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# EXPLORATORY DEVELOPMENT OF HIGH STRENGTH, STRESS-CORROSION RESISTANT ALUMINUM ALLOY FOR USE IN THICK SECTION APPLICATIONS

J. T. STALEY,
H. Y. HUNSICKER

ALCOA/ALUMINUM COMPANY OF AMERICA

TECHNICAL REPORT AFML-TR-70-256

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AFML-TR-70-256

# EXPLORATORY DEVELOPMENT OF HIGH STRENGTH, STRESS-CORROSION RESISTANT ALUMINUM ALLOY FOR USE IN THICK SECTION APPLICATIONS

J. T. Staley
H. Y. Hunsicker

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## FOREWORD

This report was prepared by the Physical Metallurgy Division, Aluminum Company of America, New Kensington, Pennsylvania under Contract F33615-69-C-1644. The contract was initiated under Project No. 7351, "Metallic Materials for Air Force Weapon System Components", Task No. 735105, "High Strength Metallic Materials for Load-Bearing Aerospace Components". The program is monitored by the Air Force Materials Laboratory, with Dr. T. M. F. Ronald, LLP, as Project Engineer. This report covers the period June 1, 1969 through September 30, 1970 and was released by the authors in October 1970.

This technical report has been reviewed and is approved.

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## ABSTRACT

An alloy has been developed which exhibits a good resistance to stress-corrosion cracking at 25 ksi or higher stress in the short-transverse direction based on 30 days exposure in the 3.5% NaCl alternate immersion test. Estimated minimum strength of three-inch thick plate exceeds the guaranteed minimum strength of the closest competing aluminum alloy by 3 ksi and the advantage increases with increasing thickness. Eccentricities in the results of 84 day alternate immersion tests and lack of data regarding performance of alloys of this type in natural environments for longer than 10 months, however, indicate that caution must be used in extrapolating the results of the accelerated tests to predict service performance.

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## SECTION I

## INTRODUCTION

The aerospace industry desires an aluminum alloy capable of developing in thick products: 1) high strength, 2) high resistance to stress-corrosion cracking, and 3) good fracture toughness for advanced, reliable, high-performance aircraft and aerospace structures. Existing commercial alloys and tempers provide one or two of these characteristics, but the combination of all three is not available. Because of the great need for such a material, several Defense Agencies have funded programs which supplement development work at major aluminum producers.

The portion of the Alcoa program reported here deals with evaluation of several promising leads that have emerged from continuing effort on this problem. The original plan was to verify encouraging results previously reported concerning effects of increasing Cu content and substituting either Mn or Zr for Cr in 7075-type alloys (1) and to determine effects of substituting elements other than Zr or Mn for Cr in such alloys.

The base composition selected for evaluating effects of ancillary elements was 6% Zn, 2.3% Mg, 2.3% Cu, 0.09% Fe, and 0.05% Si. Alcoa alloy MA15 consists of the foregoing base composition with 0.12% Zr and was included for comparison and to verify promising results previously reported.(1) Other variants included an alloy containing 0.12% Zr and 0.05% Cr and alloys containing 0.15% V either alone or in combination with .05% Cr, 0.15% Mn, or 0.12% Zr. Another alloy contained 0.25% Fe in combination with 0.25% Ni. A 7175-type alloy was included for comparison and control. This composition had a Zn content higher than the upper limit for 7175 (6.1% Zn max.) and a Cr content under the minimum (0.18% Cr min.). The actual composition was intermediate between that of 7175 and 7049, somewhat closer to 7175.

Because of coarse, primary $Al_{12}Mg_2V$ constituent particles present in plate rolled from five of the original nine alloys, and because of promising results with MA15, the program was altered and additional alloys containing Zr were evaluated. Eight alloys containing 4.6-6% Zn, 1.75-2.5% Mg, and 1.9-3% Cu, 0.10-.12% Zr, and 0-0.17% Mn were selected to provide additional information regarding MA15 type alloys. A Cr-free version of a chromium-containing alloy that looked promising in another investigation except for its high quench-sensitivity (2) was also selected for evaluation. It contained 8.1% Zn, 2.4% Mg, 1.7% Cu, and 0.13% Zr.

The objective of this program is the development of a high-strength aluminum alloy suitable for large forgings, thick plate, and extruded sections. This alloy shall be capable of production using presently available commercial processes and heat treatments, and it shall have the following minimum properties:

1. A minimum longitudinal 0.2% yield strength of 72,000 psi in three-inch plate.

2. A minimum longitudinal 0.2% yield strength of 63,000 psi in eight-inch forgings.

3. A minimum short-transverse stress-corrosion threshold stress of 25,000 psi (as measured in alternate immersion salt solution tests).

4. A minimum toughness, $K_{Ic}$, of 35,000 psi $\sqrt{in.}$

5. A minimum fatigue strength equal to that of 7075-T6.

## SECTION II

## MATERIAL

### 1. CASTING

All alloys were semi-continuously cast by the direct-chill process to 12" x 38" x 60-70" ingots (2700-3000 lbs) and stress relieved at 650 F. Chemical analyses are presented in Table 1.

### 2. FABRICATION

Stress-relieved ingots were scalped to ten inches thick, and rolling sections were fabricated to plate according to the schedules in Figures 1 and 2. Pieces of Alloys 3 and 7 were rejected during ultrasonic inspection because of indications of planar cracks parallel with the surface. Additional ingot sections of these alloys were preheated and hot rolled to four inches thick as described in Figure 1 then hot rolled at 700 F to 2-1/2-inch thick plate. Because of unwelded ingot porosity present in the rolled plate of Alloys 10, 11, 12, 14 and 15, additional plate was prepared from these compositions by preforging and rolling as described in Figure 3. The preforged plate was metallographically sound.

Results of structural examinations of the ingots and the plate are presented in Appendix I.

### 3. HEAT TREATMENT

Pieces of rolled plate were heat treated as described in Figures 4 and 5. The preforged plate was solution heat treated, quenched, and precipitation heat treated at 250 F as described in Figure 5, but the precipitation treatment times at 325 F were adjusted to shorter times as described in the data. Heating to the second step precipitation treatment temperature was programmed to simulate typical plant heating curves for full scale furnace loads. Heat-up time for the 325 F treatment was 10-1/2 hours, and heat-up time for the 350 F treatment was three hours. Timing for the precipitation heat treatments began when the temperature reached control temperature minus 10 degrees F.

### 4. TESTING

#### a. Tensile Properties

Tensile properties of all items were determined using duplicate standard specimens oriented in the long-transverse direction. In addition, properties were usually determined in the short-transverse direction and for some items in the longitudinal direction. Either 1/2" or 1/4" dia. long-transverse and longitudinal orientation specimens were taken from mid-

planes of the 2" and 2-1/2" thick plate and from midway between midplanes and rolled surfaces of the 4" thick plate. One-eighth inch diameter short-transverse direction specimens were taken midway between rolled surfaces.

b. Stress-Corrosion Cracking

The stress-corrosion cracking characteristics of selected items were determined using 1/8" diameter short-transverse orientation specimens exposed by alternate immersion in a 3.5% NaCl solution and in the New Kensington atmosphere. Stress-corrosion tests were conducted as described in reference(2) with two exceptions:

(1) The 3.5% NaCl alternate immersion test conditions were controlled according to Federal Test Method 823 except temperature and humidity were uncontrolled.

(2) Triplicate specimens were stressed at different levels in the two environments:

(a) 25 ksi, 30 ksi, and 35 ksi in the alternate immersion test.

(b) 25 ksi, 40 ksi, and 75% of their respective 0.2% yield strengths in the New Kensington atmosphere.

The alternate immersion test was terminated after 84 days; the test in the industrial atmosphere of New Kensington, Pennsylvania, is continuing.

c. Electrical Conductivity

The electrical conductivities of all pieces were measured on the rolled surfaces with a model FM-100 Magnatest.

d. Fracture Toughness

The fracture toughness of certain items were determined using L-W* (longitudinal) and T-L* (short-transverse) specimens of the type described in Figure 6.

* 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).

## SECTION III

## RESULTS

### 1. TENSILE PROPERTIES

Long-transverse tensile properties of alloys containing 0.12% V were determined, but because coarse $Al_{12}Mg_2V$ particles rendered them unsuitable for use as structural materials, the properties are of only academic interest and relegated to Appendix II, Tables 59 through 63. The data do indicate, however, that 0.12% V increased the quench sensitivity to such an extent that such alloys would not meet target properties in thick sections.

Tensile properties of Alloys 5, 6, 8 and 9 are presented in Tables 2 through 5. These data confirm that chromium-free Al-Zn-Mg alloys containing more than 2% copper develop substantially higher strengths after precipitation treatments in the 325 F - 350 F range than they do after the usual T6 treatment for high-strength 7XXX aluminum alloys of 24 hours at 250 F. The data also reveal that adding as little as 0.05% Cr had no effect on strength of cold-water-quenched plate precipitation heat treated 24 hours at 250 F, but lessened the strength increase attainable by subsequent precipitation treatments at 325 F or 350 F and further decreased the strength of more slowly quenched material. The marked quench sensitivity and monotonic decrease in strength upon precipitation heat treating at 325 or 350 F following first-step precipitation at 250 F that are characteristic of alloys with higher Cr content are evident for the 7175-type composition, Alloy 8. Substituting 0.24% Fe and 0.28% Ni for 0.12% Zr affected the quenching response and precipitation characteristics in a manner similar to the addition of 0.05% Cr.

Elongations of Alloy 9 (Zr) and Alloy 5 (Zr and Cr) were lower than those of 7175-type Alloy 8 after identical heat treatments, but were comparable to the elongations of this alloy when collated on an equal strength basis. Elongations of Alloy 6 (Fe and Ni) were lower than those of the other alloys.

Tensile properties of Alloys 10 through 18 are presented in Tables 6 through 14. Strength progressively increased and per cent elongation decreased with increasing magnesium content and was considerably less affected by variations in either zinc or copper contents. Alloys with less than 2.3% Mg showed more loss in strength with time at 325 F than alloys containing high Mg. Quench rate also affected elongation as well as strength. Effects of Mg content and quenching conditions on long-transverse tensile properties of 4-inch thick plate are presented in Figure 7. Long-transverse elongations of slowly quenched 4-inch thick plate in alloys containing

less than 2.35% Mg were substantially higher than those of the compositions containing more than 2.5% Mg. It should be pointed out that this plate received less hot working reduction (60%) than is generally required to develop the full elongation in the long-transverse direction that is associated with plate produced with normal reductions of 75% or greater.

Because the concomitant large increase in per cent elongation and small increase in strength of alloys containing the lower Mg contents were unusual, broken tensile specimens of several alloys were investigated using a scanning electron microscope. Results of these examinations are detailed in Appendix II. Briefly, the scanning electron microscope revealed that differences in elongation reflected differences in fracture mode; per cent elongation increased as per cent intergranular fracture decreased. Slow quenching decreased the amount of intergranular fracture in alloys containing 1.75% and 2.25% Mg but did not affect the relatively large amount of intergranular fracture in the alloy containing 2.5% Mg. Attempts to correlate grain boundary precipitation as revealed by transmission electron microscopic technique with fracture mode were inconclusive.

Effects of precipitation heat treating time at 325 F and fabricating practice on long-transverse yield strengths of Alloys 10 through 18 are illustrated in Figures 8 through 12. Long-transverse strengths of plate quenched in cold water are plotted. Similar plots for Alloys 5, 6, 8 and 9 are included for comparison of aging curves. These data indicate that strengths after a given precipitation heat treatment were affected very little by fabricating practice.

## 2. STRESS-CORROSION CRACKING

Results of the accelerated stress-corrosion cracking tests employing 1/8"-diameter short-transverse tensile specimens exposed at constant strains by alternate immersion in 3.5% NaCl solution are presented in Tables 15 through 27. Notations referenced to the "days to failure" for individual specimens denote classifications of crack characteristics based upon metallographic examinations of the failed specimens.

Performance of the 7175-type Alloy 8 is presented in Table 17. Development of resistance to SCC at the three stress levels, 25, 30, 35 ksi, with this alloy required precipitation times at 325 or 350 F that produced long-transverse yield strengths of 65 ksi or lower. In comparison, mill-fabricated and heat treated 2 to 2.5 in. thick 7075-T7351, SCC-resistant under the same testing conditions at 41 ksi for 30 days, has an average long-transverse yield strength of about 60 ksi.

Among the first group materials (2.5 in. plate) Alloy 9 (MA15) provided highly encouraging results surpassing those of 7175 type Alloy 8. No failures were encountered in the 84-day test with specimens stressed at 25 ksi with conditions of precipitation heat treatment that provided long-transverse yield

strengths up to and including 78 ksi. Based on a 30-day testing period, all specimens of this composition plate having yield strengths to and including 78 ksi were intact at applied stresses to 35 ksi. These results considered alone would provide an extremely optimistic outlook for the MA15 composition. However, as will be evident, the enthusiasm offered by the performance of this material is moderated by the less-promising performance of closely-related compositions.

By comparison with Alloy 9, no benefit in SCC performance could be discerned from the addition of 0.05% Cr to the Zr-containing alloy. In fact, the results were distinctly inferior. The SCC evaluation of Alloy 6 (Fe + Ni addition) was restricted in view of the unattractive elongation values. The alloy offered no SCC advantage.

Disregarding for the present the significance of failure mode based on the metallographic examinations, results of the accelerated stress-corrosion tests of Alloys 10-18 were distinctly less encouraging than those obtained with the initial composition of the MA15 type (Alloy 9). Alloys 10, 11, 12, 13, and 15 were intended to assist in defining the composition limits of MA15. Among this group none of the 17 variants of composition, thickness, fabrication, or heat treatment having a long-transverse YS of 74 ksi or higher survived the 84-day test period without failure of one or more specimens at 25 ksi. On a 30-day test basis, seven of the items having YS of 74 ksi or higher were intact at the 25 ksi stress level. There are 37 items in this group that had long-transverse YS of 70 ksi and higher. A summary of the per cent of these items that survived without failure at each stress level as well as all lower stresses for two periods of exposure, 30 and 84 days, is shown below:

Per cent of items from Alloys 10, 11, 12, 13 and 15 having Y.S. $\geq$70 ksi showing no failure at indicated stress and at all lower stresses in indicated exposure period

| Stress, ksi | Exposure Period, Days 30 | 84 |
|---|---|---|
| 25 | 68% | 38% |
| 30 | 49% | 24% |
| 35 | 32% | 14% |

Interpretation of the accelerated stress-corrosion test data in a simple, clear-cut manner involved difficulties associated with eccentricities such as those cases in which failures occurred at a certain stress but not at a higher stress, the significance of the metallographic observations concerning differences in

apparent failure mode, and some cases in which material was apparently more resistant with a shorter time of second-step precipitation heat treatment. Because of these difficulties, a "percent survival" method of comparative analysis was employed. For this analysis, the per cent of the total number of specimens exposed at each stress that survived without failure is plotted as a function of the applied stress. Such curves are generally of sigmoidal shape, indicative of the lack of a sharply defined threshold stress. This procedure permits relative comparison with the performance under the same conditions of testing with alloys currently being used and generally having established service records.

For this purpose, data from all of the Cr-free, Zr-containing alloys except 16 (high Zn, low Cu) were combined. Differences in fabrication, plate thickness and quench were disregarded, but the data were segregated into two sets corresponding with two final precipitation heat treating practices, 18 hours at 325 F and 24 hours at 325 F. The two curves derived in this manner for the broad group of experimental Zr-containing alloys based on per cent survival after 84 days exposure are shown in Figure 13. For comparison purposes, corresponding curves from tests of 7075-T651, 7079-T651 and 2024-T851 plate and 2024-T852 forgings are provided. On this basis, the accelerated stress-corrosion test performance of the experimental alloys places them in an order of ranking between the 2024-T852 forgings and the 2024-T851 plate. No stress-corrosion cracking difficulties have been encountered with these two alloy-temper-product combinations, although service experience of 2024-T852 forgings is somewhat limited.

Specific performance depended strongly upon second-step precipitation heat treatment time. When precipitation heat treated 18 hours at 325 F (average long-transverse yield strength 73 ksi for all cold water quenched material, 70 ksi for all hot water quenched material), 90% of the specimens stressed at 25 ksi survived, and over 50% of those stressed at 35 ksi survived. A substantially higher percentage survived with the longer final precipitation heat treatment of 24 hours at 325 F. With this treatment the average long-transverse yield strength with a cold water quench was 71 ksi, while the average with a hot water quench was 67 ksi.

Experimental alloys within a restricted range of Cu and Mg performed better than the broader alloy group as a whole. Combined performance of Alloys 9, 12, 14, 15 and 17 is presented in Figure 14. When precipitation heat treated 24 hours at 325 F, 97% of the specimens stressed at 25 and 30 ksi survived the 84-day alternate immersion test. The average yield strengths for this alloy group were 69 ksi for the 80 F quench and 65 ksi for the 180 F quench. An average survival rate of 80% at the same two stresses was obtained with these alloys after precipitation heat treating 18 hours at 325 F with average Y.S. of 73 ksi for material quenched in cold water, 70 ksi for material quenched in hot water.

Analyzing the stress-corrosion data on the basis of a 30-day exposure rather than an 84-day exposure significantly reduced the number of eccentricities previously discussed, particularly the incidence of fractured specimens which revealed no evidence of typical stress-corrosion cracking. Percent survival plots for the broad and restricted alloy groups are presented in Figures 15 and 16, respectively. Decreasing the test period substantially increased the performance of the experimental alloys while it had relatively little effect on the performance of the standard alloys.

The relationships of strength and per cent survival for the combined stress levels of 25 and 30 ksi for the entire group of Zr-containing Cr-free alloys containing less than 8% Zn and the restricted group can be summarized as follows:

| Alloys | Second-Step Precip. H.T. | Avg. % Survival 25 and 30 ksi 30 days | 84 days | Avg. Y.S. CWQ | Avg. Y.S. HWQ |
|---|---|---|---|---|---|
| 9,10,11, 12,13,14, 15,17,18 | 18 hrs 325 F | 87% | 66% | 73 ksi | 70 ksi |
| | 24 hrs 325 F | 98% | 85% | 71 ksi | 67 ksi |
| 9,12,14, 15,17 | 18 hrs 325 F | 97% | 80% | 73 ksi | 70 ksi |
| | 24 hrs 325 F | 100% | 97% | 69 ksi | 65 ksi |

The increased resistance provided by the longer precipitation is accompanied by a significant strength trade-off.

As a means of monitoring corrosion attack, tensile tests were performed on unstressed short-transverse specimens removed from the alternate immersion exposure after periods of one week, one month, and twelve weeks. Data for per cent losses in tensile strength of these specimens based on initial strengths of corresponding unexposed specimens are listed in Tables 28 through 40. Also included are the per cent losses in tensile strength of stressed specimens which survived the 84-day test.

These data indicate that most of the alloys suffered such high losses in tensile strength during this relatively severe exposure that determining resistance to stress-corrosion cracking would be hampered by losses from mechanical rupture. Metallographic evidence confirmed the large number of fractured specimens which exhibited no evidence of intergranular stress-corrosion cracking but exhibited severe localized corrosion and associated mechanical cracks.

Stress-corrosion performances in the New Kensington atmosphere for Alloys 5, 6, 8, and 9 (185 days) and Alloys 10-18 (100 days) are presented in Tables 41 through 53. About 93%

of the specimens from Alloys 9, 12, 14, 15 and 17 precipitation heat treated 18 hours at 325 F have survived at a stress level of 75% of the yield strength (up to 55 ksi) and 100% of the specimens from these materials stressed at the lower levels have survived. All specimens from these alloys precipitation heat treated 24 hours at 325 F are intact regardless of stress level.

## 3. ELECTRICAL CONDUCTIVITY

Electrical conductivities of Alloys 5, 6, 8, and 9 are presented in Tables 54 and 55 and the electrical conductivities of Alloys 10-18 are presented in Table 56. Conductivities were measured and recorded in the event that some empirical relationship may eventually be found between electrical conductivity and resistance to stress-corrosion cracking in the atmosphere. No attempt will be made to correlate electrical conductivity with the results of the alternate immersion test.

## 4. FRACTURE TOUGHNESS

Plane strain stress intensity factors, $K_{Ic}$, for Alloy 9 quenched in cold water and precipitation heat treated 18 hours at 325 F are presented in Table 57. Original tests of two-inch thick longitudinal specimens of Alloy 9 indicated that results were invalid because fatigue crack front curvature exceeded the amount allowed by ASTM specifications. The curved crack fronts are illustrated in Figure 17. To provide meaningful data, one-inch thick specimens were machined from the broken two-inch thick specimens and tested. The 2-1/2-inch thick plate of Alloy 9, nominal MA15, did not develop target fracture toughness.

Plane strain fracture toughness for Alloy 14 (5.8% Zn, 2.3% Mg, 3% Cu, 0.1% Zr) is presented in Table 58. Two-inch thick plate quenched in cold water and precipitation heat treated 18 hours at 325 F developed fracture toughness slightly lower than that of Alloy 9 and comparable material quenched in hot water developed even lower toughness.

## SECTION IV

## DISCUSSION

### 1. STRESS-CORROSION RESISTANCE AND STRENGTH

Although none of the materials produced demonstrated a capability of meeting all target properties, alloys within a definable composition range appear to offer a combination of properties that are advantageous relative to those of established commercial alloys, particularly in thick sections. Alloys containing 1.9-3% Cu, 1.9-2.6% Mg, and 0.1% Zr with a nominal Zn content of 6% are indicated to develop after a second-step precipitation heat treatment of 24 hours at 325 F a resistance to stress-corrosion cracking in the alternate immersion test intermediate between that of 2024-T852 forgings and 2024-T851 plate. Cu and Mg contents of experimental alloys in relationship to these composition limits are presented in Figure 18.

Alloys within a restricted composition range of 2.25-2.75% Cu and 1.9-2.4% Mg performed better. A high resistance to stress-corrosion cracking in the accelerated test at 25-30 ksi stress is indicated after a second-step precipitation heat treatment of 18 hours at 325 F, while even higher resistance to stress-corrosion cracking is indicated after a second-step precipitation heat treatment of 24 hours at 325 F. These restructed Cu and Mg limits are also plotted in Figure 18 for comparison.

Average strengths of these alloys approximated target minimum strengths, but guaranteed minimum strengths would necessarily be lower. Guaranteed minimum strengths are properly calculated using statistical analysis of a sufficient number of commercially fabricated lots, but this method cannot be used in this case. In the present work several thicknesses and fabricating practices were employed, however, so that if these results are combined with test results of previous investigations, we can estimate the minimum yield strength with some degree of confidence. Because strength of these alloys appeared to depend to a high degree on Mg content, regression lines for long-transverse yield strength of experimental Al-Zn-Mg-Cu-Zr alloys in four conditions versus Mg content were determined. All of the Al-Zn-Mg-Cu-Zr alloys except the high Zn Alloy 16 and the low Mg Alloy 11 along with NAVAIR Alloys 4, 6, 7 and 10 were used in the analysis.[2] The 99% confidence limit at 1.9% Mg content was calculated using the conditions which had the highest standard error of estimate. This value is the estimated minimum strength for Al-Zn-Mg-Cu-Zr alloys containing a minimum of 1.9% Mg. Plots of regression lines and 99% confidence limits for the four conditions are plotted in Figures 19 through 22. The four conditions and the estimated minimum long-transverse yield strengths are tabulated below:

| Figure | 2nd Step P.H.T. | 2nd Step Quench | Estimated Minimum Strength |
|---|---|---|---|
| 19 | 18 hrs 325 F | Cold Water | 67 ksi |
| 20 | 18 hrs 325 F | Hot Water | 65 ksi |
| 21 | 24 hrs 325 F | Cold Water | 61 ksi |
| 22 | 24 hrs 325 F | Hot Water | 59 ksi |

Estimated minimum yield strengths of the material quenched in cold water are considered to be appropriate for three-inch thick products, and estimated minimum strengths of the materials quenched in hot water are considered to be appropriate for eight-inch thick products.

Estimated minimum strengths did not meet the target, but did exceed strengths of commercial alloys. The advantage of the experimental alloys over 7079-T651, 7075-T651, and 7079-T7351 plate are illustrated in Figure 23. Estimated minimum yield strength of experimental alloys precipitation heat treated 18 or 24 hours at 325 F exceeded guaranteed minimum yield strength of 7079-T651 by 7 or 1 ksi, respectively, at 2.5-3 inch thickness, and the advantage increased with increasing thickness.

2. FRACTURE TOUGHNESS

Fracture toughness tests on Alloy 9, nominal MA15, confirm other data[10] and indicate that three-inch thick plate of this alloy type will not develop target fracture toughness in any direction. These and other data indicate, however, that the fracture toughness meets or exceeds that of commercial aluminum alloys when comparing the same products at equivalent strengths.

Tests on Alloy 14, 3% Cu, confirm that toughness decreases as the amount of intermetallic constituent increases. These data suggest that the copper content should be a maximum of 2.75% to minimize the amount of $Al_2CuMg$ and thus maintain high toughness.

Toughness of the high iron Alloy 15 was not determined, but other data indicate that iron content should be maintained at a low level to provide high toughness.

## SECTION V

## SUMMARY

Eighteen alloys containing 4.6-8.1% Zn, 1.7-3% Cu, 1.75-2.6% Mg, and up to 0.13% Zr, 0.17% Cr, 0.24% Fe, 0.28% Ni, 0.17% Mn, 0.15% V, 0.05% Ti, and 0.06% Si were cast as 12" thick ingots and fabricated to 2"-4" thick plate. Preliminary results indicated that an alloy containing 6% Zn, 2.3% Mg, 2.5% Cu, and 0.12% Zr developed an attractive combination of high strength, low quench-sensitivity, and high resistance to stress-corrosion cracking in the alternate immersion test. Additional tests on related alloys indicated that small differences in Cu and Mg appeared to impart large differences in resistance to stress-corrosion cracking. Moreover, longer precipitation heat treatment times and consequent lower strengths were required to produce a given level of resistance to stress-corrosion cracking than were anticipated from results of initial experiments. Consequently, target strength could not be attained at target resistance to stress-corrosion cracking. Moreover, target fracture toughness was not attained in the tempers examined.

Al-Zn-Mg-Cu-Zr alloys, however, do seem to have the ability to develop a combination of strength in thick sections and resistance to stress-corrosion cracking in the alternate immersion test superior to that of commercial alloys. When precipitation heat treated 24 hours at 250 F followed by 24 hours at 325 F, an alloy containing a minimum of 1.9% Mg has a tentative minimum yield strength at three-inch thickness exceeding that of 7079-T6 by 3 ksi, and the advantage increases with increasing thickness. Thirty-day alternate immersion tests indicate that material in this temper containing up to 2.6% Mg and 1.9 to 3% Cu will have a high resistance to stress-corrosion cracking at 25 ksi. Results of longer exposures in the alternate immersion test are difficult to interpret because of various eccentricities, but indicate that a cautious attitude must be taken regarding stress-corrosion performance until long time atmospheric exposures are complete. Another reason for caution regarding stress-corrosion performance is the lack of data to determine correlation between results of 3.5% NaCl alternate immersion tests and exposures in natural environments for periods longer than ten months for Al-Zn-Mg-Cu-Zr alloys of this type.

Average fracture toughness of this material is expected at least to match that of other aluminum alloys when compared on an equal strength and equivalent product basis, but material containing $Al_2CuMg$ constituent is expected to have lower toughness.

Material containing a maximum of 2.4% Mg and 2.25 to 2.75% Cu has the same estimated minimum strength as the material having broader composition limits, but the resistance to stress-corrosion cracking and fracture toughness is expected to be higher.

## SECTION VI

## CONCLUSIONS

1. An alloy which exceeds the strength of commercial alloys in thick sections in a temper which appears to confer target resistance to stress-corrosion cracking in the 3.5% NaCl alternate immersion test was developed but strength and toughness were below the target. Verification of resistance to stress-corrosion cracking must await the results of long-time atmospheric exposure.

2. For optimum combination of strength in thick sections, resistance to stress-corrosion cracking, and fracture toughness, the following composition limits are proposed: 5.5-6.5% Zn, 1.9-2.4% Mg, 2.25-2.75% Cu, 0.08-0.14% Zr, 12% max. Fe, .10% max. Si, and .04% max. Ti.

3. When precipitation heat treated 24 hours at 250 F followed by 24 hours at 325 F, this material is expected to develop a high resistance to stress-corrosion cracking in the 3.5% NaCl alternate immersion test at stress levels of 25 ksi or higher in the short-transverse direction. Estimated minimum longitudinal yield strength of three-inch material is 61 ksi and of eight-inch material is 59 ksi. These strengths are higher than the guaranteed minimum strengths of commercial alloys.

4. Typical fracture toughness values for this alloy are expected to meet or exceed those for 7075-T6 and 7079-T6 at equivalent thicknesses.

## SECTION VII

## RECOMMENDATIONS

It is recommended that a commercial-scale heat of the optimum composition be produced and tested as initially proposed for Phase II.

## SECTION VIII

## REFERENCES


(1) J. T. Staley, "Investigation to Develop a High Strength Stress-Corrosion Resistant Aluminum Aircraft Alloy," Final Report, Naval Air Systems Command Contract N00019-69-C-0292, January 20, 1970.

(2) J. T. Staley, "Investigation to Improve the Stress-Corrosion Resistance of Aluminum Alloys Through Alloy Additions and Specialized Heat Treatment," Final Report, Naval Air Systems Command Contract N00019-68-C-0146, February 28, 1969.

(3) D. O. Sprowls and J. A. Nock, Jr., U.S. Patent 3,198,676, August 3, 1965, (Alcoa).

(4) J. T. Staley, R. H. Brown, R. Schmidt, "Heat Treating Characteristics of High Strength Al-Zn-Mg-Cu Alloys With and Without Silver Additions," presented at 1970 Western Metal and Tool Conference, Los Angeles, California, March 11, 1970.

(5) H. Y. Hunsicker, J. T. Staley, R. H. Brown, "Stress-Corrosion Resistance of High-Strength Al-Zn-Mg-Cu Alloys With and Without Silver Additions," presented at 1970 Western Metal and Tool Conference, Los Angeles, California, March 11, 1970.

(6) J. L. McMillan and M. V. Hyatt, "Development of High-Strength Aluminum Alloys With Improved Stress-Corrosion Resistance," AFML-TR-68-148, Air Force Materials Laboratory, June 1968.

(7) M. V. Hyatt and H. W. Schimmelbusch, "Development of a High-Strength, Stress-Corrosion Resistant Aluminum Alloy for Use in Thick Sections," AFML-TR-70-109, Air Force Materials Laboratory, May 1970.

(8) D. S. Thompson and S. A. Levy, "High Strength Aluminum Alloy Development," AFML-TR-70-171, Air Force Materials Laboratory, August 1970.

(9) J. T. Staley, "Development of a High Strength, Stress-Corrosion Resistant Naval Aircraft Aluminum Alloy," N00019-70-C-0118 Bi-monthly progress letters March 3, 1970, April 27, 1970, June 24, 1970.

(10) J. T. Staley, "Development of a High Strength, Stress-Corrosion Resistant Naval Aircraft Aluminum Alloy," N00019-70-C-0118, Final Report.

TABLE 1

CHEMICAL ANALYSES

| S. No. | Alloy | Zn | Mg | Cu | Zr | Mn | Cr | V | Fe | Ni | Si | Ti |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 367799 | 1 | 6.06 | 2.33 | 2.39 | 0.01 | 0.00 | 0.00 | 0.13 | 0.07 | 0.00 | 0.06 | 0.01 |
| 367800 | 2 | 6.06 | 2.43 | 2.49 | 0.00 | 0.01 | 0.04 | 0.13 | 0.09 | 0.00 | 0.05 | 0.02 |
| 367801 | 3 | 5.99 | 2.40 | 2.46 | 0.00 | 0.13 | 0.00 | 0.13 | 0.09 | 0.00 | 0.06 | 0.04 |
| 367802 | 4 | 5.97 | 2.38 | 2.29 | 0.12 | 0.00 | 0.00 | 0.12 | 0.10 | 0.00 | 0.05 | 0.06 |
| 367803 | 5 | 5.88 | 2.33 | 2.30 | 0.12 | 0.01 | 0.05 | 0.00 | 0.09 | 0.00 | 0.04 | 0.04 |
| 367804 | 6 | 5.93 | 2.40 | 2.25 | 0.01 | 0.00 | 0.00 | 0.02 | 0.25 | 0.27 | 0.05 | 0.03 |
| 367805 | 7 | 5.73 | 2.28 | 2.56 | 0.12 | 0.00 | 0.01 | 0.14 | 0.09 | 0.00 | 0.05 | 0.03 |
| 367806 | 8 | 6.35 | 2.39 | 1.63 | 0.00 | 0.00 | 0.17 | 0.00 | 0.10 | 0.00 | 0.05 | 0.04 |
| 373468 | 9* | 5.92 | 2.26 | 2.49 | 0.12 | 0.02 | 0.00 | 0.00 | 0.09 | 0.00 | 0.04 | 0.01 |
| 379390 | 10 | 5.77 | 2.30 | 1.94 | 0.11 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.05 | 0.04 |
| 379391 | 11 | 5.95 | 1.75 | 2.31 | 0.12 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.05 | 0.04 |
| 379392 | 12 | 5.54 | 1.99 | 1.95 | 0.11 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.04 | 0.07 |
| 379393 | 13 | 5.24 | 2.59 | 2.54 | 0.12 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.04 | 0.03 |
| 379394 | 14 | 5.76 | 2.32 | 2.96 | 0.11 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.04 | 0.06 |
| 379395 | 15 | 5.67 | 2.25 | 2.27 | 0.10 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.06 | 0.04 |
| 379396 | 16 | 8.10 | 2.41 | 1.72 | 0.13 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.04 | 0.02 |
| 379397 | 17 | 4.60 | 2.26 | 2.42 | 0.11 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.04 | 0.03 |
| 379398 | 18 | 5.61 | 2.52 | 2.24 | 0.11 | 0.17 | 0.00 | 0.00 | 0.08 | 0.00 | 0.05 | 0.02 |

*Alcoa MA15

Table 2

TENSILE PROPERTIES OF 2-1/2 INCH THICK PLATE IN ALLOY 5

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El. % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El. % |
|---|---|---|---|---|---|---|---|---|---|
| 367803 | A | 80 F | None | 81.7 | 70.2 | 10.0 | ---- | ---- | --- |
| | 1B | 80 F | To 350 F | 80.1 | 71.1 | 8.5 | ---- | ---- | --- |
| | 1C | 80 F | 2 hrs. @ 350 F | 81.4 | 75.3 | 8.0 | 78.0 | 71.4 | 3.5 |
| | 1D | 80 F | 4 hrs. @ 350 F | 79.5 | 72.5 | 10.0 | 76.8 | 71.0 | 3.1 |
| | 1E | 80 F | 6 hrs. @ 350 F | 75.5 | 67.3 | 10.0 | 74.0 | 65.6 | 4.9 |
| | 1F | 80 F | 8 hrs. @ 350 F | 74.1 | 64.9 | 11.0 | ---- | ---- | --- |
| | 1G | 80 F | 10 hrs. @ 350 F | 71.9 | 61.2 | 10.0 | ---- | ---- | --- |
| | 1H | 80 F | 12 hrs. @ 350 F | 70.3 | 58.9 | 10.5 | ---- | ---- | --- |
| | 2B | 80 F | To 325 F | 80.4 | 70.7 | 9.0 | ---- | ---- | --- |
| | 2C | 80 F | 6 hrs. @ 325 F | 81.5 | 74.6 | 7.5 | ---- | ---- | --- |
| | 2D | 80 F | 12 hrs. @ 325 F | 81.4 | 74.3 | 8.0 | 76.8 | 71.0 | 2.6 |
| | 2E | 80 F | 18 hrs. @ 325 F | 80.0 | 73.0 | 8.0 | 76.6 | 70.2 | 3.6 |
| | 2F | 80 F | 24 hrs. @ 325 F | 78.3 | 70.7 | 9.0 | 75.6 | 68.2 | 4.1 |
| | 2G | 80 F | 30 hrs. @ 325 F | 77.0 | 68.7 | 9.0 | 75.0 | 66.6 | 5.5 |
| | 2H | 80 F | 36 hrs. @ 325 F | 75.7 | 66.9 | 9.5 | ---- | ---- | --- |
| | 6E | 180 F | 18 hrs. @ 325 F | 72.4 | 63.1 | 9.5 | 70.4 | 60.6 | 5.2 |
| | 6F | 180 F | 24 hrs. @ 325 F | 71.2 | 61.6 | 9.5 | 69.0 | 59.6 | 5.4 |
| | 6G | 180 F | 30 hrs. @ 325 F | 68.9 | 59.0 | 9.0 | ---- | ---- | --- |
| | 6H | 180 F | 36 hrs. @ 325 F | 68.2 | 58.1 | 9.0 | ---- | ---- | --- |

Solution treated 8 hours at 890 F, quenched as indicated.
Precipitation heat treated 24 hours at 250 F after four days at room temperature.
Properties are average of duplicate 1/4 inch diameter, one inch gage length long-transverse specimens and duplicate 1/8 inch diameter, one-half inch gage length short-transverse specimens.
Yield strength is 0.2 per cent offset.
--- = Properties not determined.

