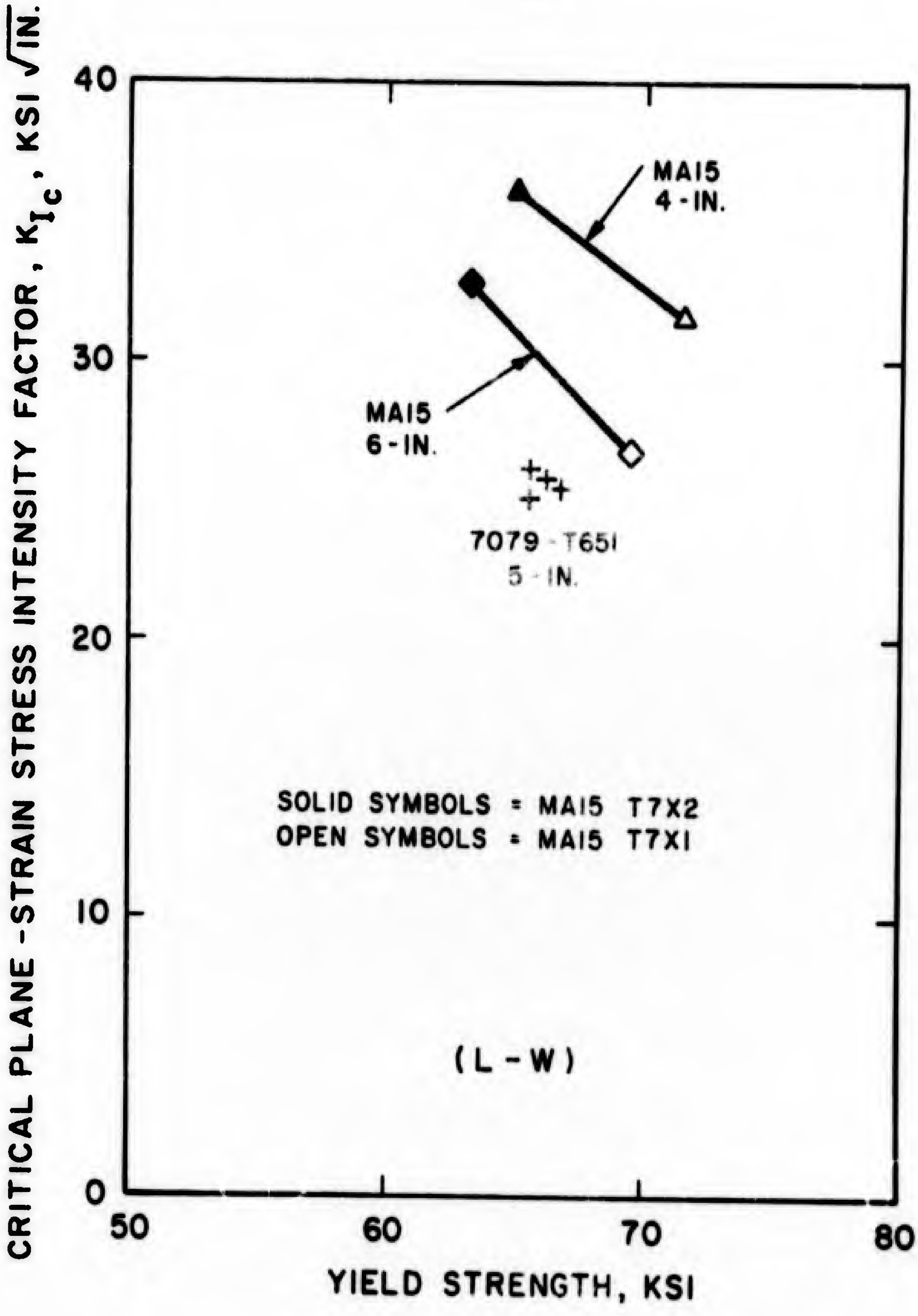


FIG. 33 LONGITUDINAL FRACTURE TOUGHNESS
4-6-IN. PLATE

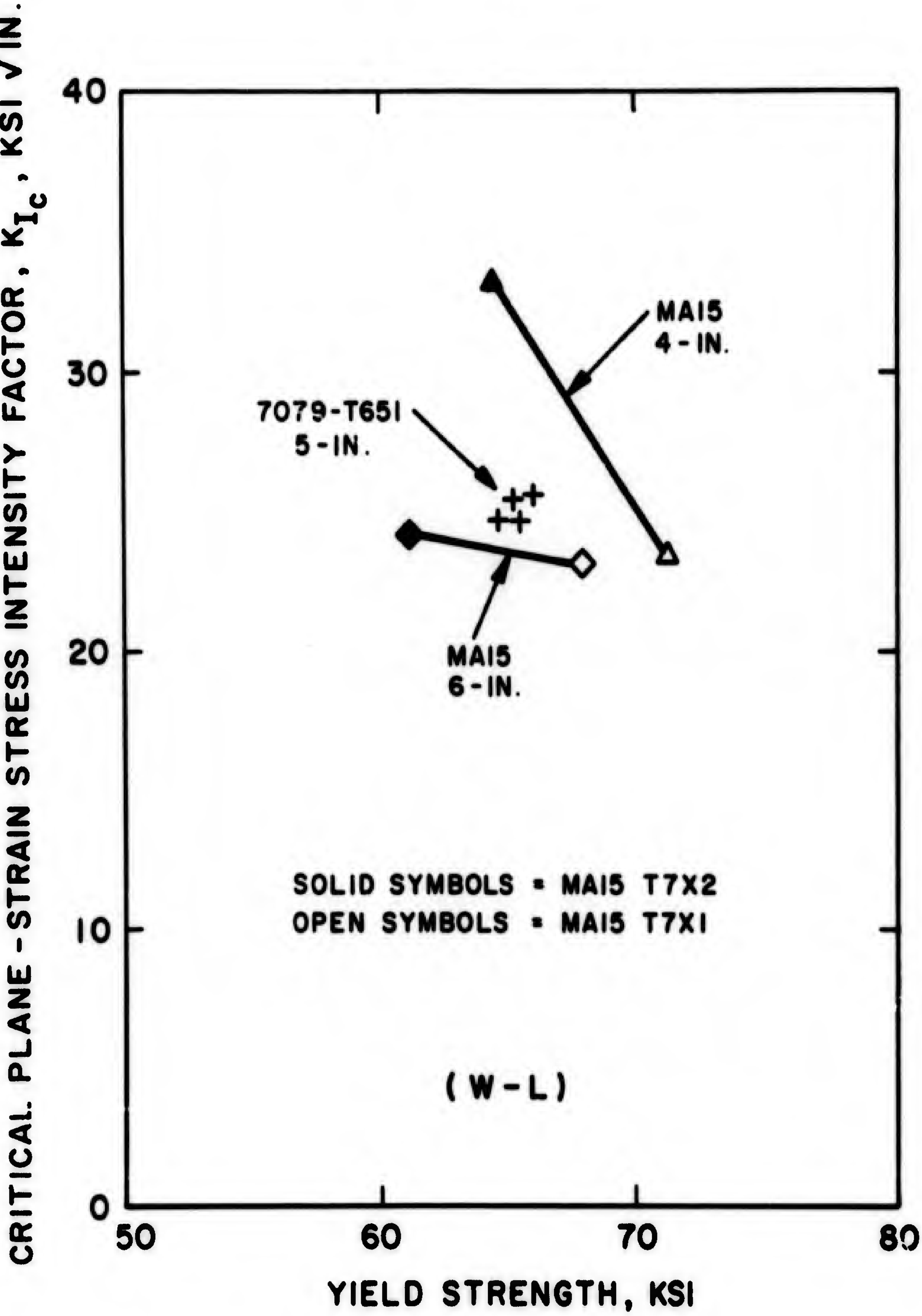


FIG. 34 LONG-TRANSVERSE FRACTURE TOUGHNESS
4-6-IN. PLATE

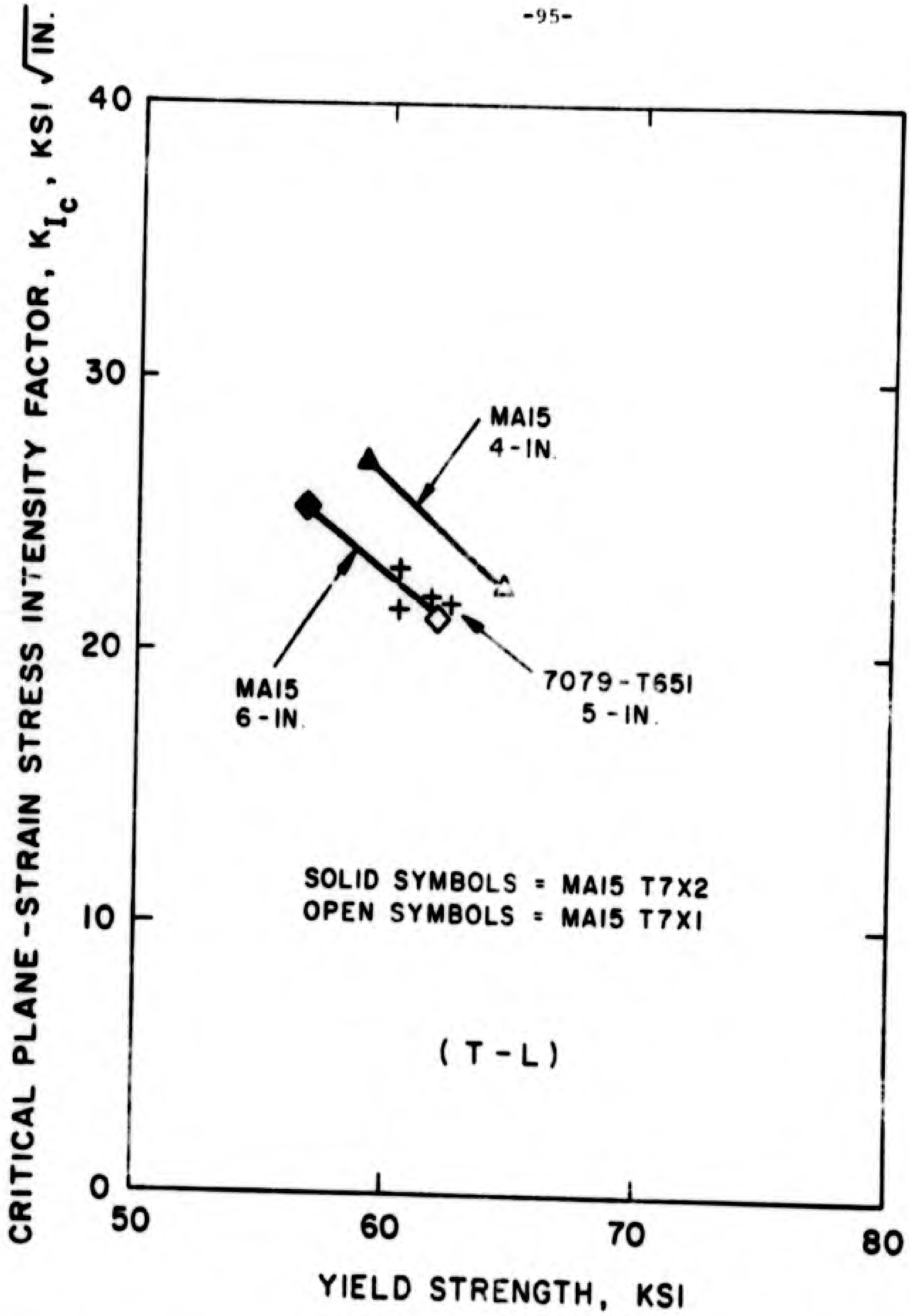


FIG. 35 SHORT-TRANSVERSE FRACTURE TOUGHNESS

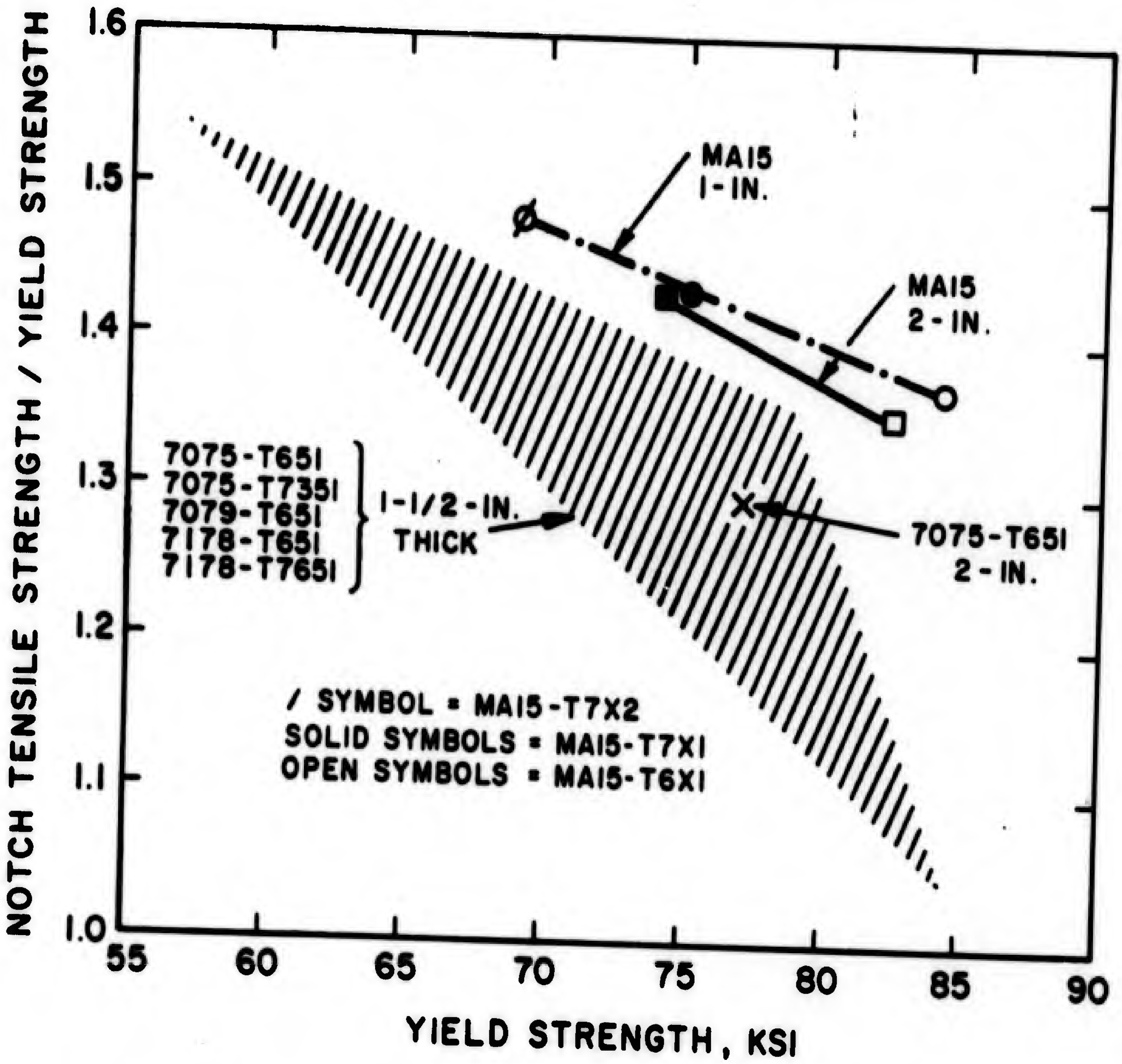