5.9% Zn, 2.3% Mg, 2.3% Cu, 0.12% Zr, 0.05% Cr

Table 3

TENSILE PROPERTIES OF 2-1/2 INCH THICK PLATE IN ALLOY 6

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El. % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El. % |
|---|---|---|---|---|---|---|---|---|---|
| 367804 | A | 80 F | None | 79.0 | 70.2 | 7.0 | ---- | ---- | --- |
| | 1B | 80 F | To 350 F | 77.7 | 70.4 | 6.0 | ---- | ---- | --- |
| | 1C | 80 F | 2 hrs. @ 350 F | 80.0 | 76.5 | 5.0 | 73.8 | 70.4 | 1.5 |
| | 1D | 80 F | 4 hrs. @ 325 F | 78.8 | 74.9 | 5.5 | 73.0 | 70.2 | 1.5 |
| | 1E | 80 F | 6 hrs. @ 350 F | 77.0 | 71.6 | 8.0 | 71.1 | 68.0 | 1.7 |
| | 1F | 80 F | 8 hrs. @ 350 F | 74.9 | 68.4 | 8.0 | ---- | ---- | --- |
| | 1G | 80 F | 10 hrs. @ 350 F | 72.5 | 64.0 | 8.0 | ---- | ---- | --- |
| | 1H | 80 F | 12 hrs. @ 350 F | 71.3 | 62.7 | 8.0 | ---- | ---- | --- |
| | 2B | 80 F | To 325 F | 77.3 | 69.1 | 6.5 | ---- | ---- | --- |
| | 2C | 80 F | 6 hrs. @ 325 F | 78.9 | 73.4 | 6.0 | 68.2 | 67.6 | 0.9 |
| | 2D | 80 F | 12 hrs. @ 325 F | 78.6 | 73.6 | 5.0 | 67.2 | 67.2 | 0.6 |
| | 2E | 80 F | 18 hrs. @ 325 F | 77.7 | 72.4 | 5.5 | 70.6 | 69.4 | 0.9 |
| | 2F | 80 F | 24 hrs. @ 325 F | 76.9 | 70.6 | 7.0 | ---- | ---- | --- |
| | 2G | 80 F | 30 hrs. @ 325 F | 75.3 | 69.0 | 6.5 | ---- | ---- | --- |
| | 2H | 80 F | 36 hrs. @ 325 F | 74.5 | 67.5 | 7.5 | ---- | ---- | --- |
| | 6E | 180 F | 18 hrs. @ 325 F | 71.9 | 63.0 | 6.5 | 62.8 | 61.8 | 0.8 |
| | 6F | 180 F | 24 hrs. @ 325 F | 70.6 | 61.7 | 8.0 | ---- | ---- | --- |
| | 6G | 180 F | 30 hrs. @ 325 F | 70.3 | 61.9 | 6.5 | 60.2 | 57.1 | 1.3 |
| | 6H | 180 F | 36 hrs. @ 325 F | 69.8 | 61.2 | 8.0 | 60.0 | 57.8 | 1.3 |

Solution treated 8 hours at 890 F, quenched as indicated.
Precipitation heat treated 24 hours at 250 F after four days at room temperature.
Properties are average of duplicate 1/4 inch diameter, one inch gage length long-transverse specimens and duplicate 1/8 inch diameter, one-half gage length short-transverse specimens.
Yield strength is 0.2 per cent offset.
--- = Properties not determined.

5.9% Zn, 2.4% Mg, 2.3% Cu, 0.25% Fe, 0.27% Ni

Table 4

TENSILE PROPERTIES OF 2-1/2 INCH THICK PLATE IN 7175 TYPE ALLOY 8

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El. % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El. % |
|---|---|---|---|---|---|---|---|---|---|
| 367806 | A | 80 F | None | 81.4 | 69.6 | 9.5 | 78.8 | 63.8 | 7.3 |
| | 1B | 80 F | To 350 F | 79.5 | 69.7 | 10.0 | ---- | ---- | --- |
| | 1C | 80 F | 2 hrs. @ 350 F | 78.0 | 69.0 | 10.0 | 75.0 | 65.8 | 4.7 |
| | 1D | 80 F | 4 hrs. @ 350 F | 74.8 | 65.2 | 10.0 | 73.4 | 62.2 | 6.1 |
| | 1E | 80 F | 6 hrs. @ 350 F | 71.7 | 60.7 | 10.0 | 70.6 | 58.7 | 7.0 |
| | 1F | 80 F | 8 hrs. @ 350 F | 70.1 | 58.4 | 10.0 | ---- | ---- | --- |
| | 1G | 80 F | 10 hrs. @ 350 F | 68.1 | 55.7 | 11.5 | ---- | ---- | --- |
| | 1H | 80 F | 12 hrs. @ 350 F | 67.0 | 54.1 | 11.2 | ---- | ---- | --- |
| | 2B | 80 F | To 325 F | 79.8 | 69.4 | 9.0 | ---- | ---- | --- |
| | 2C | 80 F | 6 hrs. @ 325 F | 79.2 | 69.9 | 9.0 | 75.6 | 67.4 | 5.0 |
| | 2D | 80 F | 12 hrs. @ 325 F | 77.6 | 67.8 | 10.0 | 75.6 | 64.6 | 6.3 |
| | 2E | 80 F | 18 hrs. @ 325 F | 75.9 | 65.9 | 9.5 | 74.2 | 63.1 | 5.9 |
| | 2F | 80 F | 24 hrs. @ 325 F | 74.5 | 64.1 | 10.0 | 72.8 | 62.2 | 6.5 |
| | 2G | 80 F | 30 hrs. @ 325 F | 73.2 | 62.4 | 10.0 | 71.6 | 61.0 | 6.1 |
| | 2H | 80 F | 36 hrs. @ 325 F | 72.6 | 61.5 | 11.0 | ---- | ---- | --- |
| | 6E | 180 F | 18 hrs. @ 325 F | 66.0 | 53.0 | 10.0 | ---- | ---- | --- |
| | 6F | 180 F | 24 hrs. @ 325 F | 65.1 | 52.3 | 10.0 | ---- | ---- | --- |
| | 6G | 180 F | 30 hrs. @ 325 F | 63.7 | 50.8 | 10.0 | ---- | ---- | --- |
| | 6H | 180 F | 36 hrs. @ 325 F | 62.7 | 49.8 | 11.0 | ---- | ---- | --- |

Solution treated 8 hours at 890 F, quenched as indicated.
Precipitation heat treated 24 hours at 250 F after four days at room temperature.
Properties are average of duplicate 1/4 inch diameter, one inch gage length long-transverse specimens and duplicate 1/8 inch diameter, one-half inch gage length short-transverse specimens.
Yield strength is 0.2 per cent offset.
— = Properties not determined.

6.4% Zn, 2.4% Mg, 1.6% Cu, 0.17% Cr

Table 5

TENSILE PROPERTIES OF 2-1/2 INCH THICK PLATE IN ALLOY 9

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El. % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El. % |
|---|---|---|---|---|---|---|---|---|---|
| 373468 | A | 80 F | None | 81.1 | 70.2 | 8.0 | ---- | ---- | --- |
| | 1B | 80 F | To 350 F | 80.9 | 72.3 | 7.5 | ---- | ---- | --- |
| | 1C | 80 F | 2 hrs. @ 350 F | 82.8 | 77.6 | 5.8 | 77.8 | 71.6 | 2.0 |
| | 1D | 80 F | 4 hrs. @ 350 F | 79.9 | 74.0 | 6.8 | 75.8 | 69.8 | 3.0 |
| | 1E | 80 F | 6 hrs. @ 350 F | 76.8 | 69.1 | 10.0 | 73.6 | 67.2 | 3.7 |
| | 1F | 80 F | 8 hrs. @ 350 F | 73.7 | 65.1 | 8.8 | 72.0 | 63.0 | 5.3 |
| | 1G | 80 F | 10 hrs. @ 350 F | 71.9 | 61.9 | 9.8 | ---- | ---- | --- |
| | 1H | 80 F | 12 hrs. @ 350 F | 70.2 | 59.5 | 10.0 | ---- | ---- | --- |
| | 2B | 80 F | To 325 F | 80.7 | 72.3 | 7.8 | ---- | ---- | --- |
| | 2C | 80 F | 6 hrs. @ 325 F | 82.3 | 76.7 | 5.2 | ---- | ---- | --- |
| | 2D | 80 F | 12 hrs. @ 325 F | 82.1 | 76.9 | 5.0 | 77.4 | 71.6 | 2.1 |
| | 2E | 80 F | 18 hrs. @ 325 F | 80.9 | 74.7 | 8.2 | 76.3 | 71.1 | 2.1 |
| | 2F | 80 F | 24 hrs. @ 325 F | 79.4 | 72.5 | 8.0 | 76.9 | 69.5 | 4.3 |
| | 2G | 80 F | 30 hrs. @ 325 F | 77.3 | 69.5 | 9.0 | 75.4 | 67.5 | 4.6 |
| | 2H | 80 F | 36 hrs. @ 325 F | 76.0 | 67.8 | 9.0 | 73.1 | 66.6 | 3.9 |
| | 6E | 180 F | 18 hrs. @ 325 F | 76.5 | 68.6 | 6.5 | 72.6 | 66.9 | 2.1 |
| | 6F | 180 F | 24 hrs. @ 325 F | 75.6 | 62.6 | 6.5 | 71.1 | 64.3 | 3.4 |
| | 6G | 180 F | 30 hrs. @ 325 F | 73.9 | 65.3 | 7.8 | 68.7 | 62.8 | 3.1 |
| | 6H | 180 F | 36 hrs. @ 325 F | 72.8 | 64.0 | 8.5 | 67.3 | 60.6 | 2.6 |

Solution treated 8 hours at 890 F, quenched as indicated.
Precipitation heat treated 24 hours at 250 F after four days at room temperature.
Properties are average of duplicate 1/4 inch diameter, one inch gage length long-transverse specimens and duplicate 1/8 inch diameter, one-half inch gage length short-transverse specimens.
Yield strength is 0.2 per cent offset.
— = Properties not determined.

5.9% Zn, 2.3% Mg, 2.5% Cu, 0.12% Zr

TABLE 6

TENSILE PROPERTIES OF ALLOY 10
S-No. 379390

| Code | Plate Thick. | 2nd Step Hrs PHT at 325 F | Longitudinal T.S. ksi | Longitudinal Y.S. ksi | Longitudinal El % in 4D | Longitudinal R of A % | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El % in 4D | Long-Transverse R of A % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El % in 4D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7A | 2" | 12 | 83.8 | 77.9 | 13.5 | 30 | 83.4 | 77.7 | 11.8 | 22 | 82.5 | 76.9 | 6.0 |
| 7D | 2" | 18 | 79.7 | 73.5 | 12.8 | 27 | 79.3 | 73.5 | 12.0 | 26 | 79.5 | 72.3 | 6.0 |
| 7F | 2" | 24 | 79.4 | 72.5 | 14.5 | 38 | 80.1 | 73.6 | 13.0 | 28 | 79.8 | 73.7 | 8.0 |
| 8A | 2" | 12 | 81.0 | 74.3 | 11.5 | 24 | 81.4 | 76.0 | 11.0 | 18 | 80.6 | 71.0 | 6.0 |
| 8D | 2" | 18 | 80.1 | 74.3 | 12.8 | 26 | 78.3 | 71.8 | 10.5 | 16 | 80.4 | 72.5 | 7.0 |
| 8F | 2" | 24 | 79.0 | 72.2 | 13.0 | 32 | 77.4 | 70.2 | 10.5 | 16 | 77.4 | 70.3 | 8.0 |
| 3A | 2" | 18 | | | | | 78.5 | 72.5 | 10.5 | 18 | 78.0 | 70.3 | 6.5 |
| 3B | 2" | 24 | | | | | 75.9 | 68.9 | 11.5 | 22 | 77.1 | 68.7 | 6.5 |
| 3C | 2" | 36 | | | | | 73.4 | 65.6 | 11.0 | 22 | 71.9 | 63.7 | 7.7 |
| 1A | 4" | 18 | | | | | 79.5 | 74.0 | 4.8 | 6 | 73.6 | 67.3 | 4.0 |
| 1B | 4" | 24 | | No Test | | | 77.3 | 70.7 | 6.5 | 6 | 74.4 | 67.1 | 4.0 |
| 1C | 4" | 36 | | | | | 75.1 | 67.5 | 7.3 | 10 | 70.3 | 62.0 | 4.0 |
| 2A | 4" | 18 | | | | | 77.2 | 71.6 | 11.0 | 24 | 75.1 | 68.6 | 4.0 |
| 2B | 4" | 24 | | | | | 74.9 | 68.2 | 11.5 | 24 | 73.5 | 66.7 | 4.0 |
| 2C | 4" | 36 | | | | | 72.9 | 65.3 | 12.3 | 26 | 69.8 | 62.4 | 5.0 |

Codes 7 and 8 preforged

5.8% Zn, 2.3% Mg, 1.9% Cu, 0.1% Zr

Solution treated 8 hrs at 890 F.
Codes 7, 3, and 1 quenched in water at 60-70 F. Codes 8 and 2 quenched in water at 175-180 F.
Precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
Longitudinal and long-transverse properties are average of duplicate 0.505" dia. specimens.
Longitudinal and long-transverse specimens from two-in thick plate taken from mid-plane.
Long-transverse specimens from four-inch thick plate taken from quarter-plane.
Short-transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

TABLE 7

TENSILE PROPERTIES OF ALLOY 11
S-No. 379391

| Code | Plate Thick. | 2nd Step Hrs PHT at 325 F | Longitudinal T.S. ksi | Longitudinal Y.S. ksi | Longitudinal El % in 4D | Longitudinal R of A % | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El % in 4D | Long-Transverse R of A % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El % in 4D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7A | 2" | 12 | 79.8 | 74.9 | 13.5 | 28 | 80.8 | 77.1 | 12.2 | 22 | 79.0 | 74.0 | 6.0 |
| 7B | 2" | 15 | 78.2 | 72.1 | 14.2 | 32 | 78.6 | 73.8 | 13.0 | 26 | 77.0 | 72.0 | 8.0 |
| 7D | 2" | 18 | 76.9 | 69.4 | 14.0 | 38 | 77.2 | 70.7 | 12.2 | 24 | 76.8 | 70.5 | 8.0 |
| 8A | 2" | 12 | 80.0 | 74.9 | 13.0 | 26 | 79.0 | 75.3 | 10.5 | 18 | 79.8 | 74.9 | 5.0 |
| 8B | 2" | 15 | 78.3 | 72.3 | 13.8 | 32 | 78.4 | 72.9 | 10.5 | 16 | 77.2 | 70.2 | 4.0 |
| 8D | 2" | 18 | 75.4 | 68.9 | 14.0 | 30 | 75.2 | 69.1 | 11.8 | 20 | 74.6 | 66.7 | 4.0 |
| 3A | 2" | 18 | | | | | 73.3 | 65.5 | 12.0 | 24 | 71.5 | 63.1 | 7.5 |
| 3B | 2" | 24 | | | | | 69.2 | 60.9 | 13.0 | 28 | 69.7 | 58.7 | 8.0 |
| 3C | 2" | 36 | | | | | 66.3 | 56.8 | 13.0 | 26 | 66.8 | 55.2 | 9.2 |
| 1A | 4" | 18 | | | | | 75.8 | 70.1 | 8.0 | 11 | 70.1 | 62.4 | 6.5 |
| 1B | 4" | 24 | | No Test | | | 70.9 | 62.7 | 9.3 | 12 | 66.9 | 57.4 | 7.0 |
| 1C | 4" | 36 | | | | | 68.1 | 58.7 | 10.5 | 16 | 64.4 | 54.2 | 7.5 |
| 2A | 4" | 18 | | | | | 72.1 | 66.4 | 12.5 | 33 | 68.9 | 61.3 | 7.2 |
| 2B | 4" | 24 | | | | | 69.1 | 61.5 | 13.8 | 32 | 69.3 | 59.1 | 7.5 |
| 2C | 4" | 36 | | | | | 66.6 | 57.3 | 13.8 | 36 | 64.7 | 53.3 | 8.0 |

Codes 7 and 8 preforged

6% Zn, 1.8% Mg, 2.3% Cu, 0.1% Zr

Solution treated 8 hrs at 890 F.
Codes 7, 3, and 1 quenched in water at 60-70 F. Codes 8 and 2 quenched in water at 175-180 F.
Precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
Longitudinal and long-transverse properties are average of duplicate 0.505" dia. specimens.
Longitudinal and long-transverse specimens from two-inch thick plate taken from mid-plane.
Long-transverse specimens from four-inch thick plate taken from quarter-plane.
Short-transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

**TABLE 8**

**TENSILE PROPERTIES OF ALLOY 12**
S-No. 379392

| Code | Plate Thick. | 2nd Step Hrs. PHT at 325 F | Longitudinal T.S. ksi | Longitudinal Y.S. ksi | Longitudinal El % in 4D | Longitudinal R of A % | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El % in 4D | Long-Transverse R of A % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El % in 4D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7A | 2" | 12 | 81.8 | 76.2 | 13.2 | 29 | 80.9 | 76.1 | 11.8 | 24 | 81.1 | 74.0 | 4.0 |
| 7C | 2" | 16 | 80.4 | 73.9 | 14.8 | 34 | 80.2 | 74.7 | 12.8 | 27 | 80.6 | 73.3 | 8.0 |
| 7G | 2" | 20 | 80.2 | 73.6 | 14.5 | 37 | 79.1 | 73.5 | 12.5 | 26 | 79.1 | 72.1 | 6.5 |
| 8A | 2" | 12 | 82.3 | 74.9 | 10.2 | 18 | 81.4 | 76.3 | 10.5 | 17 | 79.3 | 72.4 | 6.0 |
| 8C | 2" | 16 | 78.0 | 70.9 | 12.0 | 26 | 78.5 | 72.2 | 10.5 | 17 | 76.4 | 69.6 | 2.5 |
| 8E | 2" | 20 | 78.2 | 71.4 | 11.5 | 22 | 77.6 | 71.3 | 10.5 | 17 | 76.1 | 68.7 | 4.0 |
| 3A | 2" | 18 | | | | | 76.5 | 70.6 | 11.3 | 22 | 77.3 | 69.0 | 7.0 |
| 3B | 2" | 24 | | No Test | | | 73.3 | 66.1 | 12.0 | 24 | 73.3 | 64.0 | 7.0 |
| 3C | 2" | 36 | | | | | 70.5 | 62.1 | 12.0 | 26 | 70.7 | 60.9 | 8.0 |
| 1A | 4" | 18 | | | | | 78.1 | 72.1 | 9.3 | 14 | 70.9 | 64.5 | 4.5 |
| 1B | 4" | 24 | | | | | 74.1 | 66.6 | 8.8 | 12 | 70.1 | 61.2 | 5.0 |
| 1C | 4" | 36 | | | | | 71.3 | 63.0 | 9.5 | 16 | 67.3 | 57.4 | 5.0 |
| 2A | 4" | 18 | | | | | 74.9 | 69.6 | 12.0 | 28 | 72.6 | 66.1 | 5.5 |
| 2B | 4" | 24 | | | | | 71.9 | 65.1 | 13.3 | 32 | 69.8 | 62.9 | 5.7 |
| 2C | 4" | 36 | | | | | 69.6 | 61.8 | 13.5 | 31 | 68.4 | 58.4 | 6.2 |

Codes 7 and 8 preforged

5.5% Zn, 2% Mg, 2% Cu, 0.1% Zr

Solution treated 8 hrs at 890 F.
Codes 7, 3, and 1 quenched in water at 60-70 F. Codes 8 and 2 quenched in water at 175-180 F.
Precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
Longitudinal and long-transverse properties are average of duplicate 0.505" dia. specimens.
Longitudinal and long-transverse specimens from two-inch thick plate taken from mid-plane.
Long-transverse specimens from four-inch thick plate taken from quarter-plane.
Short-transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

TABLE 9

TENSILE PROPERTIES OF ALLOY 13
S-No. 379393

| Code | Plate Thick. | 2nd Step Hrs. PHT at 325 F | Long-Transverse Properties T.S. ksi | Y.S. ksi | El % in 4D | R of A % | Short-Transverse Properties T.S. ksi | Y.S. ksi | El % in 4D |
|---|---|---|---|---|---|---|---|---|---|
| 3A | 2" | 18 | 80.9 | 75.2 | 8.5 | 12 | 79.7 | 71.4 | 4.5 |
| 3B | 2" | 24 | 78.7 | 72.9 | 8.8 | 13 | 75.9 | 67.9 | 5.0 |
| 3C | 2" | 36 | 76.1 | 68.3 | 9.5 | 16 | 74.7 | 64.8 | 5.0 |
| 1A | 4" | 18 | 78.6 | 73.7 | 3.0 | 4 | 74.5 | 69.8 | 3.0 |
| 1B | 4" | 24 | 75.2 | 70.8 | 2.5 | 5 | 72.5 | 67.3 | 3.0 |
| 1C | 4" | 36 | 75.0 | 68.2 | 5.0 | 6 | 70.7 | 64.0 | 3.7 |
| 2A | 4" | 18 | 76.6 | 71.6 | 3.3 | 2 | 73.8 | 68.8 | 3.5 |
| 2B | 4" | 24 | 74.1 | 68.6 | 4.0 | 5 | 72.7 | 67.5 | 3.5 |
| 2C | 4" | 36 | 73.0 | 66.7 | 4.0 | 5 | 68.5 | 62.8 | 3.7 |

5.2% Zn, 2.6% Mg, 2.5% Cu, 0.12% Zr

Solution heat treated 8 hr at 900 F; Codes 3 and 1 quenched in 70 F water; Code 2 quenched in 175 F water.
Precipitation Heat Treated 24 hr at 250 F after 4 days at room temperature.
Long-Transverse properties are average of duplicate 0.505" dia. specimens.
Long-Transverse specimens from two-inch thick plate taken from mid-plane.
Long-Transverse specimens from four-inch thick plate taken from quarter-plane.
Short-Transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

TABLE 10

TENSILE PROPERTIES OF ALLOY 14
S-No. 379394

| Code | Plate Thick. | 2nd Step Hrs PHT at 325 F | Longitudinal T.S. ksi | Longitudinal Y.S. ksi | Longitudinal El % in 4D | Longitudinal R of A % | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El % in 4D | Long-Transverse R of A % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El % in 4D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7B | 2" | 15 | 82.9 | 76.9 | 11.5 | 22 | 82.2 | 77.2 | 9.5 | 18 | 81.1 | 75.1 | 3.0 |
| 7D | 2" | 18 | 80.3 | 73.2 | 12.5 | 27 | 80.6 | 74.8 | 11.0 | 19 | 80.1 | 73.3 | 5.0 |
| 7F | 2" | 24 | 78.1 | 70.1 | 13.0 | 30 | 78.7 | 72.0 | 11.2 | 20 | 76.5 | 70.1 | 5.0 |
| 8B | 2" | 15 | 77.5 | 69.8 | 11.5 | 20 | 78.3 | 71.9 | 8.5 | 13 | 75.5 | 68.6 | 4.0 |
| 8D | 2" | 18 | 77.4 | 70.1 | 10.8 | 20 | 77.1 | 70.3 | 9.2 | 16 | 74.7 | 67.5 | 4.0 |
| 8F | 2" | 24 | 76.3 | 68.8 | 10.8 | 21 | 75.2 | 67.6 | 10.0 | 18 | 73.6 | 64.4 | 5.0 |
| 3A | 2" | 18 | | | | | 79.9 | 74.0 | 8.5 | 12 | 77.1 | 71.2 | 6.5 |
| 3B | 2" | 24 | | | | | 76.2 | 68.4 | 9.5 | 15 | 72.2 | 66.1 | 4.0 |
| 3C | 2" | 36 | | | | | 72.7 | 63.6 | 10.0 | 16 | 71.0 | 62.4 | 6.5 |
| 1A | 4" | 18 | | | | | 79.2 | 74.3 | 3.5 | 4 | 72.8 | 69.3 | 1.0 |
| 1B | 4" | 24 | | No Test | | | 75.8 | 68.8 | 5.0 | 6 | 70.8 | 67.6 | 1.0 |
| 1C | 4" | 36 | | | | | 73.1 | 64.7 | 6.0 | 8 | 67.2 | 61.0 | 3.2 |
| 2A | 4" | 18 | | | | | 76.2 | 70.6 | 10.0 | 17 | 72.1 | 68.0 | 3.0 |
| 2B | 4" | 24 | | | | | 73.0 | 65.6 | 10.5 | 22 | 67.6 | 63.2 | 1.5 |
| 2C | 4" | 36 | | | | | 70.4 | 61.6 | 11.0 | 24 | 65.0 | 59.6 | 2.5 |

Codes 7 and 8 preforged

5.8% Zn, 2.3% Mg, 3% Cu, 0.1% Zr

Solution treated 8 hrs at 890 F.
Codes 7, 3, and 1 quenched in water at 60-70 F. Codes 8 and 2 quenched in water at 175-180 F.
Precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
Longitudinal and long-transverse properties are average of duplicate 0.505" dia. specimens.
Longitudinal and long-transverse specimens from two-inch thick plate taken from mid-plane.
Long-transverse specimens from four-inch thick plate taken from quarter-plane.
Short-transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

TABLE 11

TENSILE PROPERTIES OF ALLOY 15
S-No. 379395

| Code | Plate Thick. | 2nd Step Hrs PHT at 325 F | Longitudinal T.S. ksi | Longitudinal Y.S. ksi | Longitudinal El % in 4D | Longitudinal R of A % | Long-Transverse T.S. ksi | Long-Transverse Y.S. ksi | Long-Transverse El % in 4D | Long-Transverse R of A % | Short-Transverse T.S. ksi | Short-Transverse Y.S. ksi | Short-Transverse El % in 4D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7A | 2" | 12 | 83.7 | 77.9 | 12.0 | 25 | 84.3 | 79.3 | 10.2 | 18 | 80.5 | 75.3 | 5.0 |
| 7D | 2" | 18 | 80.8 | 74.2 | 12.8 | 28 | 81.3 | 75.8 | 11.2 | 20 | 78.7 | 73.4 | 4.0 |
| 7G | 2" | 28 | 74.7 | 66.5 | 13.0 | 30 | 75.0 | 67.7 | 11.5 | 20 | 77.0 | 70.7 | 4.0 |
| 8A | 2" | 12 | 79.7 | 73.7 | 10.2 | 18 | 80.2 | 74.6 | 9.0 | 14 | 77.7 | 71.5 | 6.0 |
| 8D | 2" | 18 | 77.7 | 71.0 | 10.8 | 22 | 77.9 | 71.3 | 9.0 | 17 | 74.3 | 66.6 | 6.0 |
| 8G | 2" | 28 | 72.8 | 64.2 | 11.5 | 28 | 73.7 | 65.7 | 10.2 | 18 | 73.1 | 65.2 | 4.5 |
| 3A | 2" | 18 | | | | | 77.9 | 71.8 | 10.0 | 18 | 75.2 | 69.4 | 5.7 |
| 3B | 2" | 24 | | | | | 75.6 | 68.8 | 10.0 | 18 | 72.1 | 66.1 | 6.0 |
| 3C | 2" | 36 | | | | | 72.2 | 63.9 | 10.5 | 20 | 69.8 | 61.5 | 5.0 |
| 1A | 4" | 18 | | | | | 78.2 | 72.3 | 5.0 | 7 | 75.1 | 68.0 | 3.0 |
| 1B | 4" | 24 | | No Test | | | 76.2 | 69.6 | 6.8 | 10 | 68.6 | 63.8 | 3.0 |
| 1C | 4" | 36 | | | | | 73.6 | 65.8 | 7.5 | 10 | 66.5 | 60.1 | 3.5 |
| 2A | 4" | 24 | | | | | 76.1 | 70.6 | 10.5 | 20 | 74.9 | 68.5 | 2.0 |
| 2B | 4" | 24 | | | | | 74.1 | 66.8 | 10.5 | 20 | 72.1 | 64.9 | 4.0 |
| 2C | 4" | 36 | | | | | 71.3 | 63.5 | 11.5 | 24 | 65.7 | 59.9 | 3.0 |

Codes 7 and 8 Preforged 5.7% Zn, 2.3% Mg, 2.3% Cu, 0.1% Zr, 0.2% Fe

Solution treated 8 hours at 890 F.
Codes 7, 3, and 1 quenched in water at 60-70 F. Codes 8 and 2 quenched in water at 175-180 F.
Precipitation heat treated 24 hours at 250 F after 4 days at room temperature.
Longitudinal and long-transverse properties are average of duplicate 0.505" dia. specimens.
Longitudinal and long-transverse specimens from two-inch thick plate taken from mid-plane.
Long-transverse specimens from four-inch thick plate taken from quarter-plane.
Short-transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

TABLE 12

TENSILE PROPERTIES OF ALLOY 16
S-No. 379396

| Code | Plate Thick. | 2nd Step Hrs. PHT at 325 F | Long-Transverse Properties T.S. ksi | Y.S. ksi | El % in 4D | R of A % | Short-Transverse Properties T.S. ksi | Y.S. ksi | El % in 4D |
|---|---|---|---|---|---|---|---|---|---|
| 3C | 2" | 8 | 82.6 | 78.8 | 8.5 | 16 | 80.9 | 75.5 | 2.5 |
| 3A | 2" | 18 | 78.5 | 72.7 | 11.3 | 20 | 76.4 | 69.7 | 4.2 |
| 3B | 2" | 24 | 74.5 | 66.8 | 11.0 | 20 | 73.1 | 64.6 | 4.5 |
| 1C | 4" | 8 | 84.2 | 80.9 | 2.8 | 4 | 78.6 | 73.7 | 2.2 |
| 1A | 4" | 18 | 77.7 | 73.7 | 3.5 | 4 | 72.6 | 66.7 | 3.0 |
| 1B | 4" | 24 | 75.9 | 69.3 | 5.5 | 6 | 71.1 | 62.8 | 4.5 |
| 2C | 4" | 8 | 82.4 | 79.3 | 2.0 | 2 | 78.4 | 74.3 | 2.0 |
| 2A | 4" | 18 | 74.0 | 69.2 | 3.0 | 4 | 72.9 | 67.3 | 2.0 |
| 2B | 4" | 24 | 73.6 | 66.7 | 4.8 | 6 | 68.9 | 63.8 | 2.7 |

8.1% Zn, 2.4% Mg, 1.7% Cu, 0.13% Zr

Solution heat treated 8 hr at 880 F; Codes 3 and 1 quenched in 70 F water; Code 2 quenched in 175 F water.
Precipitation Heat Treated 24 hr at 250 F after 4 days at room temperature.
Long-Transverse properties are average of duplicate 0.505" dia. specimens.
Long-Transverse specimens from two-inch thick plate taken from mid-plane.
Long-Transverse specimens from four-inch thick plate taken from quarter-plane.
Short-Transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

TABLE 13

TENSILE PROPERTIES OF ALLOY 17
S-No. 379397

| Code | Plate Thick. | 2nd Step Hrs. PHT at 325 F | Long-Transverse Properties T.S. ksi | Y.S. ksi | El % in 4D | R of A % | Short-Transverse Properties T.S. ksi | Y.S. ksi | El % in 4D |
|---|---|---|---|---|---|---|---|---|---|
| 3A | 2" | 18 | 78.2 | 71.6 | 9.8 | 14 | 76.0 | 68.3 | 4.5 |
| 3B | 2" | 24 | 76.8 | 70.1 | 10.0 | 14 | 74.8 | 66.5 | 6.7 |
| 3C | 2" | 36 | 75.1 | 67.4 | 10.3 | 18 | 73.3 | 64.2 | 6.2 |
| 1A | 4" | 18 | 76.0 | 70.8 | 3.0 | 4 | 72.0 | 65.3 | 3.5 |
| 1B | 4" | 24 | 74.0 | 69.6 | 3.3 | 4 | 71.2 | 64.0 | 4.0 |
| 1C | 4" | 36 | 74.1 | 66.3 | 6.0 | 7 | 69.1 | 61.9 | 4.0 |
| 2A | 4" | 18 | 76.9 | 70.5 | 5.0 | 6 | 72.1 | 66.5 | 4.0 |
| 2B | 4" | 24 | 73.0 | 64.9 | 5.0 | 7 | 69.5 | 63.2 | 4.5 |
| 2C | 4" | 36 | 72.1 | 63.0 | 6.0 | 6 | 67.4 | 61.1 | 4.0 |

4.6% Zn, 2.26% Mg, 2.4% Cu, 0.11% Zr

Solution heat treated 8 hr at 910 F; Codes 3 and 1 quenched in 70 F water; Code 2 quenched in 175 F water.
Precipitation Heat Treated 24 hr at 250 F after 4 days at room temperature.
Long-Transverse properties are average of duplicate 0.505" dia. specimens.
Long-Transverse Specimens from two-inch thick plate taken from mid-plane.
Long-Transverse specimens from four-inch thick plate taken from quarter-plane.
Short-Transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

TABLE 14

TENSILE PROPERTIES OF ALLOY 18
S-No. 379398

| Code | Plate Thick. | 2nd Step Hrs. PHT at 325 F | Long-Transverse Properties T.S. ksi | Long-Transverse Properties Y.S. ksi | Long-Transverse Properties El % in 4D | Long-Transverse Properties R of A % | Short-Transverse Properties T.S. ksi | Short-Transverse Properties Y.S. ksi | Short-Transverse Properties El % in 4D |
|---|---|---|---|---|---|---|---|---|---|
| 3A | 2" | 18 | 79.5 | 72.8 | 8.5 | 14 | 78.0 | 70.1 | 4.5 |
| 3B | 2" | 24 | 78.0 | 70.6 | 9.0 | 16 | 76.9 | 69.1 | 5.5 |
| 3C | 2" | 36 | 75.5 | 67.9 | 9.8 | 15 | 73.2 | 65.0 | 5.5 |
| 1A | 4" | 18 | 77.7 | 73.9 | 2.5 | 4 | 73.8 | 67.4 | 4.0 |
| 1B | 4" | 24 | 76.4 | 71.2 | 3.8 | 4 | 70.7 | 64.2 | 4.0 |
| 1C | 4" | 36 | 74.6 | 68.3 | 4.5 | 7 | 70.4 | 62.1 | 4.2 |
| 2A | 4" | 18 | 77.1 | 71.9 | 3.5 | 4 | 73.6 | 67.6 | 3.5 |
| 2B | 4" | 24 | 75.5 | 69.8 | 3.8 | 5 | 72.5 | 64.8 | 4.0 |
| 2C | 4" | 36 | 73.3 | 66.6 | 5.0 | 6 | 69.2 | 61.9 | 4.0 |

5.6% Zn, 2.5% Mg, 2.2% Cu, 0.11% Zr, 0.17% Mn

Solution heat treated 8 hr at 900 F; Codes 3 and 1 quenched in 70 F water; Code 2 quenched in 175 F water.
Precipitation Heat Treated 24 hr at 250 F after 4 days at room temperature.
Long-Transverse properties are average of duplicate 0.505" dia. specimens.
Long-Transverse specimens from two-inch thick plate taken from mid-plane.
Long-Transverse specimens from four-inch thick plate taken from quarter-plane.
Short-Transverse properties are average of duplicate 0.125" dia. specimens taken midway between rolled surfaces.

TABLE 15

STRESS-CORROSION PERFORMANCE OF ALLOY 5
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|
| 1C | 80 F | 2 hrs at 350 F | 75 | 71 | 7,7,13† | 39†7†20 | 37†50†73 |
| 1D | 80 F | 4 hrs at 350 F | 73 | 71 | 57†65,52† | 57†57†83 | 81,83,OK |
| 1E | 80 F | 6 hrs at 350 F | 67 | 66 | 73,OK,OK | OK,OK,OK | OK,OK,OK |
| 2D | 80 F | 12 hrs at 325 F | 74 | 71 | 7,8,7 | 7†18†39 | 17†66,57† |
| 2E | 80 F | 18 hrs at 325 F | 73 | 70 | 39,49†51† | 76,76,68 | 33,OK,OK |
| 2F | 80 F | 24 hrs at 325 F | 71 | 68 | 31,52†37 | 83,OK,OK | OK,OK,OK |
| 2G | 80 F | 30 hrs at 325 F | 69 | 6[illegible] | 83,OK,OK | OK,OK,OK | OK,OK,OK |
| 6E | 180 F | 18 hrs at 325 F | 63 | 61 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6F | 180 F | 24 hrs at 325 F | 62 | 60 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

2-1/2" thick plate solution treated 8 hrs at 890 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after four days at room temperature.

Triplicate 1/8" diameter short-transverse orientation specimens exposed 1/23/70 at each stress level.
OK = Specimen intact at end of test, 84 days.
† Metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.

S No. 367803

5.9% Zn, 2.3% Mg, 2.3% Cu, 0.12% Zr, 0.05% Cr

TABLE 16

STRESS-CORROSION PERFORMANCE OF ALLOY 6
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Second Step Precipitation Heat Treatment | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|
| 1D | 4 hrs at 350 F | 75 | 70 | 3,3,3 | 6†5,23 | 34,3,15† |
| 1E | 6 hrs at 350 F | 72 | 68 | 34,45†42† | 31,16†57* | OK,OK,OK |
| 2D | 12 hrs at 325 F | 74 | 67 | 3,3+,OK | 3,3+,OK | 4†3,3 |
| 2E | 18 hrs at 325 F | 72 | 69 | 81,3,3 | 6,7†,OK | OK,OK,OK |

2-1/2" thick plate solution treated 8 hrs at 890 F, quenched in water at 80 F, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
Triplicate 1/8" dia. short-transverse orientation specimens exposed 1/23/70 at each stress level unless otherwise indicated.

OK = Specimen intact at end of test, 84 days.
† = Metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = Metallographic examination revealed both transgranular and intergranular cracks.
+ = Duplicate specimens exposed.

S. No. 367804
5.9% Zn, 2.4% Mg, 2.2% Cu, 0.24% Fe, 0.28% Ni

TABLE 17

STRESS-CORROSION PERFORMANCE OF 7175-TYPE ALLOY 8 PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Second Step Precipitation Heat Treatment | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|
| A | None | 70 | 64 | 1,1,1 | 1,1,1 | 3,3,3 |
| 1C | 2 hrs at 350 F | 69 | 66 | 6,8†,17† | 10†,39†,20 | 66,66,OK |
| 1D | 4 hrs at 350 F | 65 | 62 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 1E | 6 hrs at 350 F | 61 | 59 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2C | 6 hrs at 325 F | 70 | 67 | 3,2,3 | 3,3,3 | 3,3,3† |
| 2D | 12 hrs at 325 F | 68 | 65 | 41†,5,[illegible] | 5,6,3 | 4†,5,5 |
| 2E | 18 hrs at 325 F | 66 | 63 | 76,OK,OK | 68,OK,OK | OK,OK,OK |
| 2F | 24 hrs at 325 F | 64 | 62 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2G | 30 hrs at 325 F | 62 | 61 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

2-1/2" thick plate solution treated 8 hrs at 890 F, quenched in water at 80 F, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
Triplicate 1/8" dia. short-transverse orientation specimens exposed.

OK = Specimen intact at end of test, 84 days.
† = Metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.

S. No. 367806
6.4% Zn, 2.4% Mg, 1.6% Cu, 0.17% Cr

TABLE 18

STRESS-CORROSION PERFORMANCE OF ALLOY 9
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|
| 1C | 80 F | 2 hrs at 350 F | 78 | 72 | 49*,36,61 | OK,OK,OK | OK,OK,OK |
| 1D | 80 F | 4 hrs at 350 F | 74 | 70 | 83,OK,OK | OK,OK,OK | OK,OK,OK |
| 1E | 80 F | 8 hrs at 350 F | 69 | 63 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2D | 80 F | 12 hrs at 325 F | 77 | 72 | 80,81,84 | 42†,57*,OK | OK,OK,OK |
| 2E | 80 F | 18 hrs at 325 F | 75 | 71 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2F | 80 F | 24 hrs at 325 F | 73 | 70 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2G | 80 F | 30 hrs at 325 F | 70 | 68 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2H | 80 F | 36 hrs at 325 F | 68 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6E | 180 F | 18 hrs at 325 F | 69 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6F | 180 F | 24 hrs at 325 F | 63 | 64 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6G | 180 F | 30 hrs at 325 F | 65 | 63 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6H | 180 F | 36 hrs at 325 F | 64 | 61 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

2-1/2" thick plate solution treated 8 hrs at 890 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after four days at room temperature.

Triplicate 1/8" diameter short-transverse orientation specimens exposed.

OK = Specimen intact at end of test, 84 days.
† Metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* Metallographic examination revealed both intergranular and transgranular cracks.

S No. 373468

6% Zn, 2.3% Mg, 2.5% Cu, 0.12% Zr

TABLE 19

STRESS-CORROSION PERFORMANCE OF ALLOY 10
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 74 | 67 | 84$^{t}$,OK,OK | 29*,65$^{t}$,OK | 5$^{n}$,OK,OK |
| 1B | 4" | Rolled | CWQ | 24 | 71 | 67 | OK,OK,OK | 84$^{t}$,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 72 | 69 | 69,76,OK | 47*,81,8$^{s}$ | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 68 | 67 | 13,69$^{s}$,OK | 65$^{t}$,78$^{s}$,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 65 | 62 | 33$^{t}$,OK,OK | OK,OK,OK | 81$^{t}$,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 72 | 70 | 11,OK,OK | 11*,OK,OK | OK,OK,OK |
| 7A | 2" | Preforged | CWQ | 12 | 78 | 77 | 4,5,6 | 3,5,8* | 16*,19,OK |
| 7D | 2" | Preforged | CWQ | 18 | 74 | 72 | 8*,12,19 | 27†,38,69 | 44*,OK,OK |
| 7F | 2" | Preforged | CWQ | 24 | 74 | 73 | 6*,19,39 | 61,61,67$^{t}$ | 60$^{t}$,OK,OK |
| 8A | 2" | Preforged | HWQ | 12 | 76 | 71 | 4,3,4 | 4,8†,12 | 4,65$^{t}$,OK |
| 8D | 2" | Preforged | HWQ | 18 | 72 | 72 | 4,8,10† | 4,8,8 | 8,10,44 |
| 8F | 2" | Preforged | HWQ | 24 | 70 | 70 | 10,11,16 | 8*,51,65$^{t}$ | 19*,76,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4-5 days at room temperature.
CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.
Triplicate short-transverse orientation specimens exposed.
OK = Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.
† = metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.
s = failed outside gage length at shoulder under protective coating.

S. No. 379390

5.8% Zn, 2.3% Mg, 1.9% Cu, 0.1% Zr

TABLE 20

STRESS-CORROSION PERFORMANCE OF ALLOY 11
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs. PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 70 | 62 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 66 | 61 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7A | 2" | Preforged | CWQ | 12 | 77 | 74 | 4,6*,8 | 13,14,29 | 29*,53,65t |
| 7B | 2" | Preforged | CWQ | 15 | 74 | 72 | 25*,35,39 | 44,45,61t | 44,52,OK |
| 7D | 2" | Preforged | CWQ | 18 | 71 | 70 | 5,12,17t | 16t,16*,19 | 33*,52,[illegible]t |
| 8A | 2" | Preforged | HWQ | 12 | 75 | 75 | 3,3,3 | 3,3,5 | 4,8n,26 |
| 8B | 2" | Preforged | HWQ | 15 | 73 | 70 | 6,6,8† | 13,14*,19 | 8†,29,47 |
| 8D | 2" | Preforged | HWQ | 18 | 69 | 67 | 11*,22,26* | 45,47,OK | OK,OK,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4-5 days at room temperature.
CWQ = quenched in water at room temperature
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.
Triplicate short-transverse orientation specimens exposed.

OK = Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.
† = metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.

S. No. 379391
6% Zn, 1.8% Mg, 2.3% Cu, 0.1% Zr

TABLE 21

STRESS-CORROSION PERFORMANCE OF ALLOY 12
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 72 | 65 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 70 | 66 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 65 | 63 | 84$^{t}$,OK,OK | OK,OK,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 62 | 58 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 71 | 69 | 75$^{t}$,82$^{t}$,OK | 84$^{t}$,OK,OK | OK,OK,OK |
| 3B | 2" | Rolled | CWQ | 24 | 66 | 64 | 84$^{t}$,OK,OK | OK,OK,OK | OK,OK,OK |
| 7A | 2" | Preforged | CWQ | 12 | 76 | 74 | 17*,21,28 | 33†,33,44† | 67$^{t}$,84*,OK |
| 7C | 2" | Preforged | CWQ | 16 | 74 | 73 | 45,65,65$^{t}$ | 47,61$^{t}$,OK | 84$^{t}$,OK,OK |
| 7E | 2" | Preforged | CWQ | 20 | 75 | 72 | 28*,33,44 | 39,84$^{t}$,OK | 54,OK,OK |
| 8A | 2" | Preforged | HWQ | 12 | 76 | 72 | 5,5,6 | 4,4,4 | 7n,19*,51 |
| 8C | 2" | Preforged | HWQ | 16 | 72 | 70 | 5,8,62$^{t}$ | 10†,10,42 | 19*,65$^{t}$,OK |
| 8E | 2" | Preforged | HWQ | 20 | 71 | 69 | 4,7,17† | 4†,45,69 | 78$^{t}$,OK,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4-5 days at room temperature.
CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.
Triplicate short-transverse orientation specimens exposed.
OK = Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.
† = metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.

S. No. 379392
5.5% Zn, 2% Mg, 2% Cu, 0.1% Zr

TABLE 22

STRESS-CORROSION PERFORMANCE OF ALLOY 13
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 74 | 70 | 8*,36,54$^{n}$ | 56$^{n}$,60$^{n}$,OK | 54†,OK,OK |
| 1B | 4" | Rolled | CWQ | 24 | 71 | 67 | 76$^{t}$,84$^{t}$,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 72 | 69 | 6,8*,69 | 9*,14,36 | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 69 | 67 | 20$^{n}$,62$^{t}$,OK | OK,OK,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 67 | 63 | 44*,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 75 | 71 | 14$^{n}$,14,19$^{t}$ | 3$^{n}$,36,OK | 51,OK,OK |
| 3B | 2" | Rolled | CWQ | 24 | 73 | 68 | 29*,OK,OK | OK,OK,OK | OK,OK,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Triplicate short-transverse specimens exposed.

OK - Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.
† = metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.

S. No. 379393
5.2% Zn, 2.6% Mg, 2.5% Cu, 0.1% Zr

TABLE 23

STRESS-CORROSION PERFORMANCE OF ALLOY 14
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 74 | 69 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 71 | 68 | 47*,OK,OK | 84t,OK,OK | 78n,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 66 | 63 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 75 | 71 | 65t,84t,OK | OK,OK,OK | OK,OK,OK |
| 7B | 2" | Preforged | CWQ | 15 | 77 | 75 | 15*,81,OK | 84t,OK,OK | OK,OK,OK |
| 7D | 2" | Preforged | CWQ | 18 | 75 | 73 | 55t,65,OK | OK,OK,OK | OK,OK,OK |
| 7F | 2" | Preforged | CWQ | 24 | 72 | 70 | OK,OK,OK | OK,OK,OK | 69t,OK,OK |
| 8B | 2" | Preforged | HWQ | 15 | 72 | 69 | 56n,69†,OK | 69t,OK,OK | 15†,OK,OK |
| 8D | 2" | Preforged | HWQ | 18 | 70 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 8F | 2" | Preforged | HWQ | 24 | 68 | 64 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

Solution heat treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.
Triplicate short-transverse orientation specimens exposed.

OK = Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.
† = metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.

S. No. 379394
5.8% Zn, 2.3% Mg, 3.0% Cu, 0.1% Zr

TABLE 24

STRESS-CORROSION PERFORMANCE OF ALLOY 15
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 72 | 68 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 1B | 4" | Rolled | CWQ | 24 | 70 | 64 | 56t,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 71 | 69 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 67 | 65 | 69t,OK,OK | OK,OK,OK | 57n,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 64 | 60 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 72 | 69 | 46*,OK,OK | OK,OK,OK | OK,OK,OK |
| 7A | 2" | Preforged | CWQ | 12 | 79 | 75 | 3,3,2 | 4†,5†,12* | 3†,61t,69 |
| 7D | 2" | Preforged | CWQ | 18 | 76 | 73 | 12n,29,29 | 29*,35*,OK | 42†,OK,OK |
| 8A | 2" | Preforged | HWQ | 12 | 75 | 72 | 2,4,2 | 2,3,3 | 3,2,5† |
| 8D | 2" | Preforged | HWQ | 18 | 71 | 67 | 10n,32,32 | 5†,10n,33 | 28*,OK,OK |
| 8G | 2" | Preforged | HWQ | 28 | 66 | 65 | 35*,38*,44 | 64t,65,69t | OK,OK,OK |

Solution heat treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
CWQ = quenched in cold water.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.
Triplicate short-transverse orientation specimens exposed.
OK = Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.
† = metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.

S. No. 379395
5.7% Zn, 2.3% Mg, 2.3% Cu, 0.1% Zr, 0.2% Fe

TABLE 25

STRESS-CORROSION PERFORMANCE OF ALLOY 16
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1C | 4" | Rolled | CWQ | 8 | 81 | 74 | 14$^{n}$,14,29 | 33$^{*}$,65,OK | 65,83$^{st}$,OK |
| 1A | 4" | Rolled | CWQ | 18 | 74 | 67 | 36$^{*}$,65$^{s}$,83$^{st}$ | 69$^{s}$,69$^{s}$,*82$^{s}$ | 65$^{s}$,65$^{s}$,OK |
| 2C | 4" | Rolled | HWQ | 8 | 79 | 74 | 3,3,4 | 4,4,6$^{\dagger}$ | 6,21$^{\dagger}$,29 |
| 2A | 4" | Rolled | HWQ | 18 | 69 | 67 | 4,5,10$^{\dagger}$ | 4,36,69 | 5,21$^{\dagger}$,69$^{s}$ |
| 2B | 4" | Rolled | HWQ | 24 | 67 | 64 | 18$^{*}$,67$^{s}$,69$^{s}$ | 65$^{s}$,65$^{s}$,69$^{s}$ | 69$^{s}$,69$^{s}$,69$^{s}$ |
| 3C | 2" | Rolled | CWQ | 8 | 79 | 76 | 14$^{*}$,14,16 | 17$^{*}$,29,29 | 35,62,65$^{t}$ |
| 3A | 2" | Rolled | CWQ | 18 | 73 | 70 | 51,53,60 | 65$^{t}$,83$^{t}$,OK | OK,OK,OK |

Solution heat treated 8 hrs at 880 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Triplicate short-transverse orientation specimens exposed.

OK = Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.
† = metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.
s = failed outside gage length at shoulder under protective coating.

S. No. 379396
8.1% Zn, 2.4% Mg, 1.7% Cu, 0.1% Zr

TABLE 26

STRESS-CORROSION PERFORMANCE OF ALLOY 17
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 71 | 65 | OK,OK,OK | 65$^{t}$,OK,OK | OK,OK,OK |
| 1B | 4" | Rolled | CWQ | 24 | 70 | 64 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 71 | 67 | 33*,36*,65$^{t}$ | 60$^{n}$,84$^{t}$,OK | 36$^{\dagger}$,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 65 | 63 | 65$^{t}$,84$^{t}$,OK | OK,OK,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 63 | 61 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 72 | 68 | 35*,84$^{t}$,84$^{t}$ | 56,57$^{\dagger}$,OK | OK,OK,OK |
| 3B | 2" | Rolled | CWQ | 24 | 70 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3C | 2" | Rolled | CWQ | 36 | 67 | 64 | 65$^{t}$,84$^{t}$,OK | OK,OK,OK | OK,OK,OK |

Solution heat treated 8 hours at 910 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Triplicate short-transverse orientation specimens exposed.

OK = Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.
† = metallographic examination revealed characteristic evidence of intergranular stress-corrosion cracks.
* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.

S. No. 379397
4.6% Zn, 2.3% Mg, 2.4% Cu, 0.1% Zr

TABLE 27

STRESS-CORROSION PERFORMANCE OF ALLOY 18
PLATE IN 3.5% NaCl ALTERNATE IMMERSION TEST

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level 35 ksi | 30 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 71 | 65 | 33$^{n}$,69,72 | 33*,56$^{n}$,74 | OK,OK,OK |
| 1B | 4" | Rolled | CWQ | 24 | 70 | 64 | 42*,47*,81 | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 71 | 67 | 6,6,8 | 8*,11*,19* | 24*,61$^{t}$,65 |
| 2B | 4" | Rolled | HWQ | 24 | 65 | 63 | 32*,76,OK | 69,OK,OK | 35*,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 63 | 61 | 42*,67,OK | 62$^{t}$,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 72 | 68 | 6$^{n}$,9,9$^{n}$ | 16*,36,42 | 8,36,72 |
| 3B | 2" | Rolled | CWQ | 24 | 70 | 67 | 29,37*,48 | 78$^{t}$,78$^{t}$,84$^{t}$ | OK,OK,OK |

Solution heat treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Triplicate short-transverse orientation specimens exposed.

OK = Specimen intact at end of test, 84 days.
n = no secondary cracks observed metallographically.

* = metallographic examination revealed both intergranular and transgranular cracks.
t = metallographic examination revealed transgranular cracks and no intergranular cracks.

S. No. 379398
5.6% Zn, 2.5% Mg, 2.2% Cu, 0.1% Zr, 0.17% Mn

TABLE 28

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF SPECIMENS OF ALLOY 5

| Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Type of Attack | | Per Cent Loss in Strength of Specimens Exposed for Indicated Times | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Unstressed | | | Stressed (84 days) | | |
| | | | Major | Minor | 7 Days | 28 Days | 84 Days | 35 ksi | 30 ksi | 25 ksi |
| 1C | 80 F | 2 hrs at 350 F | I | IF | 8 | 28 | 35 | F | F | F |
| 1D | 80 F | 4 hrs at 350 F | I | IF | 11 | 14 | 27 | F | F | 46 |
| 1E | 80 F | 6 hrs at 350 F | P | I+IF | 6 | 13 | 23 | 40 | 35 | 33 |
| 2D | 80 F | 12 hrs at 325 F | I | IF | 6 | 20 | 30 | F | F | F |
| 2E | 80 F | 18 hrs at 325 F | I | IF | 9 | 20 | 43 | F | F | 43 |
| 2F | 80 F | 24 hrs at 325 F | I | IF | 9 | 14 | 25 | F | 52 | 41 |
| 2G | 80 F | 30 hrs at 325 F | P | I+IF | 5 | 16 | 26 | 51 | 49 | 40 |
| 6E | 180 F | 18 hrs at 325 F | P | I+IF | 6 | 15 | 26 | 35 | 33 | 32 |
| 6F | 180 F | 24 hrs at 325 F | P | I+IF | 6 | 14 | 28 | 37 | 33 | 28 |

Single unstressed 1/8" diameter short-transverse orientation specimens removed after indicated times.

S. No. 367803

5.9% Zn, 2.3% Mg, 2.3% Cu, 0.12% Zr, 0.05% Cr

I = Intergranular - IF = Interfragment - P = Pitting

F = All stressed specimens exposed at this stress level fractured during exposure period.

TABLE 29

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF SPECIMENS OF ALLOY 6

| Code | Second Step Precipitation Heat Treatment | Type of Attack | Per Cent Loss in Strength of Specimens Exposed for Indicated Times | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Stressed | | | Unstressed (84 days) | | |
| | | | 7 Days | 28 Days | 84 Days | 35 ksi | 30 ksi | 25 ksi |
| 1D | 4 hrs at 350 F | I | 15 | 27 | 39 | F | F | F |
| 1E | 6 hrs at 350 F | I | 8 | 24 | 16 | F | F | 52 |
| 2D | 12 hrs at 325 F | I | 3 | 16 | N.E. | F | F | F |
| 2E | 18 hrs at 325 F | I | 16 | 22 | 35 | F | 46 | 57 |

All quenched in water at 80 F.

Single unstressed 1/8" diameter short-transverse orientation specimens removed after indicated times.

S. No. 367804

5.9% Zn, 2.4% Mg, 2.2% Cu, 0.24% Fe, 0.28% Ni

N.E. = not exposed

I = intergranular

F = All stressed specimens exposed at this stress level fractured during exposure period.

TABLE 30

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF SPECIMENS OF 7175-TYPE ALLOY 8

| Code | Second Step Precipitation Heat Treatment | Type of Attack | | Per Cent Loss in Strength of Specimens Exposed for Indicated Times | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Unstressed | | | Stressed (84 days) | | |
| | | Major | Minor | 7 Days | 28 Days | 84 Days | 35 ksi | 30 ksi | 25 ksi |
| A | None | P | I+IF | 12 | 17 | 25 | F | F | F |
| 1C | 2 hrs at 300 F | P | I+IF | 7 | 12 | 22 | F | F | 40 |
| 1D | 4 hrs at 300 F | P | I | 4 | 9 | 19 | 55 | 30 | 39 |
| 1E | 6 hrs at 300 F | P | I | 2 | 6 | 17 | 29 | 25 | 17 |
| 2C | 6 hrs at 325 F | P | I | 7 | 15 | 20 | F | F | F |
| 2D | 12 hrs at 325 F | P | I | 10 | 17 | 36 | F | F | F |
| 2E | 18 hrs at 325 F | P | I | 10 | 18 | 35 | 60 | 43 | 44 |
| 2F | 24 hrs at 325 F | P | I | 7 | 15 | 32 | 41 | 39 | 26 |
| 2G | 30 hrs at 325 F | P | I | 8 | 16 | 36 | 39 | 25 | 21 |

All quenched in water at 80 F.

Single unstressed 1/8" diameter short-transverse orientation specimens removed after indicated time.

S. No. 367806

6.4% Zn, 2.4% Mg, 1.6% Cu, 0.17% Cr

I = Intergranular - IF = Interfragment - P = Pitting

F = All stressed specimens exposed at this stress level fractured during exposure period.

TABLE 31

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF SPECIMENS OF ALLOY 9

| Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Type of Attack | | Per Cent Loss in Strength of Specimens Exposed for Indicated Times | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Unstressed | | | Stressed (84 days) | | |
| | | | Major | Minor | 7 Days | 28 Days | 84 Days | 35 ksi | 30 ksi | 25 ksi |
| 1C | 80 F | 2 hrs at 350 F | I | IF | [illegible] | 11 | 23 | F | 31 | 40 |
| 1D | 80 F | 4 hrs at 350 F | IF | | 4 | 7 | 17 | 40 | 26 | 21 |
| 1E | 80 F | 6 hrs at 350 F | P | I+IF | 3 | 8 | 16 | 26 | 23 | 19 |
| 2D | 80 F | 12 hrs at 325 F | I | IF | 5 | 13 | 22 | F | 33 | 25 |
| 2E | 80 F | 18 hrs at 325 F | I | IF | 4 | 11 | 18 | 33 | 22 | 25 |
| 2F | 80 F | 24 hrs at 325 F | P | I+IF | 6 | 12 | 24 | 41 | 27 | 21 |
| 2G | 80 F | 30 hrs at 325 F | P | IF | 6 | 13 | 20 | 28 | 23 | 20 |
| 2H | 80 F | 36 hrs at 325 F | P | IF | 4 | 13 | 21 | 26 | 21 | 20 |
| 6E | 180 F | 18 hrs at 325 F | I | IF | 4 | 9 | 36 | 2 | 21 | 21 |
| 6F | 180 F | 24 hrs at 325 F | P | I+IF | 7 | 8 | N.E. | 25 | 23 | 20 |
| 6G | 180 F | 30 hrs at 325 F | P | I+IF | 3 | 8 | 19 | 24 | 20 | 21 |
| 6H | 180 F | 36 hrs at 325 F | P | IF | 3 | 6 | 16 | 22 | 21 | 19 |

Single unstressed 1/8" diameter short-transverse orientation specimens removed after indicated times.

S. No. 373468

6% Zn, 2.3% Mg, 2.5% Cu, 0.12% Zr

N.E. = not exposed

I = Intergranular - IF = Interfragment - P = Pitting

F = All stressed specimens exposed at this stress level fractured during exposure period.

TABLE 32

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 10

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed (84 Days) 35 ksi | Stressed (84 Days) 30 ksi | Stressed (84 Days) 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | CWQ | 18 | IF | I | 9 | 22 | 26 | 35 | 68 | 42 |
| 1B | 4" | CWQ | 24 | IF | | 15 | 20 | 27 | 25 | 22 | 28 |
| 2A | 4" | HWQ | 18 | IF | | 13 | 23 | 35 | 43 | F | 33 |
| 2B | 4" | HWQ | 24 | IF | | 12 | 20 | 24 | 22 | 24 | 24 |
| 2C | 4" | HWQ | 36 | IF | | 9 | 17 | 26 | 26 | 26 | 20 |
| 3A | 2" | CWQ | 18 | I | IF | 12 | 19 | 25 | 54 | 34 | 35 |
| 7A | 2" | CWQ | 12 | IF | I | 15 | 23 | 30 | F | F | 43 |
| 7D | 2" | CWQ | 18 | I | IF | 13 | 27 | 38 | F | F | 47 |
| 7F | 2" | CWQ | 24 | IF | I | 12 | 21 | 28 | F | F | 78 |
| 8A | 2" | HWQ | 12 | IF | | 14 | 24 | 36 | F | F | 46 |
| 8D | 2" | HWQ | 18 | IF | | 16 | 29 | 32 | F | F | F |
| 8F | 2" | HWQ | 24 | IF | | 12 | 23 | 30 | F | F | 36 |

Solution treated 8 hours at 900 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4-5 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.

Single unstressed 1/8" diameter short-transverse orientation specimens removed after indicated times.
F = failed during exposure.

S. No. 379390

5.8% Zn, 2.3% Mg, 1.9% Cu, 0.1% Zr

TABLE 33

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 11

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed (84 Days) 35 ksi | Stressed (84 Days) 30 ksi | Stressed (84 Days) 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | CWQ | 18 | IF | | 9 | 23 | 34 | 47 | 42 | 39 |
| 2A | 4" | HWQ | 18 | IF | | 9 | 4 | 88 | 39 | 45 | 41 |
| 7A | 2" | CWQ | 12 | IF | | 8 | 17 | 46 | F | F | F |
| 7B | 2" | CWQ | 15 | IF | | 6 | 17 | 35 | F | F | 62 |
| 7D | 2" | CWQ | 18 | IF | | 5 | 16 | 31 | F | F | F |
| 8A | 2" | HWQ | 12 | IF | | 3 | 29 | 33 | F | F | F |
| 8B | 2" | HWQ | 15 | IF | | 7 | 34 | 27 | F | F | F |
| 8D | 2" | HWQ | 18 | IF | | 6 | 19 | 28 | F | 42 | 53 |

Solution treated 8 hours at 900 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4-5 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.

Single short-transverse orientation specimens removed after indicated times.

F = failed during exposure.

S. No. 379391

6% Zn, 1.8% Mg, 2.3% Cu, 0.1% Zr

TABLE 34

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 12

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed 35 ksi | Stressed 30 ksi | Stressed 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | CWQ | 18 | IF | | 7 | 15 | 22 | 43 | 33 | 24 |
| 2A | 4" | HWQ | 18 | IF | | 6 | 15 | 29 | 36 | 27 | 32 |
| 2B | 4" | HWQ | 24 | IF | | 5 | 10 | 28 | 35 | 31 | 33 |
| 2C | 4" | HWQ | 36 | P | IF | 7 | 18 | 30 | 30 | 25 | 30 |
| 3A | 2" | CWQ | 18 | | | 11 | 25 | 29 | 52 | 37 | 47 |
| 3B | 2" | CWQ | 24 | P | IF | 10 | 19 | 27 | 31 | 39 | 31 |
| 7A | 2" | CWQ | 12 | IF | | 7 | 22 | 25 | F | F | 33 |
| 7C | 2" | CWQ | 16 | IF | I | 7 | 19 | 34 | F | 54 | 49 |
| 7E | 2" | CWQ | 20 | IF | | 7 | 19 | 32 | F | 43 | 37 |
| 8A | 2" | HWQ | 12 | IF | | 13 | 32 | 52 | F | F | F |
| 8C | 2" | HWQ | 16 | IF | | 13 | 25 | 42 | F | F | 57 |
| 8E | 2" | HWQ | 20 | IF | | 11 | 24 | 35 | F | F | 42 |

Solution treated 8 hours at 900 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4-5 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.

Single short-transverse orientation specimens removed after indicated times.

F = failed during exposure

S. No. 379392

5.5% Zn, 2% Mg, 2% Cu, 0.1% Zr

TABLE 35

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 13

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed 35 ksi | Stressed 30 ksi | Stressed 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | CWQ | 18 | IF | | 14 | 27 | 41 | F | 60 | 44 |
| 1B | 4" | CWQ | 24 | P | IF | 9 | 20 | 29 | 32 | 31 | 32 |
| 2A | 4" | HWQ | 18 | IF | | 12 | 15 | 38 | F | F | 49 |
| 2B | 4" | HWQ | 24 | IF | | 11 | 15 | 32 | 47 | 43 | 31 |
| 2C | 4" | HWQ | 36 | P | IF | 6 | 18 | 26 | 44 | 30 | 32 |
| 3A | 2" | CWQ | 18 | IF | I | 10 | 22 | 31 | F | 36 | 47 |
| 3B | 2" | CWQ | 24 | P | IF | 6 | 15 | 22 | 30 | 49 | 26 |

Solution treated 8 hours at 900 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Single short-transverse specimens removed after indicated times.

F = failed during exposure.

S. No. 379393

5.2% Zn, 2.6% Mg, 2.5% Cu, 0.1% Zr

TABLE 36

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 14

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed 35 ksi | Stressed 30 ksi | Stressed 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | CWQ | 18 | P | IF | 8 | 11 | 33 | 35 | 32 | 30 |
| 2A | 4" | HWQ | 18 | IF | | 12 | 23 | 29 | 35 | 42 | 43 |
| 2B | 4" | HWQ | 24 | P | IF | 9 | 19 | 26 | 41 | 31 | 41 |
| 3A | 2" | CWQ | 18 | P | IF | 11 | 28 | 29 | 54 | 37 | 36 |
| 7B | 2" | CWQ | 15 | IF | | 10 | 28 | 50 | 48 | 35 | 37 |
| 7D | 2" | CWQ | 18 | P | IF | 11 | 24 | 32 | 43 | 48 | 39 |
| 7F | 2" | CWQ | 24 | P | IF | 12 | 22 | 35 | 60 | 48 | 45 |
| 8B | 2" | HWQ | 15 | IF | | 13 | 25 | 34 | 16 | 44 | 37 |
| 8D | 2" | HWQ | 18 | IF | | 12 | 25 | 30 | 34 | 38 | 31 |
| 8F | 2" | HWQ | 24 | IF | | 12 | 25 | 38 | 32 | 36 | 40 |

Solution heat treated 8 hours at 900 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.

Single short-transverse orientation specimens removed after indicated times.

S. No. 379394

5.8% Zn, 2.3% Mg, 3.0% Cu, 0.1% Zr

TABLE 37

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 15

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed 35 ksi | Stressed 30 ksi | Stressed 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | CWQ | 18 | IF | | 14 | 25 | 33 | 38 | 38 | 34 |
| 1B | 4" | CWQ | 24 | P | IF | 2 | 15 | 23 | 41 | 31 | 24 |
| 2A | 4" | HWQ | 18 | IF | | 10 | 20 | 31 | 36 | 41 | 31 |
| 2B | 4" | HWQ | 24 | P | IF | 10 | 23 | 34 | 44 | 37 | 37 |
| 2C | 4" | HWQ | 36 | P | | 9 | 19 | 28 | 46 | 40 | 33 |
| 3A | 2" | CWQ | 18 | P | IF | 6 | 18 | 34 | 52 | 44 | 29 |
| 7A | 2" | CWQ | 12 | IF | I | 10 | 30 | 26 | F | F | F |
| 7D | 2" | CWQ | 18 | IF | I | 12 | 22 | 30 | F | 27 | 48 |
| 8A | 2" | HWQ | 12 | IF | | 13 | 34 | 41 | F | F | F |
| 8D | 2" | HWQ | 18 | IF | I | 12 | 34 | 43 | F | F | 48 |
| 8G | 2" | HWQ | 28 | P | IF | 12 | 21 | 54 | F | F | 34 |

Solution heat treated 8 hours at 900 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4 days at room temperature.

CWQ = quenched in cold water.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.

Single short-transverse orientation specimens removed after indicated times.

F = failed during exposure

S. No. 379395

5.7% Zn, 2.3% Mg, 2.3% Cu, 0.1% Zr, 0.2% Fe

TABLE 38

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 16

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed 35 ksi | Stressed 30 ksi | Stressed 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1C | 4" | CWQ | 8 | IF | I | 11 | 11 | 27 | F | 48 | 72 |
| 1A | 4" | CWQ | 18 | P | | 3 | 20 | 23 | F | F | 28 |
| 2C | 4" | HWQ | 8 | IF | I | 15 | 18 | 45 | F | F | F |
| 2A | 4" | HWQ | 18 | IF | | 10 | 10 | 72 | F | F | F |
| 2B | 4" | HWQ | 24 | IF | I | 5 | 24 | 29 | F | F | F |
| 3C | 2" | CWQ | 8 | IF | I | 20 | 0 | 23 | F | F | F |
| 3A | 2" | CWQ | 18 | P | | 7 | 17 | 21 | F | 66 | 54 |

Solution heat treated 8 hours at 880 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Single short-transverse orientation specimens removed after indicated times.

S. No. 379396

8.1% Zn, 2.4% Mg, 1.7% Cu, 0.1% Zr

TABLE 39

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 17

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed 35 ksi | Stressed 30 ksi | Stressed 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | CWQ | 18 | IF | | 9 | 23 | 34 | 46 | 31 | 34 |
| 1B | 4" | CWQ | 24 | IF | | 7 | 18 | 30 | 28 | 23 | 30 |
| 2A | 4" | HWQ | 18 | P | IF | 0 | 25 | 30 | F | 46 | 34 |
| 2B | 4" | HWQ | 24 | P | | 3 | 20 | 28 | 35 | 41 | 29 |
| 2C | 4" | HWQ | 36 | P | IF | 0 | 15 | 22 | 32 | 26 | 29 |
| 3A | 2" | CWQ | 18 | IF | I | 8 | 22 | 31 | F | 31 | 32 |
| 3B | 2" | CWQ | 24 | IF | | 13 | 19 | 25 | 54 | 48 | 42 |
| 3C | 2" | CWQ | 36 | IF | | 14 | 13 | 34 | 28 | 43 | 38 |

Solution heat treated 8 hours at 910 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Single short-transverse orientation specimens removed after indicated times.

F = failed during exposure.

S. No. 379397

4.6% Zn, 2.3% Mg, 2.4% Cu, 0.1% Zr

TABLE 40

EFFECT OF EXPOSURE TIME IN 3.5% NaCl ALTERNATE IMMERSION TEST ON LOSS IN STRENGTH OF UNSTRESSED SPECIMENS OF ALLOY 18

| Code | Plate Thick | Quench | 2nd Step Hrs PHT at 325 F | Type of Attack Major | Type of Attack Minor | Per Cent Loss in Strength of Specimens Exposed for Indicated Times: Unstressed 7 Days | Unstressed 28 Days | Unstressed 84 Days | Stressed 35 ksi | Stressed 30 ksi | Stressed 25 ksi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | CWQ | 18 | IF | | 13 | 26 | 31 | F | F | 54 |
| 1B | 4" | CWQ | 24 | IF | | 8 | 17 | 30 | F | 27 | 32 |
| 2A | 4" | HWQ | 18 | IF | I | 22 | 26 | 44 | F | F | F |
| 2B | 4" | HWQ | 24 | IF | | 21 | 22 | 34 | 38 | 48 | 39 |
| 2C | 4" | HWQ | 36 | P | | 10 | 19 | 25 | 77 | 32 | 33 |
| 3A | 2" | CWQ | 18 | I | IF | 14 | 23 | 37 | F | F | F |
| 3B | 2" | CWQ | 24 | IF | | 12 | 24 | 44 | F | F | 43 |

Solution heat treated 8 hours at 900 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Single short-transverse oreintation specimens removed after indicated times.