FIG. 36 LONGITUDINAL NOTCH TOUGHNESS
1-2-IN. PLATE

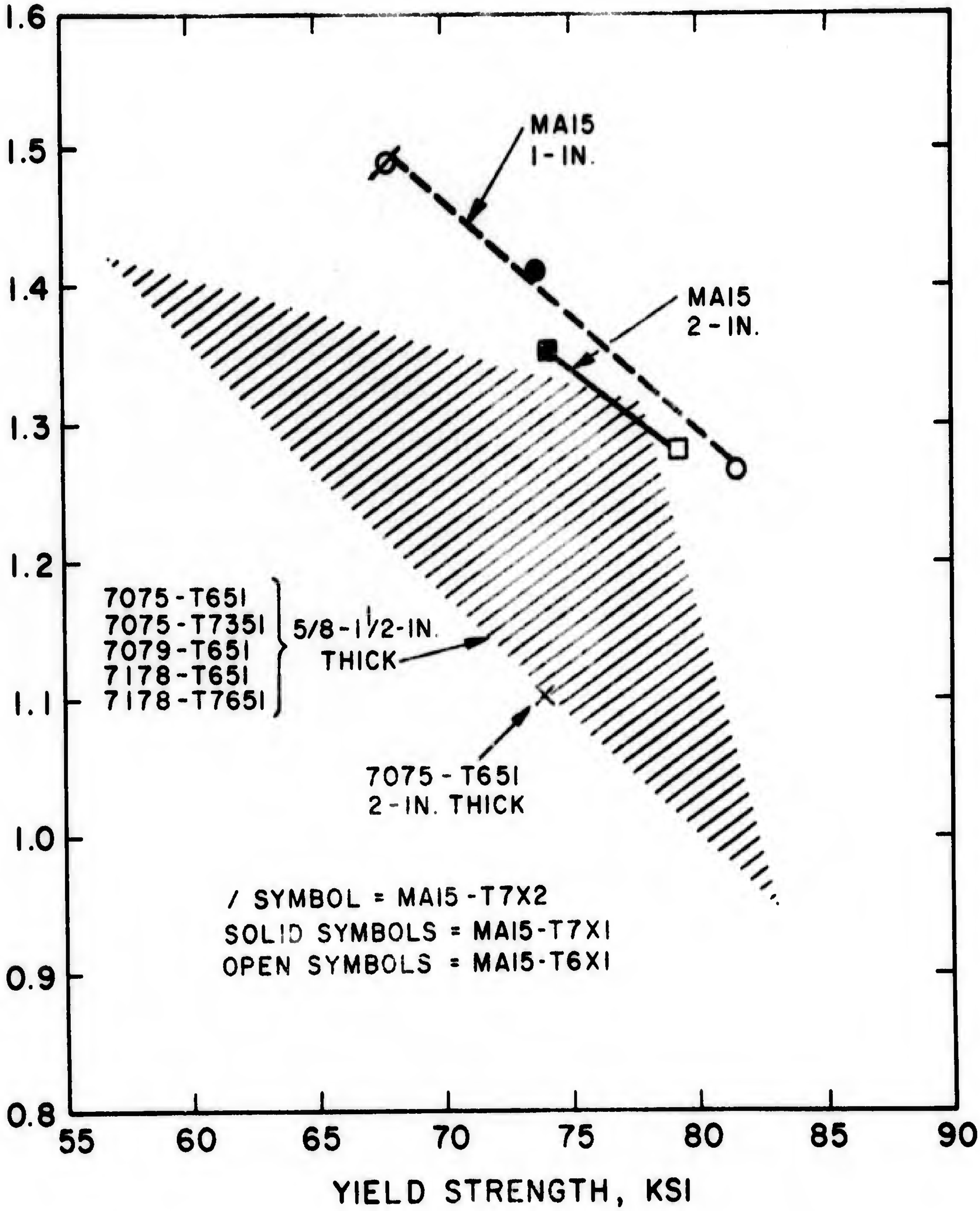


FIG. 37 LONG-TRANSVERSE NOTCH TOUGHNESS
5/8-2-IN. PLATE

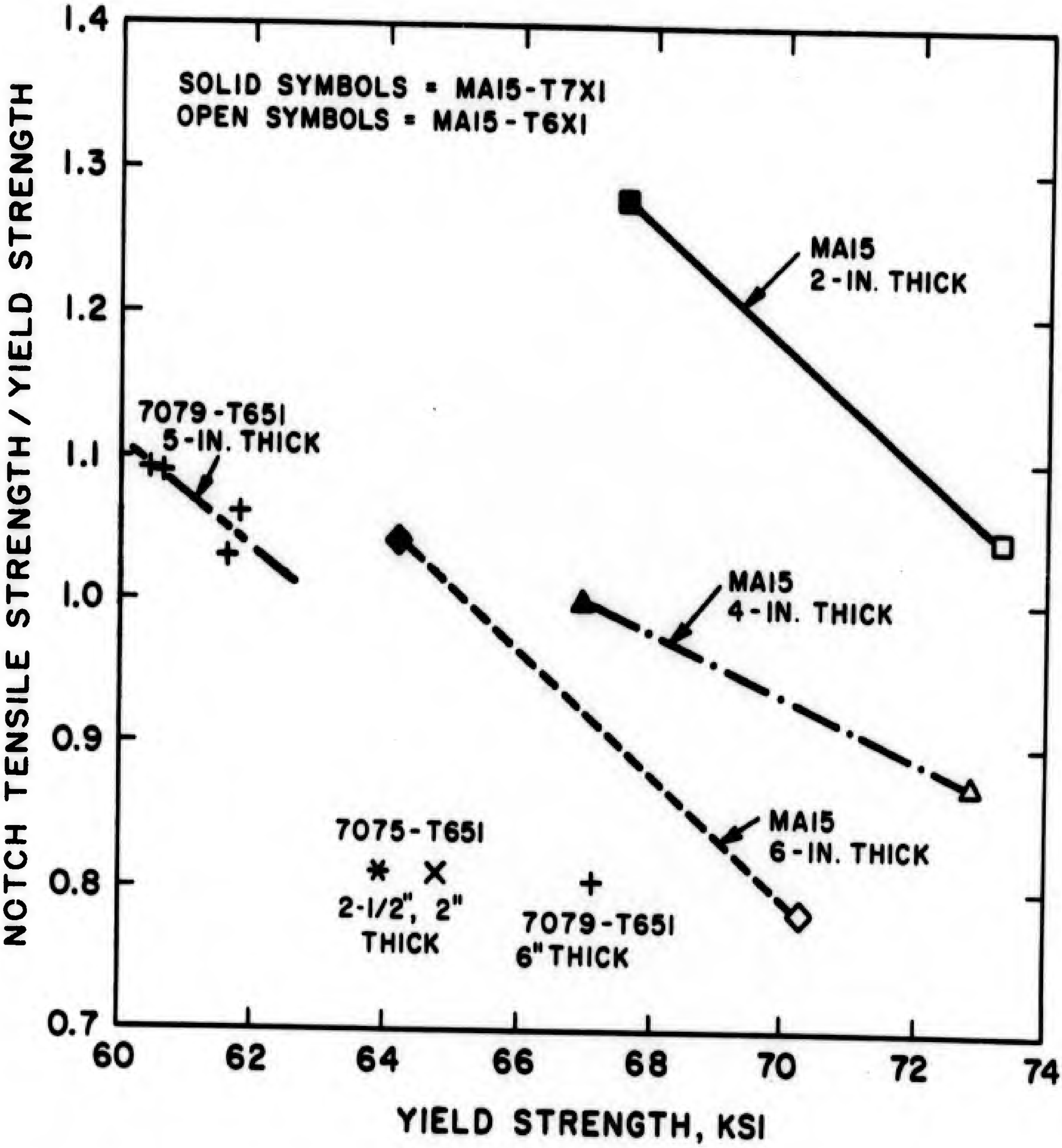


FIG. 38 SHORT-TRANSVERSE NOTCH TOUGHNESS
2-6-IN. PLATE

APPENDIX

INTERPRETATION OF STRESS-CORROSION TESTS

Accelerated stress-corrosion tests are necessary for alloy development studies, but the results must be interpreted with caution. The philosophy of the Alcoa Research Laboratories in regard to these tests, the need for a better accelerated test, and some of the cautions that must be observed in interpreting results were presented in Reference 1 and will not be repeated in detail. Some comments also found in Reference 2 are reiterated, however, because of their relevance to interpretation of the stress-corrosion tests in this investigation.

Intergranular vs Transgranular Fracture

The characteristic mode of stress-corrosion cracking in aluminum alloys is along grain or grain fragment boundaries, but highly stressed specimens of resistant materials such as 7075-T73 and 2219-T87 have occasionally fractured in the 3.5% NaCl alternate immersion test. Metallographic examination of such fractured specimens generally has failed to detect any evidence of stress-corrosion cracking, but instead, has revealed transgranular cracks emanating from sites of localized corrosion. Therefore, such failures have been regarded as mechanical overload failures resulting from severe corrosion. The tendency for such failures is greatest for alloys and tempers that have a high resistance to intergranular corrosion and to stress-corrosion cracking combined with a high strength and a moderate-to-low notch toughness.