S. No. 379398

5.6% Zn, 2.5% Mg, 2.2% Cu, 0.1% Zr, 0.17% Mn

TABLE 41

STRESS-CORROSION PERFORMANCE OF ALLOY 5 PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|
| 1C | 80 F | 2 hrs at 350 F | 75.3 | 71.4 | 30,33,68 | 133,OK,OK | OK,OK,OK |
| 1D | 80 F | 4 hrs at 350 F | 72.5 | 71.0 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 1E | 80 F | 6 hrs at 350 F | 67.3 | 65.6 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2D | 80 F | 12 hrs at 325 F | 74.3 | 71.0 | 23,23,51 | 51,93,OK | OK,OK,OK |
| 2E | 80 F | 18 hrs at 325 F | 73.0 | 70.2 | 152,184,OK | OK,OK,OK | OK,OK,OK |
| 2F | 80 F | 24 hrs at 325 F | 70.7 | 68.2 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2G | 80 F | 30 hrs at 325 F | 68.7 | 66.6 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6E | 180 F | 18 hrs at 325 F | 63.1 | 60.6 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6F | 180 F | 24 hrs at 325 F | 61.6 | 59.6 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

2-1/2" thick plate solution treated 8 hrs at 890 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after four days at room temperature.

Triplicate 1/8" diameter short-transverse orientation specimens exposed 2/11/70.
OK means no failure.
S. No. 367803

5.9% Zn, 2.3% Mg, 2.3% Cu, 0.12% Zr, 0.05% Cr

TABLE 42

STRESS-CORROSION PERFORMANCE OF ALLOY 6
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Second Step Precipitation Heat Treatment | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level 75% Y.S. | 30 ksi | 25 ski |
|---|---|---|---|---|---|---|
| 1D | 4 hrs at 350 F | 74.9 | 70.2 | 89,138,OK | OK,OK,OK | OK,OK,OK |
| 1E | 6 hrs at 350 F | 71.6 | 68.0 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2D | 12 hrs at 325 F | 73.6 | 67.2 | 26,68,128 | 57,68,OK | OK,OK,OK |
| 2E | 18 hrs at 325 F | 72.4 | 69.4 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

2-1/2" thick plate solution treated 8 hrs at 890 F, quenched in water at 80 F, precipitation heat treated 24 hrs at 250 F after four days at room temperature.

Triplicate 1/8" diameter short-transverse orientation specimens exposed 2/11/70.
OK means no failure.
S. No. 367804

5.9% Zn, 2.4% Mg, 2.2% Cu, 0.24% Fe, 0.28% Ni

TABLE 43

STRESS-CORROSION PERFORMANCE OF 7175-TYPE ALLOY 8 PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Second Step Precipitation Heat Treatment | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|
| A | None | 69.6 | 63.8 | 12,12,12 | 12,16,17 | 16,26,30 |
| 1C | 2 hrs at 350 F | 69.0 | 65.8 | 117,133,OK | 117,OK,OK | OK,OK,OK |
| 1D | 4 hrs at 350 F | 65.2 | 62.2 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 1E | 6 hrs at 350 F | 60.7 | 58.7 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2C | 6 hrs at 325 F | 69.9 | 67.4 | 20,20,20 | 23,23,23 | 138,OK,OK |
| 2D | 12 hrs at 325 F | 67.8 | 64.6 | 86,96,OK | OK,OK,OK | OK,OK,OK |
| 2E | 18 hrs at 325 F | 65.9 | 63.1 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2F | 24 hrs at 325 F | 64.1 | 62.2 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2G | 30 hrs at 325 F | 62.4 | 61.0 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

2-1/2" thick plate solution treated 8 hrs at 890 F, quenched in water at 80 F, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.

Triplicate 1/8" dia. short-transverse orientation specimens exposed 2/11/70.
OK means no failure.
S. No. 367806

6.4% Zn, 2.4% Mg, 1.6% Cu, 0.17% Cr

TABLE 44

STRESS-CORROSION PERFORMANCE OF ALLOY 9
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|
| 1C | 80 F | 2 hrs at 350 F | 77.6 | 71.6 | 154,163,OK | OK,OK,OK | OK,OK,OK |
| 1D | 80 F | 4 hrs at 350 F | 74.0 | 69.8 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 1E | 80 F | 8 hrs at 350 F | 69.1 | 63.0 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2D | 80 F | 12 hrs at 325 F | 76.9 | 71.6 | 96,128,170 | OK,OK,OK | OK,OK,OK |
| 2E | 80 F | 18 hrs at 325 F | 74.7 | 71.1 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2F | 80 F | 24 hrs at 325 F | 72.5 | 69.5 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2G | 80 F | 30 hrs at 325 F | 69.5 | 67.5 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2H | 80 F | 36 hrs at 325 F | 67.8 | 66.6 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6E | 180 F | 18 hrs at 325 F | 68.6 | 66.9 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6F | 180 F | 24 hrs at 325 F | 62.6 | 64.3 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6G | 180 F | 30 hrs at 325 F | 65.3 | 62.8 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 6H | 180 F | 36 hrs at 325 F | 64.0 | 60.6 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

2-1/2" thick plate solution treated 8 hrs at 890 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after four days at room temperature.

Triplicate 1/8" diameter short-transverse orientation specimens exposed 2/11/70.
OK means no failure.
S. No. 373468

6% Zn, 2.3% Mg, 2.5% Cu, 0.12% Zr

TABLE 45

STRESS-CORROSION PERFORMANCE OF ALLOY 10
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 74 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 1B | 4" | Rolled | CWQ | 24 | 71 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 72 | [illegible] | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 68 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 65 | 62 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 72 | 70 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7A | 2" | Preforged | CWQ | 12 | 78 | 77 | 20,44,52 | OK,OK,OK | OK,OK,OK |
| 7D | 2" | Preforged | CWQ | 18 | 74 | 72 | 52,99,OK | OK,OK,OK | OK,OK,OK |
| 7F | 2" | Preforged | CWQ | 24 | 74 | 73 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 8A | 2" | Preforged | HWQ | 12 | 76 | 71 | 15,36,52 | OK,OK,OK | OK,OK,OK |
| 8D | 2" | Preforged | HWQ | 18 | 72 | 72 | 31,50,69 | OK,OK,OK | OK,OK,OK |
| 8F | 2" | Preforged | HWQ | 24 | 70 | 70 | 71,92,97 | OK,OK,OK | OK,OK,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4-5 days at room temperature.
CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.

Triplicate short-transverse orientation specimens exposed 5/19/70.
OK means no failure.

S. No. 379390
5.8% Zn, 2.3% Mg, 1.9% Cu, 0.1% Zr

TABLE 46

STRESS-CORROSION PERFORMANCE OF ALLOY 11
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 70 | 62 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 66 | 61 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7A | 2" | Preforged | CWQ | 12 | 77 | 74 | 97,OK,OK | OK,OK,OK | OK,OK,OK |
| 7B | 2" | Preforged | CWQ | 15 | 74 | 72 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7D | 2" | Preforged | CWQ | 18 | 71 | 70 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 8A | 2" | Preforged | HWQ | 12 | 75 | 75 | 22,48,64 | 44,71,OK | OK,OK,OK |
| 8B | 2" | Preforged | HWQ | 15 | 73 | 70 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 8D | 2" | Preforged | HWQ | 18 | 69 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4-5 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.

Triplicate short-transverse orientation specimens exposed 5/19/70.

OK means no failure.

S. No. 379391

6% Zn, 1.8% Mg, 2.3% Cu, 0.1% Zr

TABLE 47

STRESS-CORROSION PERFORMANCE OF ALLOY 12
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 72 | 65 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 70 | 66 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 65 | 63 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 62 | 58 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 71 | 69 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3B | 2" | Rolled | CWQ | 24 | 66 | 64 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7A | 2" | Preforged | CWQ | 12 | 76 | 74 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7C | 2" | Preforged | CWQ | 16 | 74 | 73 | 69,OK,OK | OK,OK,OK | OK,OK,OK |
| 7E | 2" | Preforged | CWQ | 20 | 75 | 72 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 8A | 2" | Preforged | HWQ | 12 | 76 | 72 | 64,64,73 | 92,OK,OK | OK,OK,OK |
| 8C | 2" | Preforged | HWQ | 16 | 72 | 70 | 73,OK,OK | OK,OK,OK | OK,OK,OK |
| 8E | 2" | Preforged | HWQ | 20 | 71 | 69 | 55,OK,OK | OK,OK,OK | OK,OK,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4-5 days at room temperature.
CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.
Triplicate short-transverse orientation specimens exposed 5/19/70.
OK means no failure.

S. No. 379392
5.5% Zn, 2% Mg, 2% Cu, 0.1% Zr

TABLE 48

STRESS-CORROSION PERFORMANCE OF ALLOY 13
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 74 | 70 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 1B | 4" | Rolled | CWQ | 24 | 71 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 72 | 69 | 31,41,73 | 24,OK,OK | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 69 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 67 | 63 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 75 | 71 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3B | 2" | Rolled | CWQ | 24 | 73 | 68 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Triplicate short-transverse orientation specimens exposed 5/19/70.

OK means no failure.

S. No. 379393
5.2% Zn, 2.6% Mg, 2.5% Cu, 0.1% Zr

TABLE 49

STRESS-CORROSION PERFORMANCE OF ALLOY 14
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 74 | 69 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 71 | 68 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 66 | 63 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 74 | 71 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7B | 2" | Preforged | CWQ | 15 | 77 | 75 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7D | 2" | Preforged | CWQ | 18 | 75 | 73 | 92,OK,OK | OK,OK,OK | OK,OK,OK |
| 7F | 2" | Preforged | CWQ | 24 | 72 | 70 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 8B | 2" | Preforged | HWQ | 15 | 72 | 69 | 50*92,OK | OK,OK,OK | OK,OK,OK |
| 8D | 2" | Preforged | HWQ | 18 | 70 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 8F | 2" | Preforged | HWQ | 24 | 68 | 64 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

Solution treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hours at 250 F after 4 days at room temperature.
CWQ = quenched in water at room temperature.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.
Triplicate short-transverse orientation specimens exposed 5/19/70.
OK means no failure.

* = specimen contained internal discontinuity.

S. No. 379394
5.8% Zn, 2.3% Mg, 3.0% Cu, 0.1% Zr

TABLE 50

STRESS-CORROSION PERFORMANCE OF ALLOY 15
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 72 | 68 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 1B | 4" | Rolled | CWQ | 24 | 70 | 64 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 71 | 69 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 67 | 65 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 36 | 64 | 60 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 72 | 69 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 7A | 2" | Preforged | CWQ | 12 | 79 | 75 | 13,50,71 | 48,52,97 | OK,OK,OK |
| 7D | 2" | Preforged | CWQ | 18 | 76 | 73 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 8A | 2" | Preforged | HWQ | 12 | 75 | 72 | 48,55,69 | 69,69,OK | OK,OK,OK |
| 8D | 2" | Preforged | HWQ | 18 | 71 | 67 | 64,92,OK | OK,OK,OK | OK,OK,OK |
| 8G | 2" | Preforged | HWQ | 28 | 66 | 65 | | | |

Solution heat treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.
CWQ = quenched in cold water.
HWQ = 4" plate quenched in water at 175 F; 2" plate quenched in water at 180 F.
Triplicate short-transverse orientation specimens exposed 5/19/70.
OK means no failure.

S. No. 379395
5.7% Zn, 2.3% Mg, 2.3% Cu, 0.1% Zr, 0.2% Fe

TABLE 51

STRESS-CORROSION PERFORMANCE OF ALLOY 16
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1C | 4" | Rolled | CWQ | 8 | 81 | 74 | 64,71,76 | 64,OK,OK | 28,OK,OK |
| 1A | 4" | Rolled | CWQ | 18 | 74 | 67 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 2C | 4" | Rolled | HWQ | 8 | 79 | 74 | 48,48,48 | 66,71,97 | OK,OK,OK |
| 2A | 4" | Rolled | HWQ | 18 | 69 | 67 | 52,64,OK | 92,92,OK | OK,OK,OK |
| 2B | 4" | Rolled | HWQ | 24 | 67 | 64 | OK,OK,OK | OK,OK,OK | OK,OK,OK |
| 3C | 2" | Rolled | CWQ | 8 | 79 | 76 | 64,71,76 | OK,OK,OK | OK,OK,OK |
| 3A | 2" | Rolled | CWQ | 18 | 73 | 70 | OK,OK,OK | OK,OK,OK | OK,OK,OK |

Solution heat treated 8 hrs at 880 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Triplicate short-transverse orientation specimens exposed 5/19/70.
OK means no failure.

S. No. 379396
8.1% Zn, 2.4% Mg, 1.7% Cu, 0.1% Zr

TABLE 52

STRESS-CORROSION PERFORMANCE OF ALLOY 17.
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 71 | 65 | | | |
| 1B | 4" | Rolled | CWQ | 24 | 70 | 64 | | | |
| 2A | 4" | Rolled | HWQ | 18 | 71 | 67 | | | |
| 2B | 4" | Rolled | HWQ | 24 | 65 | 63 | | No Failures | |
| 2C | 4" | Rolled | HWQ | 36 | 63 | 61 | | | |
| 3A | 2" | Rolled | CWQ | 18 | 72 | 68 | | | |
| 3B | 2" | Rolled | CWQ | 24 | 70 | 67 | | | |
| 3C | 2" | Rolled | CWQ | 36 | 67 | 64 | | | |

Solution heat treated 8 hrs at 910 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Triplicate short-transverse orientation specimens exposed 5/19/70.
Blank means no failure.

S. No. 379397
4.6% Zn, 2.3% Mg, 2.4% Cu, 0.1% Zr

TABLE 53

STRESS-CORROSION PERFORMANCE OF ALLOY 18
PLATE IN NEW KENSINGTON ATMOSPHERE

| Code | Plate Thickness | Fab. Process | Quench | 2nd Step Hrs PHT at 325 F | Yield Strength (ksi) L-T | Yield Strength (ksi) S-T | Days to Fracture After Exposure at Indicated Stress Level: 75% Y.S. | 40 ksi | 25 ksi |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 4" | Rolled | CWQ | 18 | 71 | 65 | | | |
| 1B | 4" | Rolled | CWQ | 24 | 70 | 64 | | | |
| 2A | 4" | Rolled | HWQ | 18 | 71 | 67 | No Failures | | |
| 2B | 4" | Rolled | HWQ | 24 | 65 | 63 | | | |
| 2C | 4" | Rolled | HWQ | 36 | 63 | 61 | | | |
| 3A | 2" | Rolled | CWQ | 18 | 72 | 68 | | | |
| 3B | 2" | Rolled | CWQ | 24 | 70 | 67 | | | |

Solution heat treated 8 hrs at 900 F, quenched as indicated, precipitation heat treated 24 hrs at 250 F after 4 days at room temperature.

CWQ = quenched in water at room temperature.
HWQ = quenched in water at 175 F.

Triplicate short-transverse orientation specimens exposed 5/19/70.
Blank means no failure.

S. No. 379398
5.6% Zn, 2.5% Mg, 2.2% Cu, 0.1% Zr, 0.17% Mn

Table 54

ELECTRICAL CONDUCTIVITIES OF 2-1/2 INCH THICK PLATE QUENCHED IN WATER AT ROOM TEMPERATURE

| Alloy | S - No. | Second Step Precipitation Heat Treatment (Hrs at 350 F) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | None | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
| 5 | 367803-1 | 30.2 | 32.2 | 36.0 | 37.7 | 39.5 | 40.1 | 40.9 | 41.1 |
| 6 | 367804-1 | 30.7 | 31.8 | 35.1 | 37.0 | 38.4 | 39.6 | 40.3 | 40.7 |
| 8 | 367806-1 | 32.0 | 34.3 | 38.5 | 40.2 | 41.4 | 42.0 | 42.6 | 43.0 |
| 9 | 373468-1 | 31.2 | 33.2 | 37.3 | 38.8 | 40.3 | 41.6 | 42.2 | 42.5 |

| Alloy | S - No. | Second Step Precipitation Heat Treatment (Hrs at 325 F) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | None | 0 | 6 | 12 | 18 | 24 | 30 | 36 |
| 5 | 367803-2 | 30.2 | 31.6 | 34.4 | 36.5 | 37.4 | 38.5 | 39.5 | 40.1 |
| 6 | 367804-2 | 30.7 | 31.1 | 33.3 | 34.7 | 36.1 | 37.5 | 38.4 | 38.7 |
| 8 | 367806-2 | 32.0 | 33.1 | 36.8 | 38.4 | 40.0 | 41.1 | 41.6 | 42.0 |
| 9 | 373468-2 | 31.2 | 31.8 | 34.3 | 36.9 | 38.8 | 39.5 | 40.5 | 41.3 |

All precipitation heat treated 24 hours at 250 F after four days at room temperature.

Table 55

ELECTRICAL CONDUCTIVITIES OF 2-1/2 INCH THICK PLATE QUENCHED IN WATER AT 180 F AND PRECIPITATION HEAT TREATED AT 325 F

| | | Second Step Precipitation Heat Treatment (Hrs at 325 F) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Alloy | S - No. | None | 0 | 6 | 12 | 18 | 24 | 30 | 36 |
| 5 | 367803-6 | 34.1 | 35.3 | 37.6 | 39.8 | 40.1 | 41.5 | 42.1 | 42.4 |
| 6 | 367804-6 | 32.5 | 32.8 | 35.1 | 36.4 | 37.8 | 39.5 | 39.8 | 40.0 |
| 8 | 367806-6 | 37.7 | 39.1 | 40.1 | 41.0 | 42.4 | 43.1 | 43.9 | 44.6 |
| 9 | 373468-6 | 32.8 | 34.1 | 37.1 | 39.1 | 40.3 | 41.1 | 41.7 | 42.6 |

All precipitation heat treated 24 hours at 250 F after four days at room temperature.

TABLE 56

ELECTRICAL CONDUCTIVITIES OF ALLOYS 10-18

| Code | 2nd Step Hrs. PHT at 325 F | Alloys 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7A | 12 | 37.9 | 39.6 | 37.8 | -- | -- | 36.7 | -- | -- | -- |
| 7B | 15 | -- | 40.5 | -- | -- | 36.9 | -- | -- | -- | -- |
| 7C | 16 | -- | -- | 39.4 | -- | -- | -- | -- | -- | -- |
| 7D | 18 | 38.5 | 41.4 | -- | -- | -- | 38.8 | -- | -- | -- |
| 7E | 20 | -- | -- | 39.6 | -- | -- | -- | -- | -- | -- |
| 7F | 24 | 40.7 | -- | -- | -- | 39.0 | -- | -- | -- | -- |
| 7G | 28 | -- | -- | -- | -- | -- | 40.1 | -- | -- | -- |
| 8A | 12 | 38.2 | 40.8 | 39.0 | -- | -- | 37.8 | -- | -- | -- |
| 8B | 15 | -- | 41.4 | -- | -- | 39.5 | -- | -- | -- | -- |
| 8C | 16 | -- | -- | 40.3 | -- | -- | -- | -- | -- | -- |
| 8D | 18 | 39.3 | 42.5 | -- | -- | 40.5 | 39.0 | -- | -- | -- |
| 8E | 20 | -- | -- | 40.5 | -- | -- | -- | -- | -- | -- |
| 8F | 24 | 41.3 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8G | 28 | -- | -- | -- | -- | -- | 41.3 | -- | -- | -- |
| 3A | 18 | 39.4 | 40.7 | 39.8 | 37.9 | 38.0 | 38.4 | 40.8 | 37.9 | 35.8 |
| 3B | 24 | 40.0 | 42.0 | 41.1 | 38.3 | 39.6 | 39.1 | 42.1 | 39.4 | 37.0 |
| 3C | 36 | 41.3 | 43.5 | 42.1 | 39.9 | 41.0 | 41.0 | 38.4* | 40.6 | 37.6 |
| 1A | 18 | 39.0 | 41.1 | 39.5 | 37.6 | 37.4 | 38.7 | 41.1 | 37.9 | 36.2 |
| 1B | 24 | 40.6 | 42.1 | 41.1 | 39.1 | 39.3 | 39.9 | 41.3 | 38.5 | 37.2 |
| 1C | 36 | 41.5 | 43.4 | 42.0 | 40.2 | 40.9 | 41.1 | 38.6* | 41.1 | 38.0 |
| 2A | 18 | 38.5 | 42.1 | 40.0 | 38.6 | 39.9 | 39.1 | 41.0 | 38.5 | 36.9 |
| 2B | 24 | 39.6 | 42.9 | 41.4 | 39.5 | 40.1 | 39.8 | 41.4 | 40.1 | 38.4 |
| 2C | 36 | 40.6 | 44.0 | 42.8 | 42.1 | 41.2 | 40.3 | 38.2* | 41.0 | 38.6 |

* 8 hrs. at 325 F PHT.

See Tables 10 through 18 for pertinent fabrication data and tensile properties.

TABLE 57

PLANE STRAIN FRACTURE TOUGHNESS ALLOY 9 PLATE

| Spec. No. | Specimen* Orientation | Specimen Thickness | Crack Length | $2.5\left[\frac{K_Q}{Y.S.}\right]^2$ | $K_{Ic}$ ksi $\sqrt{in.}$ |
|---|---|---|---|---|---|
| L1 | L-W | 2.01 | 2.58 | 0.34 | 25.6 (1) (2) (3) |
| L2 | L-W | 2.01 | 2.61 | 0.42 | 28.6 (1) (2) |
| L3 | L-W | 1.00 | 1.05 | 0.39 | 29.9 |
| L4 | L-W | 1.00 | 1.04 | 0.39 | 30.0 |
| L5 | L-W | 1.00 | 1.04 | 0.39 | 30.1 |
| N1 | T-L | 1.00 | 1.08 | 0.35 | 26.2 |
| N2 | T-L | 1.00 | 1.07 | 0.37 | 26.8 |
| N3 | T-L | 1.00 | 1.06 | 0.36 | 26.6 |

S. No. 373468 Code 2E

CWQ, PHT 24 hrs 250F + 18 hrs 325 F
5.9% Zn, 2.3% Mg, 2.5% Cu, 0.12% Zr

(1) Not valid. Crack length/width not between 0.45 and 0.55.
(2) Not valid. Fatigue crack front curvature exceeded the allowed amount.
(3) Not valid. Stress intensity was too high for last step of fatigue cracking.

*First letter is direction of stress. Second letter is direction of crack propagation.
L = length, longitudinal; W = width, long-tranverse; T = thickness, short-transverse.

TABLE 58

PLANE STRAIN FRACTURE TOUGHNESS ALLOY 14 PLATE

| Code | Plate Thickness | Fabricating Practice | Quench | Spec. No. | Specimen* Orientation | Specimen Thickness | Crack Length | $2.5\left[\frac{K_Q}{Y.S.}\right]^2$ | $K_{Ic}$ ksi $\sqrt{in.}$ |
|---|---|---|---|---|---|---|---|---|---|
| -3A | 2" | Rolled | CWQ | L1 | L-W | 1.50 | 1.83 | 0.31 | 25.9 |
| | | | | L2 | L-W | 1.50 | 1.70 | 0.33 | 26.4 |
| | | | | N1 | T-L | 0.75 | 0.81 | 0.25 | 22.3 |
| | | | | N2 | T-L | 0.75 | 0.81 | 0.26 | 23.4 |
| -7D | 2" | Preforged | CWQ | L1 | L-W | 1.00 | 1.14 | 0.35 | 27.6 |
| | | | | L2 | L-W | 1.00 | 1.12 | 0.35 | 27.5 |
| | | | | N1 | T-L | 0.75 | 0.82 | 0.26 | 23.6 |
| -8D | 2" | Preforged | HWQ | L1 | L-W | 1.50 | 1.70 | 0.32 | 25.1 |
| | | | | L2 | L-W | 1.50 | 1.67 | 0.26 | 22.8 |
| | | | | N1 | T-L | 0.75 | 0.78 | 0.14 | 15.9 |

S. No. 379394

CWQ = Quenched in water at R.T.
HWQ = Quenched in water at 180 F.

PHT 24 hrs 250 F + 18 hrs 325 F

5.8% Zn, 2.3% Mg, 3% Cu, 0.11% Zr

*First letter is direction of stress. Second letter is direction of crack propagation.
L = length, longitudinal; W = width, long-transverse; T = thickness, short-transverse.

DC Cast
12" x 38" x 60"
Ingot

|

Stress-Relieve
at 650 F

|

Machine to 10" x 14" x 12"
Rolling Sections

|

Preheat 20 hrs at 850 F

|

Hot Roll at 750 F
4" x 14" x 30"

|

Saw to 4" x 14" x 12"

|

Hot Roll at 600 F
to 2-1/2" x 14" x 22"

|

Ultrasonically Inspect

Figure 1 - Fabrication, Alloys 1-9

DC Cast
12" x 38" x 60"
Ingot

|

Stress-Relieve
at 650 F

|

Machine to 10" x 14" x 32"
Rolling Sections

|

Ultrasonically Inspect

|

Preheat 20 hrs at 850 F

|

Hot Roll at 760 F
7" x 14" x 51"

|

Reheat 10 hrs at 850 F

|

Hot Roll at 760 F
to 4" x 14" x 76"

|

Saw to 4" x 14" x 24"

|

Hot Roll one piece at 750 F
to 2" x 14" x 48"

|

Ultrasonically Inspect

Figure 2 - Fabrication of Rolled Plate, Alloys 10-18

10" x 14" x 12"
Scalped Ingot Section

Ultrasonically Inspect

Preheat Overnight
at 900 F

Hot Forge to
5" x 14" x 24"
at 750 F

Reheated Overnight
at 900 F

Hot Roll
to 2" x 14" x 60"

Ultrasonically Inspect

Figure 3 - Fabrication of Preforged Plate
(Alloys 10, 11, 12, 14 & 15)

Hot Rolled 2-1/2" x 15" x 22" Plate Sections

Solution Heat Treat
8 hrs at 890 F

Quench

A. Cold Water

B. 180 F Water

After 4 days at Room Temperature
Precipitation Heat Treat 24 hrs at 250 F

Section and Precipitation Heat Treat as Follows:

A. Cold Water Quenched Sections:

0, 2, 4, 6, 8, 10, 12 hrs at 350 F
0, 6, 12, 18, 24, 30, 36 hrs at 325 F

B. 180 F Water Quenched Sections:

18, 24, 30, 36 hrs at 325 F

Figure 4 - Heat Treatment (Alloys 1-9)

Hot Rolled 2" x 14" x 24" (2 pieces) Plate Sections
4" x 14" x 24"

Solution Heat Treat
9 hrs at 900 F†

Quench

2" & 4"
Cold Water

2"
175 F Water

After 4 days at Room Temperature
Precipitation Heat Treat 24 hrs at 250 F

Section and Precipitation Heat Treat as Follows:

Alloy 16

8, 18, 24 hrs at 325 F

Other Alloys

18, 24, 36 hrs at 325 F

† Alloy 16, 880 F; Alloy 17, 910 F

Figure 5 - Heat Treatment of Rolled Plate (Alloys 10-18)

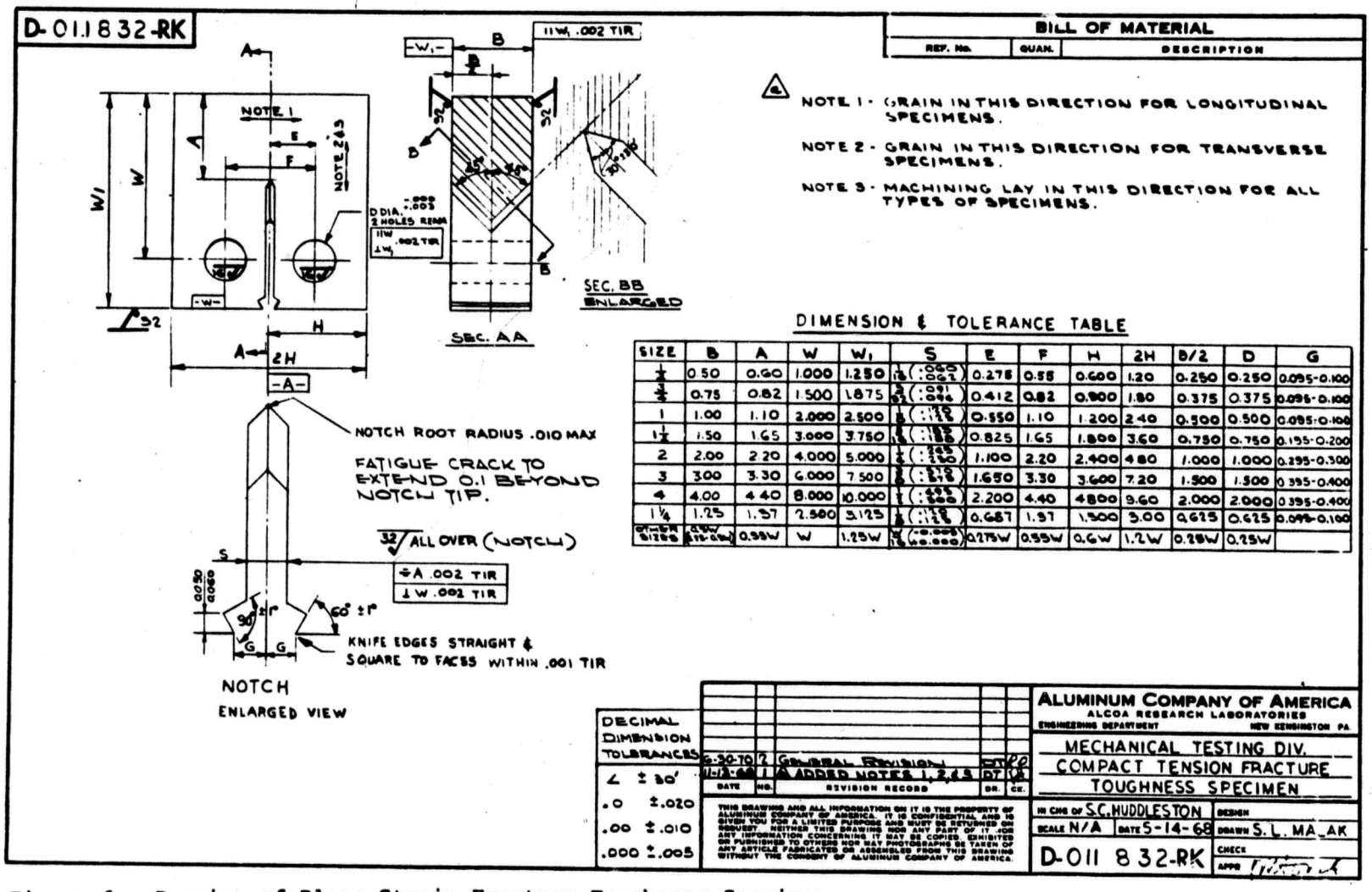



Figure 6. Drawing of Plane-Strain Fracture Toughness Specimen.

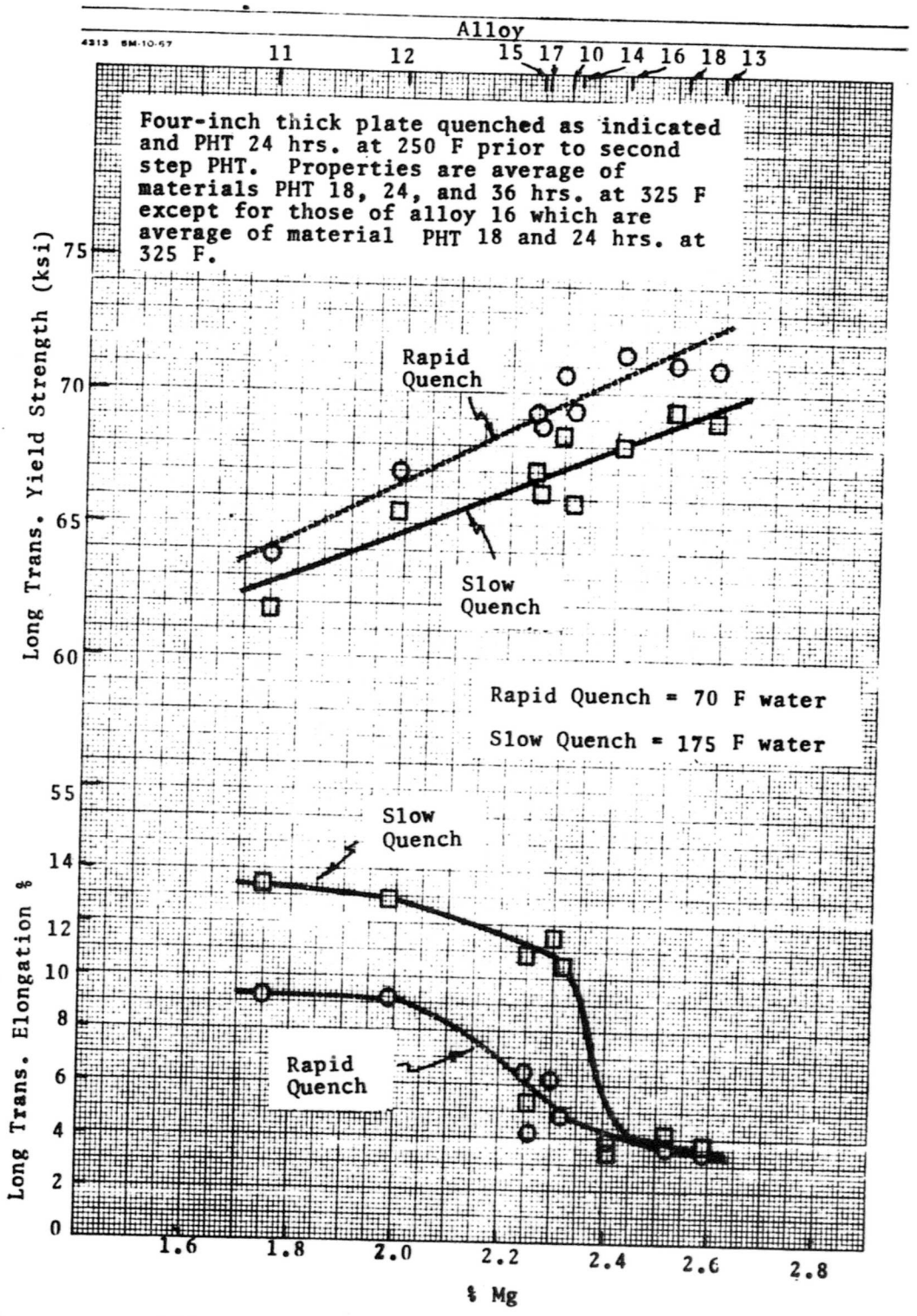



Fig. 7 Effect of Mg Content and Quenching Conditions on Long Transverse Tensile Properties of 4" Thick Plate

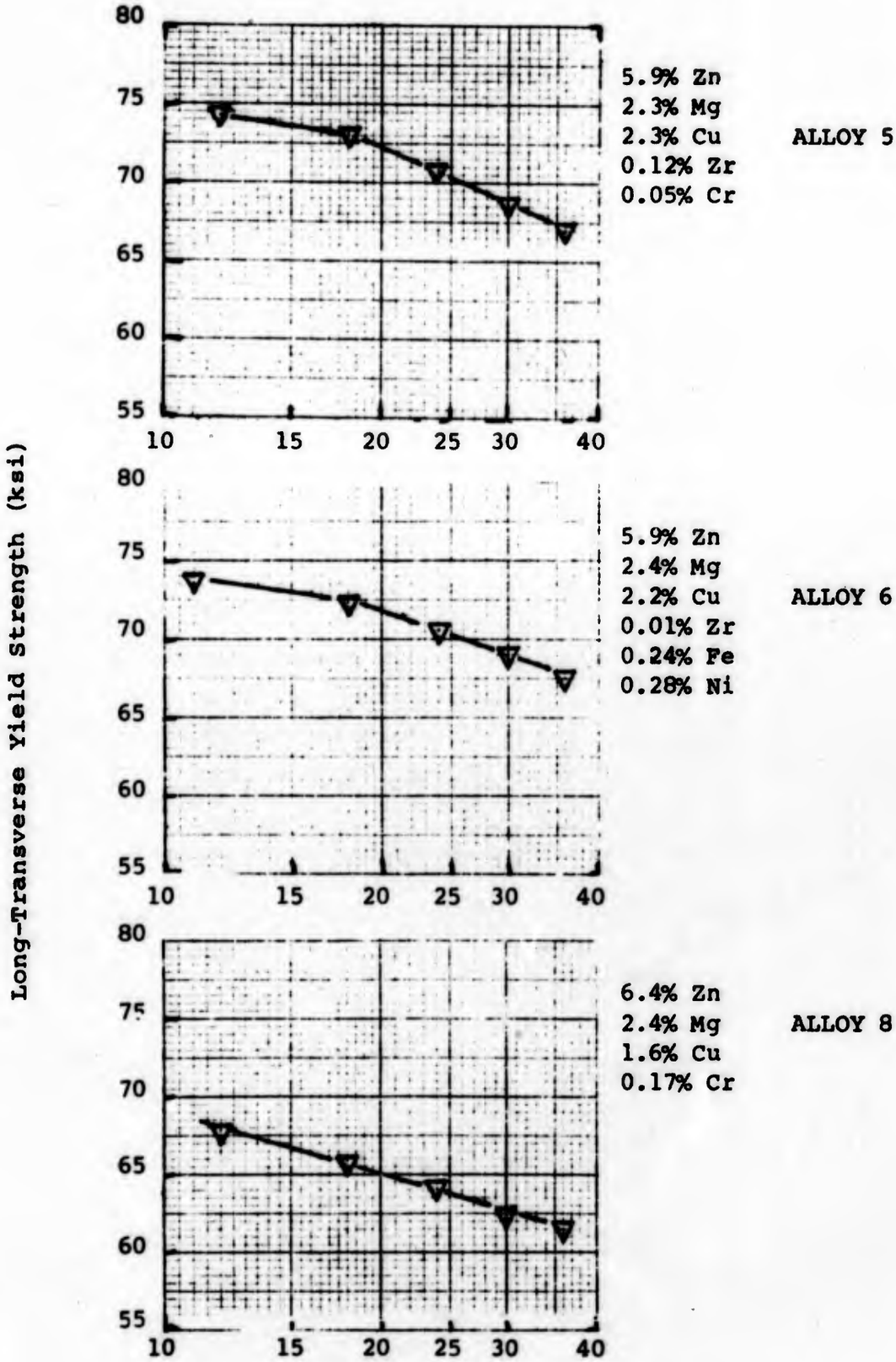



Fig. 8 Aging Curves for Alloys 5, 6, and 8.

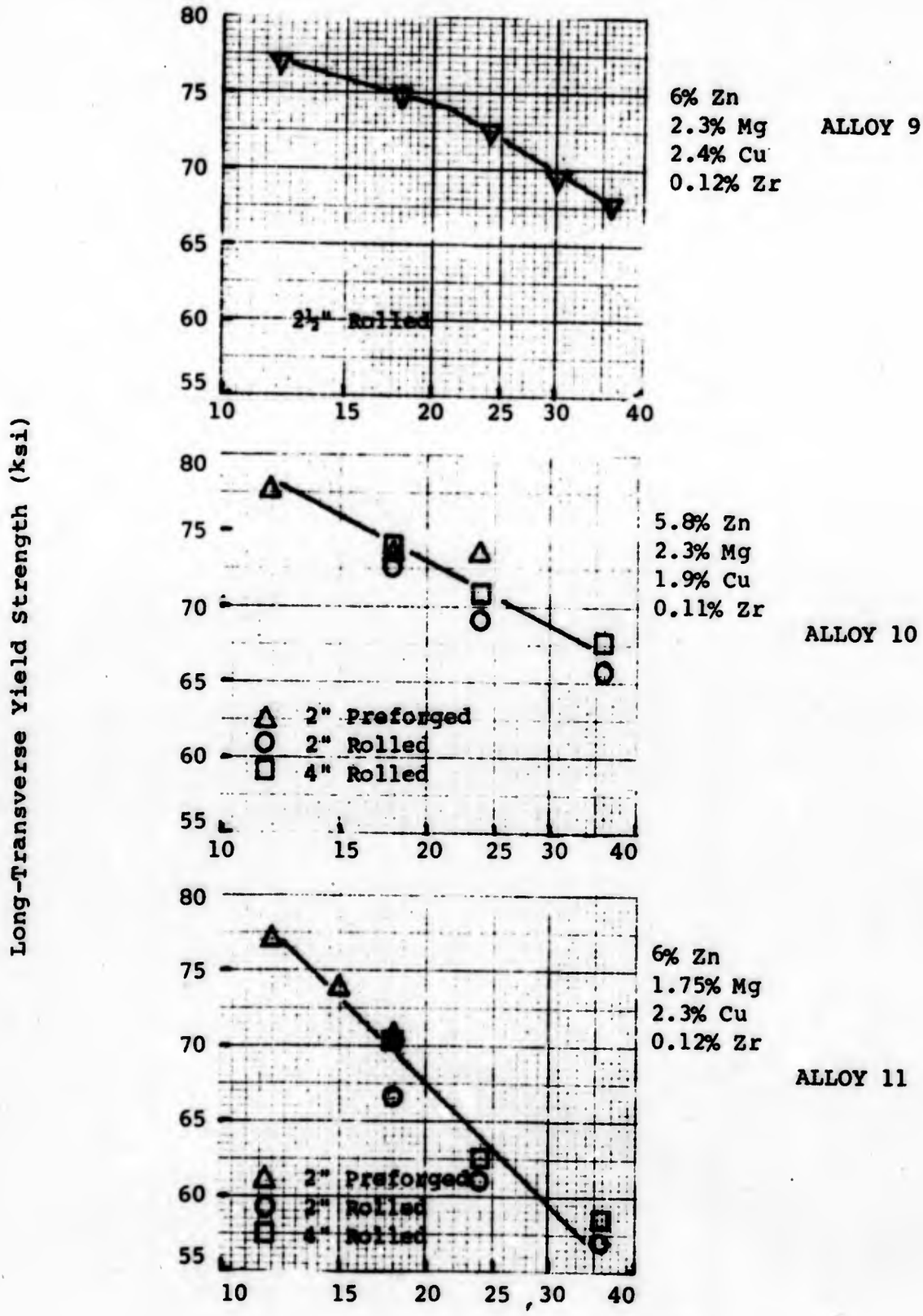



Fig. 9 Aging Curves for Alloys 9, 10, and 11.

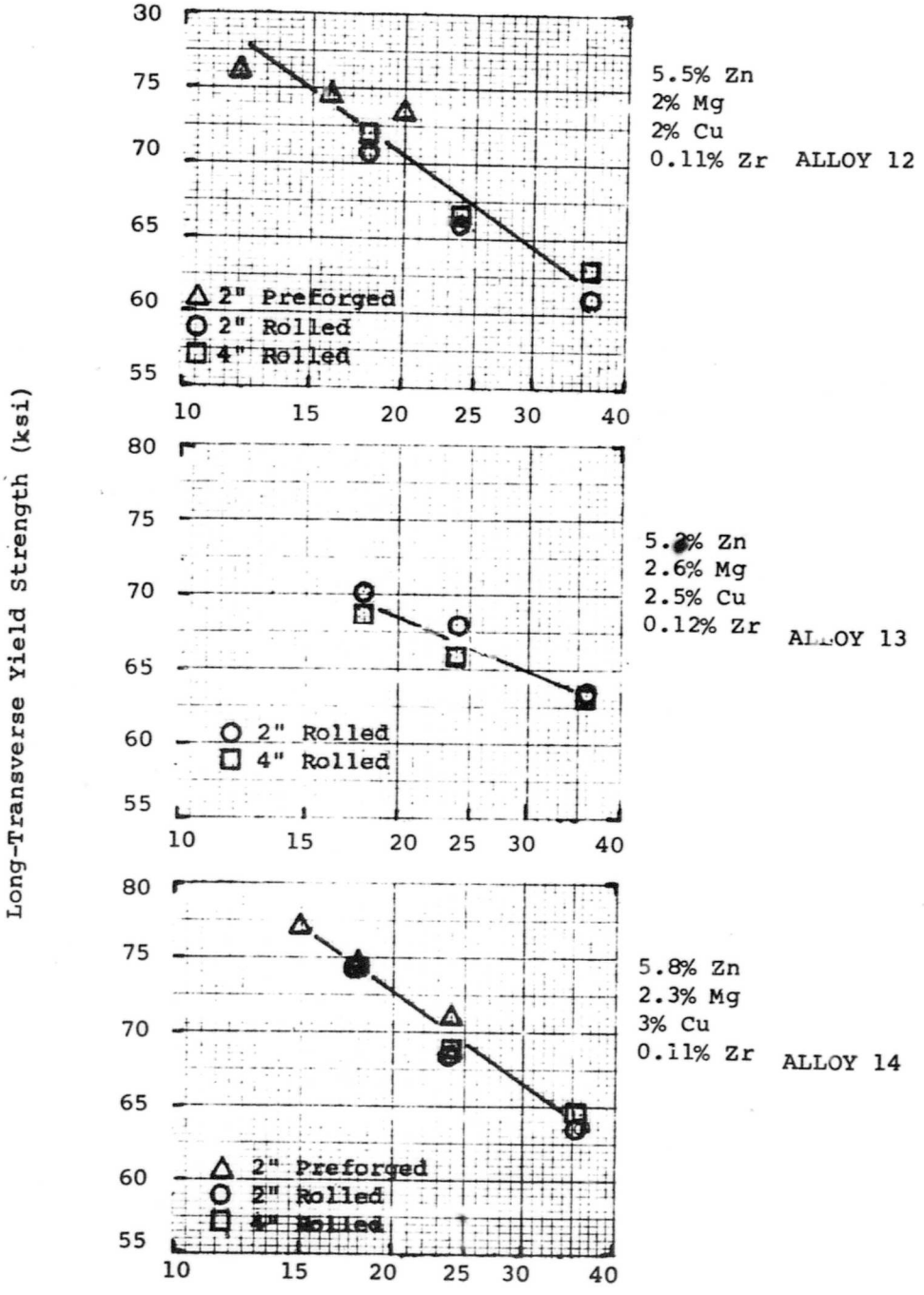



**Fig. 10** Aging Curves for Alloys 12, 13, and 14.

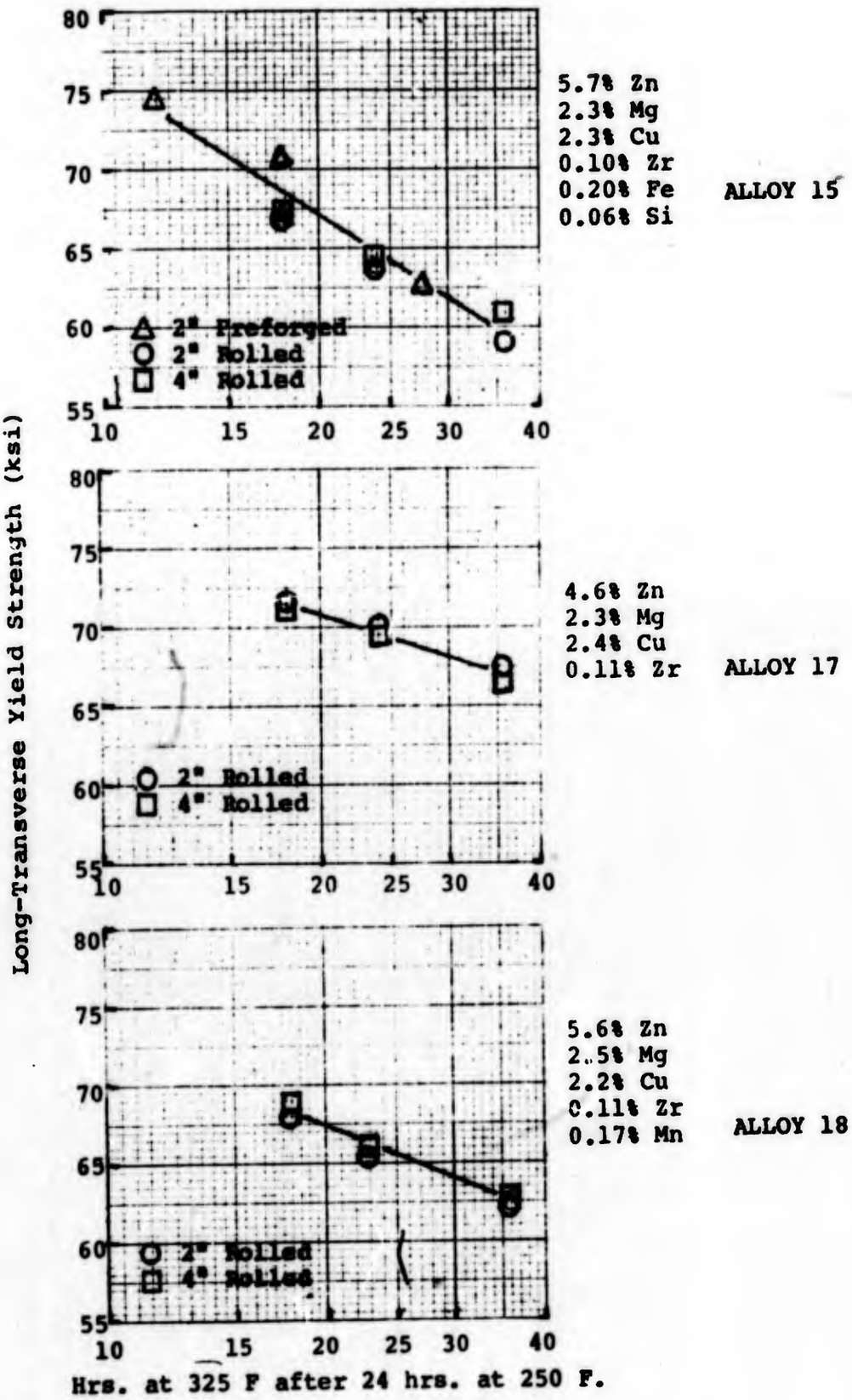



Fig. 11 Aging Curves for Alloys 15, 17, and 18.

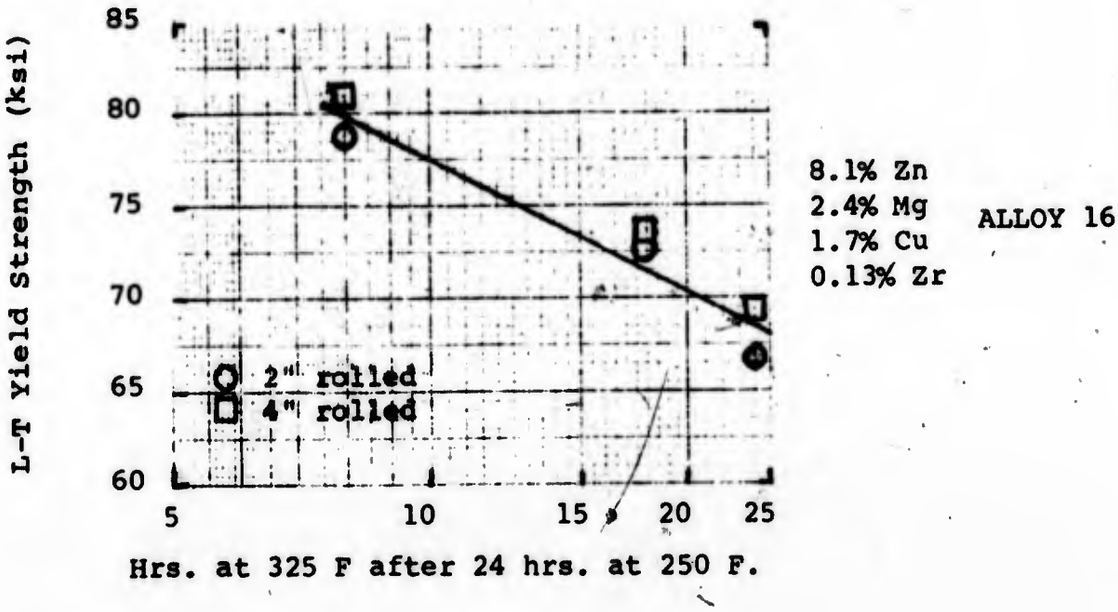



Fig.12 Aging Curve for Alloy 16

Note that time scale is different than for other alloys.

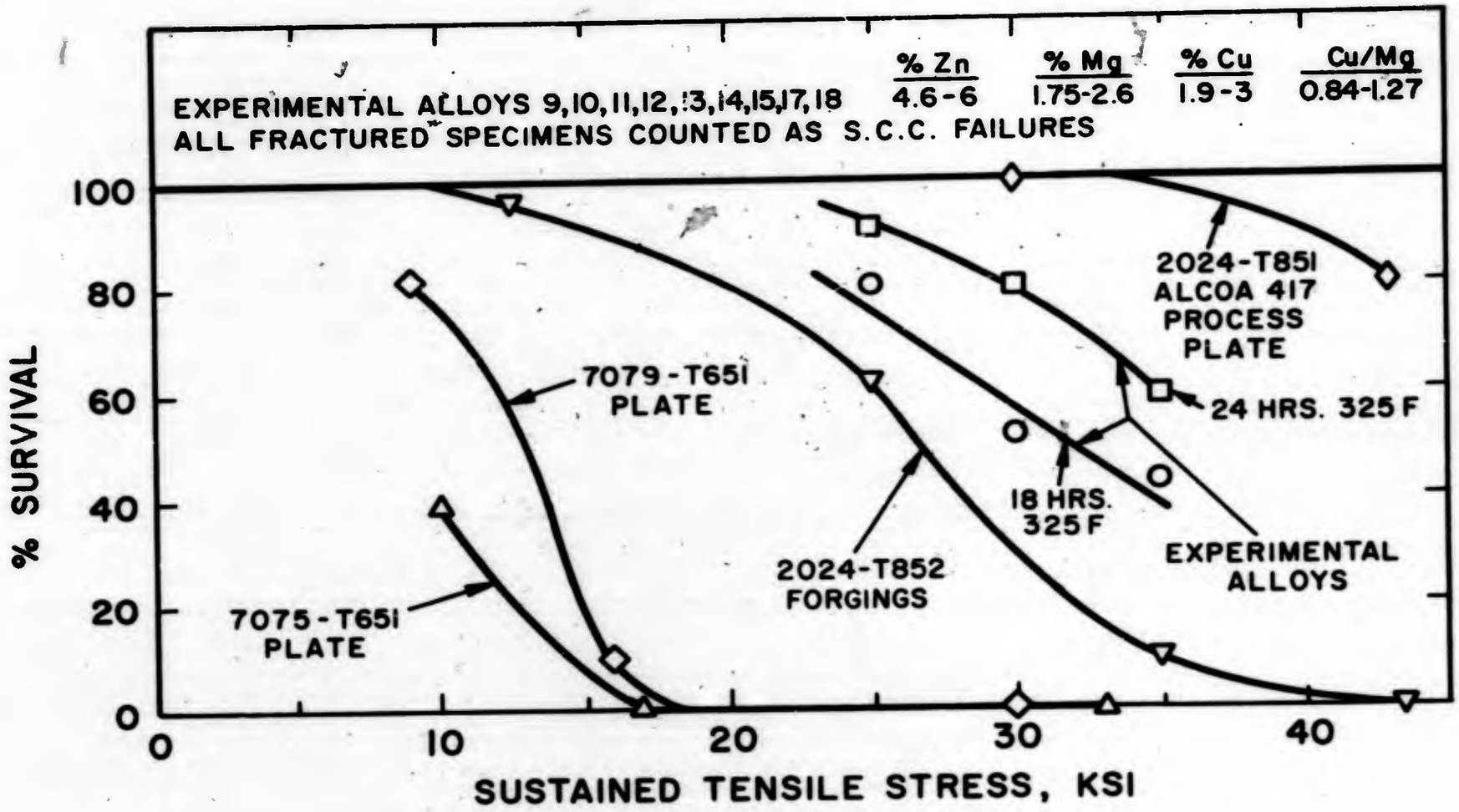



FIG. 13 SHORT-TRANSVERSE STRESS-CORROSION TESTS IN 3.5 % NaCl BY ALTERNATE IMMERSION - 84 DAYS.

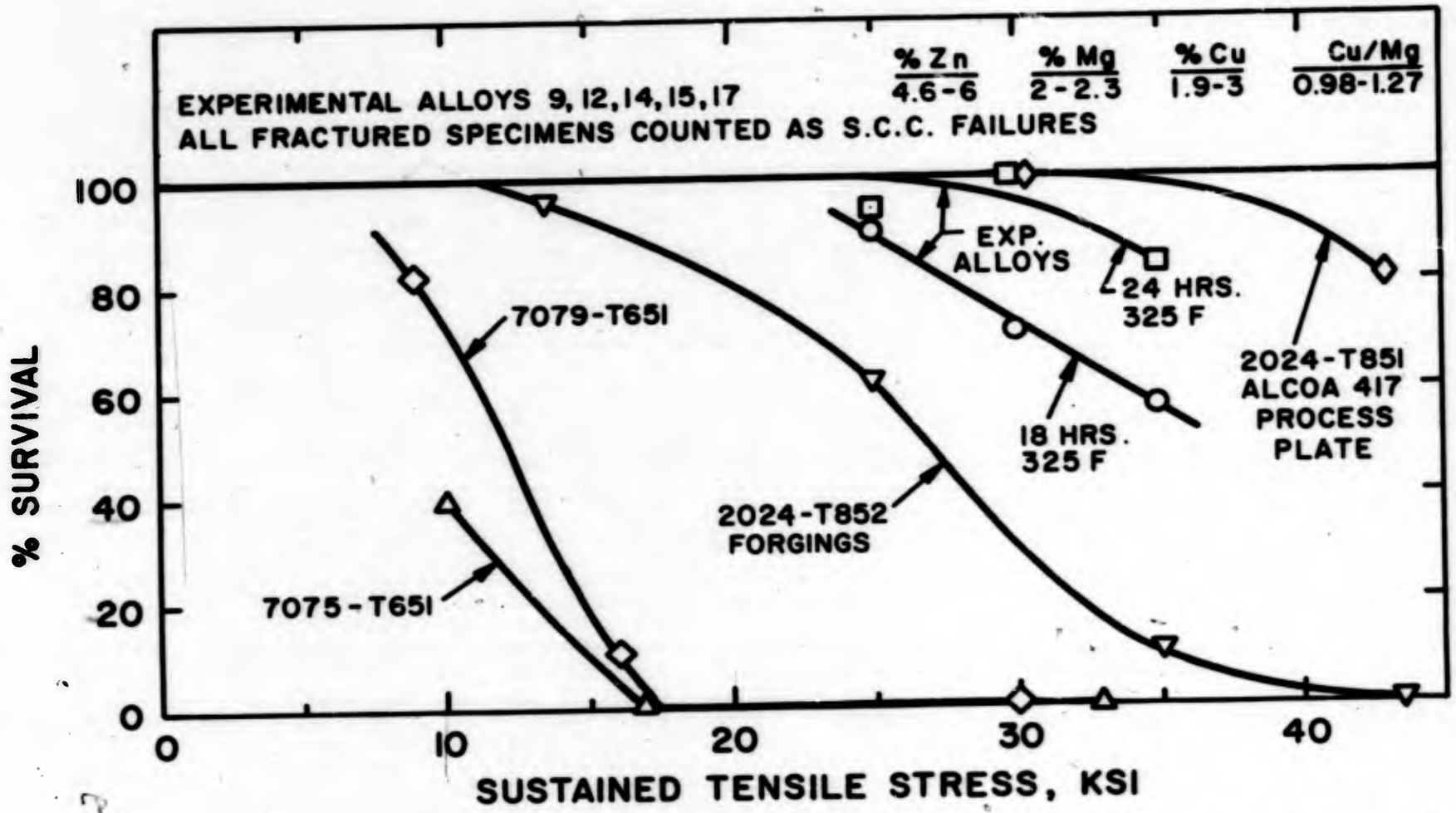



FIG. 14 SHORT-TRANSVERSE STRESS-CORROSION TESTS IN 3.5 % NaCl BY ALTERNATE IMMERSION - 84 DAYS.

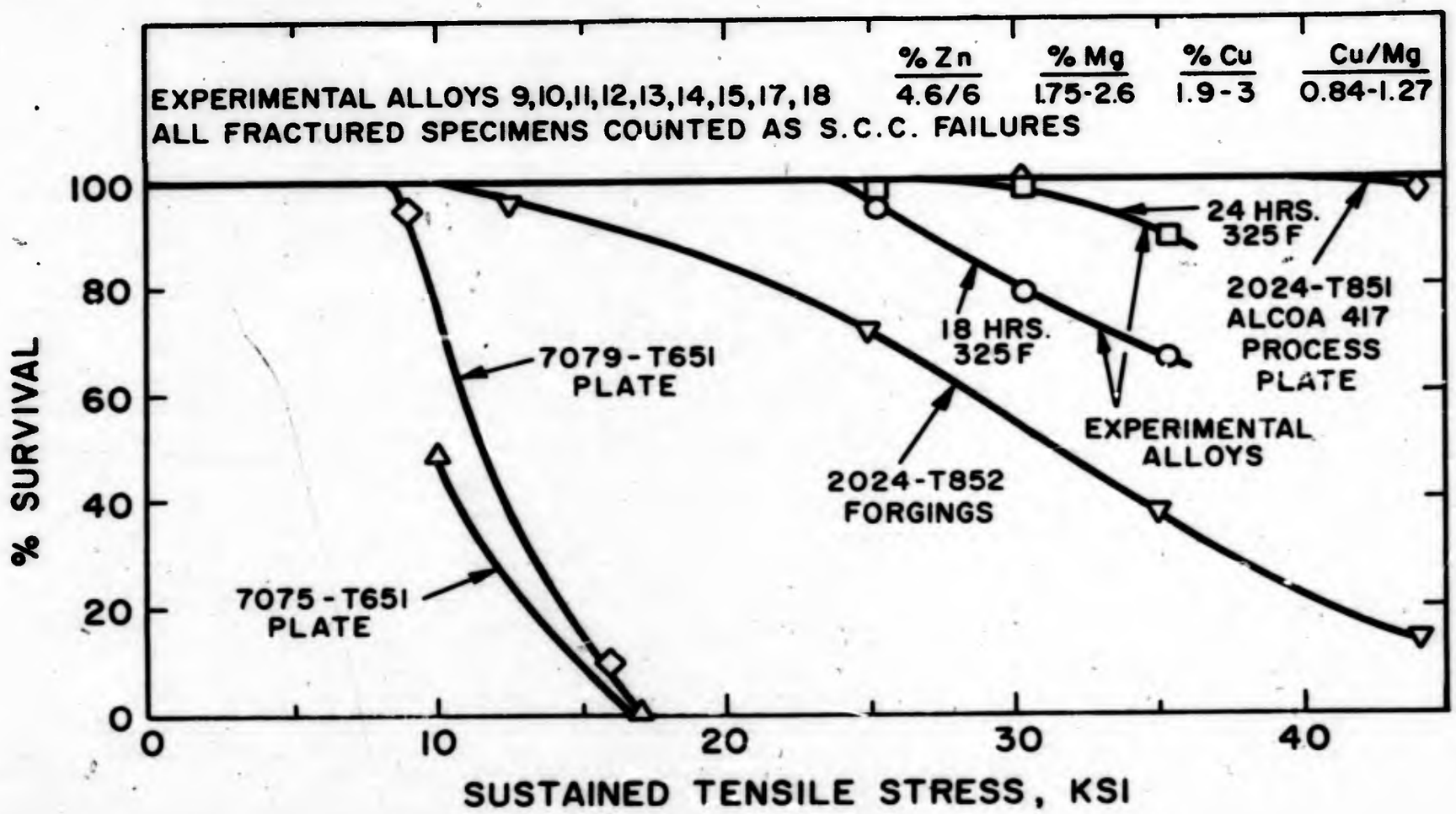



FIG. 15 SHORT-TRANSVERSE STRESS-CORROSION TESTS IN 3.5 % NaCl BY ALTERNATE IMMERSION - 30 DAYS.

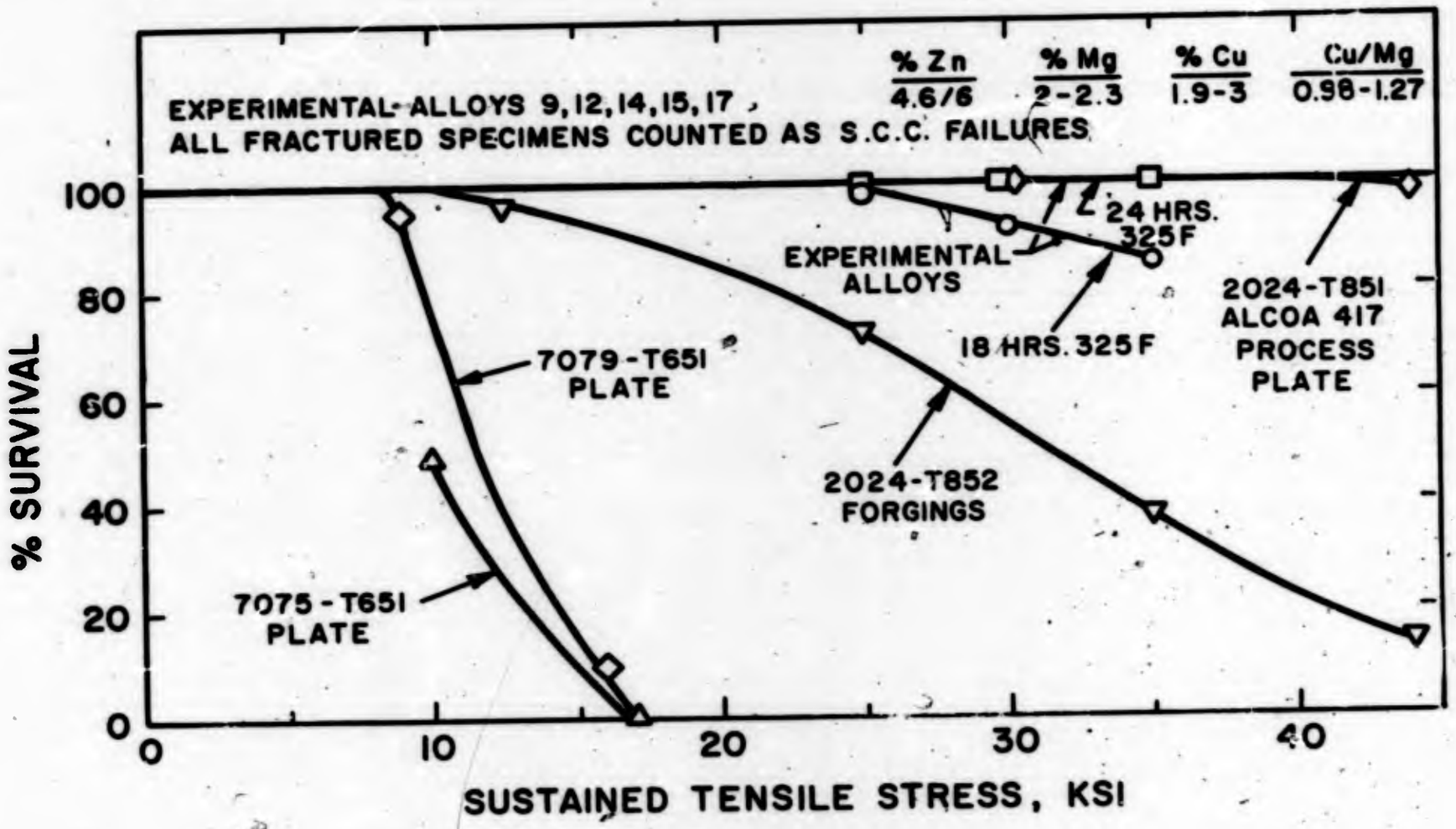



FIG. 16 SHORT-TRANSVERSE STRESS-CORROSION TESTS IN 3.5 % NaCl BY ALTERNATE IMMERSION - 30 DAYS.