Exposing unstressed specimens along with those that are stressed and tension testing them after several time periods is a means of monitoring the extent of corrosion. High losses in tensile strength of the unstressed specimens are indicative of severe corrosion and place added importance on the metallographic examination to determine fracture mode of the stressed specimens.

The 3.5% NaCl Alternate Immersion Test

The 3.5% NaCl alternate immersion test has proven to be reliable for Al-Zn-Mg-Cu-Cr alloys such as 7075 (1.6% Cu) and 7178 (2.0% Cu), and this test was used for the development of the stress-corrosion resistant alloy-tempers 7075-T73 and 7178-T76. Atmospheric exposures of various 7075-T73 products in both seacoast and inland industrial locations for periods up to 8 years have confirmed the reliability and validity of the alternate immersion test in assessing service performance of this type of alloy. The correlation between the performances in the alternate immersion tests of alloys containing lower copper than that found in 7075 with their performances in natural environments, however, is low.[8]

Because of the high copper content of the experimental alloys in this investigation, we expect a good correlation between the results of the alternate immersion test and the results of extended atmospheric exposure. To be specific, if specimens of an alloy and temper fracture during the alternate immersion test when stressed at a particular level and exhibit the characteristic evidence of stress-corrosion cracks along grain and grain fragment boundaries, we have a high confidence that the material will be susceptible to atmospheric stress-corrosion cracking at the same stress level. Likewise, if an adequate number of samples of an alloy and temper are intact after exposure in the alternate immersion test at a particular stress level, we have a high confidence that the material will be resistant to atmospheric stress-corrosion cracking.

If specimens fracture during the alternate immersion test and we do not detect characteristic stress-corrosion cracks along grain and grain fragment boundaries but do detect transgranular cracks initiating at sites of localized corrosion, however, our confidence in our ability to predict their atmospheric stress-corrosion resistance becomes lower. If the specimens fracture early in the test, we have a low confidence that the material is resistant to atmospheric stress-corrosion cracking because we have no evidence that the specimens would not have suffered stress-corrosion cracks if they had not fractured because of mechanical overload. On the other hand, if the specimens fracture near the end of the test our confidence that the material is resistant to atmospheric stress-corrosion cracking becomes higher because the probability increases that the specimens were in test for a time sufficient to permit stress-corrosion cracks to develop if the material were susceptible.

Interpreting the Performance of Specimens Which Fractured During the Current Investigation

During a previous investigation, performance of 1/8" diameter short-transverse orientation specimens was categorized as follows using metallographic examination and times to fracture as criteria:

1) <u>Susceptible to Stress-Corrosion Cracking</u>

At least one specimen of the pair fractured early in the test or metallographic examination of representative specimens which fractured after longer times revealed the characteristic evidence of secondary stress-corrosion cracks along grains or grain fragment boundaries.

2) <u>Probably Highly Resistant to Stress-Corrosion Cracking</u>

The specimens either were intact or else they fractured near the end of the test after they had corroded appreciably. Metallographic examination of representative fractured specimens revealed no secondary characteristic stress-corrosion cracks along grain or grain fragment boundaries, but did reveal cracks that were predominantly transgranular emanating from the sites of localized corrosion.

3) <u>Questionable Resistance to Stress-Corrosion Cracking</u>

At least one specimen fractured after a short-to-intermediate time in test. Metallographic examination failed to disclose evidence of characteristic stress-corrosion cracking along grain or grain fragment boundaries, but generally revealed cracks that were mixed mode, although predominantly transgranular, emanating from sites of localized corrosion.

Using these same criteria, fractured 1/8" diameter short-transverse orientation specimens of MA15-T6X1 are classified in

Category 1, similar fractured specimens of MA15-T7X2 are classified in Category 2, and similar fractured specimens of MA15-T7X1 are classified in Categories 1, 2 or 3 depending on plate thickness and applied stress.