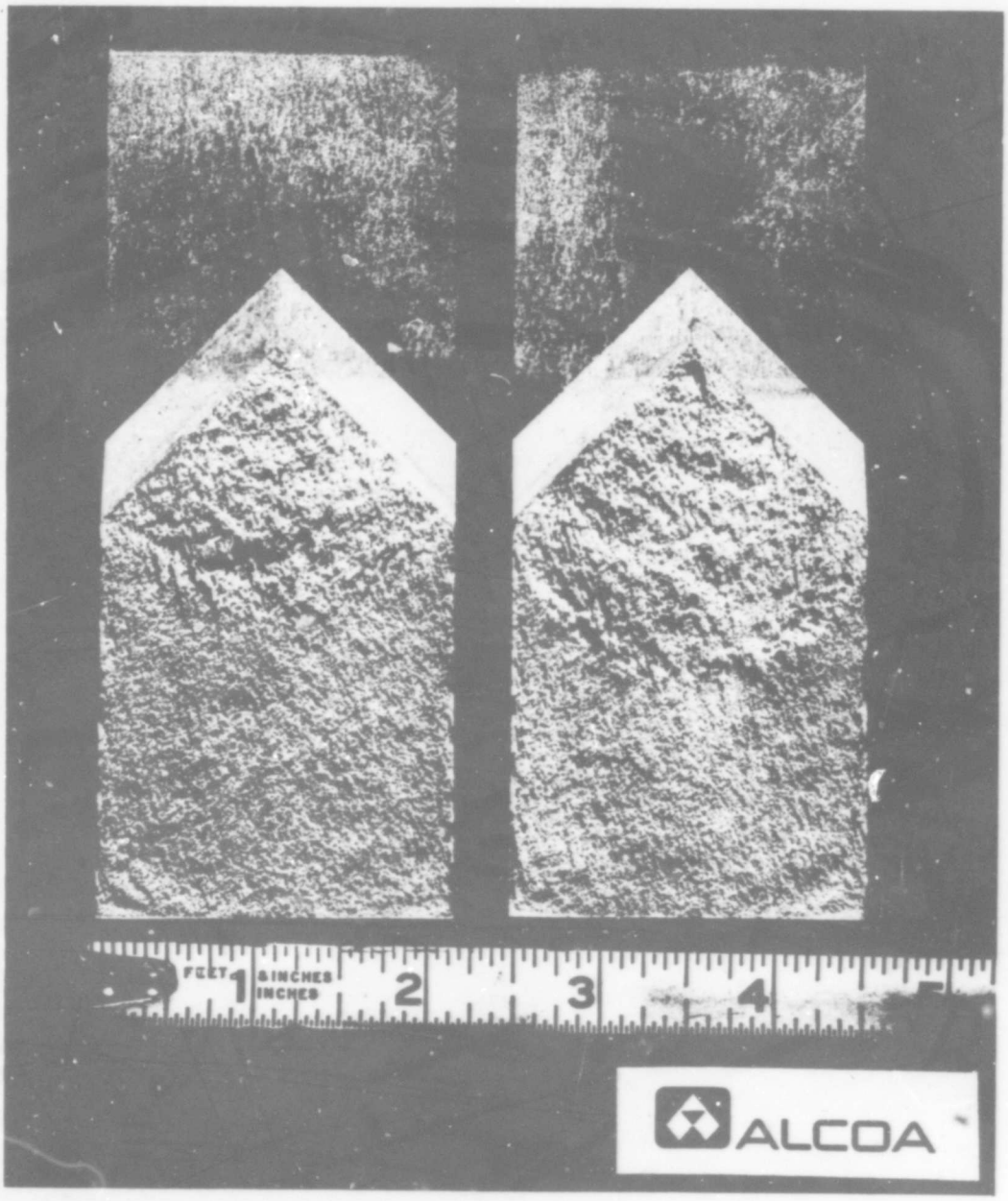



FIG. 17 ILLUSTRATES EXCESSIVE AMOUNT OF FATIGUE CRACK CURVATURE IN TWO-INCH THICK SPECIMENS OF ALLOY 9

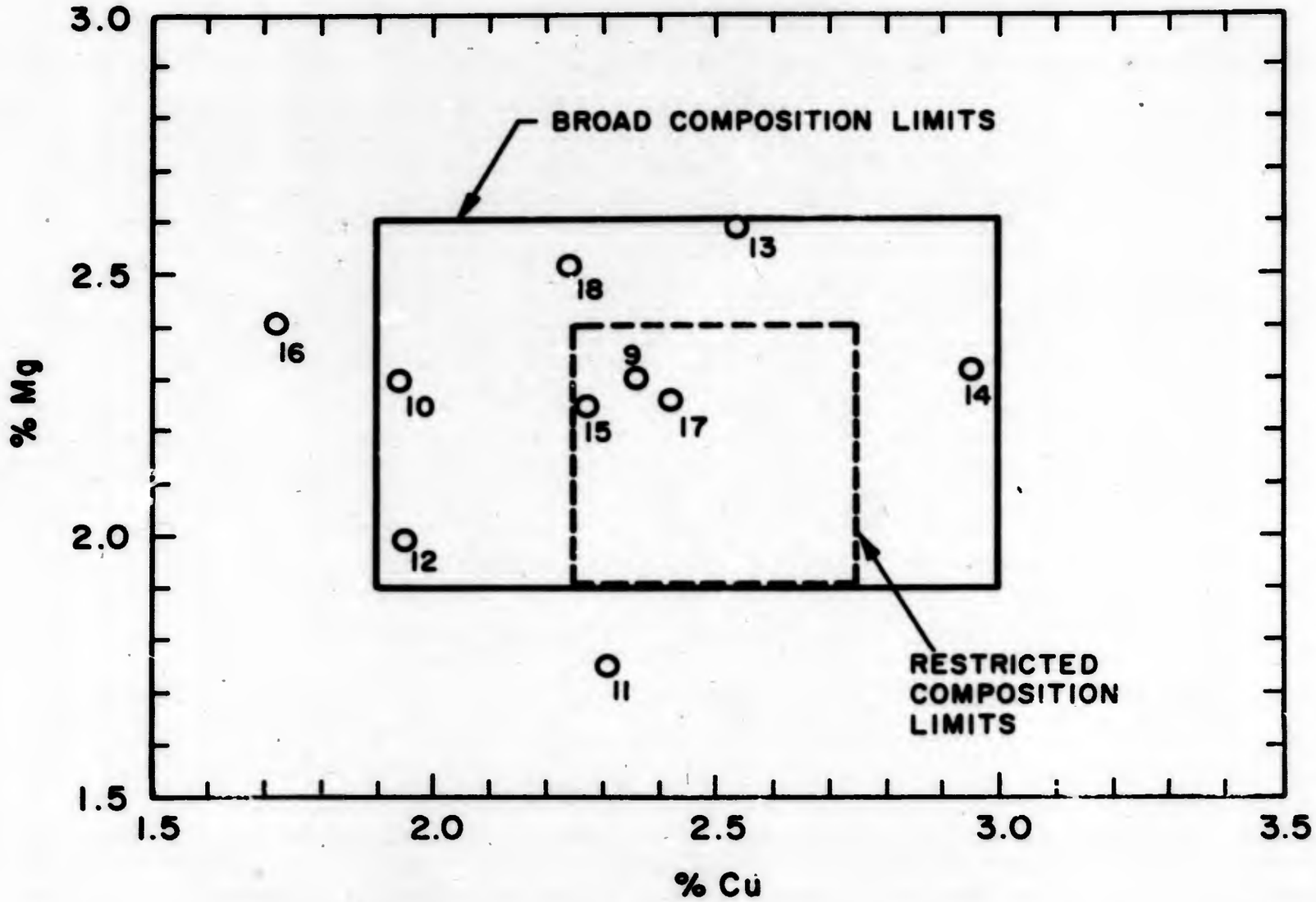



FIG. 18 COPPER VS MAGNESIUM PLOTS - EXPERIMENTAL ALLOYS

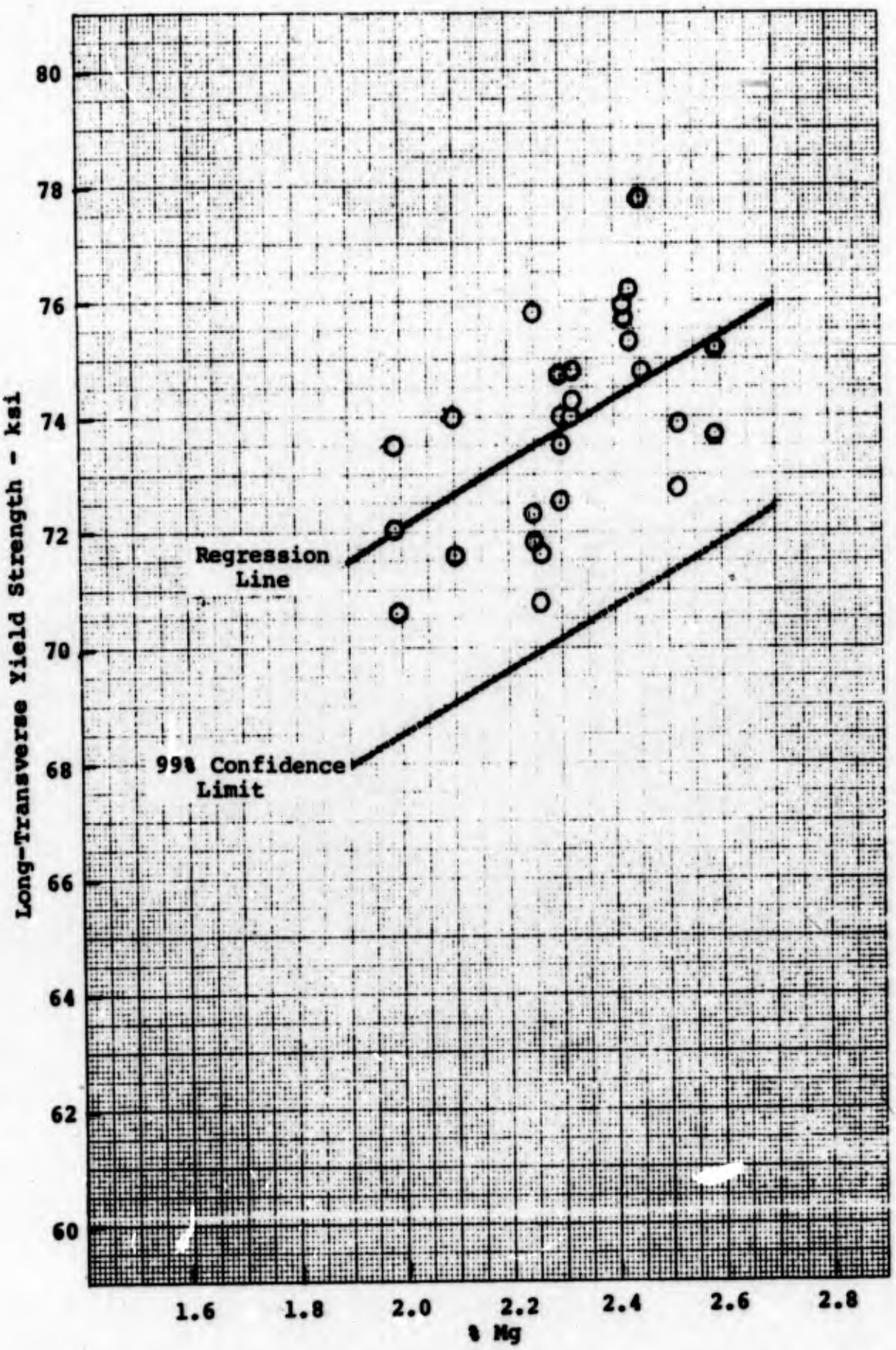



Fig. 19 % Mg vs Y.S., Cold Water Quench - 18 hrs 325 F PHT.

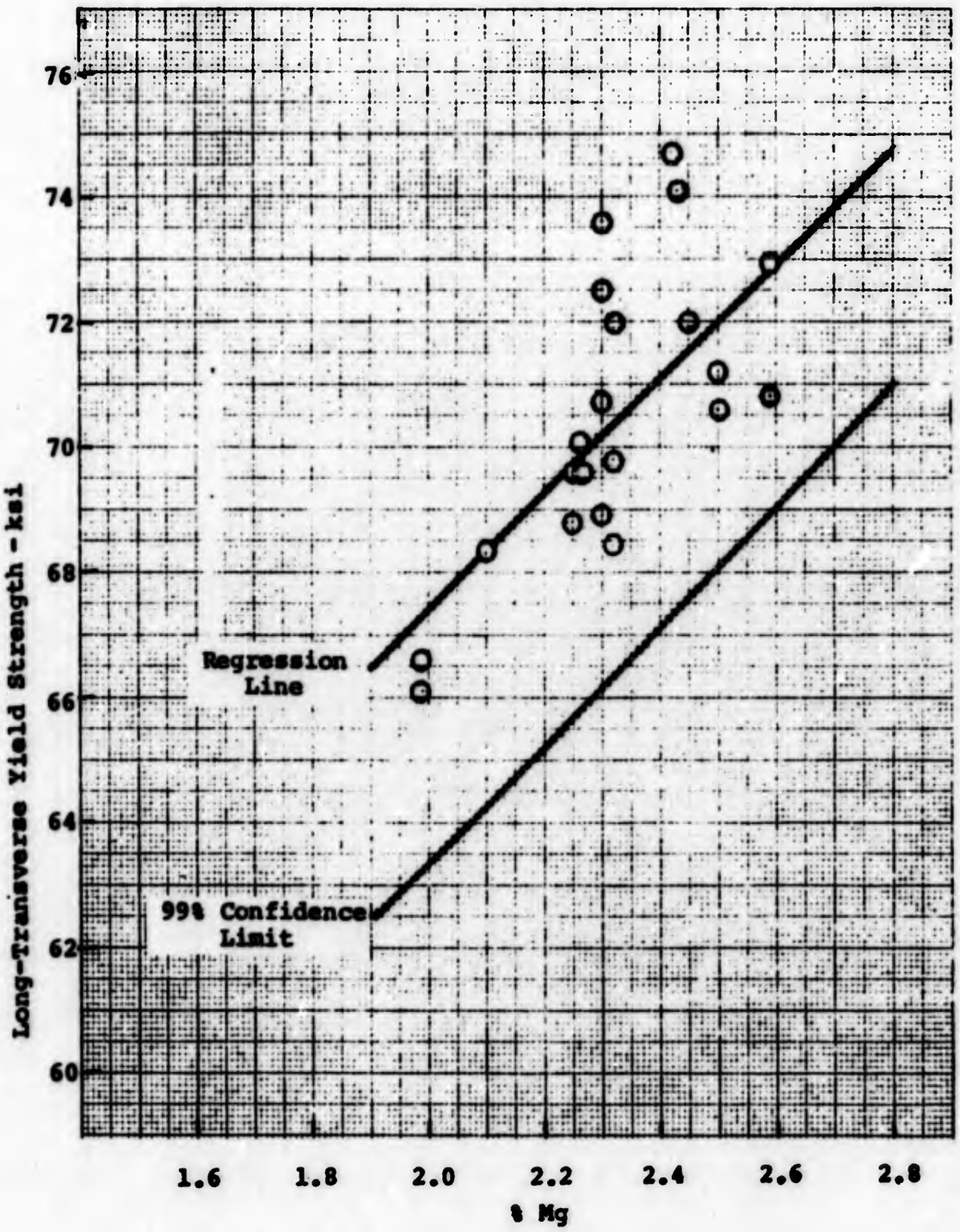



Fig. 20 % Mg vs Y.S., Cold Water Quench - 24 hrs 325 F PHT.

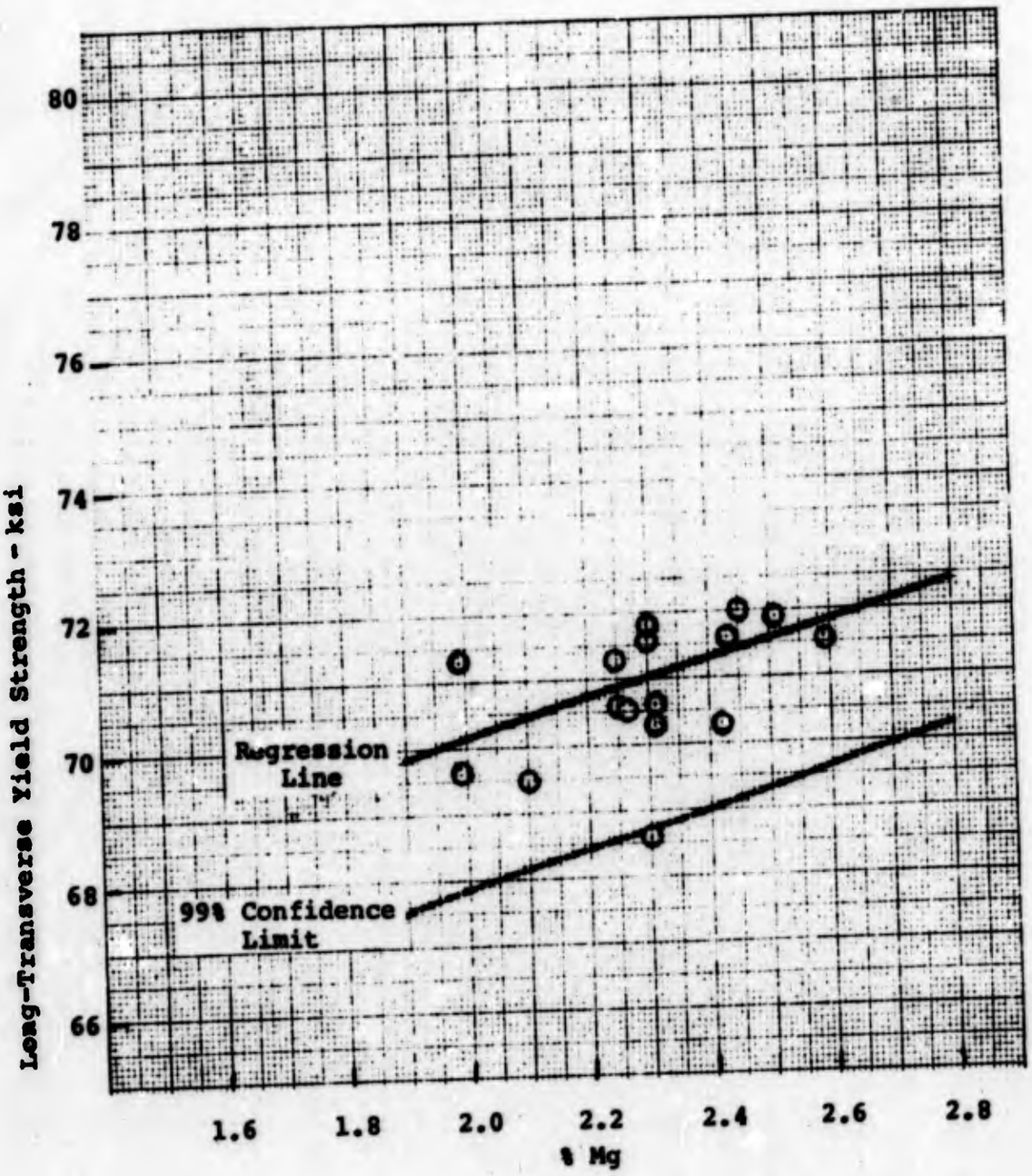



Fig. 21 % Mg vs Y.S. Hot Water Quench - 18 hrs 325 F PHT.

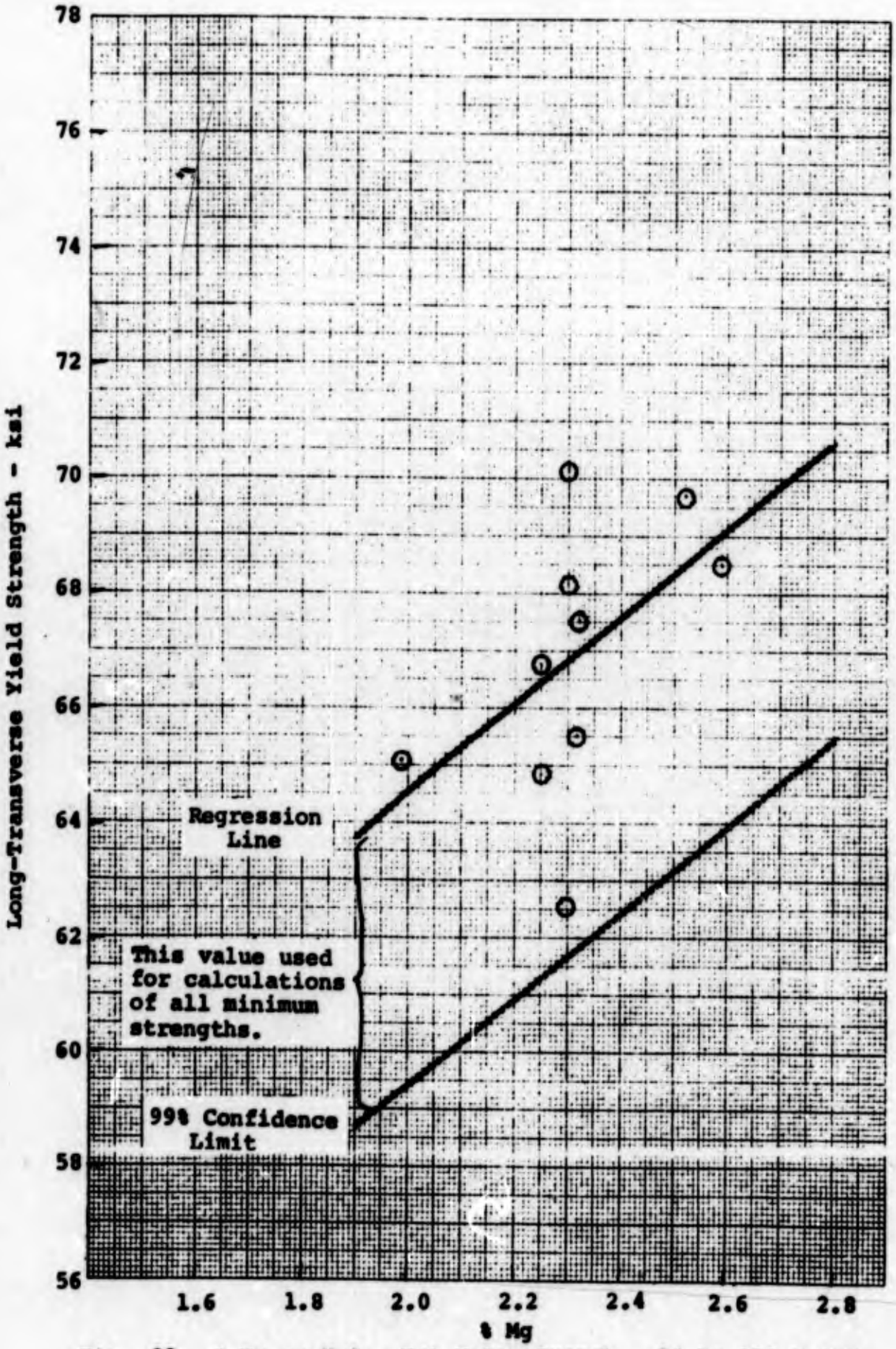



Fig. 22 % Mg vs Y.S., Hot Water Quench - 24 hr 325 F PHT.

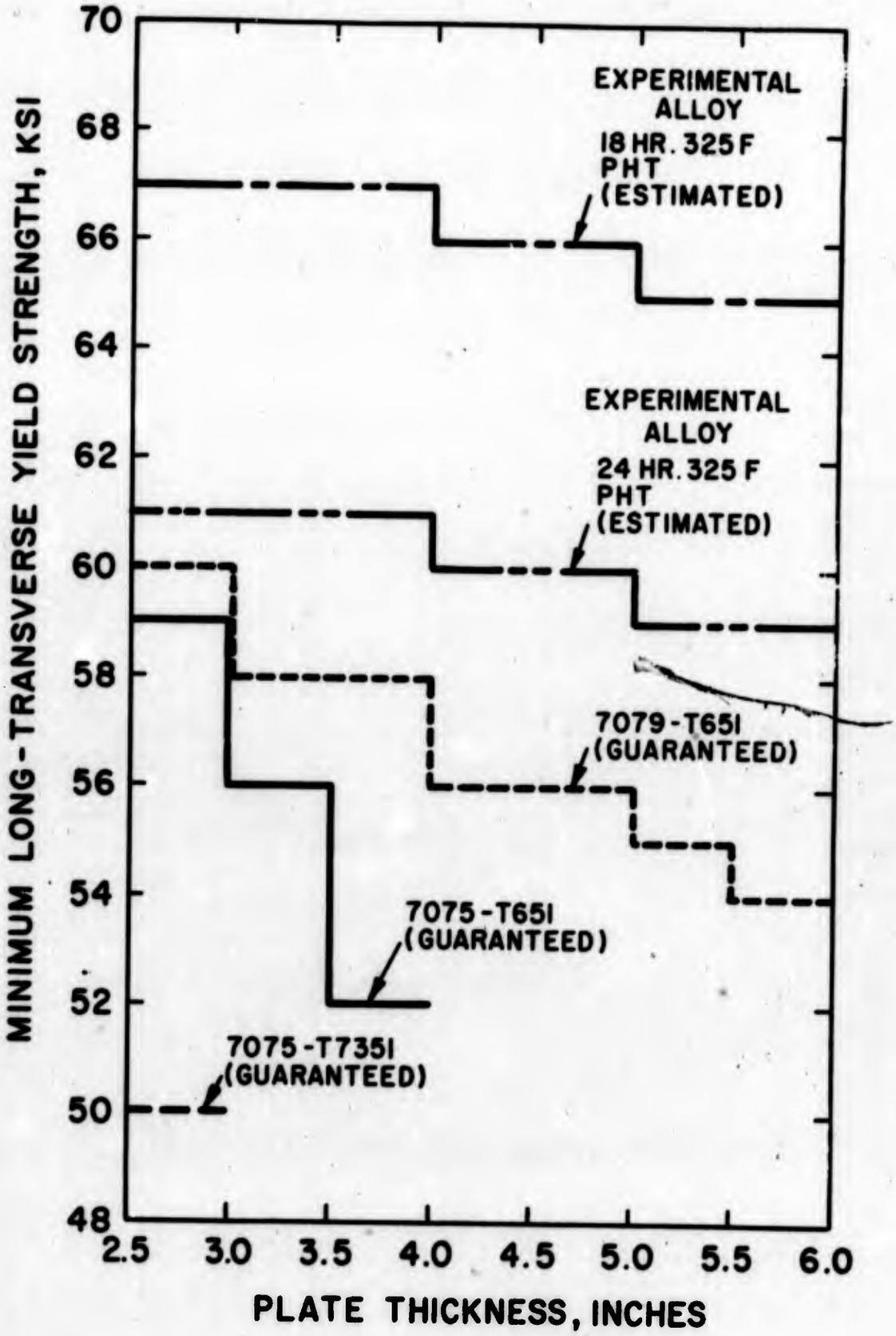



FIG.23 MINIMUM YIELD STRENGTHS OF PLATE

## APPENDIX I

## STRUCTURE OF MATERIAL

### 1. INGOT

Ingot slices from all alloys except Alloy 18 were etched and examined. Samples of ingots were also examined metallographically. The macrostructures and microstructures of the plate were examined; the degrees of recrystallization were determined by standard x-ray techniques, and phases present were determined using the x-ray camera and procedure described previously.[2]

Ingot macrostructures can be divided into three categories:

a. Equiaxed throughout. (Alloys 6, 10, 12, 15 and 7175-type Alloy 8)

b. Equiaxed surrounded by a shell of columnar grains less than 3/4" thick. (Alloys 2, 3, 11, 14, and 16)

c. Equiaxed surrounded by a 3/4" to 1-1/2" thick shell of columnar grains. (Alloys 1, 4, 5, 7, 9, 13, 17)

Photographs of typical macrostructures are presented in Figures 24, 25, and 26.

Metallographic examination revealed that average dendrite cell sizes were .002" ± .0005" and were apparently not related to composition.

Coarse, intermetallic particles identified by the electron microprobe and by x-ray diffraction analysis as $Al_{12}Mg_2V$ were found in all ingots containing V. A photomicrograph illustrating these particles is presented in Figure 27. A slight amount of porosity is also indicated.

### 2. PLATE

Representative macrostructures of rolled plate are presented in Figures 28 through 33. Evidence of the columnar grains originally present in some of the ingots was found near the rolled surfaces in some 4-inch thick plate. The structures are representative of structures of high strength aluminum alloy plate.

Microstructures of longitudinal cross sections of all of the alloys except those containing V are presented in Figures 34 through 46. The grains of all except Alloy 6 (Fe and Ni)

were characteristic of high-strength aluminum alloys in that they were elongated and fragmented. The grains of Alloy 6, however, were relatively equiaxed.

Effect of fabricating practice on grain structure is evident in Figures 38 through 46. Grains in 2-inch thick rolled plate were more elongated than those in 4-inch thick plate, while grains in preforged plate were the most highly directional.

Degrees of recrystallization of the plate are presented in Tables 59 and 60. All materials had started to recrystallize, and Alloy 6 (Fe-Ni) was almost completely recrystallized. The 2-inch thick rolled plate usually exhibited a greater degree of recrystallization than either the 2-inch thick preforged plate or the 4-inch thick rolled plate.

Phases detected are presented in Tables 61 and 62. M phase, $Mg(Zn,Cu,Al)_2$, is readily soluble at the solution temperature, so its presence is attributed to precipitation. S phase, $Al_2CuMg$, is soluble in all of the alloys except 14 (3% Cu), but complete solubility requires solution treatment for extended times only slightly below the melting range. Increasing work prior to solution treatment and solution treating at 900 F rather than 890 F appeared to decrease the amount of this phase after identical solution time. Iron and nickel combined to form $FeNiAl_9$, but some Fe also combined with Cu and Al to form $(Fe,Cu)Al_6$ in addition to $Al_7Cu_2Fe$. The latter phase was detected in all of the alloys.

Table 59

DEGREES OF RECRYSTALLIZATION IN
2-1/2 INCH THICK PLATE

| S-No. | Alloy | Sample Location: Mid-Plane | Sample Location: Quarter-Plane |
|---|---|---|---|
| 367799 | 1 | Complete | Partial |
| 367800 | 2 | Partial | Partial |
| 367801 | 3 | Partial | Partial |
| 367802 | 4 | Partial | Started |
| 367803 | 5 | Partial | Started |
| 367804 | 6 | Almost Complete | Complete |
| 367805 | 7 | Partial | Started |
| 367806 | 7175 | Partial | Started |
| 367807 | NAVAIR 4 | Partial | Started |

Solution Treated 8 hours at 890 F, Quenched in Water at Room Temperature.

TABLE 60

DEGREES OF RECRYSTALLIZATION IN TWO-INCH AND FOUR-INCH THICK PLATE

| S. No. | Alloy | Plate Thickness | Fab. Practice | Sample Location Mid-Plane | Sample Location Quarter-Plane |
|---|---|---|---|---|---|
| 379390 | 10 | 4" | Rolled | Started | Started |
| | | 2" | Rolled | Partial | Almost Complete |
| | | 2" | Preforged | Started | Started |
| 379391 | 11 | 4" | Rolled | Started | Started |
| | | 2" | Rolled | Partial | Almost Complete |
| | | 2" | Preforged | Started | Started |
| 379392 | 12 | 4" | Rolled | Started | Partial |
| | | 2" | Rolled | Partial | Almost Complete |
| | | 2" | Preforged | Started | Started |
| 379393 | 13 | 4" | Rolled | Started | Started |
| | | 2" | Rolled | Started | Partial |
| 379394 | 14 | 4" | Rolled | Started | Partial |
| | | 2" | Rolled | Partial | Almost Complete |
| | | 2" | Preforged | Partial | Partial |
| 379395 | 15 | 4" | Rolled | Started | Partial |
| | | 2" | Rolled | Partial | Almost Complete |
| | | 2" | Preforged | Partial | Partial |
| 379396 | 16 | 4" | Rolled | Started | Started |
| | | 2" | Rolled | Started | Partial |
| 379397 | 17 | 4" | Rolled | Started | Started |
| | | 2" | Rolled | Started | Partial |
| 379398 | 18 | 4" | Rolled | Started | Started |
| | | 2" | Rolled | Started | Partial |

Table 61

PHASES DETECTED IN 2-1/2 INCH THICK PLATE

Phases Detected and Relative Amounts Present

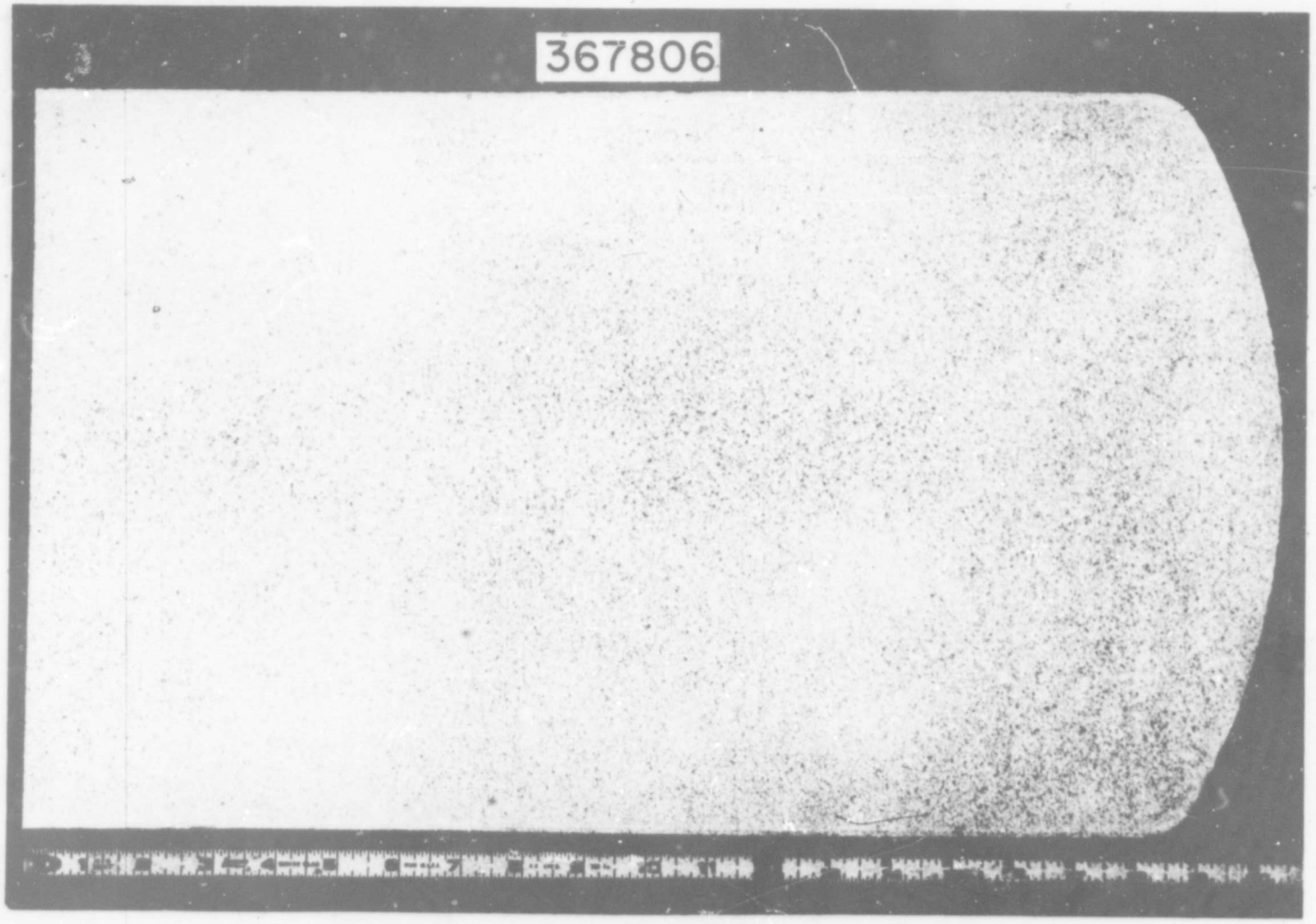
| S. No. | Alloy | $Al_7Cu_2Fe$ | $(Fe,Cu)Al_6$ | $Mg_2Si$ | S | M | E | $Al_{12}Mg_2V$ | $FeNiAl_9$ |
|---|---|---|---|---|---|---|---|---|---|
| 367799 | 1 | Medium | -- | Trace | V.Small | Small | - | Medium | -- |
| 367800 | 2 | " | -- | " | Small | " | - | Large | -- |
| 367801 | 3 | " | -- | " | Small | " | - | Large | -- |
| 367802 | 4 | " | -- | " | V.Small | " | - | Medium | -- |
| 367803 | 5 | " | -- | " | V.Small | " | - | -- | -- |
| 367804 | 6 | " | Small | " | Small | " | - | -- | Small |
| 367805 | 7 | " | -- | " | Small | " | | Large | -- |
| 367806 | 7175 | " | -- | " | -- | " | Medium | -- | -- |
| 373468 | NAVAIR 4 | " | -- | " | Small | Trace | - | -- | -- |

S = $Al_2CuMg$
M = $Mg(Zn,Cu,Al)_2$
E = $Al_{12}Mg_2Cr$

TABLE 62

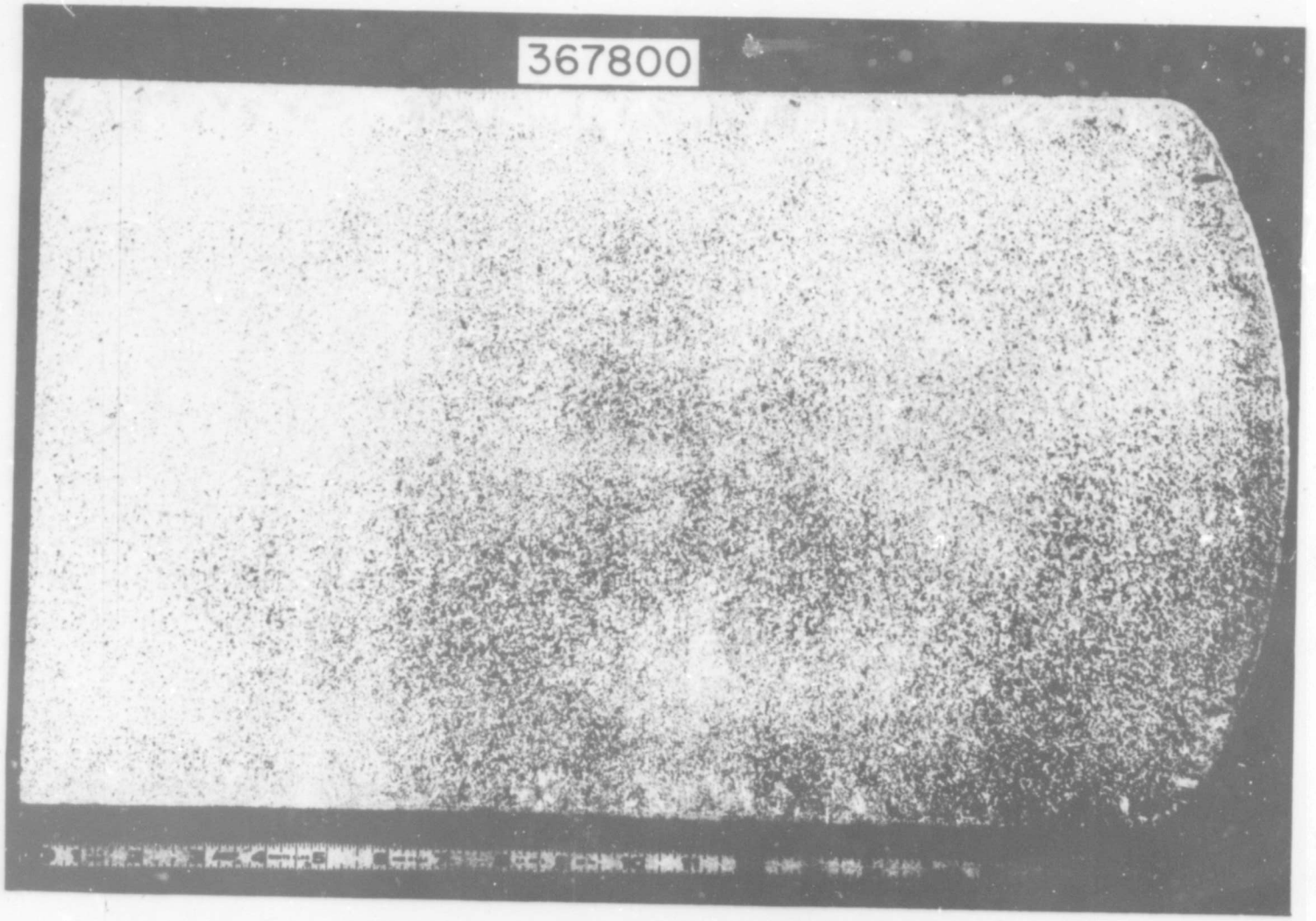
PHASES DETECTED IN TWO-INCH AND FOUR-INCH THICK PLATE

| S. No. | Alloy | Plate Thickness | Fab. Practice | $Al_7Cu_2Fe$ | $(Fe,Mn,Cu)Al_6$ | $Mg_2Si$ | S | M | $Al_{12}Fe_3Si$ |
|---|---|---|---|---|---|---|---|---|---|
| 379390 | 10 | 4" | Rolled | Medium | -- | Small | V.small | Small | -- |
| | | 2" | Rolled | Medium | -- | Small | -- | Small | -- |
| | | 2" | Preforged | Medium | -- | V.small | -- | Small | -- |
| 379391 | 11 | 4" | Rolled | Medium | -- | Trace | Trace | V.small | -- |
| | | 2" | Rolled | Medium | -- | Trace | -- | V.small | -- |
| | | 2" | Preforged | Medium | -- | V.small | -- | V.small | -- |
| 379392 | 12 | 4" | Rolled | Medium | -- | Trace | Trace | Small | -- |
| | | 2" | Rolled | Medium | -- | Trace | -- | Small | -- |
| | | 2" | Preforged | Medium | -- | Trace | -- | Small | -- |
| 379393 | 13 | 4" | Rolled | Medium | -- | Trace | Large | Small | -- |
| | | 2" | Rolled | Medium | -- | Trace | Large | Small | -- |
| 379394 | 14 | 4" | Rolled | Medium | -- | Trace | Large | Small | -- |
| | | 2" | Rolled | Medium | -- | Trace | Large | Small | -- |
| | | 2" | Preforged | Medium | -- | V.small | Large | Small | -- |
| 379395 | 15 | 4" | Rolled | Large | -- | Small | -- | Medium | Trace |
| | | 2" | Rolled | Large | -- | Small | V.small | Medium | Trace |
| | | 2" | Preforged | Large | -- | Small | -- | Medium | -- |
| 379396 | 16 | 4" | Rolled | Medium | -- | Trace | -- | Small | -- |
| | | 2" | Rolled | Medium | -- | Trace | -- | Small | -- |
| 379397 | 17 | 4" | Rolled | Medium | -- | Trace | V.small | Small | -- |
| | | 2" | Rolled | Medium | -- | Trace | Small | Small | -- |
| 379398 | 18 | 4" | Rolled | Small | Trace | Trace | Medium | V.small | -- |
| | | 2" | Rolled | Small | Trace | Trace | Medium | Trace | -- |



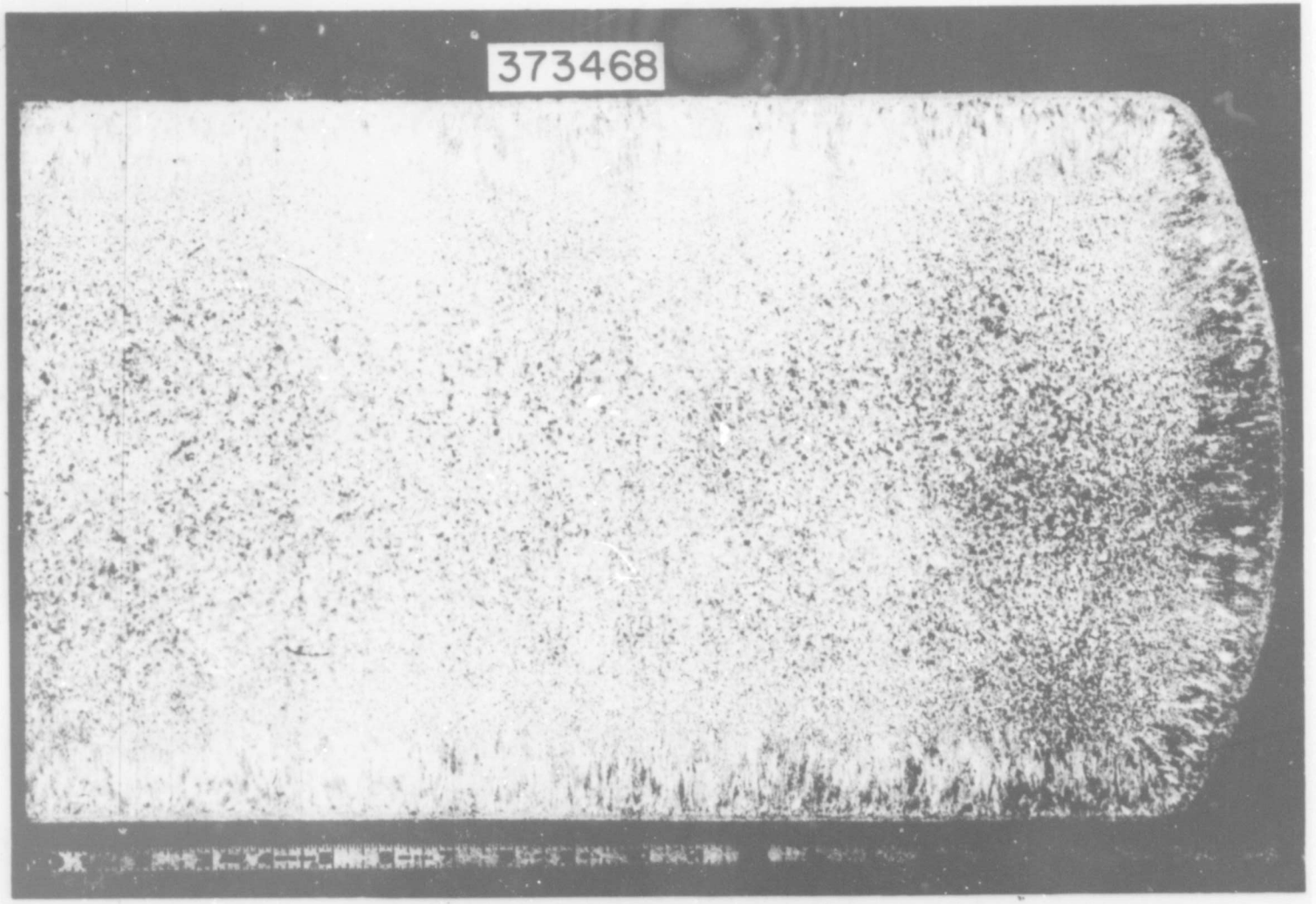

ALLOY 8

FIG. 24 TYPICAL MACROSTRUCTURE OF ALLOYS 6, 8, 10, 12, AND 15.



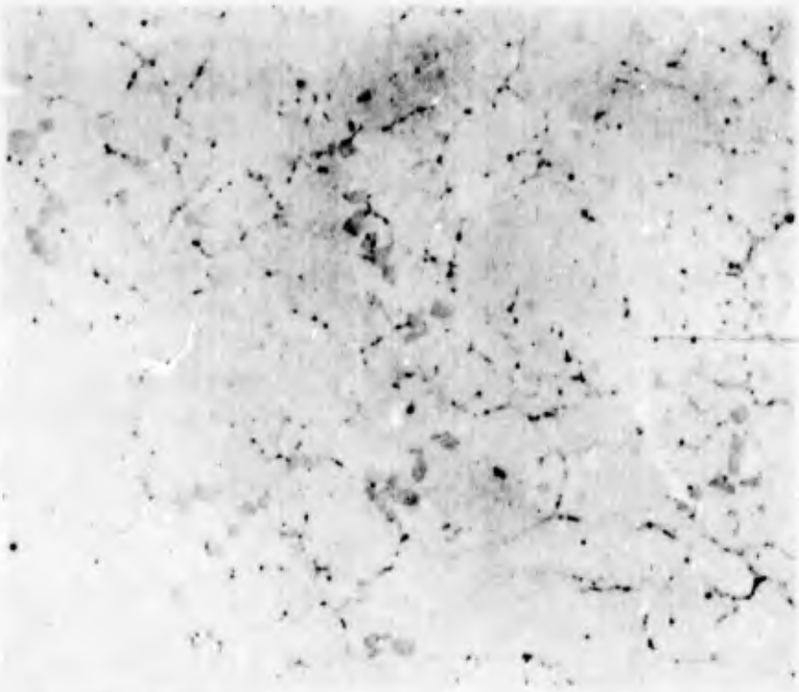

ALLOY 2

FIG. 25 TYPICAL MACROSTRUCTURE OF ALLOYS 2, 3, 11, 14, AND 16.




ALLOY 9

FIG. 26 TYPICAL MACROSTRUCTURE OF ALLOYS 1,4,5,7,9, AND 17.



S. NO. 367799 100X AS POLISHED
NEG. NO. 176264 INGOT

S. NO. 367799 100X LIGHT KELLERS ETCH
NEG. NO. 176265 PLATE

FIG. 27 $Al_{12}Mo_2V$ PARTICLES IN INGOT AND PLATE-
ALLOY I.

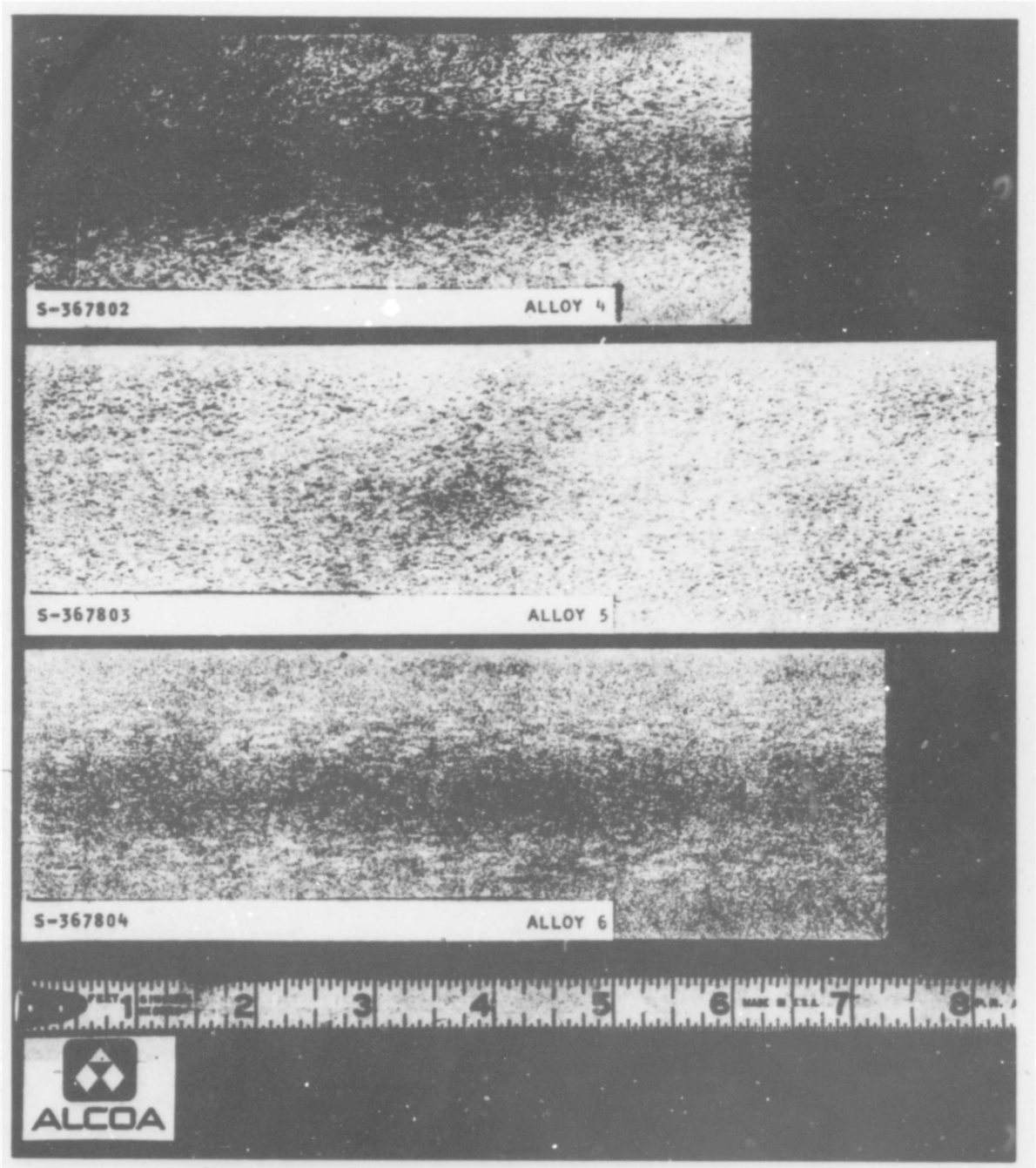



FIG. 28 MACROSTRUCTURE OF ALLOYS 4, 5, AND 6 PLATE.

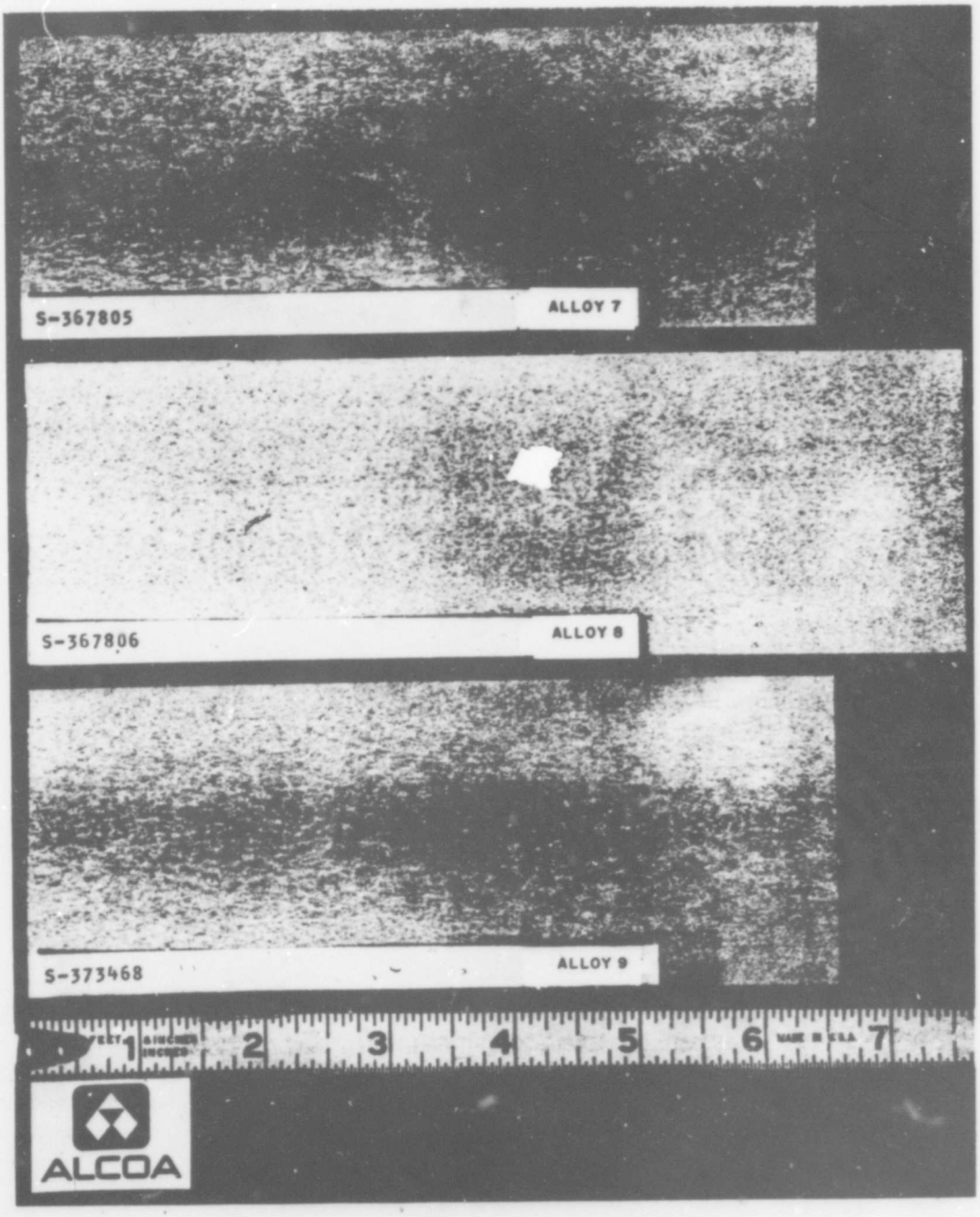



FIG. 29 MACROSTRUCTURE OF ALLOYS 7, 8, AND 9 PLATE.

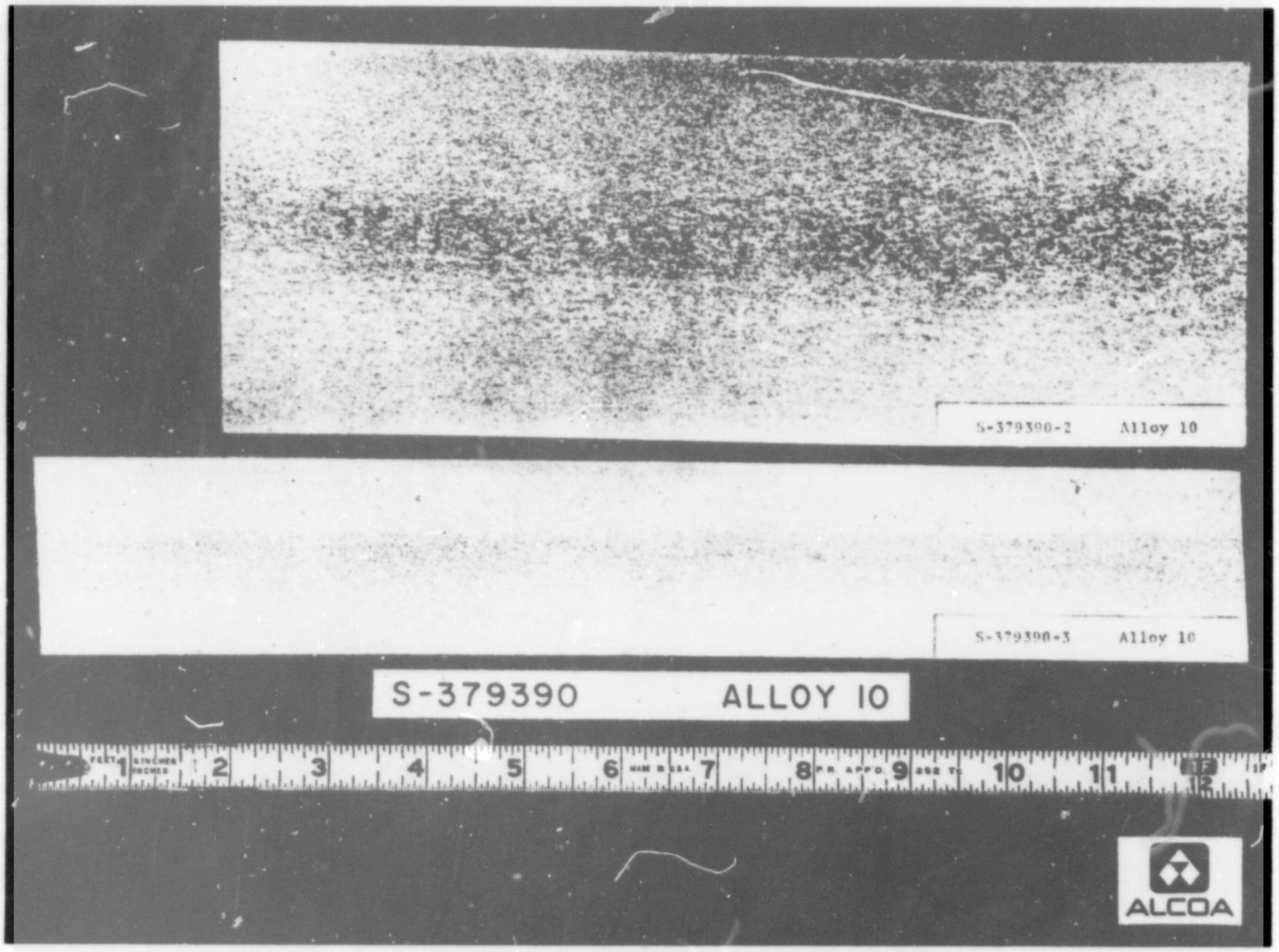



FIG. 30 MACROSTRUCTURE OF ALLOY 10 ROLLED PLATE

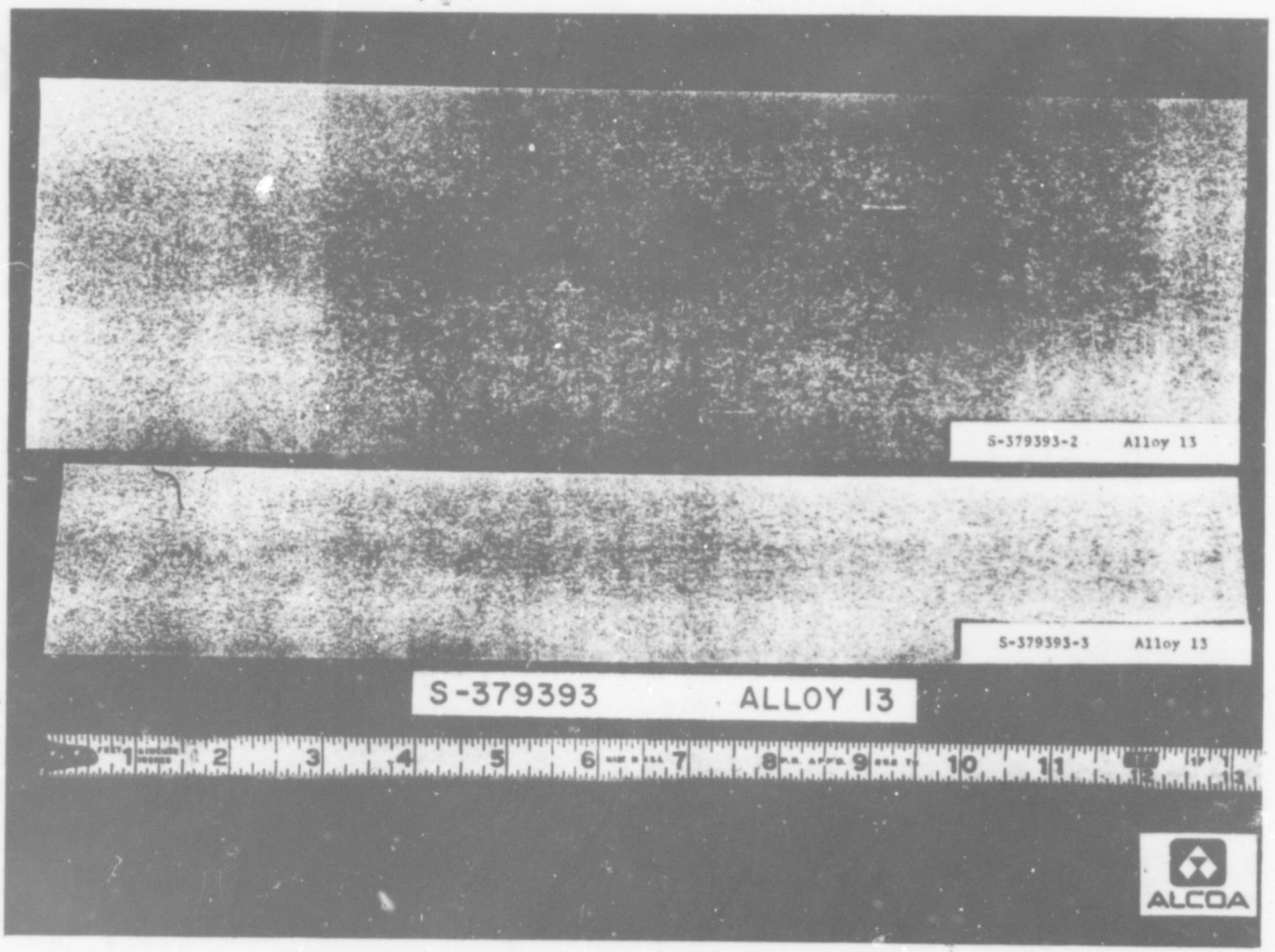



FIG. 31 MACROSTRUCTURE OF ALLOY 13 ROLLED PLATE

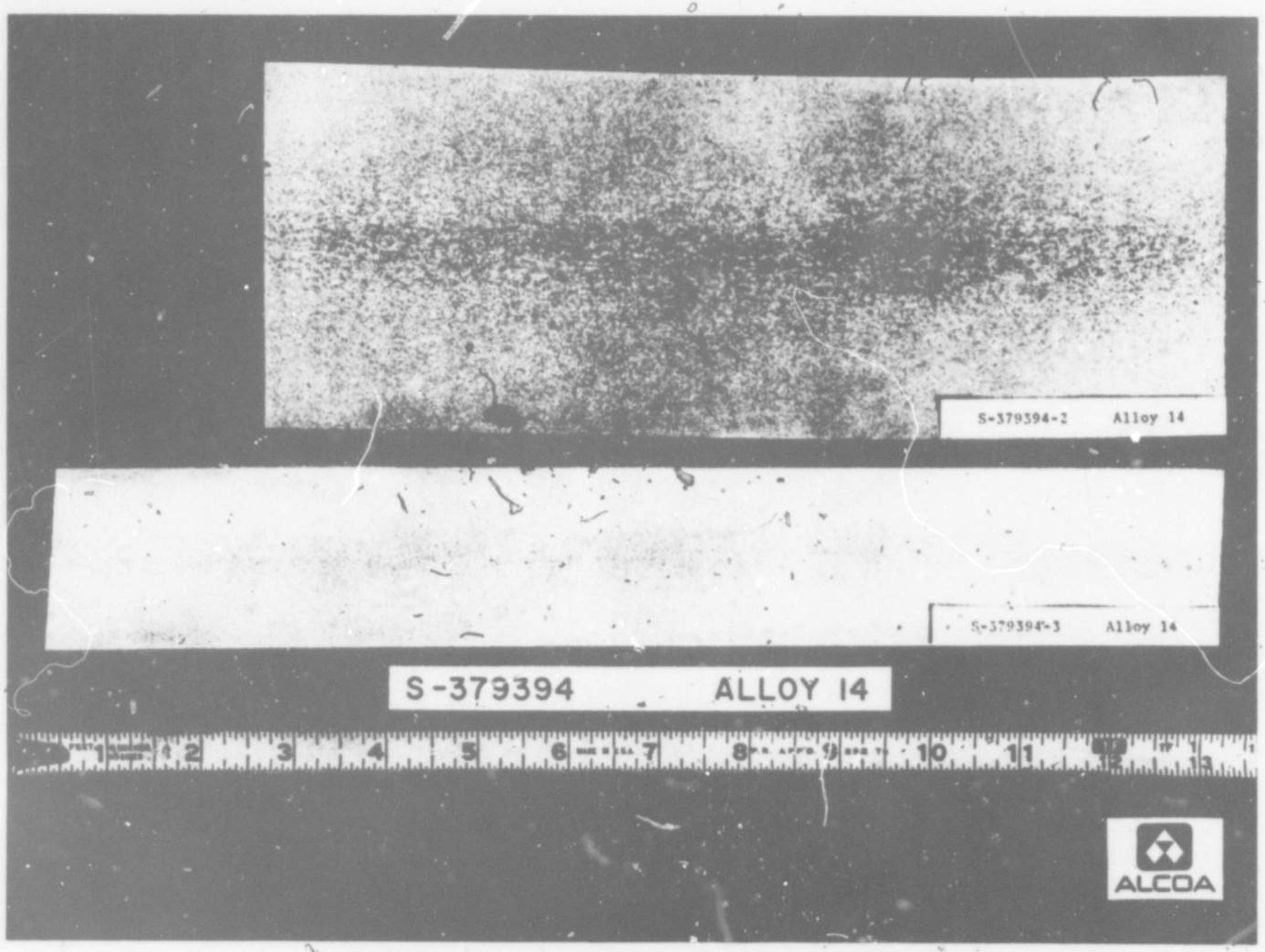



FIG. 32 MACROSTRUCTURE OF ALLOY 14 ROLLED PLATE

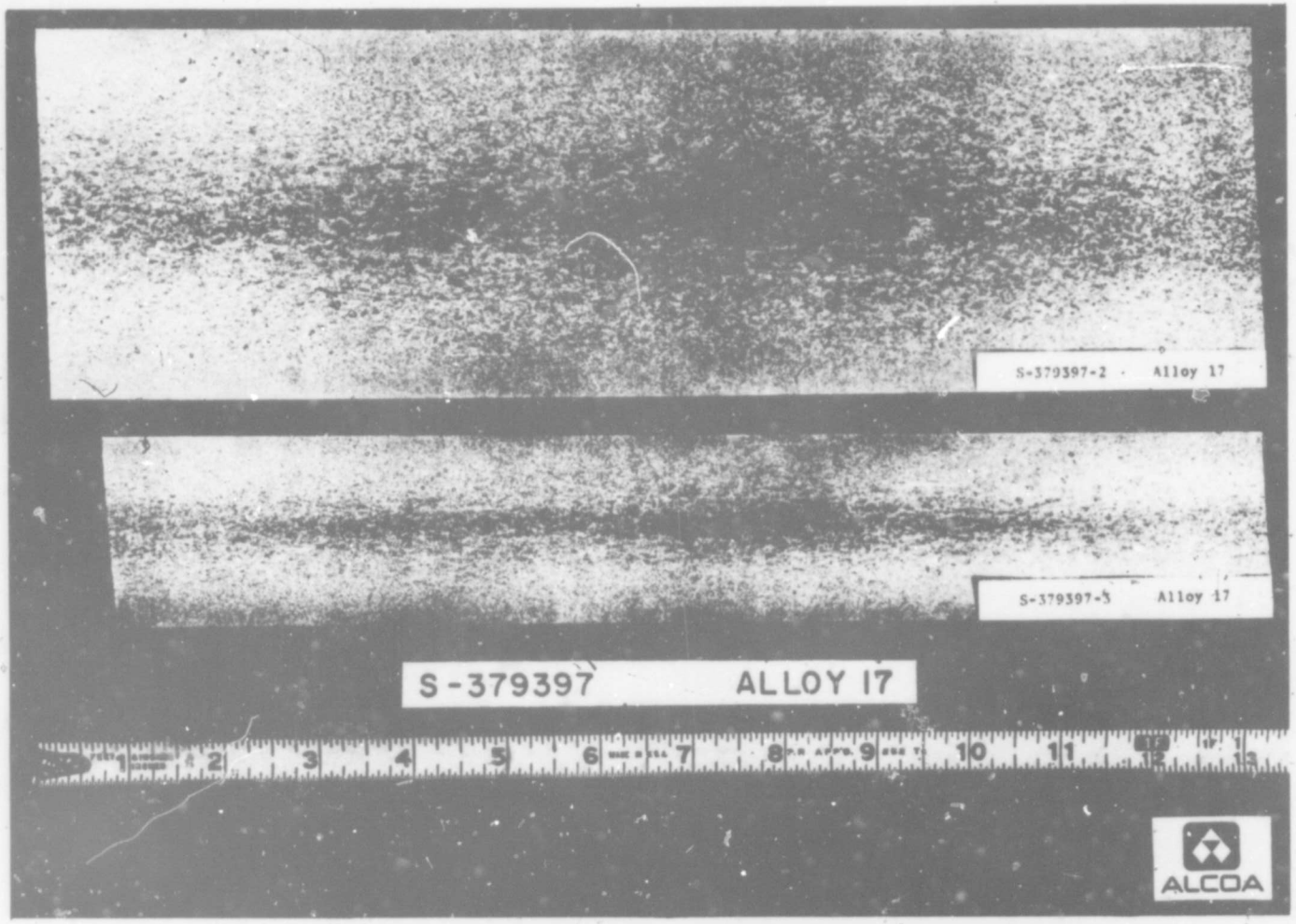
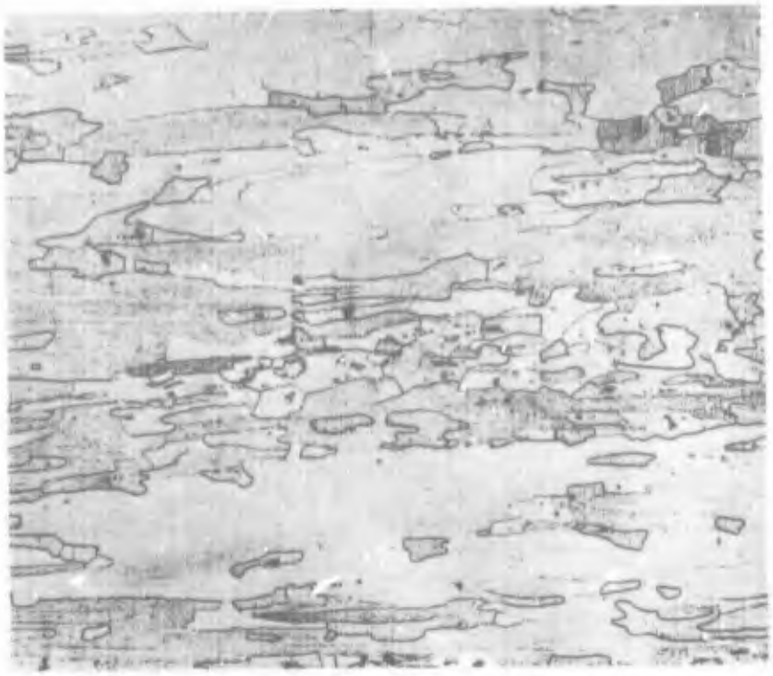



FIG. 33 MACROSTRUCTURE OF ALLOY 17 ROLLED PLATE



S.NO.367803 NEG.NO.176267 KELLER'S

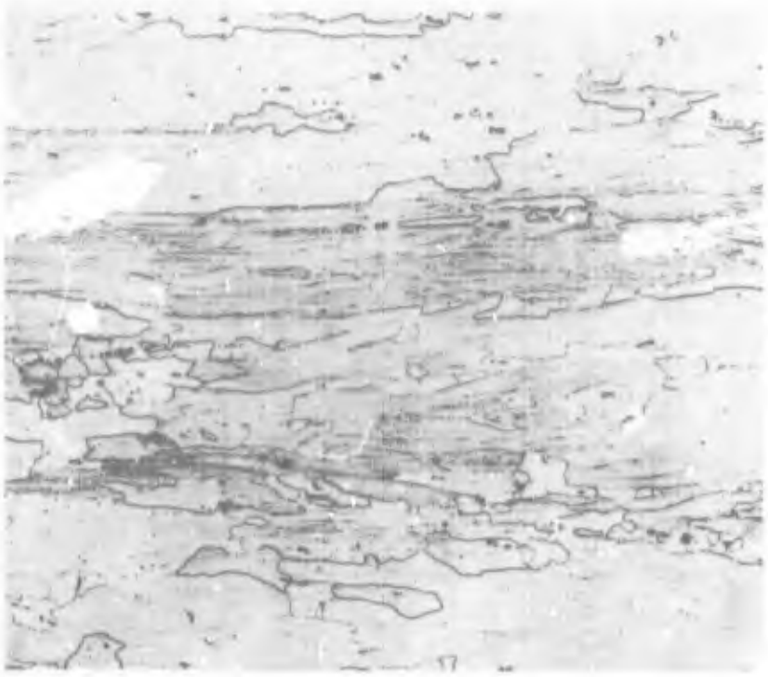
100X

FIG.34 GRAIN STRUCTURE OF ALLOY 5 PLATE

S.NO.367804 NEG.NO.176269 KELLER'S

100X

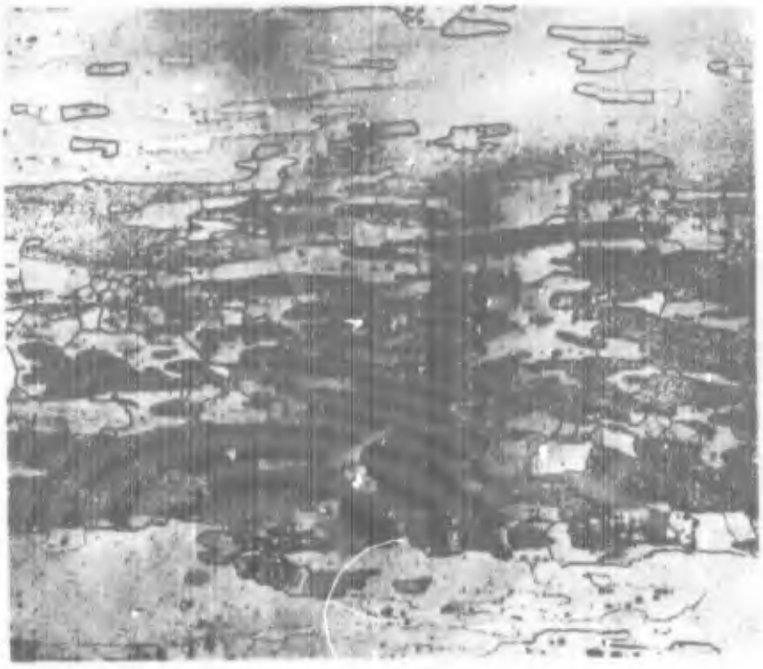
FIG. 35 GRAIN STRUCTURE OF ALLOY 6 PLATE



S.NO.367806 NEG.NO.176271 KELLER'S

100X

FIG.36 GRAIN STRUCTURE OF
7175 TYPE ALLOY 8 PLATE



S.NO.373468 NEG.NO.176273 KELLER'S

100X

FIG.37 GRAIN STRUCTURE OF ALLOY 9 PLATE

S-NO. 379390-1 NEG. NO. 177888 KELLER'S
FOUR-INCH THICK PLATE

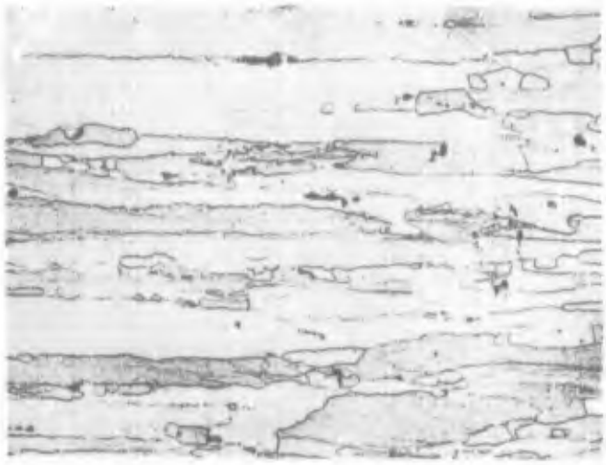
S-NO. 379390-3 NEG. NO. 177906A KELLER'S
TWO-INCH THICK ROLLED PLATE

S-NO. 379390-7 NEG. NO. 179858 KELLER'S
TWO-INCH THICK PREFORGED PLATE

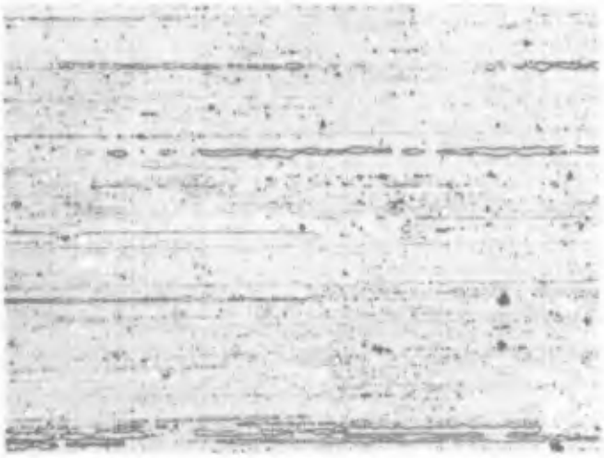
100X

FIG.38 GRAIN STRUCTURE OF ALLOY IC PLATE

S-NO. 379391-1 NEG. NO. 177890A KELLER'S
FOUR-INCH THICK PLATE



S-NO.379391-3 NEG. NO. 177908A KELLER'S
TWO-INCH THICK ROLLED PLATE

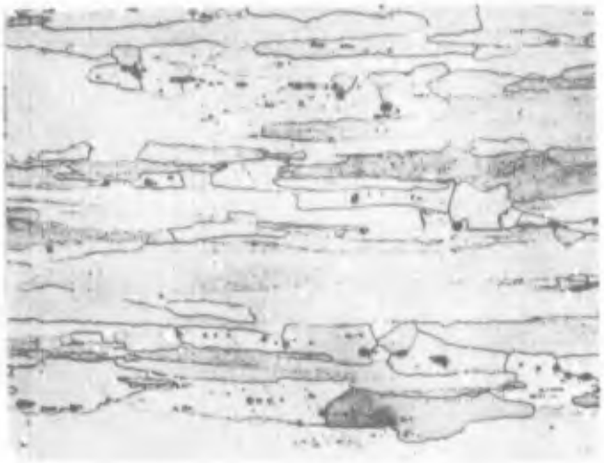


S-NO. 379391-7 NEG. NO. 179859 KELLER'S
TWO-INCH THICK PREFORGED PLATE

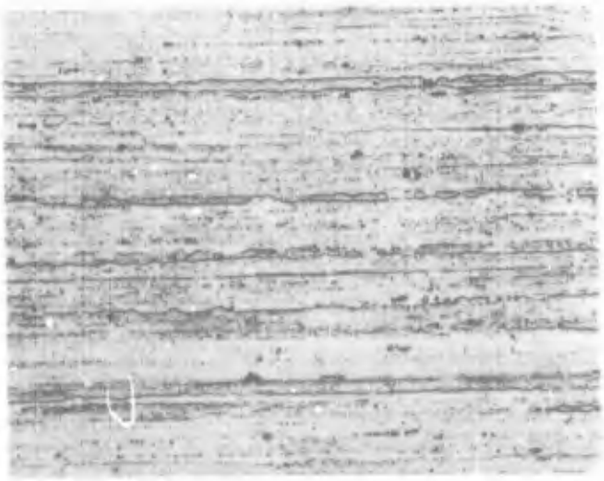
100X

FIG.39 GRAIN STRUCTURE OF ALLOY II PLATE

S-NO. 379392-1 NEG. NO. 177892A KELLER'S
FOUR-INCH THICK PLATE



S-NO. 379392-3 NEG. NO. 177910A KELLER'S
TWO-INCH THICK ROLLED PLATE



S-NO. 379392-7 NEG. NO. 179860 KELLER'S
TWO-INCH THICK PREFORGED PLATE

100X

FIG.40 GRAIN STRUCTURE OF ALLOY 12 PLATE

S-NO. 379393-1 NEG. NO. 177894A KELLER'S
FOUR-INCH THICK PLATE

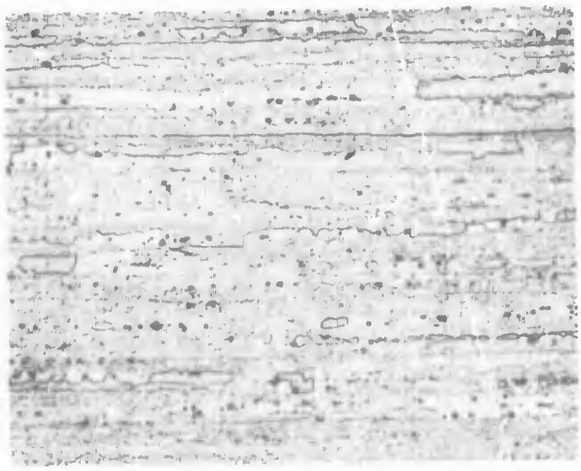
S-NO. 379393-3 NEG. NO. 177912A KELLER'S
TWO-INCH THICK ROLLED PLATE

100X

FIG.41 GRAIN STRUCTURE OF ALLOY 13 PLATE

S-NO. 379394-1 NEG. NO. 177896A KELLER'S
FOUR-INCH THICK PLATE

S-NO. 379394-3 NEG. NO. 177914-A KELLER'S
TWO-INCH THICK ROLLED PLATE

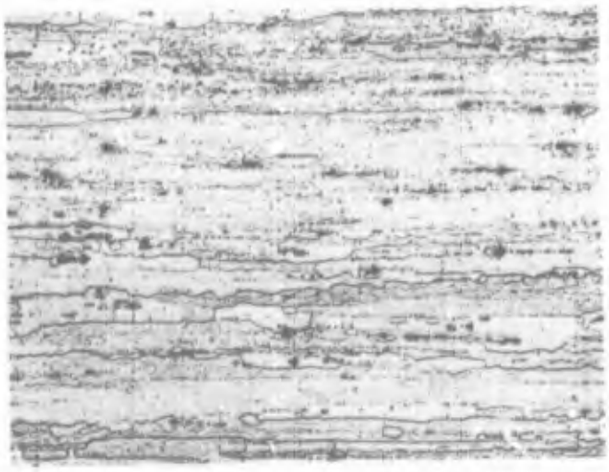


S-NO. 379394-7 NEG. NO. 179861 KELLER'S
TWO-INCH THICK PREFORGED PLATE
100X

FIG.42 GRAIN STRUCTURE OF ALLOY 14 PLATE

S-NO.379395-1 NEG. NO. 177898A KELLER'S
FOUR-INCH THICK PLATE

S-NO. 379395-3 NEG. NO.177916A KELLER'S
TWO-INCH THICK ROLLED PLATE

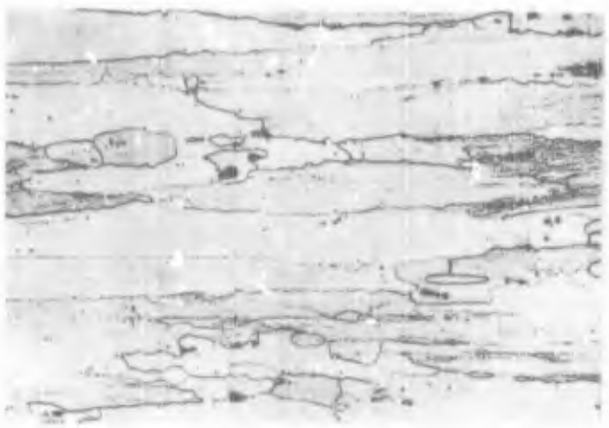


S-NO. 379395-7 NEG. NO. 179862 KELLER'S
TWO-INCH THICK PREFORGED PLATE

100X

FIG.43 GRAIN STRUCTURE OF ALLOY 15 PLATE

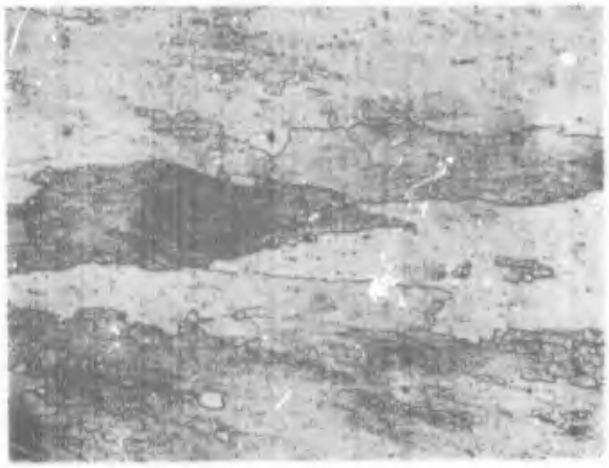
S-NO. 379396-1 NEG. NO. 177900A KELLER'S
FOUR-INCH THICK PLATE



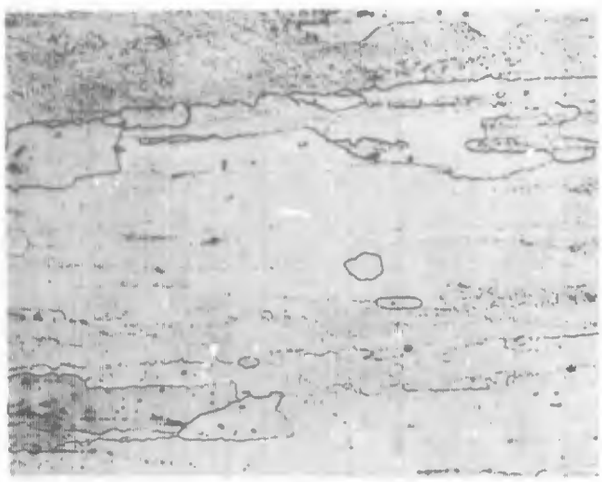
S-NO. 379396-3 NEG. NO. 177918A KELLER'S
TWO-INCH THICK ROLLED PLATE

100'

FIG. 44 GRAIN STRUCTURE OF ALLOY 16 PLATE



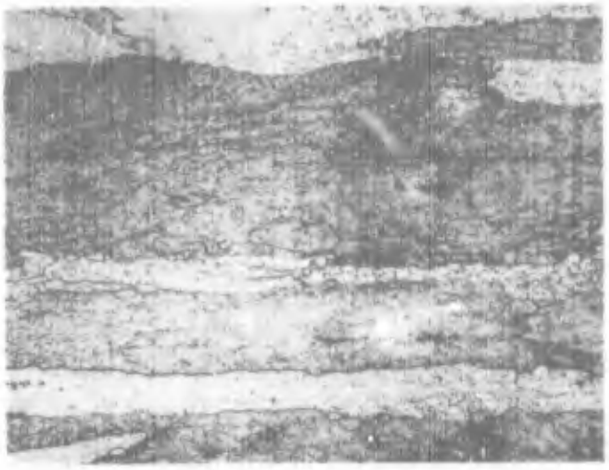
S-NO. 379397-1 NEG. NO. 177902A KELLER'S
FOUR-INCH THICK PLATE



S-NO. 379397-3 NEG. NO. 177920A KELLER'S
TWO-INCH THICK ROLLED PLATE

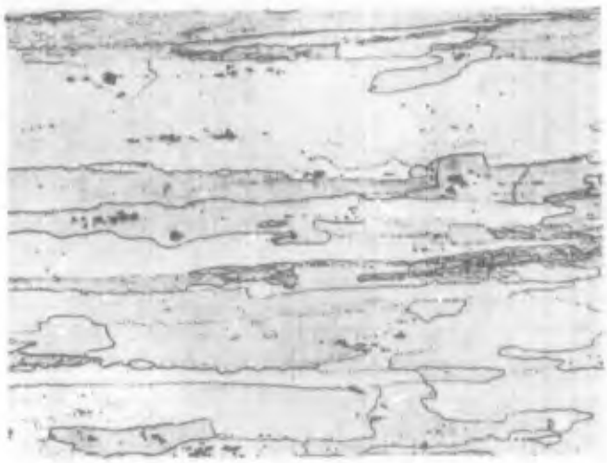
100X

FIG.45 GRAIN STRUCTURE OF ALLOY 17 PLATE



S-NO. 379398-1 NEG. NO. 177904A KELLER'S

FOUR-INCH THICK PLATE



S-NO. 379398-3 NEG. NO. 177922A KELLER'S

TWO-INCH THICK ROLLED PLATE

100X

FIG.46 GRAIN STRUCTURE OF ALLOY 18 PLATE

APPENDIX II

TENSILE PROPERTIES OF ALLOYS CONTAINING VANADIUM

TABLE 63

LONG-TRANSVERSE DIRECTION TENSILE PROPERTIES OF 2-1/2-INCH THICK PLATES IN ALLOY 1

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T. S. ksi | Y. S. ksi | El. % |
|---|---|---|---|---|---|---|
| 367799 | A | 80 F | None | 76.6 | 67.3 | 5.5 |
| | 1B | 80 F | To 350 F | 76.4 | 68.9 | 4.8 |
| | 1C | 80 F | 2 hrs. @ 350 F | 77.5 | 74.2 | 3.5 |
| | 1D | 80 F | 4 hrs. @ 350 F | 75.6 | 71.2 | 4.0 |
| | 1E | 80 F | 6 hrs. @ 350 F | 73.7 | 67.0 | 6.5 |
| | 1F | 80 F | 8 hrs. @ 350 F | 71.6 | 63.9 | 6.5 |
| | 1G | 80 F | 10 hrs. @ 350 F | 69.8 | 59.9 | 8.0 |
| | 1H | 80 F | 12 hrs. @ 350 F | 68.1 | 57.8 | 8.0 |
| | 2B | 80 F | To 325 F | 75.4 | 69.5 | 3.5 |
| | 2C | 80 F | 6 hrs. @ 325 F | 78.7 | 75.1 | 3.0 |
| | 2D | 80 F | 12 hrs. @ 325 F | 78.1 | 75.2 | 2.2 |
| | 2E | 80 F | 18 hrs. @ 325 F | 77.0 | 73.2 | 2.5 |
| | 2F | 80 F | 24 hrs. @ 325 F | 73.8 | 70.7 | 3.0 |
| | 2G | 80 F | 30 hrs. @ 325 F | 72.3 | 68.0 | 3.8 |
| | 2H | 80 F | 36 hrs. @ 325 F | 71.5 | 66.0 | 5.0 |
| | 6E | 180 F | 18 hrs. @ 325 F | 66.7 | 58.1 | 5.2 |
| | 6F | 180 F | 24 hrs. @ 325 F | 66.3 | 56.1 | 6.0 |
| | 6G | 180 F | 30 hrs. @ 325 F | 65.6 | 55.4 | 6.2 |
| | 6H | 180 F | 36 hrs. @ 325 F | 63.0 | 52.9 | 6.8 |

Solution treated 8 hours at 890 F, quenched as indicated.
Precipitation heat treated 24 hours at 250 F after four days at room temperature.

Properties are average of duplicate 1/4 inch diameter, one inch gage length specimens

Yield strength is 0.2 per cent offset.

6.1% Zn, 2.3% Mg, 2.4% Cu, 0.13% V

TABLE 64

LONG-TRANSVERSE DIRECTION TENSILE PROPERTIES OF 2-1/2-INCH THICK PLATES IN ALLOY 2

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T. S. ksi | Y. S. ksi | El. % |
|---|---|---|---|---|---|---|
| 367800 | A | 80 F | None | 77.8 | 66.6 | 8.8 |
| | 1B | 80 F | To 350 F | 78.1 | 69.0 | 7.8 |
| | 1C | 80 F | 2 hrs. @ 350 F | 78.5 | 72.2 | 7.2 |
| | 1D | 80 F | 4 hrs. @ 350 F | 76.6 | 69.8 | 7.2 |
| | 1E | 80 F | 6 hrs. @ 350 F | 73.9 | 65.6 | 8.5 |
| | 1F | 80 F | 8 hrs. @ 350 F | 71.3 | 62.0 | 9.0 |
| | 1G | 80 F | 10 hrs. @ 350 F | 69.5 | 58.9 | 9.0 |
| | 1H | 80 F | 12 hrs. @ 350 F | 67.9 | 56.9 | 9.5 |
| | 2B | 80 F | To 325 F | 78.2 | 69.1 | 7.8 |
| | 2C | 80 F | 6 hrs. @ 325 F | 78.8 | 72.4 | 7.5 |
| | 2D | 80 F | 12 hrs. @ 325 F | 78.0 | 71.9 | 6.2 |
| | 2E | 80 F | 18 hrs. @ 325 F | 76.7 | 70.6 | 5.0 |
| | 2F | 80 F | 24 hrs. @ 325 F | 75.5 | 68.2 | 9.0 |
| | 2G | 80 F | 30 hrs. @ 325 F | 73.9 | 66.2 | 7.0 |
| | 2H | 80 F | 36 hrs. @ 325 F | 72.9 | 64.4 | 9.5 |
| | 6E | 180 F | 18 hrs. @ 325 F | 65.4 | 56.1 | 5.8 |
| | 6F | 180 F | 24 hrs. @ 325 F | 64.3 | 54.2 | 6.5 |
| | 6G | 180 F | 30 hrs. @ 325 F | 63.9 | 53.4 | 8.0 |
| | 6H | 180 F | 36 hrs. @ 325 F | 63.4 | 52.9 | 7.5 |

Solution treated 8 hours at 890 F, quenched as indicated.
Precipitation heat treated 24 hours at 250 F after four days at room temperature.

Properties are average of duplicate 1/4 inch diameter, one inch gage length specimens.

Yield strength is 0.2 per cent offset.

6.1% Zn, 2.4% Mg, 2.5% Cu, 0.04% Cr, 0.13% V

TABLE 65

LONG-TRANSVERSE DIRECTION TENSILE PROPERTIES OF 2-1/2-INCH THICK PLATES IN ALLOY 3

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T. S. ksi | Y. S. ksi | El. % |
|---|---|---|---|---|---|---|
| 367801 | A | 80 F | None | 68.2 | 64.7 | 2.0 |
| | 1B | 80 F | To 350 F | 72.5 | 66.8 | 2.5 |
| | 1C | 80 F | 2 hrs. @ 350 F | 73.8 | 69.8 | 2.8 |
| | 1D | 80 F | 4 hrs. @ 350 F | 72.5 | 69.0 | 2.0 |
| | 1E | 80 F | 6 hrs. @ 350 F | 70.2 | 64.3 | 4.0 |
| | 1F | 80 F | 8 hrs. @ 350 F | 67.8 | 61.7 | 4.5 |
| | 1G | 80 F | 10 hrs. @ 350 F | 66.9 | 58.7 | 5.5 |
| | 1H | 80 F | 12 hrs. @ 350 F | 65.4 | 56.5 | 6.5 |
| | 2B | 80 F | To 325 F | 72.4 | 67.1 | 3.0 |
| | 2C | 80 F | 6 hrs. @ 325 F | 74.8 | 69.9 | 4.0 |
| | 2D | 80 F | 12 hrs. @ 325 F | 74.2 | 69.4 | 2.5 |
| | 2E | 80 F | 18 hrs. @ 325 F | 74.2 | 68.8 | 3.0 |
| | 2F | 80 F | 24 hrs. @ 325 F | 73.5 | 67.2 | 4.0 |
| | 2G | 80 F | 30 hrs. @ 325 F | 73.0 | 65.2 | 5.0 |
| | 2H | 80 F | 36 hrs. @ 325 F | 71.9 | 65.4 | 5.0 |
| | 6E | 180 F | 18 hrs. @ 325 F | 63.2 | 57.8 | 3.0 |
| | 6F | 180 F | 24 hrs. @ 325 F | 61.9 | 54.8 | 4.5 |
| | 6G | 180 F | 30 hrs. @ 325 F | 61.6 | 53.3 | 4.5 |
| | 6H | 180 F | 36 hrs. @ 325 F | 60.0 | 52.6 | 3.5 |

Solution treated 8 hours at 890 F, quenched as indicated.

Precipitation heat treated 24 hours at 250 F after four days at room temperature.

Properties are average of duplicate 1/4 inch diameter, one inch gage length specimens.

Yield strength is 0.2 per cent offset.

**6% Zn, 2.4% Mg, 2.5% Cu, 0.13% Mn, 0.13% V**

TABLE 66

LONG-TRANSVERSE DIRECTION TENSILE PROPERTIES OF 2-1/2-INCH THICK PLATES IN ALLOY 4

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T. S. ksi | Y. S. ksi | El. % |
|---|---|---|---|---|---|---|
| 367802 | A | 80 F | None | 75.5 | 68.5 | 4.0 |
| | 1B | 80 F | To 350 F | 74.6 | 68.6 | 4.0 |
| | 1C | 80 F | 2 hrs. @ 350 F | 77.3 | 72.3 | 4.0 |
| | 1D | 80 F | 4 hrs. @ 350 F | 75.8 | 70.4 | 4.5 |
| | 1E | 80 F | 6 hrs. @ 350 F | 73.6 | 66.5 | 5.5 |
| | 1F | 80 F | 8 hrs. @ 350 F | 71.8 | 63.8 | 6.5 |
| | 1G | 80 F | 10 hrs. @ 350 F | 70.5 | 61.2 | 7.5 |
| | 1H | 80 F | 12 hrs. @ 350 F | 68.8 | 58.2 | 7.0 |
| | 2B | 80 F | To 325 F | 76.2 | 69.4 | 4.0 |
| | 2C | 80 F | 6 hrs. @ 325 F | 78.5 | 72.6 | 5.5 |
| | 2D | 80 F | 12 hrs. @ 325 F | 77.6 | 71.9 | 4.5 |
| | 2E | 80 F | 18 hrs. @ 325 F | 77.1 | 71.0 | 5.0 |
| | 2F | 80 F | 24 hrs. @ 325 F | 75.1 | 68.3 | 5.5 |
| | 2G | 80 F | 30 hrs. @ 325 F | 74.2 | 66.9 | 6.5 |
| | 2H | 80 F | 36 hrs. @ 325 F | 72.7 | 64.7 | 6.0 |
| | 6E | 180 F | 18 hrs. @ 325 F | 63.8 | 54.4 | 6.5 |
| | 6F | 180 F | 24 hrs. @ 325 F | 61.6 | 53.2 | 4.5 |
| | 6G | 180 F | 30 hrs. @ 325 F | 62.4 | 53.5 | 6.0 |
| | 6H | 180 F | 36 hrs. @ 325 F | 60.6 | 51.5 | 5.5 |

Solution treated 8 hours at 890 F, quenched as indicated.

Precipitation heat treated 24 hours at 250 F after four days at room temperature.

Properties are average of duplicate 1/4 inch diameter, one inch gage length specimens.

Yield strength is 0.2 per cent offset.

6% Zn, 2.4% Mg, 2.3% Cu, 0.12% Zr, 0.12% V

TABLE 67

LONG-TRANSVERSE DIRECTION TENSILE PROPERTIES OF 2-1/2-INCH THICK PLATES IN A LOY 7

| Specimen Number | Code | Quench Water Temp. | Second Step Precipitation Heat Treatment | Long-Transverse T. S. ksi | Y. S. ksi | El. % |
|---|---|---|---|---|---|---|
| 367805 | A | 80 F | None | 69.2 | 65.5 | 2.0 |
| | 1B | 80 F | To 350 F | 71.1 | 67.2 | 2.0 |
| | 1C | 80 F | 2 hrs. @ 350 F | 72.4 | 71.0 | 2.0 |
| | 1D | 80 F | 4 hrs. @ 350 F | 70.7 | 68.4 | 2.0 |
| | 1E | 80 F | 6 hrs. @ 350 F | 68.6 | 64.8 | 2.0 |
| | 1F | 80 F | 8 hrs. @ 350 F | 66.3 | 61.4 | 3.0 |
| | 1G | 80 F | 10 hrs. @ 350 F | 64.8 | 58.6 | 4.0 |
| | 1H | 80 F | 12 hrs. @ 350 F | 61.9 | 56.2 | 3.5 |
| | 2B | 80 F | To 325 F | 70.0 | 67.0 | 2.5 |
| | 2C | 80 F | 6 hrs. @ 325 F | 70.8 | 68.0 | 2.0* |
| | 2D | 80 F | 12 hrs. @ 325 F | 74.1 | 70.0 | 2.0* |
| | 2E | 80 F | 18 hrs. @ 325 F | 70.2 | 68.5 | 2.0* |
| | 2F | 80 F | 24 hrs. @ 325 F | 67.8 | 66.1 | 2.0 |
| | 2G | 80 F | 30 hrs. @ 325 F | 67.6 | 64.2 | 2.0 |
| | 2H | 80 F | 36 hrs. @ 325 F | 64.9 | 62.7 | 1.8 |
| | 6E | 180 F | 18 hrs. @ 325 F | 60.6 | 52.3 | 4.5 |
| | 6F | 180 F | 24 hrs. @ 325 F | 59.3 | 50.7 | 5.0 |
| | 6G | 180 F | 30 hrs. @ 325 F | 58.6 | 49.4 | 5.5 |
| | 6H | 180 F | 36 hrs. @ 325 F | 58.5 | 49.2 | 6.0 |

Solution treated 8 hours at 890 F, quenched as indicated.

Precipitation heat treated 24 hours at 250 F after four days at room temperature.

Properties are average of duplicate 1/4 inch diameter, one inch gage length specimens.

Yield strength is 0.2 per cent offset.

* Value for one specimen; other specimens had 0.0% El.

5.7% Zn, 2.3% Mg, 2.6% Cu, 0.12% Zr, 0.14% V

## APPENDIX III

## SCANNING AND TRANSMISSION ELECTRON MICROSCOPE EXAMINATION

Because the concomitant large increase in per cent elongation and small decrease in strength exhibited by several of the experimental alloys was unusual, broken specimens were examined using a Cambridge Stereoscan scanning electron microscope. Specimens from Alloys 11, 15, and 18 were selected to illustrate the phenomenon. Quench practice and tensile properties are listed below:

| Alloy | S - No. | Quench Water Temp. | Long-Transverse Y.S. ksi | Long-Transverse % El. in 2" |
|---|---|---|---|---|
| 11 | 379391-1B | 70 F | 63 | 9 |
| | -2B | 175 F | 62 | 14 |
| 15 | 379395-1B | 70 F | 70 | 7 |
| | -2B | 175 F | 67 | 11 |
| 18 | 379398-1B | 70 F | 71 | 4 |
| | -2B | 175 F | 70 | 4 |

Similar features were seen on the center of the fracture where failure initiated and on the shear lips towards the edge of the specimens.

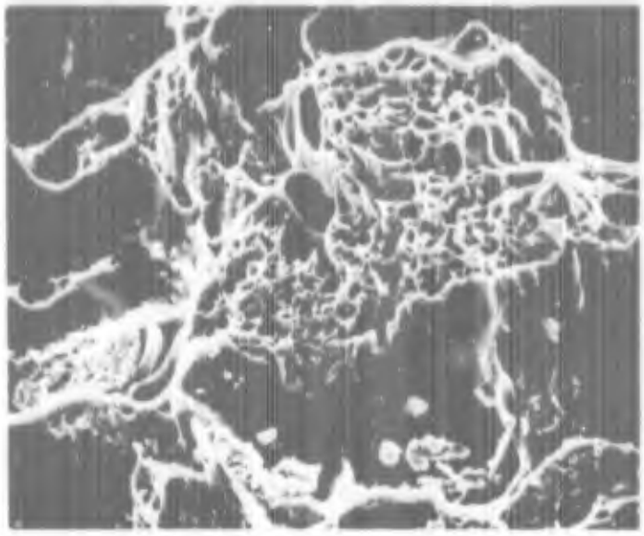
Amount of dimpling on the fracture correlated with the elongation observed.

In the low magnesium Alloy 11, patches of fine dimples were separated by rather flat featureless regions (Figure 47). Fewer featureless regions appeared in the specimen from the plate quenched in hot water.

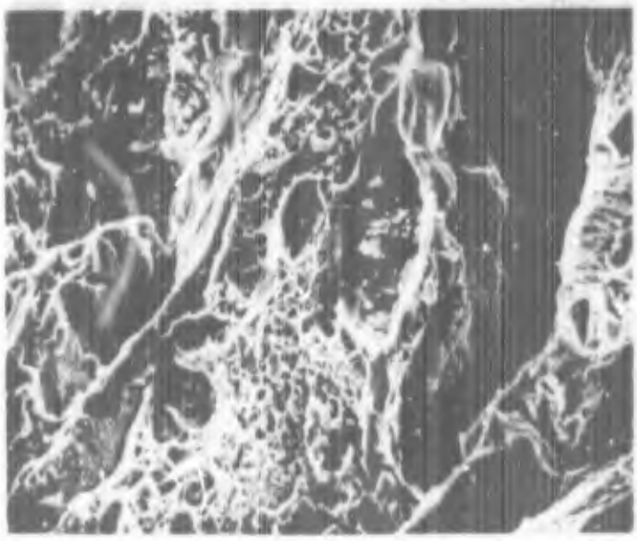
Fracture in the high iron, intermediate magnesium Alloy 15 was influenced by $Al_7Cu_2Fe$ particles (Figure 48), and the two quenches produced different amounts of dimpling.

In the high magnesium alloy, dimpling was very limited and the fracture was faceted (Figure 49). Both quenches produced similar features.

Transmission electron microscopy of broken specimens and of additional samples taken from the plate was used to examine the structure at high resolution. No consistent structural feature such as amount of grain boundary precipitation could be correlated with tensile elongation or fracture appearance.

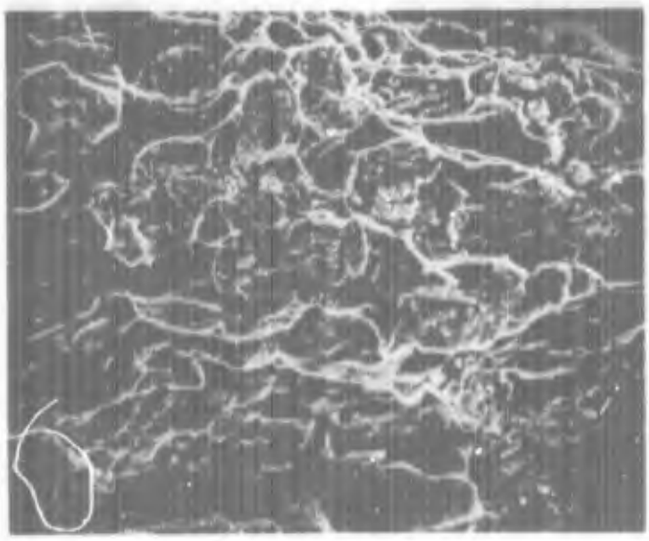


C.W.Q. 9.3%EL. 550X

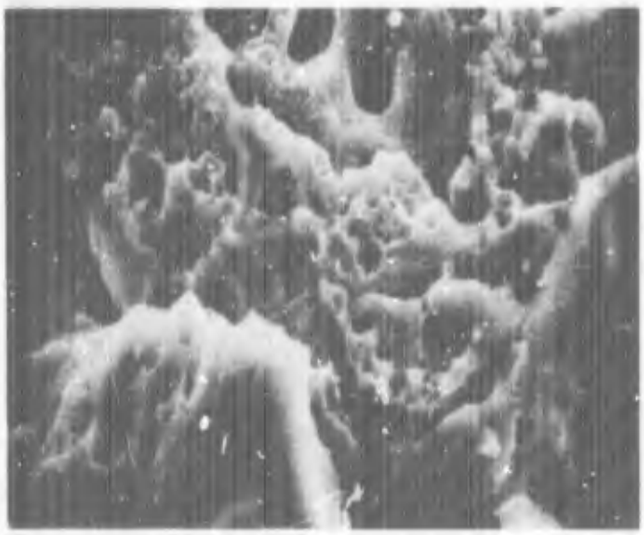


H.W.Q. 13.8%EL. 500X

FIG. 47 FRACTURE IN ALLOY II, 1.75% Mg



C.W.Q. 6.8%EL. 500X



H.W.Q. 10.5%EL. 2000X

FIG. 48 FRACTURE IN ALLOY 15, 2.25% Mg, 0.2% Fe

C.W.Q. 3.8%EL. 2000X

H.W.Q. 3.8%EL. 2000X

FIG. 49 FRACTURE IN ALLOY 18, 2.5 % Mg

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13. ABSTRACT

An alloy has been developed which exhibits a good resistance to stress-corrosion cracking at 25 ksi or higher stress in the short-transverse direction based on 30 days exposure in the 3.5% NaCl alternate immersion test. Estimated minimum strength of three-inch thick plate exceeds the guaranteed minimum strength of the closest competing aluminum alloy by 3 ksi and the advantage increases with increasing thickness. Eccentricities in the results of 84 day alternate immersion tests and lack of data regarding performance of alloys of this type in natural environments for longer than 10 months, however, indicate that caution must be used in extrapolating the results of the accelerated tests to predict service performance.

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Security Classification

Security Classification

| 14 KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| 7000 Series Alloys | | | | | | |
| Quench Sensitivity | | | | | | |
| Stress Corrosion Resistance | | | | | | |
| Fracture Toughness | | | | | | |
| Heavy Section Applications | | | | | | |
| Zr Addition | | | | | | |
| Ni Addition | | | | | | |
| V Addition | | | | | | |

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